

RESULTS OF THE 2010 ALIEN SPECIES AND WĒKIU BUG
(NYSIUS WEKIUCOLA) SURVEYS ON THE SUMMIT
OF MAUNA KEA, HAWAII ISLAND

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RESULTS OF THE 2010 ALIEN SPECIES AND WĒKIU BUG (*NYSIUS WEKIUCOLA*) SURVEYS ON THE SUMMIT OF MAUNA KEA, HAWAI‘I ISLAND

FINAL REPORT

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TABLE OF CONTENTS

Executive Summary 3

Introduction..... 4

Study Area 4

Methods..... 5

Results and Discussion

 Wēkiu Bug Trap Placements in Study Area8

 Wēkiu Bug Collections8

 Alien Arthropod Species Surveys8

 Introduced Species of Concern and Potential Threats to Wēkiu Bugs18

Acknowledgments..... 19

References..... 19

Appendix A: Figures..... 21

Appendix B: Tables 24

Appendix C: Alien and Native Arthropod Tables 2010 35

LIST OF FIGURES

Figure 1. Overall study area for alien arthropod species sampling conducted during the 2010 field season..... 22

Figure 2. Overall study area for wēkiu bug sampling sites during the 2010 field season. 23

Figure 3. Wēkiu bug concentrations during the 2010 field season..... 24

LIST OF TABLES

Table 1. Alien arthropod sampling locations for the 2010 field season..... 26

Table 2. Wēkiu bug trap sites and capture data from the 2010 field season..... 32

Table 3. Summary of 2010 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using shrimp pitfall traps in June 2010..... 34

Table 4. Summary of wēkiu bugs captured at the Pu‘u Hau Kea (within the Natural Area Reserve) cinder cone in Bishop Museum related studies since 2001. Data includes using a combination of glycol and shrimp pitfall data for all years except 2007, 2008, 2009, and 2010 when only shrimp traps were used. 34

Table 5. Overall species list of native and alien arthropods found during the 2010 field season, specific sites where each taxa were found are listed in main text 36

EXECUTIVE SUMMARY

As part of a continuing long-term study, the Hawaii Biological Survey of the Bishop Museum was contracted by the Office of Mauna Kea Management (OMKM) to monitor for alien arthropod species and to continue monitoring populations of the wēkiu bug (*Nysius wekiuicola* Ashlock and Gagné), which is endemic to the Mauna Kea summit area of Hawai'i Island. A ten-day field trip was conducted in June 2010 to continue the monitoring of introduced arthropod species found at the Mauna Kea summit, and to continue monitoring wēkiu bug populations within known critical core habitats. The objective of the alien arthropod monitoring surveys was to provide information to managers on any potential threats to endemic Mauna Kea arthropod species such as the wēkiu bug. As was done in previous monitoring surveys, traps for ants were set out to determine if they are found within wēkiu bug habitat. Ants are well established at the summit regions of Haleakalā National Park on Maui and spreading, and this elevational range is well-within that of lowest elevation that wēkiu bugs have been found. Ants have caused the extinction and decline of native arthropods throughout Hawai'i. We placed traps in areas determined to be high-risk areas for ants to be found around the Mauna Kea summit region.

During the 2010 monitoring survey we collected 3,047 wēkiu bugs at selected cinder cones throughout the Mauna Kea summit region. We placed 100 alien arthropod traps at sites previously studied, at the proposed Thirty Meter Telescope (TMT), and the batch plant staging area that will be used if the TMT is built. No new resident alien species were found during the 2010 alien arthropod species monitoring season around the summit region, and species of particular concern such as ants were not found from Hale Pohaku (2,755 m) to the highest point in the Hawaiian Islands of Pu'u Wēkiu (4,205 m). Aeolian arthropod drift capture density was slightly lower than in 2009 but still reflected the same species diversity. This could be the result of dryer conditions at lower elevations resulting in lower numbers of individuals reaching the summit regions.

INTRODUCTION

The Hawaii Biological Survey of the Bishop Museum was contracted for the 2010 field season by the Office of Mauna Kea Management (OMKM) to continue to monitor and document alien arthropod species found at the Mauna Kea summit area. A baseline for alien arthropod species currently occurring at the Mauna Kea summit area has been established and species with the potential to negatively affect wēkiu bugs (*Nysius wekiuicola* Ashlock and Gagné) or other native arthropod species are being monitored. Additionally, to provide long-term capture data in areas of known critical wēkiu bug habitat, wēkiu bug population monitoring continued during the 2010 field season at the Mauna Kea summit area.

This study continues Bishop Museum's wēkiu bug research that originated in the early 1980s (Howarth and Stone 1982), and resumed again in the late 1990s to the present (Howarth *et al.* 1999, Englund *et al.* 2002, 2005, 2007, 2009, Porter and Englund 2006). The main objectives for the 2010 field seasons were to 1) conduct surveys for alien arthropod species in areas of known wēkiu bug core habitat at the Mauna Kea summit area plus less favored habitats, 2) compare the 2010 alien arthropod species composition to the 2009 field season at the summit areas on Mauna Kea where people traffic is high, including observatory buildings, the Hale Pohaku visitor center, and roadways, 3) repeat a baseline survey following the 2009 field season methods for alien arthropod species including areas around the proposed Thirty Meter Telescope (TMT), and the batch plant staging area that will be used if the TMT is built, and 4) continue to monitor wēkiu bug populations in selected known wēkiu bug habitats to provide comparisons to previous Bishop Museum surveys.

STUDY AREA

The overall study area for the 2010 field season has been thoroughly described in previous Bishop Museum reports and this can be found in Howarth *et al.* (1982), Howarth *et al.* (1999), Englund *et al.* (2002, 2005, 2007, 2009) and Porter and Englund (2006), and was similar to the 2007-2008 study area (Englund *et al.* 2009). The study area started at the Hale Pohaku visitor center and staff quarters at 2,850 m (9,300 ft) elevation, and encompassed portions of the alpine zone of the Mauna Kea volcano (Figure 1), including both the Mauna Kea Science Reserve (MKSR) and the Mauna Kea Ice Age Natural Area Reserve (NAR). For the purposes of this study, we defined cinder cones as non-vegetated, dormant volcanic cones in the alpine zone above 2,925 m, (9,600 ft). Elevations sampled for alien arthropods during 2007-2008 fieldwork ranged from a maximum of 4,205 m (13,796 ft) at the summit of Pu'u Wēkiu to a low of 2,850 m (9,300 ft) around Hale Pohaku. Visual observations were also made throughout the study area while hiking between sampling points. Tables 1-4 contain GPS coordinates, elevations, and date traps were set for all sample points within the study area. Because the present study was for both wēkiu bugs and alien arthropod species, all species (except wēkiu bugs) collected in traps during these studies were kept for further analysis. This is also

why some of the sample locations are duplicated for the alien species and wēkiu bug data tables (i.e., Tables 1 and 2). Sample locations were duplicated in Tables 1-4 when non- wēkiu bug taxa were collected in wēkiu bug pitfall traps.

Unless otherwise stated, pu'u names were derived from USGS topographic quad maps. WGS 84 datum was used for recording GPS locations. Many pu'u have not yet been given official names, and when possible these cinder cones are identified by their altitude as stated on USGS topo maps. However, when no altitudes are given names of nearby landmarks or distinctive features were used. These names should not be viewed as official, but instead allow us to more easily identify specific areas of the vast summit region of Mauna Kea. Altitudes were determined using a combination of USGS 7.5 minute topographic quad maps, a handheld altimeter, and a barometric altimeter on the GPS unit, calibrated daily at Hale Pohaku and at the elevation markers on the road up to the observatories.

METHODS

Alien Arthropod Species The objectives for the 2010 fieldwork was to documenting alien species found within the Mauna Kea summit area. Identifications were made of all arthropod species collected during the 2010 field trip with comparisons to previous catches and referenced to authoritatively identified specimens in the entomology collections. Species were identified to the lowest possible taxonomic unit, which was dependent upon expertise available for each taxonomic group.



Alien sampling at Lake Waiau
Photograph by L. Englund

The main purpose of fieldwork of the 2010 study was to continue to monitor for alien species and identify species on Mauna Kea having the potential to negatively affect wēkiu bugs and other native arthropods. To accomplish this goal we sampled at previous trapping sites over a broad range of habitats at the summit, focusing on various pathways whereby alien arthropods might first become introduced. We also sampled a wide variety of undisturbed habitat types where wēkiu bugs are historically known to have high concentrations, and nearby disturbed habitats that are associated with past or present human activities. Trapping followed the 2009

field season protocols. Yellow pan traps and yellow sticky traps were used to collect flying insects that are attracted to the color of the traps and the shimmering of the dilute ethylene glycol used in the pan traps. The pan and sticky traps were secured so that they did not become dislodged or blown from the trap sites and become scattered over the summit area. Ethylene glycol was used because it prevents freezing during the nighttime temperatures and is a preservative keeping the arthropod specimen from rotting until they can be processed and identified. Glycol pitfall traps were constructed as in previous year's wēkiu bug traps (Englund *et al.* 2002), they are baited with shrimp paste

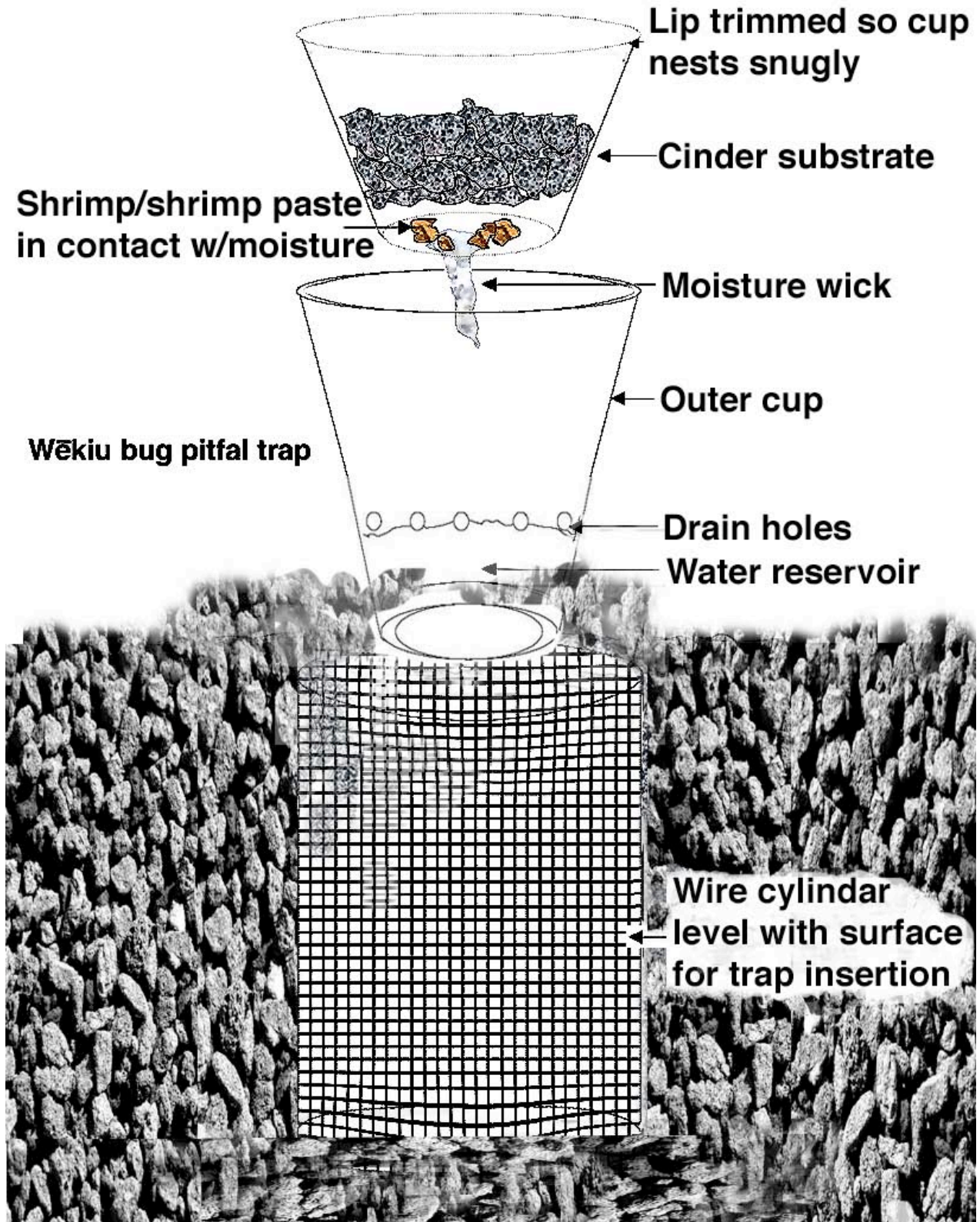
around their cup rims and around a cap-rock used to cover the traps to prevent rain or snow from filling the traps. The traps are filled with a mixture of water and glycol. The glycol pitfall traps were not placed in habitats likely to contain wēkiu bugs.

Ants have become a major concern in Hawaii and are ranked as one of the greatest threats to native arthropods including the wēkiu bug. Monitoring for the presence of ants is of the utmost importance. Ants were sampled for in high traffic areas where vehicles and people activities occur. Sampling areas included the Onizuka Visitor Center picnic and trashcan locations. The Hale Pohaku staff areas and the summit lunchroom building as well as several observatory structures were trapped for ants. Ant traps rely on baits as attractants. Peanut butter has proven to be excellent bait and it is a simple and easy way to sample for ants. Ant traps were constructed using wooden tongue depressors dipped into peanut butter and placed in areas previously sampled in 2009. The ant traps were checked at 2-3 day intervals through out the 10-day fieldwork. Shrimp baited traps were also checked. It should be noted that the shrimp bait will also attract ants and served to provide additional monitoring points.

A total of 4 different trapping methods were employed during the 2010 trapping season at selected trapping locations: 1) peanut butter mainly for ants, 2) yellow sticky traps for flying insects but also effective when placed on the ground for crawling arthropods, 3) yellow pan traps used mainly for flying insects but when placed level with the cinders acts like a shallow pitfall trap capturing crawling arthropods, and 4) a single ethylene glycol pitfall trap, effective for catching crawling as well as flying arthropods especially flies. Traps were placed between 4 and 5 meters from one another and a GPS point was recorded for each trap at each trapping location. Traps ran for a minimum of 3 days. Fluid traps were checked for evaporation and filled as needed. Table 1 in Appendix B lists the collection site localities as well as each trap coordinate.

Wēkiu Bug Sampling

As in 2009, glycol pitfall traps were not used in areas known or suspected to contain wēkiu bugs. During the 2010 fieldwork, wēkiu bug sampling consisted of using baited shrimp pitfall traps (which generally do not harm the insects) in areas of previously known wēkiu bug populations. Limited visual surveys for wēkiu bugs were also conducted. A detailed explanation of techniques used for shrimp pitfall traps in this study can be found in Englund *et al.* (2002). Individual wēkiu bug pitfall trap locations were recorded with GPS (WGS 84 datum), and locations where wēkiu bugs were visually observed. Trap locations, dates, habitat type, and habitat descriptions can be found in Appendix B, Table 2 for the 2010 sampling.



RESULTS AND DISCUSSION

The study period at the Mauna Kea summit for alien arthropod and wēkiu bug sampling ran from June 1–10, 2010. Tables 2 and 3 (Appendix B) summarize trap locations by cinder cone, elevation, date set, trap type, and GPS coordinates. Overall the 2010 wēkiu bug sample effort consisted of 50 pitfall traps and 100 alien arthropod traps.

Wēkiu Bug Trap Placements in Study Area

A total of 50 shrimp pitfall traps, were set in various cinder cone areas at selected elevations during the 2010 fieldwork season (Figure 2, Table 2). Sampled areas from 2010 included the main summit region, with permanent monitoring stations at Pu‘u Hau Kea, Pu‘u Wēkiu, Pu‘u Hau Oki, and the Pu‘u’s north, south of the VLBA, and Poi Bowl. Other areas sampled included the proposed Thirty Meter Telescope (TMT) site and the batch plant staging area that will be used if the TMT is built.

Wēkiu Bug Collections

A total of 3,047 wēkiu bugs were collected in early June 2010 during a total of 300 trap days, for an average catch of 10.12 wēkiu bugs/trap-day (Table 3). The 2010 sampling coincided with sampling done during the summer of 2009, when only 118 bugs were captured during an effort of 285 trap days. Pu‘u Hau Kea has been intensively sampled nearly every year since 2001 because of its unaltered habitat and usually high wēkiu bug captures. Wēkiu bug collection data from the Pu‘u Hau Kea monitoring station in 2010 is summarized in Table 4.

Summary of Alien Arthropod Species Collected in 2010

The following is a summary of arthropods collected in discrete sampling areas during the 2010 field season, including a brief description of sample location along with any arthropod by-catch found during wēkiu bug collections. Detailed GPS locations and additional information for these sampling sites can be found in Tables 1-4 in the appendices section. Aeolian species found during these surveys are likely not a major threat to native species at this time, and it is likely that resident alien arthropod species have greater potential impacts.

To allow more information to be displayed, we have abbreviated standard entomological terms in the tables. Often it was difficult to determine the status of a particular species, which is why many have question marks next to their habitat and their (end/adv/native/introduced) status. The following abbreviations in the 2010 species tables are based upon Nishida (2002):

end = endemic: native to the Hawaiian islands, and found only in Hawai‘i

ind = indigenous: native to the Hawaiian islands but can be found elsewhere

adv = adventive: introduced into Hawai‘i, most likely accidentally introduced

pur = purposeful introduction: introduced into Hawai‘i usually for biological control of insect and plant pests

unk = unknown

Aeolian = species is not a resident of the area where it was collected, but blown up from lower elevations

Resident = lives and reproduces in the area where the species was collected

Below are brief descriptions of the 2010 sample areas followed by a list of species for each area. Areas or sample sites with no insect collections are not included in the list below.

HP Parking Lot (lower) (Sites 001, 002, 003, 004)

Hale Pohaku parking lot area: Located near the Hale Pohaku living quarters and cafeteria, this area was located at an elevation of approximately 2,850 m. In 2010, there were no alien species of concern found around this area, although the parking lot and adjacent living area around Hale Pohaku has greater potential for new alien invertebrates than any other area with the exception of the Onizuka Visitor center. Native species of note were a healthy population of native *Hyaleus* sp. bees, along with a native seed bug (Lygaeidae). Alien ant species were not collected in this area (or anywhere at the Mauna Kea summit area at or above Hale Pohaku) in 2010.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Gnaphosidae	<i>Urozelotes rusticus</i> (L. Koch, 1872)	adv	Resident
COLEOPTERA	Carabidae	<i>Laemostenus complanatus</i> (Dejean, 1828)	adv	Resident
COLEOPTERA	Staphilinidae	?Genus ?species	unk	Resident
DERMAPTERA	Forficulidae	<i>Forficula auricularia</i> Linnaeus, 1758	adv	Resident
DIPTERA	Agromyzidae	?Genus ?species	adv	Aeolian
DIPTERA	Calliphoridae	<i>Chrysomya megacephala</i> (Fabricius, 1794)	adv	Aeolian
DIPTERA	Calliphoridae	?Genus ?species	adv	Aeolian
DIPTERA	Muscidae	?Genus ?species	adv	Aeolian
DIPTERA	Sciaridae	several species	adv	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Resident
HETEROPTERA	Lygaeidae	<i>Graptostethu smanillensis</i> (Stal, 1862)	adv	Aeolian
HETEROPTERA	Lygaeidae	<i>Nysius</i> sp.	end?	Resident
HETEROPTERA	Nabidae	<i>Nabis capsiformis</i> Germar, 1837	adv	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Resident
HYMENOPTERA	Chalcidoidea	several species	adv	Resident
HYMENOPTERA	Colletidae	<i>Hylaeus</i> sp.	end	Resident
HYMENOPTERA	Ichneumonidae	<i>Diadegma blackburni</i> (Cameron, 1883)	adv	Resident
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
LEPIDOPTERA	Lycaenidae	<i>Strymon bazochii</i> (Godart, 1824)	pur	Aeolian
LEPIDOPTERA	Oecophoridae	<i>Thyrocopa</i> sp.	end	Resident
THYSANOPTERA	Thripidae	<i>Frankliniella</i> sp.	adv	Aeolian

Onizuka Visitor Center (Sites 005, 006, 007, 008)

Although intensively sampled in 2010, no potentially threatening alien species were collected here. Sampling took place around the parking lot and around the trash cans at the visitor center, with negative results for ants. Of interest, the native *Hyaleus* sp. bees were still common at this site. The rare flightless native moth *Thyrocopa kikaelekea* recently described by Medeiros (2008) is still found at this site and is indicative of the absence of harmful alien species at and near the Onizuka Visitor Center.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Corinnidae	<i>Meriola arcifera</i> (Simon, 1886)	adv	Resident
COLEOPTERA	Crabidae	<i>Laemostenus complanatus</i> (Dejean, 1828)	adv	Resident
DERMAPTERA	Forficulidae	<i>Forficula auricularia</i> Linnaeus, 1758	adv	Resident
DIPTERA	Agromyzidae	<i>Liriomyza</i> sp.	adv	Aeolian
DIPTERA	Calliphoridae	<i>Chrysomya megacephala</i> (Fabricius, 1794)	adv	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Muscidae	?Genus?species	unk	Aeolian
DIPTERA				
DIPTERA	Phoridae	several species	unk	Aeolian
DIPTERA	Sarcophagidae	<i>Sarcophaga argyrostoma</i> (Robineau-Desvoidy, 1830)	adv	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sphaeroceridae	<i>Leptocera</i> sp.	adv	Aeolian
DIPTERA	Tachinidae	?Genus ?species	unk	Aeolian
HETEROPTERA	Lygaeidae	<i>Nysius</i> sp.	end?	Resident
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Apidae	<i>Apis mellifera</i> Linnaeus, 1758	pur	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Aeolian
HYMENOPTERA	Chalcidoidea	unknown	unk	Aeolian
HYMENOPTERA	Colletidae	<i>Hylaeus</i> sp.	end	Resident
HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Diadegma blackburni</i> (Cameron, 1883)	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Ichneumon laetus</i> Brulle, 1846	pur	Aeolian
HYMENOPTERA	Scelionidae	?Genus ?species	pur?	Aeolian
HYMENOPTERA	Sphecidae	<i>Pison hospes</i> R. Smith, 1879	adv	Aeolian
HYMEOPTERA	Pompillidae	<i>Anoplius toluca</i> (Cameron, 1893)	adv	Aeolian
LEPIDOPTERA	Oecophoridae	<i>Thyrocopa</i> sp.	end	Resident
ORTHOPTERA	Gryllidae	<i>Trigonidomorpha sjostedti</i> Chopard, 1926	adv	Resident
THYSANOPTERA	Thripidae	<i>Frankliniella</i> sp.	adv	Aeolian

VLBA Parking Lot and Wēkiu trap bycatch (Sites VLBA24, VLBA100 - 104, VLBA105 - 109)

Only 5 alien species were trapped in the region around the VLBA parking lot (3,725 m elevation), and found in the bycatch of the wēkiu traps placed at one Pu‘u north and another south of the VLBA. All species captured were aeolian.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
DIPTERA	Calliphoridae	several species	adv	Aeolian
DIPTERA	Muscidae	<i>Atherigona orientalis</i> Schiner, 1868	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
HYMENOPTERA	Scelionidae	<i>Scelio pembedoni</i> Timberlake, 1932	pur	Aeolian

Burns Cone Parking Lot (Site BURNS43)

This area was located at a parking lot at 3,667 m elevation and was near an unnamed cinder cone at the John Burns Highway sign. Sampling at this location consisted of peanut butter traps, glycol pitfall, sticky, and yellow pan traps. Ant traps were negative and no harmful alien species collected.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
DIPTERA	Ephydriidae	?Genus ?species	unk	Aeolian
DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
DIPTERA	Calliphoridae	several species	adv	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Muscidae	<i>Atherigona orientalis</i> Schiner, 1868	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Scarcophagidae	several species	unk	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
HETEROPTERA	Lygaeidae	<i>Nysius</i> sp.	end?	Resident
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
LEPIDOPTERA	Noctuidae	<i>Agrotis</i> sp.	end	Resident

Batch Plant Parking Lot (trailhead area to Lake Waiau) (Sites 048, 049, 050, 051)

The batch plant parking lot is a large, flat, graded area at approximately 4,063–4,105 m elevation, adjacent to the base of Pu‘u Hau Kea. This area is also used as a parking lot for visitor day hikes to Lake Waiau. The native aeolian psyllid (*Trioza* sp.) was present here in similar numbers to 2009. No potentially harmful introduced species were found in the batch plant parking lot area during the 2010 sampling.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
DIPTERA	Calliphoridae	<i>Chrysomya megacephala</i> (Fabricius, 1794)	adv	Aeolian
DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
DIPTERA	Calliphoridae	several species	adv	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian

DIPTERA	Muscidae	?Genus ?species	unk	Aeolian
DIPTERA	Phoridae	several species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sphaeroceridae	several species	adv	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
DIPTERA	Tachinidae	several species	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> (several spp.)	adv	Aeolian

Pu'u Hau Kea (Sites 009, 010, 011, 012, 013, 014, 015, 016, 018)

This cinder cone was part of our annual wēkiu bug monitoring during the 2010 field season. Bycatch of alien arthropod species were found in wēkiu bug shrimp traps. No potentially harmful alien arthropod species were collected here. Of interest was finding the native aquatic ephydrid *Brachydeutera hebes* in wēkiu traps; these individuals were probably breeding at nearby Lake Waiau and attracted to the rotting shrimp paste used as bait in the wēkiu bug traps.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
COLEOPTERA	Dermestidae	<i>Dermestes maculatus</i> De Geer, 1774	ind	Aeolian
DIPTERA	Ephydriidae	<i>Brachydeutera hebes</i> Cresson, 1926	end	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sphaeroceridae	several species	unk	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian
HYMENOPTERA	Ichneumonidae	?Genus ?species	unk	Aeolian

Lake Waiau (Site Waiau7)

Although part of the Natural Area Reserve and not in the Science Reserve, Lake Waiau continued to be monitored in 2010 because the moisture provided by the lake in an otherwise desert environment is a major attractant to arthropods and potentially harmful alien species. Should armful arthropods becoming established in the slightly more mild and moist microclimate around the lake's shores, they could potentially expand their range to the rest of the summit area, especially ants. The area we monitored included the Lake Waiau shoreline, grassy areas, muddy areas near shore, the intermittent stream outflow of the Lake, and the nearshore waters. The waters of Lake Waiau serve as a attractant to aeolian arthropods which can remain active during the warmer daytime hours however, it is unlikely that any of the alien (adv/pur) species shown below can withstand the near-daily freezing temperatures at the 4,000 m elevation. The 2010 trapping of the Lake Waiau area produced 20 alien predatory carabid beetle species (*Agonum muelleri*) in traps placed near the Lake Waiau shoreline. This species is of potential concern as its dietary habits overlap with that of the wēkiu bug. Collecting 20 specimens of this carabid beetle during the 2010 trapping season suggest they may be an established resident at the lake. To be conclusive, immature life stages need to be collected. Because *Agonum muelleri* has not been collected at other areas of the summit region during the 2009 and

2010 trapping seasons, we believe it is presently confined to the Lake Waiau area. It is likely this beetle is established at lower elevations in similar riparian habitats but searches were beyond the scope of the current project.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Corinnidae	<i>Meriola arcifera</i> (Simon, 1886)	adv	Resident
COLEOPTERA	Carabidae	<i>Agonum muelleri</i> (Herbst, 1784)	adv	Aolian/Resident?
COLEOPTERA	Dytiscidae	<i>Rhantus pacificus</i> (Boisduval, 1835)	end	Resident
DERMAPTERA	Forficulidae	<i>Forficula auricularia</i> Linnaeus, 1758	adv	Resident
DIPTERA	Ephydriidae	?Genus ?species	unk	Aeolian
DIPTERA	Muscidae	<i>Stomoxys calcitrans</i> (Linnaeus, 1758)	adv	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
HETEROPTERA	Lygaeidae	<i>Geocoris pallens</i> Stål, 1854	adv	Aeolian
HETEROPTERA	Lygaeidae	<i>Graptostethus manillensis</i> Stål, 1859)	adv	Resident - nymph collected
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian
LEPIDOPTERA	Unknown	specimen badly damaged	unk	Aeolian
LITHOBIOMORPHA	Lithobiidae	<i>Lithobius?</i>	unk	Resident

Pu'u Wēkiu (Sites 029-038, 042)

In 2010 we set traps for alien arthropod species around the weather station area that was operating in the bottom of Pu'u Wēkiu crater. All arthropod bycatch in the wēkiu shrimp pitfall traps were analyzed and recorded. The highest elevation in the Hawaiian archipelago is found at the Pu'u Wēkiu cinder cone, and besides the wēkiu bug the only other native arthropod collected here in 2010 was the native wolf spider (*Lycosa hawaiiensis*). All other arthropods collected were aeolian species and thus not considered a threat to the wēkiu bug.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Lycosidae	<i>Lycosa hawaiiensis</i> Simon, 1899	end	Resident
COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
DIPTERA	Calliphoridae	several species	unk	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Oestridae	<i>Hypoderma bovis</i> (Linnaeus, 1758)	adv	Aeolian
DIPTERA	Phoridae	?Genus ?species	adv	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1883	adv	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Aeolian
HYMENOPTERA	Ichneumonidae	?Genus ?species	unk	Aeolian

Pu‘u Poliahu (Sites 019–023)

Although only five wēkiu bug pitfall traps were placed here, a large amount of alien arthropod species was collected as bycatch during the 2010 field season. The volume of bycatch at Pu‘u Poliahu was similar to the catch in 2009. All species listed below were recovered from wēkiu shrimp pitfall traps and no alien species of concern were found in this known wēkiu bug habitat.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Lycosidae	<i>Lycosa hawaiiensis</i> Simon, 1899	end	Resident
COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
DIPTERA	Calliphoridae	several species	unk	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1883	adv	Aeolian
DIPTERA	Sphaeroceridae	several species	unk	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian

Poi Bowl (Sites 121-125)

Poi Bowl is the locally named bowl-shaped ski slope area behind the Subaru and Keck telescopes, and is a known area of high wēkiu bug concentration. This area was sampled with five wēkiu bug pitfall traps. Below are the alien arthropods that were found as bycatch inside the wēkiu bug traps. Because of the relatively moist conditions in the lowlands adjacent to the Mauna Kea summit, a fairly diverse composition of aeolian species was collected here. No alien species of concern were found at Poi Bowl.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
COLEOPTERA	Staphylinidae	?Genus ?species	unk	Aeolian
DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Phoridae	several species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1883	adv	Aeolian
DIPTERA	Sphaeroceridae	several species	unk	Aeolian
DIPTERA	Tachinidae	several species	adv	Aeolian
HETEROPTERA	Lygaeidae	<i>Geocoris pallens</i> Stål, 1854	adv	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Diagegma blackburni</i> (Cameron, 1883)	adv	Aeolian

Pu‘u Hau Oki and around Keck Observatory (Sites 025–028, 112)

The uppermost slopes of this cinder cone contain the Keck and Subaru Observatories. Trapping here included using alien arthropod insect traps placed near the Keck Observatory as well as wēkiu bug traps placed at selected areas of the cinder cone. A list of aeolian species recovered from all traps is found below. No potentially harmful species were collected here in 2010.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
COLEOPTERA	Staphylinidae	?Genus ?species	unk	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Sciaridae	?Genus ?species	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Sphaeroceridae	several species	unk	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
HETEROPTERA	Lygaeidae	<i>Geocoris pallens</i> Stål, 1854	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian

Summit Lunchroom (Site 110)

The area sampled here included areas inside and around the summit lunchroom building at 4223 m elevation. Insect traps were placed around the building, inside the building on trashcans, and in a long underground hallway area. Even though this area has food and high human traffic, no alien arthropod species of concerns were found here. The summit lunchroom building is apparently too cold for even cockroaches or other common insect pests to survive. No resident arthropod species were found around the lunchroom building in 2010, and all ant traps were negative as they were at other summit areas. Large muscid and calliphorid flies are occasionally a nuisance to the summit lunchroom cook staff during daytime hours, but these flies are alien aeolian species that do not survive the cold nighttime summit temperatures.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
COLEOPTERA	Staphylinidae	?Genus ?species	unk	Aeolian
DIPTERA	Agromyzidae	<i>Liriomyza</i> sp.	adv	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Phoridae	<i>Genus ?species?</i>	adv	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
DIPTERA	Tachinidae	several species	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Aeolian

Gemini Telescope (Site 111)

The Gemini telescope observatory building area was sampled with a variety of insect traps within a 0–5 m distance of the observatory buildings. It was no surprise that two wēkiu bugs were collected in our traps, because they were set a short distance from known wēkiu bug habitat. The remainder of the arthropod species collected here in 2010 was entirely aeolian and not considered residents or species that could become established in this area.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
DIPTERA	Agromyzidae	?Genus ?species	adv	Aeolian
DIPTERA	Calliphoridae	several species	unk	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Aeolian

Proposed Thirty Meter Telescope area (Sites 39, 40, 41)

This area is in the flats region within the proposed Thirty Meter Telescope (TMT) site. Wēkiu bugs have never been collected in or around the TMT site because it lies in a heavily glaciated region (Englund *et al.* 2007). In 2010 a comprehensive arthropod survey was again conducted here, including glycol pitfall and other various insect traps. Only two resident species were collected here, the large native *Lycosa* spider, a native springtail (Collembola). Baited ant traps were negative at the proposed TMT site, as they were elsewhere around the summit. The remainder of the arthropod species collected here in 2010 was entirely aeolian and not considered residents or species that could become established in this area.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
DIPTERA	Calliphoridae	<i>Chrysomya megacephala</i> (Fabricius, 1794)	adv	Aeolian
DIPTERA	Muscidae	several species	unk	Aeolian
DIPTERA	Muscoidea	?Genus ?species	unk	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	adv	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> several spp.	adv	Aeolian
HYMENOPTERA	Braconidae	?Genus ?species	adv	Aeolian
HYMENOPTERA	Chalcidoidea	several species	unk	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian

Pu‘u Pohaku (Sites 115–120)

This sample area was located in the Mauna Kea Natural Area Reserve and contains a small but consistent outlying wēkiu bug population. Two sets of alien arthropod traps were used in 2010 at this cinder cone, with one set at the base of the cinder cone, and the other set of traps near the summit around the intermittent Henderson Lake. No wēkiu bugs were captured at Pu‘u Pohaku. Bycatch from the wēkiu bug traps set at Pu‘u Pohaku are included in the species list below.

order	family	genus-species-author	end/ind/adv/pur/unk	Resident/Aeolian
ARANEAE	Lycosidae	<i>Lycosa hawaiiensis</i> Simon, 1899	end	Resident
COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
DIPTERA	Lonchopteridae	<i>Lonchoptera furcata</i> (Fallen, 1823)	adv	Aeolian
DIPTERA	Muscidae	?Genus ? species	unk	Aeolian
DIPTERA	Muscidae	<i>Haematobia irritans</i> (Linnaeus, 1758)	adv	Aeolian
DIPTERA	Phoridae	?Genus ?species	unk	Aeolian
DIPTERA	Phoridae	several species	unk	Aeolian
DIPTERA	Sarcophagidae	several species	adv	Aeolian
DIPTERA	Sciaridae	several species	unk	Aeolian
DIPTERA	Sciaridae	? <i>Bradysia</i> sp.	unk	Aeolian
DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
DIPTERA	Sepsidae	<i>Sepsis thoracica</i> (Robineau-Desvoidy, 1830)	adv	Aeolian
DIPTERA	Sphaeroceridae	several species	unk	Aeolian
DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
HETEROPTERA	Miridae	<i>Coridromius variegates</i> (Montrouzier, 1861)	adv	Aeolian, on ‘aweoweo at lower elevations
HETEROPTERA	Nabidae	<i>Nabis capsiformis</i> Germar, 1837	adv	Aeolian
HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
HYMENOPTERA	Chalcidoidea	?Genus ?species	unk	Aeolian
HYMENOPTERA	Chalcidoidea	several species	unk	Aeolian
HYMENOPTERA	Ichneumonidae	<i>Diadegma blackburni</i> (Cameron, 1883)	adv	Aeolian
HYMENOPTERA	Proctotrupeoidea	?Genus ?species	adv	Aeolian
PSOCOPTERA	Ectopsocidae	<i>Ectopsocus</i> sp.	adv	Aeolian
THYSANOPTERA	Phlaeothripidae	?Genus ?species	adv	Aeolian

Introduced Species of Concern and Potential Threats to Wēkiu Bugs

Alien ant species continue to be the greatest potential threat to wēkiu bugs at the Mauna Kea summit area. Argentine ants (*Linepithema humile*) are currently found at Haleakalā National Park, Maui in elevational ranges close to overlapping with that of the lower distribution of wēkiu bugs (Krushelnycky *et al.* 2005). At Haleakalā National Park ant invasions have been documented to decrease native arthropod species diversity, with native predators such as the large endemic wolf spider (*Lycosa* sp.) rapidly declining in the face of ant invasions (Krushelnycky and Gillespie 2008). Ants are also implicated in the decline of the rare flightless *Thyrocopa apatela* moth found around the summit area of Haleakalā crater, and a closely related flightless species (*Thyrocopa kikaeleka*) was recently described from the Mauna Kea summit region in 2008 (Medeiros 2008). The potential for ant invasion to the Mauna Kea summit region is high, as ants are abundant along the Saddle Road area around the Pu‘u Huluhulu turnoff (Evenhuis *et al.* 1996). The European earwig was very common in 2010. It is predatory and a scavenger, and thus also has the potential to interact negatively with wēkiu bugs. These earwigs have never been found above the Hale Pohaku area and apparently are unable to handle the harsher summit conditions.

An endemic wolf spider (*Lycosa* sp.) is also found at Mauna Kea and is one of the top predators of the summit region, and along with the wēkiu bug would be expected to precipitously decline if ants ever become established. Because wēkiu bugs are much more restricted in their habitat choice than the wider ranging native wolf spiders (generally the bugs are found in the upper portion of non-glaciated cinder cones), it is expected that wēkiu bugs would be even more vulnerable to ant invasions than the spiders. No new species of alien spiders were found during the 2010 fieldwork that could potentially cause impacts to wēkiu bugs or other sensitive native biota. A small alien centipede was collected from the Lake Waiau area. This is the only site during this monitoring season that it was collected at but specimens of this species were collected in earlier surveys conducted by Francis G. Howarth in the early 1980's from higher elevations at the summit region. Although a predator, this centipede is mostly a scavenger, not widespread at the summit region and at this time not believed to be a serious risk to the wēkiu bug. The alien carabid beetle (*Agonum muelleri*) appears to be increasing in numbers at the Lake Waiau area. The first specimen of *A. muelleri* was collected by Steven L. Montgomery in 2006 in a Berlese funnel from material collected near a snowbank at the UH 2.2 meter telescope at the Mauna Kea summit (Liebherr *et al.* 2009), but all other specimens since that time have been collected around the Lake Waiau shoreline. During the 2010 trapping season we collected 20 specimens of this beetle and at the present time it has not been collected at any other site during this and past Bishop Museum monitoring seasons. It seems to be restricted to the Lake area and is probably a riparian species not likely to survive the dry desert-like habitats that contain wēkiu bugs. Risk to native arthropods that are residents of the Lake Waiau area are at particular risk though.

Regular monitoring and a rapid response to any ant introduction in the summit areas, or along roadways going to the summit should continue to ensure the survival of the wēkiu bug. The European earwig mentioned above is predatory and a scavenger, and thus also

has the potential to interact negatively with wēkiu bugs at their lowest range. Earwigs have never been found above the Hale Pohaku area and apparently are unable to handle the harsher summit conditions.

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APPENDIX A: FIGURES

Figure 1. Overall study area for alien arthropod species sampling conducted during the 2010 field season.

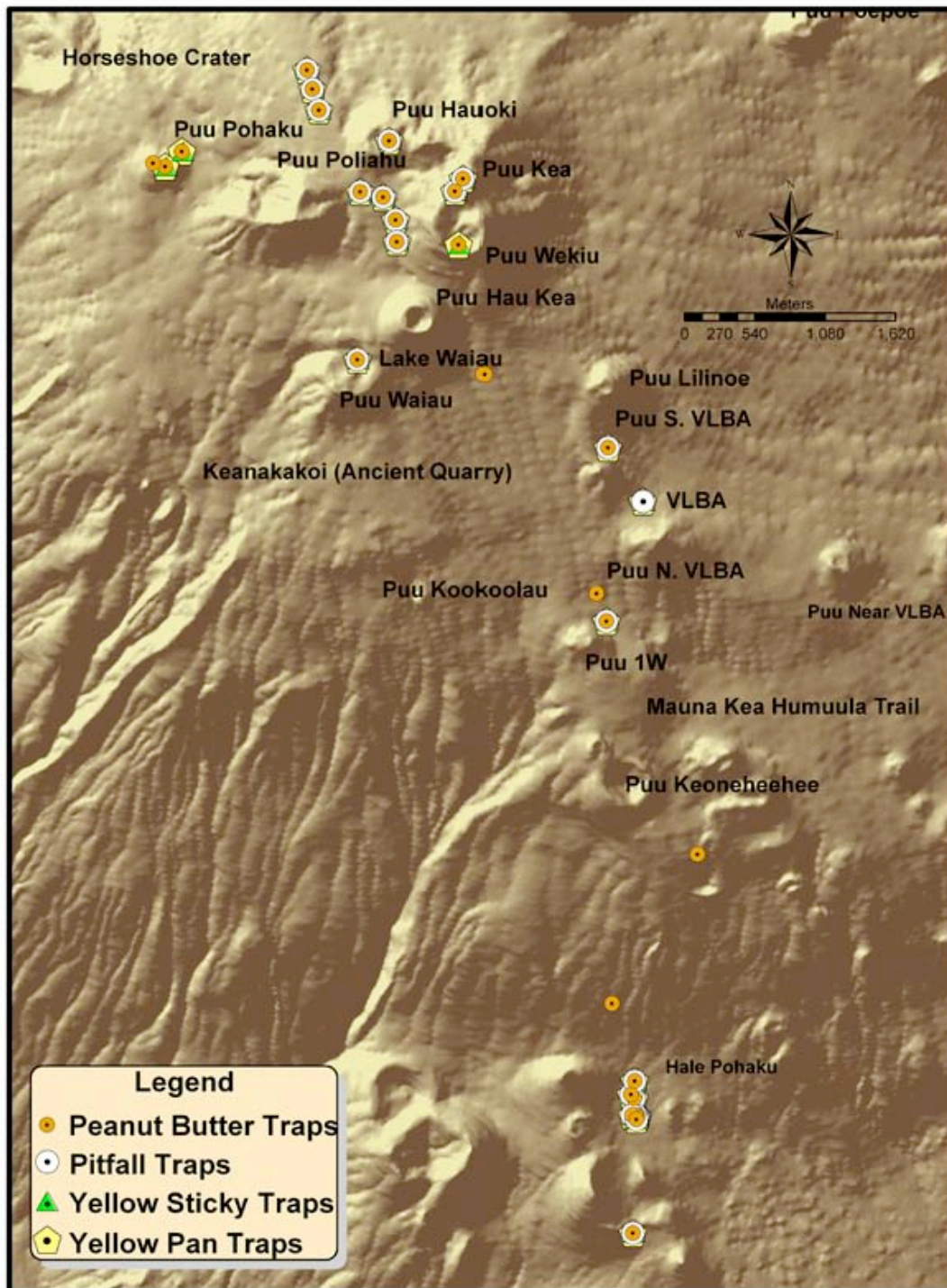


Figure 2. Overall study area for wēkiu bug sampling conducted during the 2010 field season.

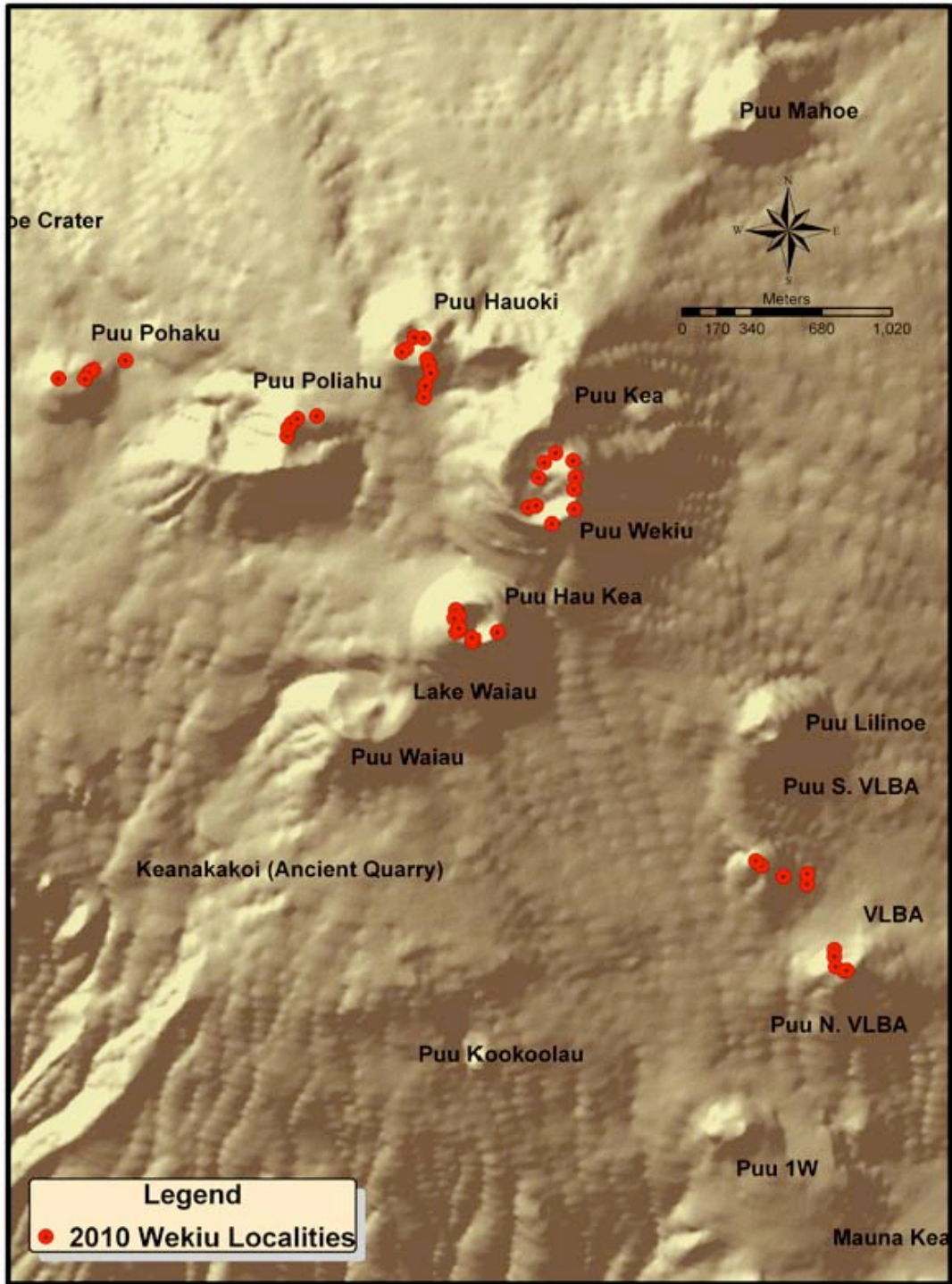
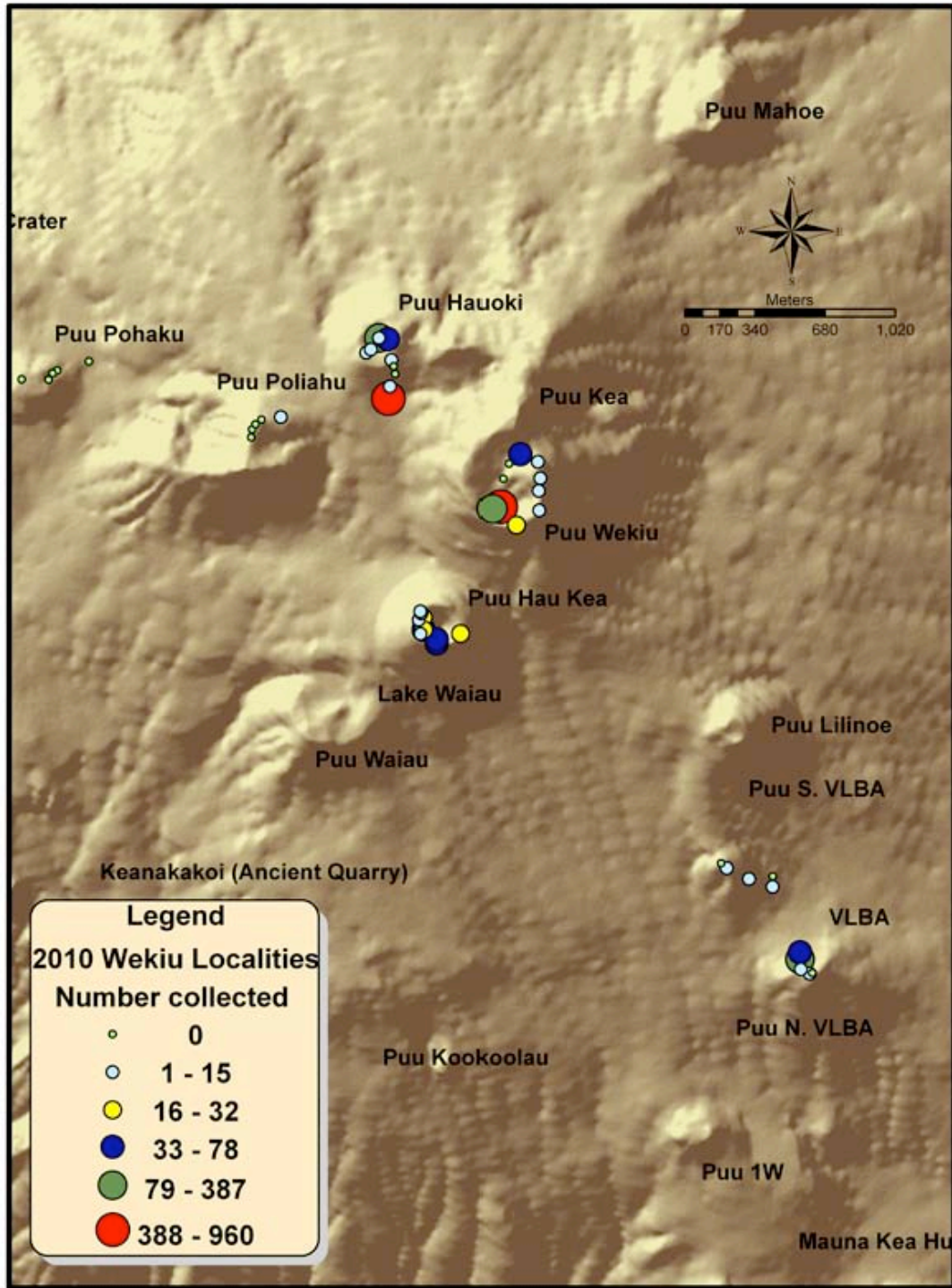


Figure 3. Wēkiu bug concentrations during the 2010 field season.



APPENDIX B: TABLES

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
Burns43	Burns Cone parking lot	4-10-June-2010	3667	19.79345	155.45855	Disturbed parking lot area	Pitfall
Burns43	Burns Cone parking lot	4-10-June-2010	3667	19.79345	155.45855	Disturbed parking lot area	Peanut butter
Burns43	Burns Cone parking lot	4-10-June-2010	3667	19.79345	155.45855	Disturbed parking lot area	Yellow pan
Burns43	Burns Cone parking lot	4-10-June-2010	3667	19.79345	155.45855	Disturbed parking lot area	Sticky trap
Lilin200	Base of Lilinoe	3-9-June-2010	3824	19.80541	155.45863	Glacier valley area	Pitfall
Lilin200	Base of Lilinoe	3-9-June-2010	3824	19.80541	155.45863	Glacier valley area	Peanut butter
Lilin200	Base of Lilinoe	3-9-June-2010	3824	19.80541	155.45863	Glacier valley area	Yellow pan
TMT39	30 meter telescope site	4-10-June-2010	4044	19.83112	155.48088	Glaciated Valley Floor area	Pitfall
TMT39	30 meter telescope site	4-10-June-2010	4044	19.83112	155.48088	Glaciated Valley Floor area	Peanut butter
TMT39	30 meter telescope site	4-10-June-2010	4044	19.83112	155.48088	Glaciated Valley Floor area	Yellow pan
TMT39	30 meter telescope site	4-10-June-2010	4044	19.83112	155.48088	Glaciated Valley Floor area	Sticky trap
TMT40	30 meter telescope site	4-10-June-2010	4058	19.82981	155.48047	Glaciated Valley Floor area	Pitfall
TMT40	30 meter telescope site	4-10-June-2010	4058	19.82981	155.48047	Glaciated Valley Floor area	Peanut butter
TMT40	30 meter telescope site	4-10-June-2010	4058	19.82981	155.48047	Glaciated Valley Floor area	Yellow pan
TMT40	30 meter telescope site	4-10-June-2010	4058	19.82981	155.48047	Glaciated Valley Floor area	Sticky trap

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
TMT41	30 meter telescope site	4-10-June-2010	4068	19.82838	155.47997	Glaciated Valley Floor area	Pitfall
TMT41	30 meter telescope site	4-10-June-2010	4068	19.82838	155.47997	Glaciated Valley Floor area	Peanut butter
TMT41	30 meter telescope site	4-10-June-2010	4068	19.82838	155.47997	Glaciated Valley Floor area	Yellow pan
TMT41	30 meter telescope site	4-10-June-2010	4068	19.82838	155.47997	Glaciated Valley Floor area	Sticky trap
VLBA24	VLBA facility parking lot	3-9-June-2010	3753	19.80174	155.45601	Disturbed area near parking lot	Pitfall
VLBA24	VLBA facility parking lot	3-9-June-2010	3753	19.80174	155.45601	Disturbed area near parking lot	Yellow pan
VLBA24	VLBA facility parking lot	3-9-June-2010	3753	19.80174	155.45601	Disturbed area near parking lot	Sticky trap
001	Hale Pohaku staff parking lot	1-7-June-2010	2851	19.76059	155.45604	staff parking, downhill end	Pitfall
001	Hale Pohaku staff parking lot	1-7-June-2010	2851	19.76059	155.45604	staff parking, downhill end	Peanut butter
001	Hale Pohaku staff parking lot	1-7-June-2010	2851	19.76059	155.45604	staff parking, downhill end	Yellow pan
001	Hale Pohaku staff parking lot	1-7-June-2010	2851	19.76059	155.45604	staff parking, downhill end	Sticky trap
002	Hale Pohaku staff parking lot	1-7-June-2010	2853	19.76086	155.45627	Lower parking lot, opposite kitchen	Pitfall
002	Hale Pohaku staff parking lot	1-7-June-2010	2853	19.76086	155.45627	Lower parking lot, opposite kitchen	Peanut butter
02	Hale Pohaku staff parking lot	1-7-June-2010	2853	19.76086	155.45627	Lower parking lot, opposite kitchen	Yellow pan
002	Hale Pohaku staff parking lot	1-7-June-2010	2853	19.76086	155.45627	Lower parking lot, opposite kitchen	Sticky trap

Hawaii biological Survey Report on the 2010 Mauna Kea Alien Arthropod Sampling

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
003	Hale Pohaku parking lot	1-7-June-2010	2865	19.75131	155.45598	parking lot, nest to kitchen	Pitfall
003	Hale Pohaku parking lot	1-7-June-2010	2865	19.75131	155.45598	parking lot, nest to kitchen	Peanut butter
003	Hale Pohaku parking lot	1-7-June-2010	2865	19.75131	155.45598	parking lot, nest to kitchen	Yellow pan
003	Hale Pohaku parking lot	1-7-June-2010	2865	19.75131	155.45598	parking lot, nest to kitchen	Sticky trap
004	Hale Pohaku parking lot near shop stairs	1-7-June-2010	2866	19.76180	155.45601	near stair case/ mamane	Pitfall
004	Hale Pohaku parking lot near shop stairs	1-7-June-2010	2866	19.76180	155.45601	near stair case/ mamane	Peanut butter
004	Hale Pohaku parking lot near shop stairs	1-7-June-2010	2866	19.76180	155.45601	near stair case/ mamane	Yellow pan
004	Hale Pohaku parking lot near shop stairs	1-7-June-2010	2866	19.76180	155.45601	near stair case/ mamane	Sticky trap
005	Onizuka Visitor Center	1-7-June-2010	2831.8	19.75933	155.45576	Disturbed area near picnic tables	Pitfall
005	Onizuka Visitor Center	1-7-June-2010	2831.8	19.75933	155.45576	Disturbed area near picnic tables	Peanut butter
005	Onizuka Visitor Center	1-7-June-2010	2831.8	19.75933	155.45576	Disturbed area near picnic tables	Yellow pan
005	Onizuka Visitor Center	1-7-June-2010	2831.8	19.75933	155.45576	Disturbed area near picnic tables	Sticky trap
006	Onizuka Visitor Center	1-7-June-2010	2833.4	19.75941	155.45587	Disturbed habitat by parking lot, uphill side of parking lot near light pole	Pitfall

Hawaii biological Survey Report on the 2010 Mauna Kea Alien Arthropod Sampling

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
006	Onizuka Visitor Center	1-7-June-2010	2833.4	19.75941	155.45587	Disturbed habitat by parking lot, uphill side of parking lot near light pole	Peanut butter
048	Batch plant area/Maxwell	2-8-June-2010	4105	19.82279	155.47687	Outside Maxwell observatory	Yellow pan
048	Batch plant area/Maxwell	2-8-June-2010	4105	19.82279	155.47687	Outside Maxwell observatory	Sticky trap
049	Batch plant area/Cal Tech	2-8-June-2010	4100	19.82243	155.47520	area adjacent to Cal Tech	Pitfall
049	Batch plant area/Cal Tech	2-8-June-2010	4100	19.82243	155.47520	area adjacent to Cal Tech	Peanut butter
049	Batch plant area/Cal Tech	2-8-June-2010	4100	19.82243	155.47520	area adjacent to Cal Tech	Yellow pan
049	Batch plant area/Cal Tech	2-8-June-2010	4100	19.82243	155.47520	area adjacent to Cal Tech	Sticky trap
050	Batch plant area, midway between Cal Tech & porta potti	2-8-June-2010	4082	19.82089	155.47426	Batch plant area, midway between Cal Tech & porta potti	Pitfall
050	Batch plant area, midway between Cal Tech & porta potti	2-8-June-2010	4082	19.82089	155.47426	Batch plant area, midway between Cal Tech & porta potti	Peanut butter
050	Batch plant area, midway between Cal Tech & porta potti	2-8-June-2010	4082	19.82089	155.47426	Batch plant area, midway between Cal Tech & porta potti	Yellow pan
050	Batch plant area, midway between Cal Tech & porta potti	2-8-June-2010	4082	19.82089	155.47426	Batch plant area, midway between Cal Tech & porta potti	Sticky trap
051	Batch plant area adjacent to porta potti	2-8-June-2010	4063	19.81938	155.47415	Cobble, gravel, sand	Pitfall

Hawaii biological Survey Report on the 2010 Mauna Kea Alien Arthropod Sampling

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
051	Batch plant area adjacent to porta potti	2-8-June-2010	4063	19.81938	155.47415	Cobble, gravel, sand	Peanut butter
051	Batch plant area adjacent to porta potti	2-8-June-2010	4063	19.81938	155.47415	Cobble, gravel, sand	Yellow pan
051	Batch plant area adjacent to porta potti	2-8-June-2010	4063	19.81938	155.47415	Cobble, gravel, sand	Sticky trap
110	Lunchroom at summit	3-9-June-2010	4223	19.82292	155.46996	Building	Pitfall
110	Lunchroom at summit	3-9-June-2010	4223	19.82292	155.46996	Building	Peanut butter
110	Lunchroom at summit	3-9-June-2010	4223	19.82292	155.46996	Building	Yellow pan
110	Lunchroom at summit	3-9-June-2010	4223	19.82292	155.46996	Building	Sticky trap
111	Gemini Telescope	3-9-June-2010	NA	19.82379	155.46938	Cobble	Pitfall
111	Gemini Telescope	3-9-June-2010	NA	19.82379	155.46938	Cobble	Peanut butter
111	Gemini Telescope	3-9-June-2010	NA	19.82379	155.46938	Cobble	Yellow pan
111	Gemini Telescope	3-9-June-2010	NA	19.82379	155.46938	Cobble	Sticky trap
112	Keck	3-9-June-2010	4174	19.82633	155.47481	Gravel/sand	Pitfall
112	Keck	3-9-June-2010	4174	19.82633	155.47481	Gravel/sand	Peanut butter
112	Keck	3-9-June-2010	4174	19.82633	155.47481	Gravel/sand	Yellow pan
112	Keck	3-9-June-2010	4174	19.82633	155.47481	Gravel/sand	Sticky trap
PB001	Mauna Kea Summit Road	2-8-June-2010	3031.5	19.76710	155.45775	Roadside by metal pole	Peanut butter
PB002	Mauna Kea Summit Road	2-8-June-2010	3390	19.77748	155.45166	Roadside in cobble	Peanut butter
PB003	Mauna Kea Summit Road	2-8-June-2010	3657.6	19.79535	155.45930	Roadside, gravel by large rock	Peanut butter
PB004	Mauna Kea Summit Road	2-8-June-2010	3932.2	19.81034	155.46770	Roadside in cobble 15' off road edge, downhill side	Peanut butter
114	Pu'u Pohaku, base, by weather station	4-10-June-2010	4001	19.82538	155.48994	Cobbly, near slope, almost flat	Peanut butter

Table 1. Alien arthropod sampling locations for the 2010 field season.

Site Number	Locality	Date	Elevation in meters	GPS (N) WGS 84	GPS (W) WGS 84	Habitat	Trap type
114	Pu'u Pohaku, base, by weather station	4-10-June-2010	4001	19.82538	155.48994	Cobbly, near slope, almost flat	Yellow pan
114	Pu'u Pohaku, base, by weather station	4-10-June-2010	4001	19.82538	155.48994	Cobbly, near slope, almost flat	Sticky trap
119	Pu'u Pohaku	4-10-June-2010	4033	19.82432	155.49113	Small boulder, flat inner crater	Peanut butter
119	Pu'u Pohaku	4-10-June-2010	4033	19.82432	155.49113	Small boulder, flat inner crater	Yellow pan
119	Pu'u Pohaku	4-10-June-2010	4033	19.82432	155.49113	Small boulder, flat inner crater	Sticky trap
120	Pu'u Pohaku	4-10-June-2010	4044	19.82454	155.49202	Summit slope, mostly cobble, some small boulders	Peanut butter
Waiau7	Lake Waiau	2-8-June-2010	3990	19.81122	155.47691	Shoreline -Lake Waiau	Sticky trap
Waiau7	Lake Waiau	2-8-June-2010	3990	19.81122	155.47691	Shoreline -Lake Waiau	Peanut butter
Waiau7	Lake Waiau	2-8-June-2010	3990	19.81122	155.47691	Shoreline -Lake Waiau	Pitfall
Waiau7	Lake Waiau	2-8-June-2010	3990	19.81122	155.47691	Shoreline -Lake Waiau	Yellow pan

Table 2. Wēkiu bug trap sites and capture data from the 2010 field season.

Sample Number	Cinder Cone	Date	Elevation in Meters	GPS (N) WGS 84	GPS (W) WGS 84	Wēkiu #'s	Trap Type
009	Pu'u Haukea	2-8-Jun-10	4124.00	19.81455	155.47333	4	Wēkiu bug
010	Pu'u Haukea	2-8-Jun-10	4120.00	19.81463	155.47339	4	Wēkiu bug
011	Pu'u Haukea	2-8-Jun-10	4116.00	19.81436	155.47325	32	Wēkiu bug
012	Pu'u Haukea	2-8-Jun-10	4125.00	19.81426	155.47346	13	Wēkiu bug
013	Pu'u Haukea	2-8-Jun-10	4118.00	19.81383	155.47322	51	Wēkiu bug
014	Pu'u Haukea	2-8-Jun-10	4128.00	19.81365	155.47336	2	Wēkiu bug
015	Pu'u Haukea	2-8-Jun-10	4124.00	19.81323	155.47261	59	Wēkiu bug
016	Pu'u Haukea	2-8-Jun-10	4115.00	19.81342	155.47261	47	Wēkiu bug
017	Pu'u Haukea	2-8-Jun-10	4116.00	19.81383	155.47322	28	Wēkiu bug
018	Pu'u Haukea	2-8-Jun-10	4126.00	19.81368	155.47151	21	Wēkiu bug
019	Pu'u Poliahu	2-8-Jun-10	4149.85	19.82215	155.48135	0	Wēkiu bug
020	Pu'u Poliahu	2-8-Jun-10	4151.68	19.82250	155.48131	0	Wēkiu bug
021	Pu'u Poliahu	2-8-Jun-10	4161.74	19.82272	155.48116	0	Wēkiu bug
022	Pu'u Poliahu	2-8-Jun-10	4160.22	19.82294	155.48088	0	Wēkiu bug
023	Pu'u Poliahu	2-8-Jun-10	4169.66	19.82306	155.47998	1 juvenile	Wēkiu bug
025	Pu'u Hau Oki	3-9-Jun-10	4151.38	19.82608	155.47586	7	Wēkiu bug
026	Pu'u Hau Oki	3-9-Jun-10	4163.57	19.82593	155.47607	15	Wēkiu bug
008	Pu'u Hau Oki	3-9-Jun-10	4144.37	19.82659	155.47549	298	Wēkiu bug
027	Pu'u Hau Oki	3-9-Jun-10	4171.49	19.82659	155.47549	4	Wēkiu bug
028	Pu'u Hau Oki	3-9-Jun-10	4161.74	19.82654	155.47507	44	Wēkiu bug
029	Pu'u Wekiū, inner slope	3-9-Jun-10	4195.57	19.82158	155.46893	46	Wēkiu bug
030	Pu'u Wekiū, outer slope	3-9-Jun-10	4214.16	19.82126	155.46812	9	Wēkiu bug
031	Pu'u Wekiū, nr. tower	3-9-Jun-10	4225.44	19.82054	155.46799	11	Wēkiu bug
032	Pu'u Wekiū, inner slope	3-9-Jun-10	4215.38	19.81999	155.46806	1	Wēkiu bug
033	Pu'u Wekiū, outer slope	3-9-Jun-10	4207.46	19.81913	155.46802	1	Wēkiu bug
034	Pu'u Wekiū, outer slope	3-9-Jun-10	4186.43	19.81848	155.46906	27	Wēkiu bug
035	Pu'u Wekiū, inner crater 2/3 down	3-9-Jun-10	4158.69	19.81917	155.47017	387	Wēkiu bug
036	Pu'u Wekiū, crater floor	3-9-Jun-10	not recorded	19.81927	155.46980	960	Wēkiu bug
037	Pu'u Wekiū	3-9-Jun-10	4177.59	19.82050	155.46971	0	Wēkiu bug
038	Pu'u Wekiū	3-9-Jun-10	4183.38	19.82116	155.46945	0	Wēkiu bug
115	Pu'u Pohaku, base nr. weather station	4-10-Jun-10	4004	19.82538	155.48891	0	Wēkiu bug
116	Pu'u Pohaku, outer slope near drainage	4-10-Jun-10	4026	19.82495	155.49039	0	Wēkiu bug

Table 2. cont. Wēkiu bug trap sites and capture data from the 2010 field season.

Sample Number	Cinder Cone	Date	Elevation in Meters	GPS (N) WGS 84	GPS (W) WGS 84	Wēkiu #'s	Trap Type
117	Pu'u Pohaku, slope adjacent to drainage	4-10-Jun-10	4035	19.82483	155.49059	0	Wēkiu bug
118	Pu'u Pohaku, flat top of Pu'u	4-10-Jun-10	4036	19.82454	155.49078	0	Wēkiu bug
120	Pu'u Pohaku, summit slope	4-10-Jun-10	4044	19.82454	155.49202	0	Wēkiu bug
Poi 121	Poi Bowl - right behind Keck	4-10-Jun-10	4168.00	19.82563	155.47490	1	Wēkiu bug
Poi 122	Poi Bowl	4-10-Jun-10	4153.00	19.82536	155.47479	0	Wēkiu bug
Poi 123	Poi Bowl - mid-way down	4-10-Jun-10	4144.00	19.82502	155.47472	0	Wēkiu bug
Poi 124	Poi Bowl	4-10-Jun-10	4123.00	19.82447	155.47495	1	Wēkiu bug
Poi 125	Poi Bowl	4-10-Jun-10	4105.00	19.82393	155.47501	623	Wēkiu bug
VLBAN 100	Pu'u N. VLBA	3-9-Jun-10	3776.00	19.80279	155.45695	4	Wēkiu bug
VLBAN 101	Pu'u N. VLBA	3-9-Jun-10	3818.00	19.80312	155.45805	1	Wēkiu bug
VLBAN 102	Pu'u N. VLBA	3-9-Jun-10	3860.00	19.80325	155.45695	0	Wēkiu bug
VLBAN 103	Pu'u N. VLBA	3-9-Jun-10	3858.00	19.80358	155.45909	1	Wēkiu bug
VLBAN 104	Pu'u N. VLBA	3-9-Jun-10	3864.00	19.80379	155.45935	0	Wēkiu bug
VLBAS 105	Pu'u S. VLBA	3-9-Jun-10	3770.00	19.79994	155.45564	78	Wēkiu bug
VLBAS 106	Pu'u S. VLBA	3-9-Jun-10	3786.00	19.79963	155.45563	252	Wēkiu bug
VLBAS 107	Pu'u S. VLBA	3-9-Jun-10	3811.00	19.79901	155.45518	9	Wēkiu bug
VLBAS 108	Pu'u S. VLBA	3-9-Jun-10	3809.00	19.79919	155.45558	5	Wēkiu bug
VLBAS 109	Pu'u S. VLBA	3-9-Jun-10	3806.00	19.79904	155.45505	0	Wēkiu bug

Table 3. Summary of 2010 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using shrimp pitfall traps in June 2010.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs visual observation only	Trap Dates	Total Trap Days ¹
Pu‘u Hau Kea	4,128 m	10	261	0	2–8 Jun	60
Pu‘u Hau Oki	4,171.49m	5	368	0	3–9 Jun	30
Pu‘u Wēkiu	4,225.44 m	10	1442	0	3–9 Jun	60
Pu‘u N. VLBA	3,864 m	5	6	0	3–9 Jun	30
Pu‘u S. VLBA	3,811 m	5	344	0	3–9 Jun	30
Pu‘u Pohaku	4,046 m	5	0	0	4–10 Jun	30
Pu‘u Poliahu	4,169.66 m	5	1	0	2–8 Jun	30
Poi Bowl	4,168 m	5	625	0	4–10 Jun	30
Totals		50	3047	0		300

¹Trap days = total nights x total traps per cinder cone.

Table 4. Summary of wēkiu bugs captured at the Pu‘u Hau Kea (within the Natural Area Reserve) cinder cone in Bishop Museum related studies since 2001. Data includes using a combination of glycol and shrimp pitfall data for all years except 2007, 2008, 2009 and 2010 when only shrimp traps were used.

Year and Month when Trapping Occurred	Total Wēkiu bugs	Trap Days	Catch Corrected for Effort (Bugs/Trap Day)
2001 (June) (Polhemus 2001) ¹	473	40	11.8
2002 (Sept)	13	48	0.27
2004 (July)	0	90	0
2005 (April/May)	20	144	0.14
2006 (April/May)	56	80	0.7
2007 (June)	217	78	2.8
2008 (July)	43	60	0.7
2009 (July)	1	60	0.02
2010 (June)	261	60	4.35
			Avg = 2.31

¹Data from Polhemus (2001) was from glycol traps only and results may not be directly comparable to our shrimp traps.

APPENDIX C: ALIEN AND NATIVE ARTHROPOD TABLES 2010

Table 5. Overall species list of native and alien arthropods found during the 2010 field season, specific sites where each taxa were found are listed in main text.

Taxa	Order	Family	Genus-Species-Author	Biogeographic Status: (end/ind adv/pur/unk)	Resident/Aeolian
1	ARANEAE	Corinnidae	<i>Meriola arcifera</i> (Simon, 1886)	adv	Resident
2	ARANEAE	Gnaphosidae	<i>Urozelotes rusticus</i> (L. Koch, 1872)	adv	Resident
3	ARANEAE	Lycosidae	<i>Lycosa hawaiiensis</i> Simon, 1899	end	Resident
4	COLEOPTERA	Carabidae	<i>Agonum muelleri</i> (Herbst, 1784)	adv	Resident
5	COLEOPTERA	Carabidae	<i>Laemostenus complanatus</i> (Dejean, 1828)	adv	Resident
6	COLEOPTERA	Cleridae	<i>Necrobia rufipes</i> (De Geer, 1775)	adv	Aeolian
7	COLEOPTERA	Dermestidae	<i>Dermestes maculates</i> De Geer, 1774	ind	Aeolian
8	COLEOPTERA	Dytiscidae	<i>Rhantus pacificus</i> (Boisduval, 1835)	end	Resident
	COLEOPTERA	Staphylinidae	?Genus ?species	unk	Aeolian
9	DERMAPTERA	Forficulidae	<i>Forficula auricularia</i> Linnaeus, 1758	adv	Resident
10	DIPTERA	Agromyzidae	?Genus ?species	adv	Aeolian
11	DIPTERA	Calliphoridae	<i>Chrysomya megacephala</i> (Fabricius, 1794)	adv	Aeolian
12	DIPTERA	Calliphoridae	<i>Lucilia sericata</i> (Meigen, 1826)	adv	Aeolian
13	DIPTERA	Calliphoridae	?Genus ?species	adv	Aeolian
14	DIPTERA	Ephydriidae	<i>Brachydeutera hebes</i> Cresson, 1926	end	Aeolian
15	DIPTERA	Ephydriidae	<i>Hydrellia tritici</i> Coquillett, 1903	adv	Aeolian
16	DIPTERA	Ephydriidae	?Genus ?species	unk	Aeolian
17	DIPTERA	Muscidae	<i>Atherigona orientalis</i> Schiner, 1868	adv	Aeolian
18	DIPTERA	Muscidae	<i>Stomoxys calcitrans</i> (Linnaeus, 1758)	adv	Aeolian
19	DIPTERA	Muscidae	several species	unk	Aeolian
20	DIPTERA	Phoridae	several species	unk	Aeolian
21	DIPTERA	Sphaeroceridae	<i>Leptocera</i> sp.	adv	Aeolian
22	DIPTERA	Sarcophagidae	several species	unk	Aeolian
23	DIPTERA	Sciaridae	several species	unk	Aeolian
24	DIPTERA	Sepsidae	<i>Sepsis biflexuosa biflexuosa</i> Strobl, 1893	adv	Aeolian
25	DIPTERA	Sepsidae	<i>Sepsis thoracica</i> (Robineau-Desvoidy, 1830)	adv	Aeolian
26	DIPTERA	Sphaeroceridae	several species	unk	Aeolian
27	DIPTERA	Syrphidae	<i>Toxomerus marginatus</i> (Say, 1823)	adv	Aeolian
28	DIPTERA	Tachinidae	several species	adv	Aeolian
29	DIPTERA	Nematocera	indet Fam.	unk	Aeolian
30	HETEROPTERA	Lygaeidae	<i>Graptostethus manillensis</i> Stål, 1859)	adv	Resident - nymph collected
31	HETEROPTERA	Lygaeidae	<i>Geocoris pallens</i> Stål, 1854	adv	Aeolian
32	HETEROPTERA	Lygaeidae	<i>Nysius</i> sp.	end?	Resident
33	HETEROPTERA	Miridae	<i>Coridromius variegates</i> (Montrouzier, 1861)	adv	Resident on 'aweoweo
34	HETEROPTERA	Miridae	<i>Spanagonicus albofasciatus</i> (Reuter, 1907)	adv	Aeolian
35	HOMOPTERA	Psyllidae	? <i>Trioza</i> sp.	end	Aeolian
36	HYMENOPTERA	Braconidae	<i>Apanteles</i> sp.	adv	Aeolian
37	HYMENOPTERA	Chalcidoidea	several species	unk	Aeolian
38	HYMENOPTERA	Colletidae	<i>Hylaeus</i> sp.	end	Resident

Table 5. Cont. Overall species list of native and alien arthropods found during the 2010 field season, specific sites where each taxa were found are listed in main text.

Taxa	Order	Family	Genus-Species-Author	Biogeographic Status: (end/ind adv/pur/unk)	Resident/Aeolian
39	HYMENOPTERA	Ichneumonidae	<i>Diadegma blackburni</i> (Cameron, 1883)	adv	Aeolian
40	HYMENOPTERA	Ichneumonidae	<i>Ichneumon cupitus</i> Cresson, 1877	adv	Aeolian
41	HYMENOPTERA	Ichneumonidae	<i>Ichneumon laetus</i> Brulle, 1846	pur	Aeolian
42	HYMENOPTERA	Ichneumonidae	?Genus ?species	unk	Aeolian
43	HYMEOPTERA	Pompillidae	<i>Anoplius toluca</i> (Cameron, 1893)	adv	Aeolian
44	HYMENOPTERA	Proctotrupoidea	?Genus ?species	adv	Aeolian
45	HYMENOPTERA	Scelionidae	<i>Scelio pembertoni</i> Timberlake, 1932	pur	Aeolian
46	HYMENOPTERA	Scelionidae	?Genus ?species	pur?	Aeolian
47	HYMENOPTERA	Sphecidae	<i>Pison hospes</i> R. Smith, 1879	adv	Aeolian
48	LEPIDOPTERA	Oecophoridae	<i>Thyrocopa kikaelekea</i> Medeiros, 2008	end	Resident
49	LEPIDOPTERA	Noctuidae	<i>Agrotis</i> sp.	end	Resident
50	LITHOBIOMORPHA	Henicopidae	<i>Lamctes</i> cf. <i>emarginatus</i> (Newport 1884)	adv	Resident
51	PSOCOPTERA	Ectopsocidae	<i>Ectopsocus</i> sp.	adv	Aeolian
52	THYSANOPTERA	Phlaeothripidae	?Genus ?species	adv	Aeolian