Results of 2005 Wēkiu Bug (*Nysius wekiuicola*) Surveys on Mauna Kea, Hawai‘i Island

Hawaii Biological Survey

Final Report **March 2006**

RESULTS OF 2005 WĒKIU BUG (*NYSIUS WEKIUICOLA*) SURVEYS

ON MAUNA KEA, HAWAIʻI ISLAND

FINAL REPORT

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EXECUTIVE SUMMARY

This study continues research conducted by the Hawaii Biological Survey of the Bishop Museum beginning in the early 1980s, resuming in 1997, and ongoing since 2002. The objectives of this study were to 1) survey for the presence or absence of wēkiu bugs at the summits of various pu‘u’s (cinder cones) located in the alpine zone of Mauna Kea, 2) determine the elevational and microhabitat distribution of wēkiu bugs on Mauna Kea, 3) assess whether different pitfall trapping methods used in earlier Bishop Museum studies provide comparable data in regard to wēkiu bug captures, 4) assess habitats among different elevations and cinder cone areas, and 5) obtain microhabitat data on wēkiu bug habitat using temperature and relative humidity loggers.

In 2005, surveys for wēkiu bug distribution and abundance at the summit area of Mauna Kea occurred in May and June, while data loggers recording microhabitat parameters such as relative humidity and temperature were installed in December 2004 and data downloaded June 2005. A wide range of areas were surveyed, including several important areas that were previously unsampled, including the area above the Pu‘u Lā‘au cabin in the western summit region, and Pu‘u Lilinoe. Sampling effort in 2005 was the highest to date of the recent studies, with 529 trap days in May and 382 trap days in June, for a total effort of 911 trap days. This compares to 274 trap days in 2004 and 398 trap days in 2002.

Important discoveries in 2005 included the finding of a new core wēkiu bug population at Pu‘u Lilinoe and the rediscovery of a large population at Pu‘u Poliahu. While both the shrimp pitfall and older style ethylene glycol traps were found to have limitations during the present study, collections of wēkiu bugs through visual observations around areas of snowbanks proved exceedingly successful. For example, as many wēkiu bugs were collected during 20 minutes of visual observations at the summit of Pu‘u Hau Kea as compared to 9 days of trapping at this cinder cone. The long-term test of trapping efficiency continued to determine whether data from shrimp pitfall traps presently used can be compared to data collected in the original 1982 study using ethylene glycol traps. Although the results remain generally inconclusive, it is apparent that glycol traps attract wēkiu bugs in a very efficient manner under certain cases of reduced snow pack, such as in the late spring. On the other hand, there appears to be little difference in trap efficiency such as in May 2005 when a large snowpack was available, or in other seasons having low wēkiu bug abundance such as in the warm and dry July 2004.

This year marked the first time wēkiu bug distribution and temperature patterns at various areas within the Mauna Kea summit were examined. Logger data indicated the summit area is marked by low mean temperatures, wide surface temperature variations, and long periods of ice and snow resulting in much less variation. A transect of loggers at various positions on Puʻu Hau Kea indicated that the bottom area of this cinder cone has much lower temperatures than are found at the summit regions. Preliminary findings from the data loggers indicate that wēkiu bugs may seek areas of thermal stability, such as the summit areas with long-lasting snowbanks. The spring months when wēkiu bugs are most active exhibited dramatic daily temperature shifts, with temperatures dropping below freezing on a nightly basis.

INTRODUCTION

The Hawaii Biological Survey of the Bishop Museum was contracted by the Office of Mauna Kea Management (OMKM) to study the distribution and habitat use of the wēkiu bug (*Nysius wekiuicola* Ashlock and Gagné), which is endemic to the Mauna Kea summit area. The current study continues Bishop Museum 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, Englund *et al.* 2005). To ensure the continued survival of this species, OMKM was interested in obtaining further information regarding wēkiu bugs in the alpine zone of Mauna Kea because so little is known about their life history, population status, and habitat requirements.

The objectives of this study were to 1) survey for the presence or absence of wēkiu bugs at the summits of various pu'u's (cinder cones) located in the alpine zone of Mauna Kea, 2) determine the elevational and microhabitat distribution of wēkiu bugs on Mauna Kea, 3) assess whether different pitfall trapping methods used in earlier Bishop Museum studies provide comparable data in regard to wēkiu bug captures, 4) assess habitats among different elevations and cinder cone areas, and 5) obtain microhabitat data in wēkiu bug habitat using temperature and relative humidity loggers.

The earliest Bishop Museum wēkiu bug studies were concentrated directly around the astronomical observatories (Gagné and Howarth 1982, Howarth and Stone 1982), while later surveys (Howarth *et al.* 1999) also examined areas in the Mauna Kea Science Reserve. Because the Mauna Kea summit region is such a remote and difficult to access area, little information was available regarding the overall elevational range and distribution of the wēkiu bug throughout the entire alpine zone. Thus, emphasis was placed on surveying previously unsampled and remote cinder cone areas during the current study. The results provided valuable new information on wēkiu bug seasonality, microhabitat climate data, geological preferences, and overall range on Mauna Kea. This information will assist in conserving and managing this rare species.

Wēkiu bug surveys for this study occurred in May and June 2005 and a wide range of elevations were assessed, ranging from a low of 11,180 ft (3,402 m) at the unnamed pu'u in the northwestern summit area to a high of 13,796 ft (4,200 m) at Pu'u Wēkiu. To assess the effectiveness of current and previous (Howarth and Stone 1982) trapping methods on wēkiu bug capture rates, Pu'u Hau Kea was sampled both in May and June 2005 using current and previous capture methods. This long-running test of trap efficiency has been conducted since 2002 (Englund *et al.* 2002) and will continue in 2006. Results from these tests are beginning to provide some answers as to whether results from the Howarth and Stone (1982) study can be realistically compared to more recent studies with different trapping methodologies.

The collection of temperature and relative humidity microhabitat physical data was important to provide more information on wēkiu bug life history and was collected from: A) areas known to have high wēkiu bug densities, B) areas that have been disturbed by development that were previously known to have high wēkiu densities, C) areas adjacent to known high quality habitats that have been shown to lack wēkiu bugs. A total of 45 data loggers were installed in December 2004 throughout the summit area, with data downloaded from these loggers downloaded in June 2005.

Geology and substrate type appear to have an important if not overriding influence on wēkiu bug distribution within the summit of Mauna Kea, and because of this it was imperative to collaborate with a qualified geologist familiar with the summit region. In 2005 Stephen Porter of the University of Washington accompanied team members in the field in attempts to ascertain whether wēkiu bugs actually have patterns of using specific types of geological formations, or whether their distributions are related to the underlying geology at the summit. This was the first time geologists have collaborated with entomologists during wēkiu bug studies, and the results may prove to be valuable in the conservation and maintenance of wēkiu bug populations in the future. These geological findings related to wēkiu bug habitat will soon be released in a separate Bishop Museum report.

STUDY AREA

The overall study area has been thoroughly described in previous Bishop Museum reports and this can be found in Howarth *et al.* (1982), Howarth *et al.* (1999), and Englund *et al.* (2002, 2005). The study area encompassed portions of the alpine zone of the Mauna Kea volcano (Figures 1-5), 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 9,600 ft (2,925 m). Elevations sampled using pitfall traps during the 2005 fieldwork study ranged from a maximum of 13,570 ft (4,137 m) at the Poi Bowl area below the Keck Observatory, to a low of 11,180 ft (3,402 m) in the northwestern summit area. Visual observations were made throughout the study area while hiking between sampling points.

Some of the most remote areas of the Mauna Kea summit were sampled for the first time in 2005, with the northwestern summit area above the Puʻu Lāʻau cabin receiving considerable collection efforts. This group of cinder cones have elevations ranging up to 11,672 ft (3,558 m), and were well within the wēkiu bugs known elevational range but had not been previously sampled because of the difficulty in accessing this area. Twenty pitfall traps ran in transects starting at the base of cinder cones.

Unless otherwise stated, puʻu names were derived from USGS topographic quad maps. WGS 84 datum was used for recording GPS locations. Many puʻu's 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 rather 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 and a handheld Suunto altimeter calibrated daily at Hale Pohaku.

METHODS

Wēkiu Bug Sampling

Sampling methodology consisted of three techniques: timed visual surveys mainly around snowbank areas, baited shrimp pitfall traps, and ethylene glycol pitfall traps. In May 2005, the main areas with snow that were sampled were Puʻu's Hau Kea, Poliahu, Horseshoe Crater, and a small patch at Puʻu's Wēkiu and Pohaku, and everywhere else lacked snow. The snow had almost completely melted by June except at Puʻu's Polihau and Hau Kea. A detailed explanation of techniques for shrimp and ethylene glycol pitfall traps used in this study can be found in Englund *et al.* (2002). Individual pitfall trap locations were recorded with GPS (WGS 84 datum), as were locations where wēkiu bugs were visually observed. As in the 2002 and 2004 Bishop Museum studies, an efficiency test of the two main types of pitfall traps used in wēkiu bug surveys was conducted both in May and June 2005. The detailed protocol for the trap efficiency test can be found in Englund *et al.* (2002). To ensure sampling was not just selective for known good wēkiu bug habitats, pitfall traps were placed in a wide range of putatively suboptimal habitats, as well as potential habitat. Locations, elevations, cinder cone area and trap type can be found in Tables 1 and 2 for the May and June sampling. A total of 5 glycol and 5 shrimp pitfall traps were placed at Puʻu Hau Kea for 9 days in the months of May and June, 2005 (Tables 1 and 2).

Temperature/Relative Humidity Probes

To obtain wēkiu bug microhabitat data in a wide variety of known and nearby suboptimal habitats (e.g., glaciated regions between cinder cones) 45 HOBO® Pro RH/Temp (Model H08-032-08) temperature probes were placed near the surface and buried 10 in (25 cm) into the substrate. These loggers record and store relative humidity and temperature data for a period of up to three years. It was necessary to provide a housing for the loggers to protect against contracting, expanding, and shifting substrates in the harsh environment of the Mauna Kea summit area. Following tests of various protective cases during the preceding study, pvc pipe caps with ventilation holes drilled in them were deemed to have the best protective qualities (Englund *et al.* 2005). The pvc cap fit snugly around the loggers, and was connected with stainless steel wire to protect the humidity sensor and prevent direct contact with the ground. Holes drilled in the cap also allowed drainage of any rainwater or snowmelt and provided air circulation. In areas of known wēkiu bug habitat (such as the summit of Puʻu Hau Kea or Puʻu Lilinoe) the loggers were placed in the exact locality where individual wēkiu bugs were observed or collected.

In December 2004, paired loggers were placed just below the surface and covered with local substrate, and also buried approximately 10 inches below the surface. Loggers were connected by approximately 3 ft (1 m) of stainless steel wire (also with flagging tape attached) to make future retrieval easier, as finding loggers was quite difficult because of their small size and high altitude effects (on researchers) within the study area.

A total of 9 pairs of loggers (18 total) were placed in a transect at Puʻu Hau Kea running through the summit cone area (Figure 4), starting at the bottom of the northwest rim and extending in a southeasterly direction into the cinder cone and down the slope to the bottom of the Puʻu Hau Kea cinder cone. These loggers recorded conditions within the Puʻu Hau Kea crater and outermost slopes, an area with some of the highest known wekiu bug densities on Mauna Kea (Englund *et al.* 2002). Each logger pair consisted of one surface and one buried in the cinder to approximately 10-12 in (25-30 cm). Loggers were placed in a wide variety of other locations, in areas known to support high wēkiu bug densities, and areas where the bugs are normally not captured (Figure 3).

Statistical Analysis for Temperature/Relative Humidity Data

After temperature data were downloaded from the loggers to an excel spreadsheet, data were summarized and graphs and statistics were done with Sigma Plot version 9.0. We reduced the number of points per day (decreased the resolution) from 96 points per day (from 1 data point recording every 15 minutes) to 6 temperature/relative humidity points per day (1 every 4 hours) to better visualize and analyze the data. By doing this the general trends in the data remained the same.

Plots were made that encompassed all surface and subsurface data points with relative humidity and temperature plots having 2 data points per day that were taken at 12 am and 12 pm. These plots are shown in Figures 12–13 and 18–19. To assess the long-term temperature regime at each locality with a working logger, linear regressions of date and temperature, and date and relative humidity were made (Figures 8–11, 14-17, 20–28). The regression plots have six data points per day, with one taken every 4 hours, i.e., at 12:00 pm, 4:00 am, 8:00 am, 12:00 am. The dashed red line on the regression charts is the prediction interval that encompasses 95% of the data points.

At Puʻu Hau Kea a transect of 18 surface and sub loggers placed at regular intervals up the sides of the cinder cone, down into the pit crater, and down the other side of the cone was made. Data from surface and subsurface loggers were graphed together and the combined mean (mean of all of the plots throughout the graph) superimposed on them (Figures 12–13 and 18–19). These were then graphed separately as dot plots with regression values, with the dashed red line representing the mean value of the loggers combined for each value.

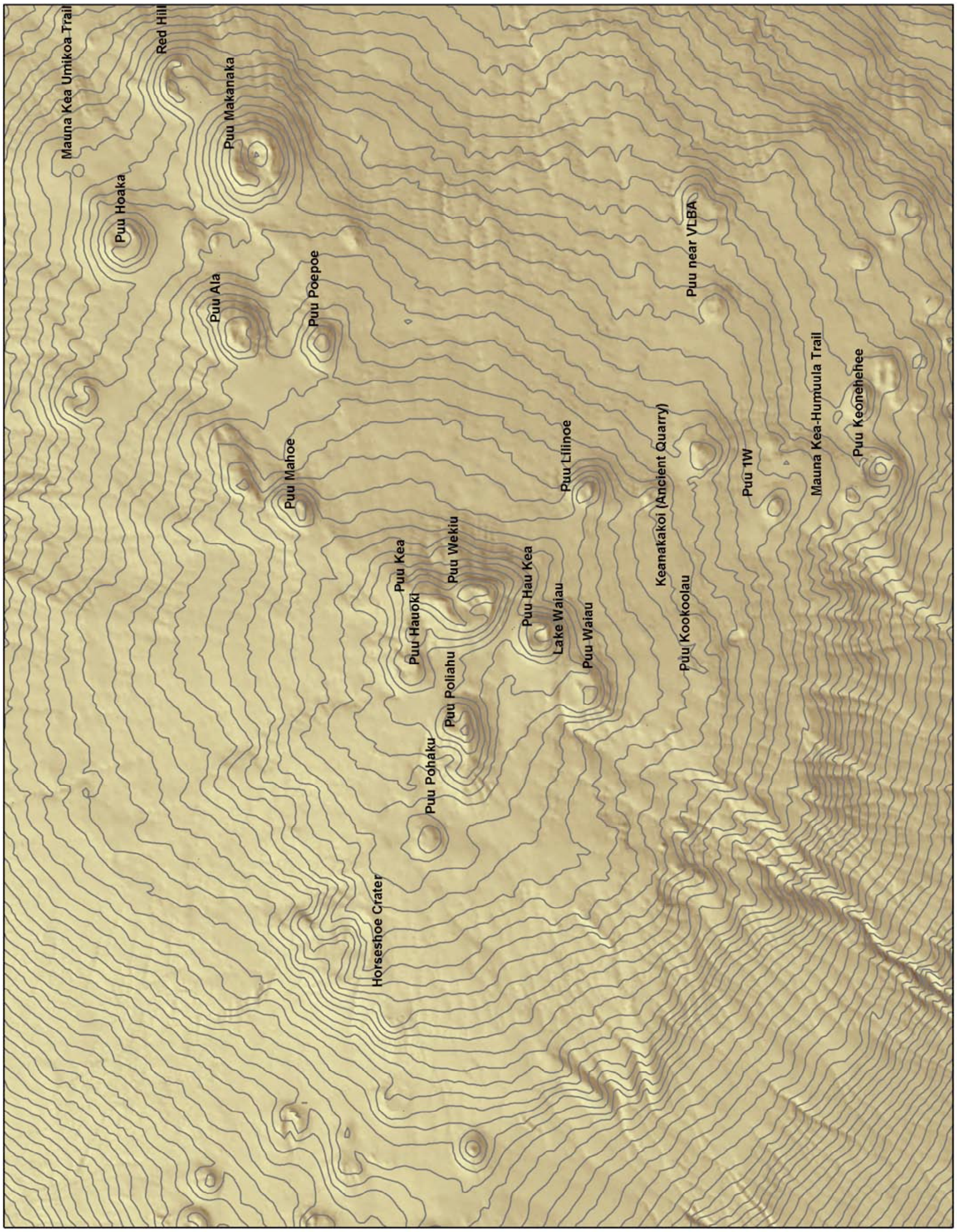

Figure 1. Overall study area and wēkiu bug sampling sites, and GPS waypoints at sample sites for 2005.

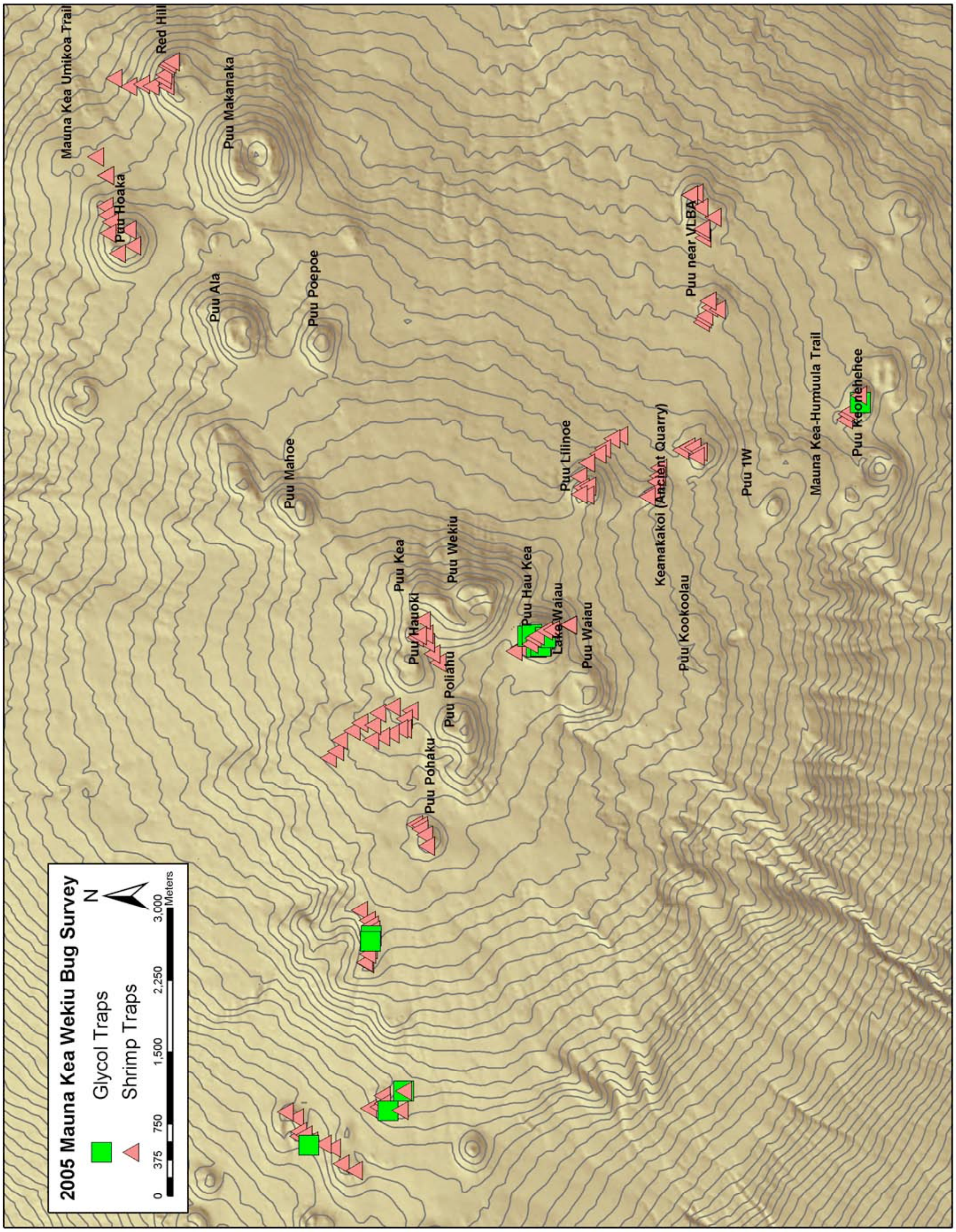

Figure 2. Overall study area and wēkiu bug sampling sites, and GPS waypoints at sample sites for 2005.

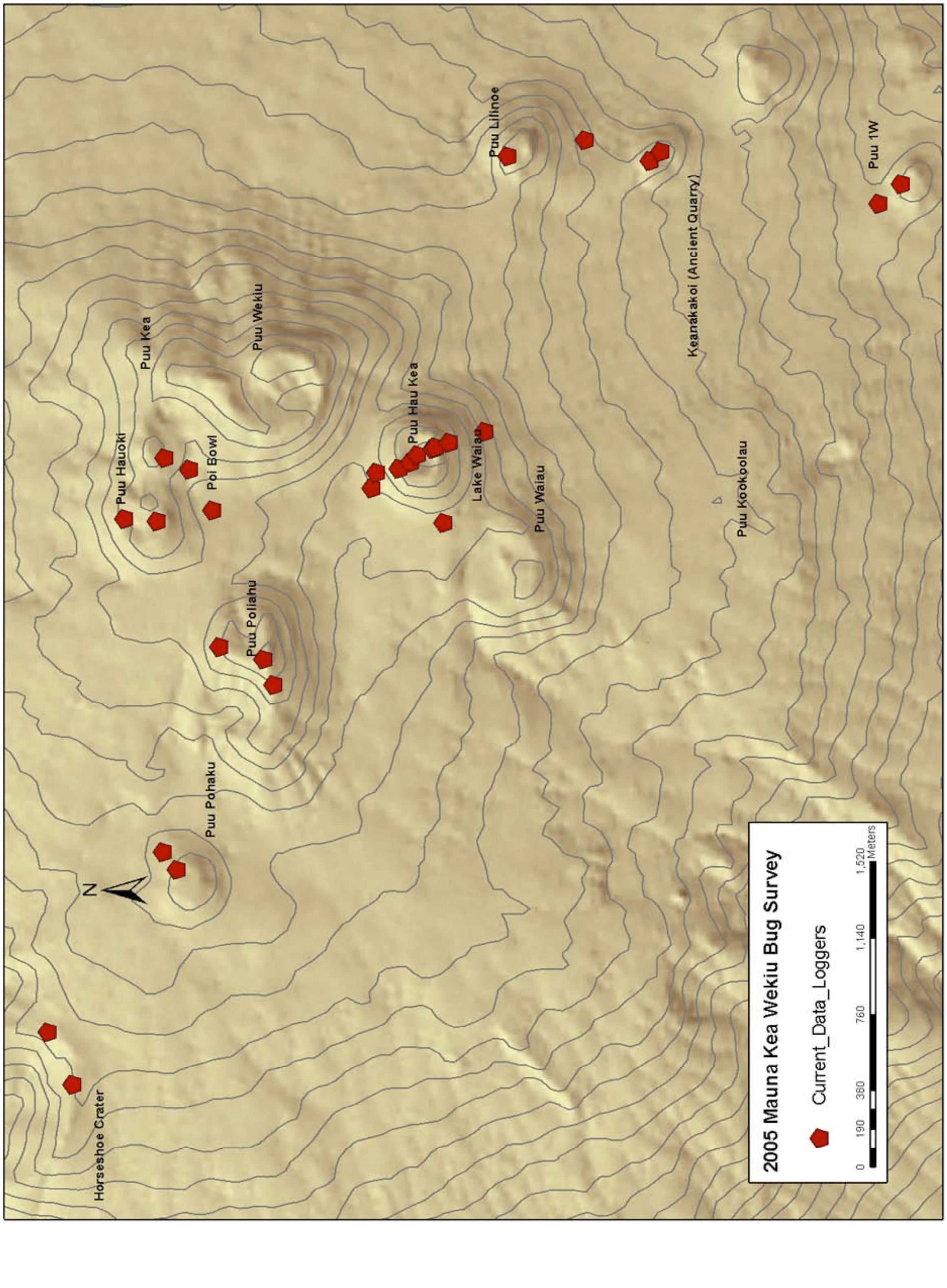

Figure 3. Temperature/Relative Humidity Data Loggers currently collecting data at the summit of Mauna Kea.

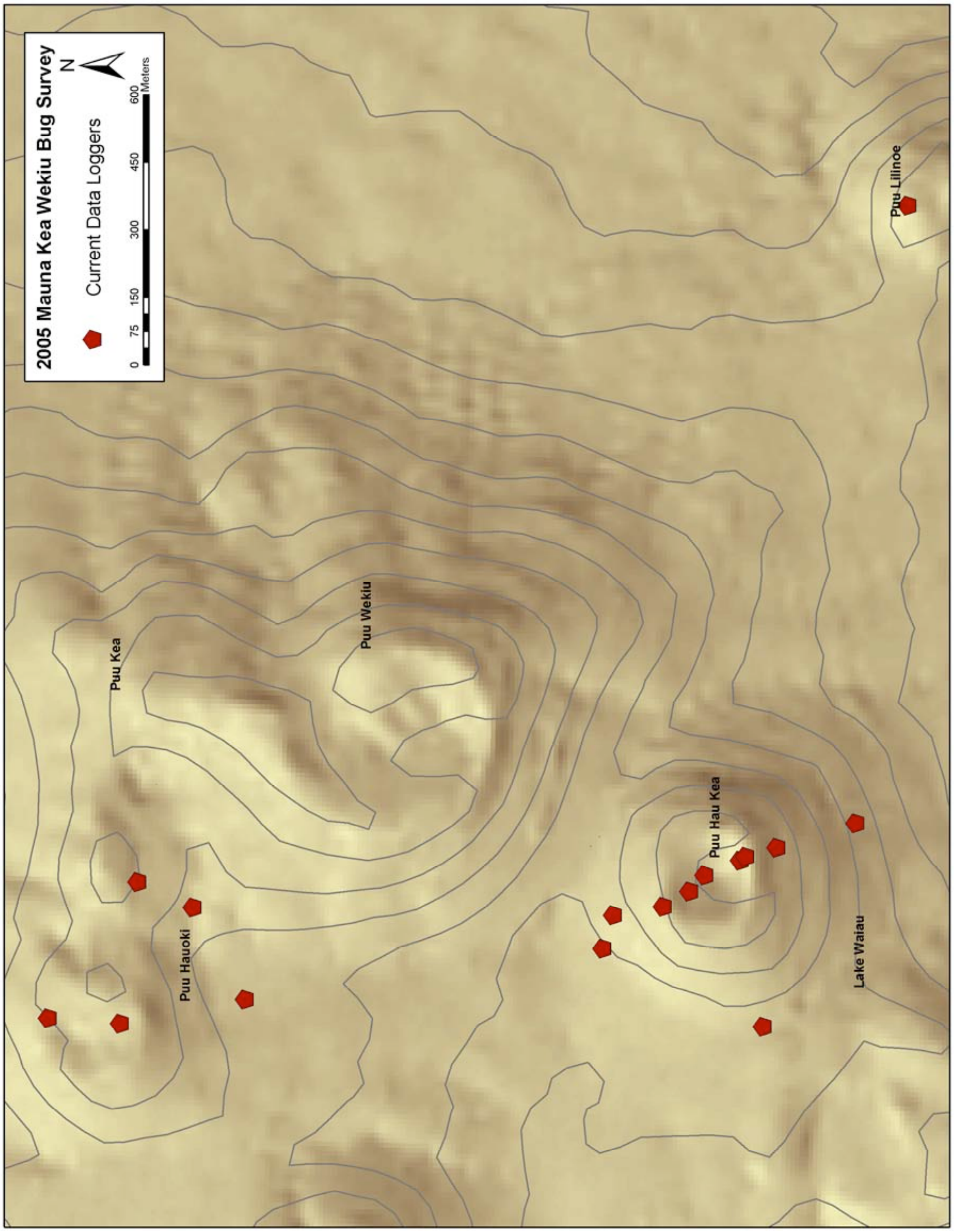

Figure 4. Close-up of Temperature/Relative Humidity Data Loggers currently collecting data, showing the paired surface/subsurface logger transect at Pu'u Hau Kea

RESULTS AND DISCUSSION

In 2005, the study period included two trips of 10 field days each in May and early June, and one four day trip in late December to download and reinstall relative humidity and temperature loggers. Tables 1 and 2 summarize trap locations by cinder cone, elevation, date set, trap type, and gps coordinates. Overall sample effort was 90 shrimp and ethylene glycol pitfall traps emplaced in May and 63 in June, for a total of 153 traps. Summaries of the numbers of wēkiu bugs either observed or collected during 2005, and sample effort can be found in Tables 4-6. Sample effort is defined by total trap days, which are the number of nights each baited shrimp or ethylene glycol pitfall trap was operating. Pitfall trap effort in 2005 was quite high, with 529 trap days in May and 382 trap days in June, for a total effort of 911 trap days. This compares to 274 trap days in 2004 (Englund *et al.* 2005) and 398 trap days in 2002 (Englund *et al.* 2002).

Trap Placements in Study Area

A total of 153 pitfall traps, built and emplaced according to protocols discussed in the Methods section, were set in various cinder cone areas at elevations from 11,180 ft (3,402 m) to 13,570 ft (4,137 m) during fieldwork in May and June 2005 (Tables 1 and 2). Sampled areas included the western summit of Mauna Kea above the Puʻu Lāʻau cabin, Puʻu Lilinoe and the cinder cones surrounding it, Puʻu Pohaku and a very large unnamed crater ("Horseshoe Crater") downslope of it. We also intensively sampled the plateau where a 30 m large telescope has been proposed (northeast of Puʻu Poliahu), and the skiing area called "Poi Bowl" that is downslope of Puʻu Hau Oki and the Keck Observatory. A comparative test of pitfall trapping efficiency between shrimp pitfall traps and ethylene glycol traps occurred at Puʻu Hau Kea with traps placed around the uppermost portion of the northern slope on the rim, and on the inside slopes in windy areas receiving large amounts of aeolian drift.

Wēkiu Bug Collections and Trapping Effectiveness

A total of 70 wēkiu bugs were observed or collected during the 2005 study, with nearly equal amounts of bugs collected in traps in May (17) and June (16), compared to 37 total wēkiu bugs collected during visual observations in 2005 (Tables 5 and 6). Likely resulting from seasonal factors, many more wēkiu bugs were collected and observed in 2005 when sampling occurred in the springtime (May and early June), as compared to only one individual collected or observed during the entire sampling period of summer 2004 (July). Far more wēkiu bugs were observed, and more could have been collected during visual collections along snowbanks at the summit of Puʻu Hau Kea in May and Puʻu Poliahu in June, but it was decided to stop collections after we succeeded in finding large numbers of wēkiu bugs during the brief 15-20 minute timed trials at these snowbanks. The large number of wēkiu bugs collected in a very short time period during visual observations at Puʻu Hau Kea in May also indicate populations there remain robust. Wēkiu bugs have apparently not been impacted from pitfall sampling conducted at Puʻu Hau Kea in previous studies, such as in June 2001 when 473 were collected in pitfall traps in only 4 days (Polhemus 2001, found in Englund *et al.* 2002).

As in previous studies, wēkiu bugs had a clear preference for cinder cone areas, and were never captured in glacial floor areas between cinder cones. For example, a total of 15 shrimp pitfall traps were placed in the general area of the glaciated plateau region where a 30 m telescope facility has recently been proposed (Table 1), and wēkiu bugs were not captured or observed in this area. Other high elevation areas close to prime wēkiu bug habitat (but also glaciated) such as the Poi Bowl area also lacked bugs, while they were relatively common in undeveloped cinder cone areas such as Puʻu Hau Kea and Puʻu Poliahu.

Both the shrimp and glycol pitfall traps were quite ineffective under certain conditions, especially when compared to visual collections along snow banks (Tables 4-6). Trap efficiency tests were conducted at a known favored wekiu bug habitat at the summit of Puʻu Hau Kea using glycol and live traps in May and June, 2005. In May, all traps were placed within 1-1.5 ft (0.3-0.5 m) away from a large snowbank [see photos of this snowbank in the Ethylene Glycol versus Shrimp Paste Pitfall Trapping Test section] both on the uphill and downhill side of the snowbank. In May, the glycol and shrimp pitfall traps, and several other shrimp traps located away from the trap efficiency testing site collected only 11 wēkiu bugs over 10 days, and this compares with visual collections of 13 bugs around these traps in approximately 20 minutes.

In June 2005, a large number of wēkiu bugs were also collected at Puʻu Poliahu below a snowbank, with 16 individuals collected in 30 minutes. Many more could have been collected, but we stopped after this large sample size was found. These results indicate that visual collections along melting snowbanks in the proper habitat can be exceedingly effective in determining wekiu bug presence, more so than current or previous trap designs. Visual collections were even effective in areas with no snow, such as Puʻu Lilinoe (1 bug collected in May) and Puʻu Wēkiu (3 bugs collected in June). Because both wēkiu bugs and snowbanks have a patchy distribution, surveying along the edge of snowbanks will continue to be important, but will continue to have limited utility in assessing wēkiu bug distribution and population status. The important point is that both types of pitfall traps may be quite ineffective under certain circumstances, and that an effective sampling plan needs to employ a diverse methodology. Of greatest importance is observers remaining vigilant for wēkiu bugs anytime they are at the Mauna Kea summit, in spite of the altitude effects.

Although elevations from 11,180 ft (3,402 m) to 13,796 ft (4,200 m) were assessed in 2005, the average elevation of wēkiu bug capture for both visual and pitfall trap sampling combined was 13,410 ft (4,088 m). This average was determined from the elevation on each cinder cone where wēkiu bugs were observed or collected, as shown in Table 3. In 2005, wēkiu bug captures ranged from a low elevation of 12,798 ft (3,810 m) at Pu‘u Lilinoe to a high of 13,765 ft (4,196 m) at Pu‘u Wēkiu. Once again, the vast majority of wēkiu bug collections came from areas near or at the summit of an individual cinder cone with just a few collected lower down at the base of the cinder cone.

Important findings of the present study included a new population at Pu‘u Lilinoe and the collection of wēkiu bugs on Pu‘u Poliahu for first time since 1982. The Pu‘u Lilinoe population represents a significant expansion of wēkiu bug habitat, and they were collected at the relatively low elevation of 12,798 ft (3,810 m). In 1982, only 8 individual bugs were collected at Pu‘u Poliahu despite thousands of wēkiu bugs collected at traps elsewhere on the summit during the same time frame of the original Howarth and Stone (1982) study. It is then of great interest to contrast the relatively high numbers of wēkiu bugs found on 5 June 2005 at Pu‘u Polihau compared to the low numbers captured in 1982, and discuss habitat conditions at where the bugs where found. A snowpack 246-330 ft (75-100 m) long, located on the northeastern side of Pu‘u Poliahu was the likely reason this area had high wēkiu bug captures in June 2005. Located at 13,613 ft (4,150 m) elevation (and close to surface temperature/relative humidity logger #754793), the snowpack at the summit of Pu‘u Poliahu was 15-18 ft (5-6 m) wide and up to 4 ft (1.5 m) in depth, with indentations or scallops along its length (see photos below). The ease of collecting wēkiu bugs appeared to result from them being concentrated around the rapidly melting snowpack which was heavily laden with aeolian drift. Wēkiu bugs were collected on very wet substrate within 8-24 in (20-60 cm) of the snowpacks edge. Surface substrate consisted of an even mix of 50% gravel and 50% cobble, but was in a surprisingly thin layer 1-3 in (3-8 cm) (see Poliahu photos of 5 June 2005). Just below this thin surface layer was a fine-ashy substrate that at the surface was very wet from the melting snow but frozen just below. The fine substrate around the snowbank area of high wēkiu bug capture did not appear to offer suitable refugia for the nighttime freezing temperatures compared to areas with larger and deeper cinder cobbles, as the saturated soil at the surface where the bugs were captured on freezes solid on a nightly basis. In places, the snowbank was an estimated 30–50 m away from thicker, larger cinder substrate that could possibly serve as nighttime refugia. Because they move quite rapidly while foraging (from our observations), it is possible that the bugs move on a diurnal basis between this relatively fine-ashy substrate along the melting snowbank to nearby areas on Pu‘u Poliahu with deeper cinder substrate.

Snowbank (left) and substrate (below) on Pu‘u Poliahu, 5 June 2005

A total of 16 wēkiu bugs were collected in only 30 minutes by two observers on Pu‘u Poliahu and after that the timed collection trial was halted, although many more were observed. Only 8 individuals were collected on Pu‘u Polihau during the nearly month long trapping effort in 1982 (Howarth and Stone 1982), in contrast to thousands of bugs collected on adjacent cinder cones during that study at the same time. The present finding of high numbers in 2005 provides evidence that this cinder cone has an important core population of wēkiu bugs, albeit with populations fluctuating from year to year.

A significant population of wēkiu bugs was found at the previously unsampled Pu‘u Lilinoe, and although this area was sampled only over a three-day period in May 2005 we collected 3 adults and 2 nymphs in live traps, and one visually. As the snowpack had already completely melted at Pu‘u Lilinoe, prey was not concentrated as at the Pu‘u Hau Kea or Pu‘u Poliahu snowbanks. In May 2005 we collected 5 wēkiu bugs at Pu‘u Lilinoe in only 30 trap days, as compared to 144 trap days and finding 7 bugs in the Pu‘u Hau Kea pitfall traps (Table 5). Pu‘u Lilinoe is one of the steepest cones with shifting cinders to over 3 ft (1 m) thick on its slopes, and our results indicate it contains a robust population. The Pu‘u Lilinoe area is an important expansion of the known core wēkiu bug habitat.

For the first time the area around the very large, unnamed crater (“Horseshoe Crater”) beyond Pu‘u Pohaku was intensively sampled in 2005. This area contained an approximately 820 ft (250 m) long, 15-20 ft (5-6 m) wide snowbank (up to 5 ft/1.75 m deep) in May. High concentrations of dead aeolian insects were found on the snowpack indicating potentially good wēkiu bug habitat conditions. Because this area appeared to have such promising wekiu bug habitat, permission was obtained to place and leave 2 glycol traps in place near the snowbank at the end of our May trip, and pull them upon on our return in June 2005. Additionally, extra bait was left around these traps in hopes of attracting the bugs, but upon checking the traps in June no wēkiu bugs were found. The lack of wēkiu bug collections at the Horseshoe Crater area in glycol traps (and during visual observations) along this major snowpack indicate the presence of a large and stable food source by itself is not enough to attract wēkiu bugs, but that geological considerations also determine whether the habitat is suitable. In 2005, we increased our use of glycol traps to help us verify the presence or absence of wekiu bugs in various areas that we sampled, such as at the cinder cones above the Pu’u Lā‘au cabin. With the exception of the month-long glycol trap effort at the Horseshoe Crater area, all glycol traps were left out the same amount of time as the live traps.

The lowest elevational record of any wēkiu bug capture so far was at a cinder cone beyond the VLBA, at an elevation of 11,715 ft (3,572 m) in 2002 (Englund *et al.* 2002). Because of this low elevation, many outlying and unsampled cinder cones may have suitable bug habitat. At least 6 large cinder cones in the western summit area (upslope of the Pu‘u Lā‘au cabin and down gradient from Pu‘u Pohaku and the ‘Horseshoe Crater’) appeared to have promising wēkiu bug habitat when viewed from the summit of Pu‘u Pohaku. As cinder cones in this area had maximum elevations of at least 11,672 ft (3,558 m) which were well within the known range of the wēkiu bug, this remote region of the Mauna Kea summit was sampled in 2005 for the first time. These cinder cones are unnamed on the USGS topo maps, but several of them have elevations published at their high points. A total of 20 pitfall traps were installed in suitable habitat in transects running up and down the cinder cones, with several

Table 1. Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in May 2005 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2005 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Hau Kea	1s	2–11 May	4,114 m	19.81489°N 155.47252°W	Shrimp
Pu‘u Hau Kea	2s	2–11 May	4,107 m	19.81447°N 155.47328°W	Shrimp
Pu‘u Hau Kea	3s	2–11 May	4,116 m	19.81410°N 155.47348°W	Shrimp
Pu‘u Hau Kea	4s	2–11 May	4,118 m	19.81363°N 155.47339°W	Shrimp
Pu‘u Hau Kea	5s	2–11 May	4,113 m	19.81332°N 155.47272°W	Shrimp
Pu‘u Hau Kea	1g	2–11 May	4,114 m	19.81489°N 155.47252°W	Glycol
Pu‘u Hau Kea	2g	2–11 May	4,107 m	19.81447°N 155.47328°W	Glycol
Pu‘u Hau Kea	3g	2–11 May	4,116 m	19.81410°N 155.47348°W	Glycol
Pu‘u Hau Kea	4g	2–11 May	4,118 m	19.81363°N 155.47339°W	Glycol
Pu‘u Hau Kea	5g	2–11 May	4,113 m	19.81332°N 155.47272°W	Glycol
Pu‘u Hau Kea	1	2–11 May	4,094 m	19.81413°N 155.47243°W	Shrimp
Pu‘u Hau Kea	2	2–11 May	4,126 m	19.81331°N 155.47206°W	Shrimp
Pu‘u Hau Kea	3	2–11 May	4,096 m	19.81269°N 155.47188°W	Shrimp
Pu‘u Hau Kea	4	2–11 May	4,006 m	19.81112°N 155.47139°W	Shrimp
Pu‘u Hau Kea	5	2–11 May	4,102 m	19°48'53.0"N 155°28'23.5"W	Shrimp
Pu‘u Hau Kea	6	2–11 May	4,089 m	19°48'52.0"N 155°28'21.9"W	Shrimp
Pu‘u Hau Kea	7	2–11 May	4,057 m	19°48'56.7"N 155°28'24.7"W	Shrimp
Pu‘u Hau Kea	8	2–11 May	4,034 m	19°48'58.2"N 155°28'25.9"W	Shrimp
Red Hill	9	3-6 May	3,421 m	19.85361°N 155.42012°W	Shrimp
Red Hill	10	3-6 May	3,479 m	19.85223°N 155.42088°W	Shrimp
Red Hill	11	3-6 May	3,521 m	19.85100°N 155.42067°W	Shrimp
Red Hill	12	3-6 May	3,558 m	19.85015°N 155.42085°W	Shrimp
Red Hill	13	3-6 May	3,645 m	19.84874°N 155.42082°W	Shrimp
Red Hill	14	3-6 May	3,632 m	19.84901°N 155.42024°W	Shrimp
Red Hill	15	3-6 May	3,627 m	19.84893°N 155.41978°W	Shrimp
Red Hill	16	3-6 May	3,609 m	19.84873°N 155.41896°W	Shrimp
Red Hill	17	3-6 May	3,605 m	19.84857°N 155.41876°W	Shrimp
Red Hill	18	3-6 May	3,605 m	19.84823°N 155.41856°W	Shrimp
Pu‘u Hoaka	19	3-6 May	3,507 m	19.85534°N 155.42747°W	Shrimp
Pu‘u Hoaka	20	3-6 May	3,528 m	19.85440°N 155.42920°W	Shrimp
Pu‘u Hoaka	21	3-6 May	3,572 m	19.85439°N 155.42920°W	Shrimp
Pu‘u Hoaka	22	3-6 May	3,599 m	19.85443°N 155.43210°W	Shrimp
Pu‘u Hoaka	23	3-6 May	3,622 m	19.85430°N 155.43291°W	Shrimp
Pu‘u Hoaka	24	3-6 May	3,650 m	19.85393°N 155.43358°W	Shrimp
Pu‘u Hoaka	25	3-6 May	3,680 m	19.85228°N 155.43431°W	Shrimp
Pu‘u Hoaka	26	3-6 May	3,697 m	19.85185°N 155.43578°W	Shrimp
Pu‘u Hoaka	27	3-6 May	3,694 m	19.85327°N 155.43652°W	Shrimp
Pu‘u Hoaka	28	3-6 May	3,679 m	19.85414°N 155.43462°W	Shrimp
Below Submillimeter Array	29	4-11 May	4,087 m	19.82588°N 155.47943°W	Shrimp
Below Submillimeter Array	30	4-11 May	4,081 m	19.82645°N 155.48022°W	Shrimp
Below Submillimeter Array	31	4-11 May	4,074 m	19.82651°N 155.48112°W	Shrimp
Below Submillimeter Array	32	4-11 May	4,073 m	19.82686°N 155.48112°W	Shrimp

Table 1 (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys. conducted in May 2005 (altitudes taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2005 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Below Submillimeter Array	33	4-11 May	4,067 m	19.82767°N 155.4+8157°W	Shrimp
Below Submillimeter Array	34	4-11 May	4,064 m	19.82856°N 155.48183°W	Shrimp
Below Submillimeter Array	35	4-11 May	4,052 m	19.82958°N 155.48218°W	Shrimp
Pu‘u Pohaku	36	4-12 May	4,009 m	19.82548°N 155.49011°W	Shrimp
Pu‘u Pohaku	37	4-12 May	4,018 m	19.82500°N 155.49016°W	Shrimp
Pu‘u Pohaku	38	4-12 May	4,027 m	19.82497°N 155.49054°W	Shrimp
Pu‘u Pohaku	39	4-12 May	4,038 m	19.82455°N 155.49109°W	Shrimp
Pu‘u Pohaku	40	4-12 May	4,049 m	19.82434°N 155.49211°W	Shrimp
Horseshoe Crater	41	4-12 May	3,917 m	19.83063°N 155.49815°W	Shrimp
Horseshoe Crater	42	4-12 May	3,921 m	19.82991°N 155.49910°W	Shrimp
Horseshoe Crater	43	4-12 May	3,918 m	19.82962°N 155.49953°W	Shrimp
Horseshoe Crater	44	4-12 May	3,910 m	19.82946°N 155.49998°W	Shrimp
Horseshoe Crater	45	4-12 May	3,914 m	19.82953°N 155.50050°W	Shrimp
Horseshoe Crater	46	12 May-8 June	3,914 m	19.82953°N 155.50050°W	Glycol
Horseshoe Crater	47	4-12 May	3,906 m	19.82973°N 155.50179°W	Shrimp
Horseshoe Crater	48	4-12 May	3,889 m	19.83004°N 155.50311°W	Shrimp
Horseshoe Crater	49	4-12 May	3,875 m	19.83016°N 155.50301°W	Shrimp
Horseshoe Crater	50	4-12 May	3,891 m	19.82985°N 155.50221°W	Shrimp
Horseshoe Crater	51	4-12 May	3,903 m	19.82961°N 155.50101°W	Shrimp
Horseshoe Crater	52	12 May-8 June	3,903 m	19.82961°N 155.50101°W	Glycol
30 m Proposed Scope	53	5-11 May	3,992 m	19.83354°N 155.48384°W	Shrimp
30 m Proposed Scope	54	5-11 May	4,008 m	19.83288°N 155.48323°W	Shrimp
30 m Proposed Scope	55	5-11 May	4,022 m	19.83248°N 155.48216°W	Shrimp
30 m Proposed Scope	56	5-11 May	4,039 m	19.83133°N 155.48131°W	Shrimp
30 m Proposed Scope	57	5-11 May	4,052 m	19.83060°N 155.48056°W	Shrimp
30 m Proposed Scope	58	5-11 May	4,058 m	19.82939°N 155.48079°W	Shrimp
30 m Proposed Scope	59	5-11 May	4,064 m	19.82893°N 155.47966°W	Shrimp
30 m Proposed Scope	60	5-11 May	4,077 m	19.82757°N 155.47906°W	Shrimp
Pu‘u Lilinoe	61	7-10 May	3,754 m	19.80626°N 155.45357°W	Shrimp
Pu‘u Lilinoe	62	7-10 May	3,776 m	19.80701°N 155.45387°W	Shrimp
Pu‘u Lilinoe	63	7-10 May	3,796 m	19.80789°N 155.45479°W	Shrimp
Pu‘u Lilinoe	64	7-10 May	3,810 m	19.80832°N 155.45529°W	Shrimp
Pu‘u Lilinoe	65	7-10 May	3,841 m	19.80937°N 155.45612°W	Shrimp
Pu‘u Lilinoe	66	7-10 May	3,902 m	19.81012 °N 155.45741°W	Shrimp
Pu‘u Lilinoe	67	7-10 May	3,971 m	19.80989°N 155.45844°W	Shrimp
Pu‘u Lilinoe	68	7-10 May	3,976 m	19.80926°N 155.45831°W	Shrimp
Pu‘u Lilinoe	69	7-10 May	3,973 m	19.80945°N 155.45917°W	Shrimp

Table 1 (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys. conducted in May 2005 (altitudes taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2005 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Lilinoe	70	7-10 May	3989 m	19.81008°N 155.45908°W	Shrimp
Unnamed N. Pu‘u VLBA	71	7-10 May	3,739 m	19.80263°N 155.45662°W	Shrimp
Unnamed N. Pu‘u VLBA	72	7-10 May	3,763 m	19.80274°N 155.45737°W	Shrimp
Unnamed N. Pu‘u VLBA	73	7-10 May	3,796 m	19.80290°N 155.45789°W	Shrimp
Unnamed N. Pu‘u VLBA	74	7-10 May	3,840 m	19.80324°N 155.45889°W	Shrimp
Unnamed N. Pu‘u VLBA	75	7-10 May	3,850 m	19.80372°N 155.45930°W	Shrimp
Unnamed N. Pu‘u VLBA	76	7-10 May	3,746 m	19.80057°N 155.45493°W	Shrimp
Unnamed S. Pu‘u VLBA	77	7-10 May	3,768 m	19.80001°N 155.45464°W	Shrimp
Unnamed S. Pu‘u VLBA	78	7-10 May	3,789 m	19.79945°N 155.45467°W	Shrimp
Unnamed S. Pu‘u VLBA	79	7-10 May	3,754 m	19.79887°N 155.45508°W	Shrimp
Unnamed S. Pu‘u VLBA	80	7-10 May	3,812 m	19.79913°N 155.45552°W	Shrimp
Total Pitfall Traps	90				

Table 2. Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in June 2005 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2005 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Hau Kea	1s	3-12 June	4,110 m	19.81488°N 155.47246°W	Shrimp
Pu‘u Hau Kea	2s	3-12 June	4,120 m	19.81441°N 155.47324°W	Shrimp
Pu‘u Hau Kea	3s	3-12 June	4,128 m	19.81408°N 155.47345°W	Shrimp
Pu‘u Hau Kea	4s	3-12 June	4,098 m	19.81364°N 155.47345°W	Shrimp
Pu‘u Hau Kea	5s	3-12 June	4,085 m	19.81330°N 155.47270°W	Shrimp
Pu‘u Hau Kea	1g	3-12 June	4,109 m	19.81488°N 155.47246°W	Glycol
Pu‘u Hau Kea	2g	3-12 June	4,125 m	19.81448°N 155.47231°W	Glycol
Pu‘u Hau Kea	3g	3-12 June	4,128 m	19.81408°N 155.47345°W	Glycol
Pu‘u Hau Kea	4g	3-12 June	4,098 m	19.81369°N 155.47339°W	Glycol
Pu‘u Hau Kea	5g	3-12 June	4,123 m	19.81326°N 155.47258°W	Glycol
Pu‘u Hau Kea	1	3-12 June	4,127 m	19.81467°N 155.47319°W	Shrimp
Pu‘u Hau Kea	2	3-12 June	4,082 m	19.81440°N 155.47263°W	Shrimp
Pu‘u Hau Kea	3	3-12 June	4055 m	19.81408°N 155.47241°W	Shrimp
Pu‘u Hau Kea	4	3-12 June	4,095 m	19.81331°N 155.47195°W	Shrimp
Pu‘u Hau Kea	5	3-12 June	4,076 m	19.81265°N 155.47186°W	Shrimp
Pu‘u Hau Kea	6	3-12 June	3,997 m	19.81107°N 155.47141°W	Shrimp
Poi Bowl	7	4-12 June	4,067 m	19.82329°N 155.47491°W	Shrimp
Poi Bowl	8	4-12 June	4,076 m	19.82384°N 155.47409°W	Shrimp
Poi Bowl	9	4-12 June	4,095 m	19.82435°N 155.47307°W	Shrimp
Poi Bowl	10	4-12 June	4,110 m	19.82451°N 155.47226°W	Shrimp
Poi Bowl	11	4-12 June	4,113 m	19.82477°N 155.47096°W	Shrimp
Poi Bowl	12	4-12 June	4,137 m	19.82543°N 155.47256°W	Shrimp
Poi Bowl	13	4-12 June	4,125 m	19.82511°N 155.47237°W	Shrimp
Pu‘u #1 S.E. VLBA	14	5-11 June	3,622 m	19.79864°N 155.44295°W	Shrimp
Pu‘u #1 S.E. VLBA	15	5-11 June	3,628 m	19.79845°N 155.44263°W	Shrimp
Pu‘u #1 S.E. VLBA	16	5-11 June	3,637 m	19.79832°N 155.44237°W	Shrimp
Pu‘u #1 S.E. VLBA	17	5-11 June	3,637 m	19.79789°N 155.44159°W	Shrimp
Pu‘u #1 S.E. VLBA	18	5-11 June	3,649 m	19.79715°N 155.44177°W	Shrimp
Pu‘u #1 S.E. VLBA	19	5-11 June	3,646 m	19.79801°N 155.44098°W	Shrimp
Pu‘u #2 S.E. VLBA	20	5-11 June	3,549 m	19.79850°N 155.43506°W	Shrimp
Pu‘u #2 S.E. VLBA	21	5-11 June	3,558 m	19.79858°N 155.43450°W	Shrimp
Pu‘u #2 S.E. VLBA	22	5-11 June	3,564 m	19.79755°N 155.43311°W	Shrimp
Pu‘u #2 S.E. VLBA	23	5-11 June	3,567 m	19.79860°N 155.43423°W	Shrimp
Pu‘u #2 S.E. VLBA	24	5-11 June	3,546 m	19.79880°N 155.43222°W	Shrimp
Pu‘u #2 S.E. VLBA	25	5-11 June	3,570 m	19.79979°N 155.43106°W	Shrimp
Pu‘u #2 S.E. VLBA	26	5-11 June	3,567 m	19.79923°N 155.43086°W	Shrimp
Pu‘u #2 S.E. VLBA	27	5-11 June	3,570 m	19.79973°N 155.43105°W	Shrimp
11,672 ft pu‘u NW summit	28	6-10 June	3,462 m	19.83528°N 155.51971°W	Shrimp
11,672 ft pu‘u NW summit	29	6-10 June	3,495 m	19.82978°N 155.51669°W	Shrimp
11,672 ft pu‘u NW summit	30	6-10 June	3,541 m	19.82889°N 155.51653°W	Shrimp
11,672 ft pu‘u NW summit	31	6-10 June	3,612 m	19.82853°N 155.51550°W	Shrimp

Table 2 (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in June 2005 (altitudes from taken from altimeter, some variation may occur).

Cinder Cone	Trap #	2005 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
11,672 ft puʻu NW summit	32	6-10 June	3,563 m	19.82848°N 155.51620°W	Shrimp
11,672 ft puʻu NW summit	33	6-10 June	3,554 m	19.82797°N 155.51692°W	Shrimp
11,672 ft puʻu NW summit	34	6-10 June	3,554 m	19.82797°N 155.51692°W	Glycol
11,672 ft puʻu NW summit	35	6-10 June	3,566 m	19.82684°N 155.51689°W	Shrimp
11,672 ft puʻu NW summit	36	6-10 June	3,583 m	19.82650°N 155.51506°W	Glycol
11,672 ft puʻu NW summit	37	6-10 June	3,583 m	19.82650°N 155.51506°W	Shrimp
Unnamed Puʻu NW summit	38	6-10 June	3,445 m	19.83640°N 155.51929°W	Shrimp
Unnamed Puʻu NW summit	39	6-10 June	3,466 m	19.83663°N 155.51755°W	Shrimp
Unnamed Puʻu NW summit	40	6-10 June	3,463 m	19.83759°N 155.51701°W	Shrimp
Unnamed Puʻu NW summit	41	6-10 June	3,433 m	19.83634°N 155.51884°W	Shrimp
Unnamed Puʻu NW summit	42	6-10 June	3,409 m	19.83582°N 155.51917°W	Shrimp
Unnamed Puʻu NW summit	43	6-10 June	3,445 m	19.83315°N 155.52039°W	Shrimp
Unnamed Puʻu NW summit	44	6-10 June	3,409 m	19.83402°N 155.52002°W	Shrimp
Unnamed Puʻu NW summit	45	6-10 June	3,482 m	19.83236°N 155.52187°W	Shrimp
Unnamed Puʻu NW summit	46	6-10 June	3,482 m	19.83538°N 155.52014°W	Glycol
Unnamed Puʻu NW summit	47	6-10 June	3,476 m	19.83112°N 155.52249°W	Shrimp
Cone at Terminal Moraine	48	8-11 June	3,524 m	19.78523°N 155.45207°W	Shrimp
Cone at Terminal Moraine	49	8-11 June	3,540 m	19.78509°N 155.45155°W	Shrimp
Cone at Terminal Moraine	50	8-11 June	3,549 m	19.78479°N 155.45126°W	Shrimp
Cone at Terminal Moraine	51	8-11 June	3,573 m	19.78388°N 155.45055°W	Shrimp
Cone at Terminal Moraine	52	8-11 June	3,567 m	19.78376°N 155.45047°W	Glycol
Cone at Terminal Moraine	53	8-11 June	3,552 m	19.78391°N 155.44980°W	Shrimp
Total Pitfall Traps	63				

Table 3. Wēkiu bug capture data from surveyed Mauna Kea cinder cones using visual collections, shrimp pitfall, and ethylene glycol pitfall traps in May and June 2005.

Cinder Cone	Date	Trap #	Trap Elevation[1]	GPS Coordinates	Wēkiu #'s	Trap Type
Pu'u Hau Kea	5 May	1s	4,114 m	19.81489°N 155.47252°W	2	shrimp
Pu'u Hau Kea	8 May	Vis	4,113 m	19.81332°N 155.47272°W	13	vis. collect
Pu'u Hau Kea	8 May	5s	4,113 m	19.81332°N 155.47272°W	1	shrimp
Pu'u Hau Kea	8 May	5g	4,113 m	19.81332°N 155.47272°W	5	glycol
Pu'u Hau Kea	8 May	1	4,094 m	19.81413°N 155.47243°W	2	shrimp
Pu'u Hau Kea	8 May	2	4,126 m	19.81331°N 155.47206°W	1	shrimp
Pu'u Pohaku	8 May	36	4,009 m	19.82548°N 155.49011°W	1	shrimp
Pu'u Lilinoe	10 May	64	3,810 m	19.80832°N 155.45529°W	2	shrimp
Pu'u Lilinoe	10 May	66	3,902 m	19.81012°N 155.45741°W	3	shrimp
Pu'u Lilinoe	10 May	Vis	3,902 m	19.81012°N 155.45741°W	1	vis. collect
Pu'u Wekiu	4 June	Vis	4,119 m	19.82245°N 155.46765°W	1	vis. collect
Pu'u Wekiu	11 June	Vis	4,184 m	19.82186°N 155.46826°W	1	vis. collect
Pu'u Wekiu	11 June	Vis	4,197 m	19.82180°N 155.46825°W	1	vis. collect
Pu'u Poliahu	5 June	Vis	4,139 m	19.82310°N 155.48026°W	2	vis. collect
Pu'u Poliahu	5 June	Vis	4,150 m	19.82310°N 155.48026°W	2	vis. collect
Pu'u Poliahu	5 June	Vis	4,127 m	19.82280°N 155.47993°W	12	vis. collect
Pu'u Hau Kea	7 June	Vis	4,128 m	19.81408°N 155.47345°W	4	vis. collect
Pu'u Hau Kea	7 June	1s	4,088 m	19.81488°N 155.47246°W	1	vis. collect
Pu'u Hau Kea	7 June	1g	4,110 m	19.81488°N 155.47246°W	1	glycol
Pu'u Hau Kea	7 June	3g	4,128 m	19.81408°N 155.47345°W	1	glycol
Pu'u Hau Kea	7 June	3	4,055 m	19.81408°N 155.47241°W	1	shrimp
Pu'u Hau Kea	7 June	4	4,095 m	19.81331°N 155.47195°W	1	shrimp
Pu'u Hau Kea	9 June	4g	4,098 m	19.81369°N 155.47339°W	1	glycol
Pu'u Hau Kea	9 June	5g	4,122 m	19.81326°N 155.47258°W	1	glycol
Pu'u Hau Kea	9 June	2	4,082 m	19.81440°N 155.47263°W	1	shrimp
Pu'u Hau Kea	12 June	1g	4,110 m	19.81488°N 155.47246°W	2	glycol
Pu'u Hau Kea	12 June	3g	4,128 m	19.81408°N 155.47345°W	2	glycol
Pu'u Hau Kea	12 June	4g	4,098 m	19.81369°N 155.47339°W	2	glycol
Pu'u Hau Kea	12 June	5g	4,123 m	19.81326°N 155.47258°W	1	glycol
Pu'u Hau Kea	12 June	5	4,076 m	19.81265°N 155.47186°W	1	shrimp
Totals					70	

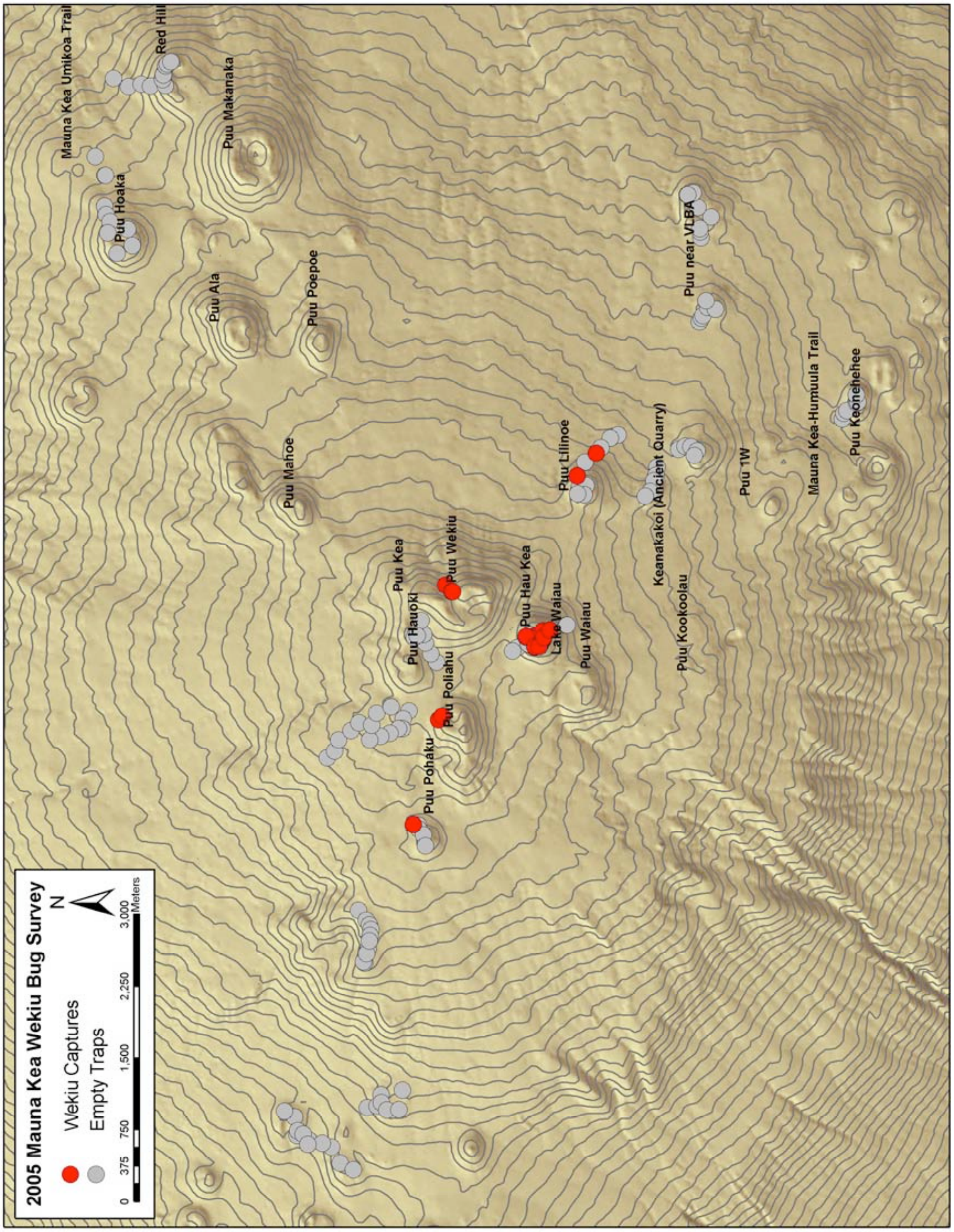

Figure 5. Overall 2005 trap effort , with successful wēkiu captures in red and unsuccessful traps in gray.

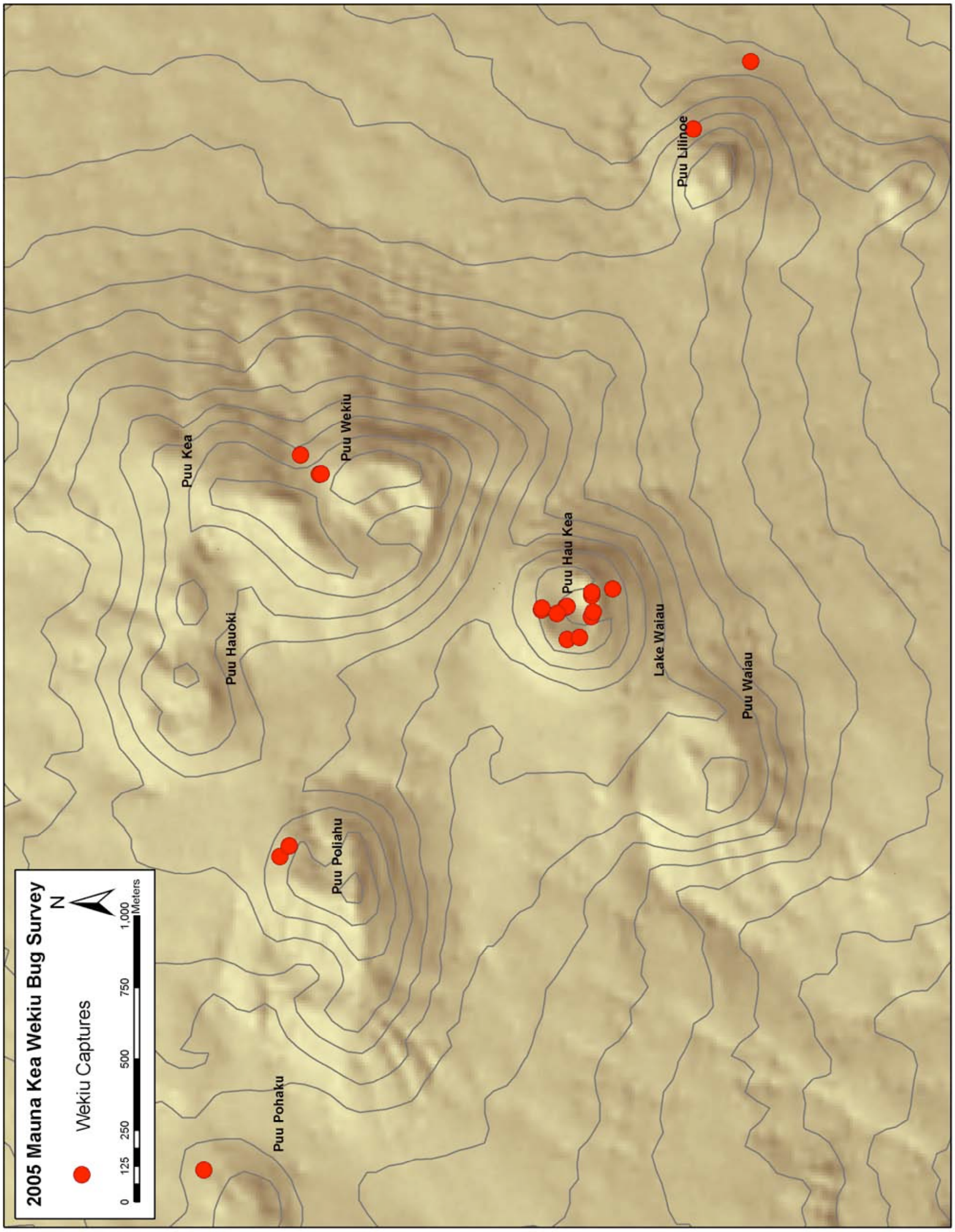

Figure 6. Wēkiu captures in 2005 within the Mauna Kea summit area, including visual and trap captures.

glycol traps also used in this area to verify the presence or absence of wēkiu bugs (Table 2). Although these cinder cones were within the elevational range of were wēkiu bugs, none were captured or observed in June 2005. Wēkiu bugs were common at Pu'u Hau Kea, Pu'u Lilinoe and Pu'u Poliahu in May and June, but the absence of them at these outlying western summit cones above the Pu'u Lā'au cabin indicates this area likely does not contain favorable wēkiu bug habitat.

Ethylene Glycol versus Shrimp Paste Pitfall Trapping Test

As discussed earlier, both types of pitfall traps were exceedingly ineffective in 2005 in collecting wēkiu bugs as compared to timed visual collections around snowbanks in the exact same locations at Pu'u Hau Kea. Although still not providing unequivocal results, tests comparing shrimp pitfall traps used in studies since 1997 and ethylene glycol traps used exclusively during the 1982 study continued.

The 2005 trapping test results are still of great interest, and combined with data from future sampling may provide additional information as to the comparability of these two sampling methods. Five wēkiu bugs were collected during the May glycol trapping as compared to three in the shrimp traps, while in June eleven were collected in glycol traps as compared to only one in shrimp pitfall traps (Table 4). While the May results were equivocal for both pitfall trap types, the June results provided the first relatively large difference between the two methods since the pitfall trap test started in 2002. Two previous attempts at testing trapping efficiency were hampered by low or nearly identical catch rates (Englund *et al.* 2002, Englund *et al.* 2005), but the June 2005 results provided the first indication that in certain instances glycol traps may be more effective than shrimp traps. Although the glycol traps in June captured many more wēkiu bugs, it is important to note that the glycol traps have much less shrimp paste smeared on and around the cup and nearby rocks than the shrimp traps. In fact, several of the glycol traps had almost no paste at all smeared on their inner cups. By the time we sampled Pu'u Hau Kea in June 2005, the snowbank at the summit rim had nearly melted and was much smaller in comparison with the snowbank in May (see photos next page). It is possible that as the snowbanks melt, the wēkiu bugs are losing their easy and steady food source and will be more readily captured in traps. The data from the summit area of Pu'u Hau Kea may corroborate this explanation, as 18 total traps captured only 11 wēkiu bugs in May, as compared to 16 traps collecting 16 bugs in June, when the snowpack was almost gone. While the data still remain inconclusive, it is apparent that glycol traps attract wēkiu bugs in a very efficient manner under certain situations, especially in the early spring time after snow melt. For example, glycol traps were much more efficient at capturing bugs during the reduced snowpack of June 2001 (Polhemus 2001, *in* Englund *et al.* 2002)

Table 4. Results of Pu'u Hau Kea paired glycol and shrimp pitfall traps surveys during May/June 2005.

Trap Type	Trap #	# wēkiu bugs collected May	# wēkiu bugs collected June	# wēkiu bugs observed on caprock[1]	wēkiu Mortality (shrimp traps)
Ethylene Glycol	1g	0	3	0	n/a
Shrimp Pitfall	1s	2	1	0	0
Ethylene Glycol	2g	0	0	0	n/a
Shrimp Pitfall	2s	0	0	0	0
Ethylene Glycol	3g	0	3	0	n/a
Shrimp Pitfall	3s	0	0	0	0
Ethylene Glycol	4g	0	3	0	n/a
Shrimp Pitfall	4s	0	0	0	0
Ethylene Glycol	5g	5	2	0	n/a
Shrimp Pitfall	5s	1	0	0	0
Total Glycol		5	11	0	n/a
Total Shrimp		3	1	0	0

[1]Wēkiu bugs not collected within trap, but observed nearby around caprock near shrimp paste

Pu'u Hau Kea on 2 May (left) and 12 June 2005 (right)

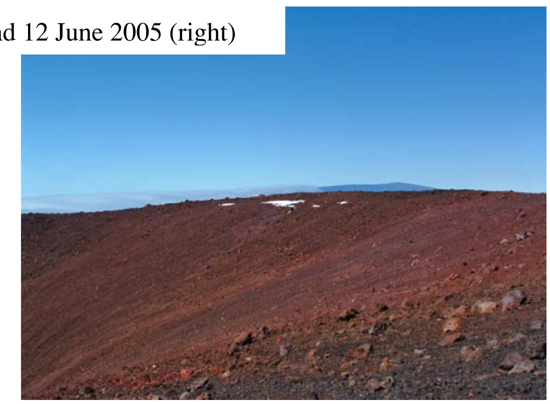

Table 5. Summary of 2005 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using both shrimp pitfall and ethylene glycol pitfall traps in May 2005.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs visual observation only[1]	Trap Dates	Total Trap Days[2]
Pu'u Hau Kea	4,119 m	18	11	13	2-11 May	144
Red Hill	3,645 m	10	0	0	3-6 May	30
Pu'u Hoaka	3,713 m	10	0	0	3-6 May	30
Below submillimeter array	4,087 m	7	0	0	4-11 May	49
Pu'u Pohaku	4,040 m	5	1	0	4-12 May	40
Horseshoe Crater- glycol traps	3,917 m	2	0	0	12 May-8 June	56
Horseshoe Crater- shrimp traps	3,917 m	10	0	0	4-12 May	80
30 m Proposed Scope area	4,077 m	8	0	0	5-11 May	40
Pu'u Lilinoe	3,989 m	10	5	1	7-10 May	30
Pu'u nr. VLBA	3,850 m	10	0	0	7-10 May	30
Totals		90	17	14		529

[1]Number of wēkiu bugs hand collected around snowbanks and near traps during 20 minute trials by 2-6 observers, but not collected in traps. [2]Trap days = total nights x total traps per cinder cone.

Table 6. Summary of 2005 sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using both shrimp pitfall and ethylene glycol pitfall traps in June 2005.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs visual observation only[1]	Trap Dates	Total Trap Days[2]
Pu'u Hau Kea	4119 m	16	16	4	3-12 June	144
Poi Bowl	4,137 m	7	0	0	4-12 June	56
Pu'u Wēkiu	4,206 m	0	0	3	n/a	n/a
Pu'u Poliahu	4,156 m	0	0	16	n/a	n/a
Pu'u #1 SE VLBA	3,649 m	6	0	0	5-11 June	36
Pu'u #2 SE VLBA	3,570 m	8	0	0	5-11 June	48
11,672 ft pu'u NW summit	3,559 m	10	0	0	6-10 June	40
Unnamed pu'u NW summit	3,482 m	10	0	0	6-10 June	40
Cone at Terminal Moraine	3,573 m	6	0	0	8-11 June	18
Totals		63	16	23		382

[1]Number of wēkiu bugs hand collected around snowbanks and near traps during 20 minute trials by 2-6 observers, but not collected in traps. [2]Trap days = total nights x total traps per cinder cone.

or in June 2005. On the other hand, there appears to be little difference in trap efficiency such as in May 2005 when a large snowpack was available, or in other seasons having low wēkiu bug abundance such as in the warm and dry July 2004 (Englund *et al.* 2005).

Temperature RH/Loggers

Areas where data loggers were installed in December 2004 and data downloaded in June 2005 can be found in Table 8, along with the success or failure of each logger in recording data. For the regression graphs, each day is represented by 4 data points taken every 6 hours. Some logger locations were moved or eliminated in December 2005, and the location of new and currently operating loggers can be found in Figures 3-4, and Table 9. The paired subsurface/surface data logger transect on Pu'u Hau Kea can be seen in Figure 4. A total of 45 loggers were placed throughout the Mauna Kea summit area during the week of 13–17 December 2004, but because they were defective only 19 actually recorded data for the entire period (Table 8, Figure 7). Data were downloaded from these loggers in June 2005. Despite the many malfunctioning loggers, the data downloaded in June 2005 provided an excellent representation of temperature conditions throughout the Mauna Kea summit region in the winter and spring seasons on some of the most important cinder cone habitats and in areas considered poor habitat (Figure 7). Data loggers were installed at several new locations in December 2005 (Table 9).

Preliminary examination of data from the loggers indicates these habitats have low mean temperatures, wide surface temperature variations, and long periods of ice and snow that is indicated by much less variation. This is shown in the surface temperature from loggers at various positions on Pu‘u Hau Kea, where the loggers were apparently covered with snow from late December to nearly April (Figure 8-13). The spring months when wēkiu bugs are most active exhibited dramatic daily temperature shifts, with temperatures dropping below freezing on a nightly basis. Regression data from individual loggers indicates similar patterns, but with subsurface loggers exhibiting less daily temperature and humidity variations. The six month temperature mean for all Pu‘u Hau Kea loggers was 2.5 °C for subsurface and 2.0 °C for surface loggers, with many more outliers apparent for the surface loggers. The subsurface loggers may in some ways more accurately reflect conditions where the wēkiu bugs are actually going to be found, i.e., slightly deeper in the substrate, especially presumably during the nighttime. Large differences between the surface and subsurface loggers were quite visible, with the subsurface temperatures always more stable.

One pattern that will be examined in greater detail as more logger data becomes available over the next several years is that cinder cone habitats with high wēkiu bug occurrences appear to have a lower and more stable temperature regime. For example, surface temperatures at Poi Bowl (Figure 21) found at an elevation (13,570 ft/4137 m) higher than all but a few cinder cones, had a much higher temperature regime than some of the core wēkiu bug habitats at Pu’u Hau Kea (Figures 11 and 17) that were actually lower in elevation (Table 7). This pattern also seems to be evident for Pu‘u Hau Oki, an area having one of the highest of wēkiu bugs as well, with lower and more stable temperatures as compared to the more variable nearby Poi Bowl. Remarkably, even within an individual cinder cone we found differences between the base and summit region. For example, at Pu‘u Hau Kea temperatures were colder in the lowest regions of the cinder cone with the summit area considerably warmer (Table 7).

As these patterns were starting to emerge, it was then worthwhile to examine the beginning and end of various regression trendlines at selected cinder cone areas at the beginning and end of the study period (Dec 2004-June 2005), and this was done in order to show overall temperature trends at a specific cinder cone. Data points were examined from areas lacking wēkiu bugs and in areas with core concentrations (Table 7). Poi Bowl not only is apparently unsuitable wēkiu bug habitat because of its fine substrate resulting from glacial scouring, but maintains a higher and less stable temperature regime than core areas such as Pu‘u Hau Oki or the summit of Pu‘u Hau Kea (Table 7). Of course, slope aspect (e.g., sun exposure) of each cinder cone slope also plays an important role in temperatures, and the influence of this on surface and subsurface temperature will have to be closely examined in the future as well. Besides the factor of mountain face exposure, and also considering geological habitat limitations (such as wēkiu bug preference for areas of cinders), more stable temperature areas at the Mauna Kea summit would lead to less extremes of freezing and thawing with presumably less physiological stress on wēkiu bugs. As more data accumulates, it may indicate whether wēkiu bugs are mainly restricted to the summit areas of cinder cones because the climate in these microhabitats are more stable. The implications for this are that any long-term shift in climate would adversely impact wēkiu bug thermal refugia at the summit of the cinder cones. It is unknown whether the many sealed surface areas such as roads and buildings have "urbanized" or appreciably warmed the summit area of Mauna Kea, and separating this factor from global climate changes could prove difficult. It is known that the telescope facilities strive keep their scopes and facilities at a constant temperature of around 0 °C for optical reasons, and thus are not major sources of warming at the summit. Obviously, areas that have been urbanized at the summit are not suitable wēkiu bug habitat, as cinders are required for survival. The existence of a core wēkiu bug population immediately next to the Keck and Subaru Telescope facilities indicates that although the buildings and roads have eliminated habitat, the structures are likely not appreciably thermally impacting wēkiu bug habitat less than 30 m away. Logger data from Pu‘u Hau Oki (urbanized) shown in Figure 22 as compared to the non-urbanized Pu‘u Hau Kea (Figure 11) and Pu‘u Wēkiu (Figure 28) indicates no appreciable warming from the adjacent Keck and Subaru facilities.

Table 7. Temperature trendlines from regression data of various loggers installed around the Mauna Kea summit area.

Cinder Cone (Elevation)	Logger #	Regression Trendline: Dec 2004 start temperature (°C)	Regression Trendline: June 2005 end Temperature (°C)
Hau Kea Surface Loggers:			
4,018 m: Keck side base of cone	789564	–4 °C	19 °C
4,037 m: Keck side midway	792729	–6 °C	8 °C
***4,079 m: inside crater**	792695	–2.5 °C	10 °C
***4,088 m: upper rim, Keck side**	792737	–2.5 °C	8 °C
Hau Kea Subsurface Loggers:			
4,018 m: Keck side base of cone	792689	–3.5 °C	7 °C
***4,085 m: inner cone**	792727	–5 °C	10 °C
4,101 m: upper rim Hilo side	792688	–1 °C	7.5 °C
Other Surface Loggers:			
Poi Bowl (4,137 m)	792721	1 °C	14 °C
***Hau Oki (4,128 m)**	792690	–4.5 °C	10 °C
Trail to Lake Waiau (3,902 m)	792718	–2.5 °C	9 °C

***Area of cinder cone with core wēkiu bug populations**

Table 8. Temperature/Relative Humidity data loggers placed on the Mauna Kea summit in December 2004, and status of data being successfully downloaded in June 2005.

Install Date	#	Logger Serial #	Logger Placement	Depth Cm	Elevation	Locality	Data Downloaded?	GPS Coordinates (WGS 84)
12/14/04	1	789564	surface	0	4,003 m	Pu‘u Hau Kea	3 June 2005	19.81622°N 155.47388°W
12/14/04	2	792689	subsurface	26	4,003 m	Pu‘u Hau Kea	3 June 2005	19.81622°N 155.47388°W
12/14/04	3	792729	surface	0	4,037 m	Pu‘u Hau Kea	3 June 2005	19.81572°N 155.47350°W
12/14/04	4	792733	subsurface	26	4,037 m	Pu‘u Hau Kea	failed	19.81572°N 155.47350°W
12/14/04	5	792737	surface	0	4,088 m	Pu‘u Hau Kea	3 June 2005	19.81488°N 155.47304°W
12/14/04	6	792703	subsurface	26	4,088 m	Pu‘u Hau Kea	failed	19.81488°N 155.47304°W
12/14/04	7	792695	surface	0	4,085 m	Pu‘u Hau Kea	3 June 2005	19.81351°N 155.47212°W
12/14/04	8	792727	subsurface	22	4,085 m	Pu‘u Hau Kea	3 June 2005	19.81351°N 155.47212°W
12/14/04	9	792698	surface	0	4,058 m	Pu‘u Hau Kea	failed	19.81413°N 155.47243°W
12/14/04	10	792709	subsurface	20	4,058 m	Pu‘u Hau Kea	failed	19.81413°N 155.47243°W
12/14/04	11	792728	surface	0	4,079 m	Pu‘u Hau Kea	failed	19.81444°N 155.47276°W
12/14/04	12	792691	subsurface	26	4,079 m	Pu‘u Hau Kea	3 June 2005	19.81444°N 155.47276°W
12/14/04	13	792735	surface	0	4,101 m	Pu‘u Hau Kea	failed	19.81331°N 155.47205°W
12/14/04	14	792688	subsurface	26	4,101 m	Pu‘u Hau Kea	3 June 2005	19.81331°N 155.47205°W
12/14/04	15	792715	subsurface	26	4,003 m	Pu‘u Hau Kea	failed	19.81272°N 155.47183°W
12/14/04	16	792710	surface	0	4,064 m	Pu‘u Hau Kea	failed	19.81272°N 155.47183°W
12/14/04	17	792723	surface	0	4,003 m	Nr. trail to Lake Waiau	failed	19.81109°N 155.47139°W
12/14/04	18	792807	subsurface	26	4,003 m	Nr. trail to Lake Waiau	failed	19.81109°N 155.47139°W
12/15/04	19	792718	surface	0	3,902 m	Nr. trail to Lake Waiau	3 June 2005	19.81416°N 155.47534°W
12/15/04	20	792690	surface	0	4,143 m	Pu‘u Hau Oki	5 June 2005	19.82565°N 155.47549°W
12/15/04	21	792686	subsurface	26	4,143 m	Pu‘u Hau Oki	failed	19.82565°N 155.47549°W
12/15/04	22	792702	surface	0	4,139 m	Pu‘u Hau Oki	failed	19.82728°N 155.47522°W
12/15/04	23	754789	subsurface	26	4,139 m	Pu‘u Hau Oki	failed	19.82728°N 155.47522°W
12/15/04	24	792721	surface	0	4,167 m	Poi Bowl, upper	5 June 2005	19.82547°N 155.47255°W
12/15/04	25	792731	surface	0	4,099 m	Poi Bowl, mid	failed	19.82435°N 155.47308°W
12/15/04	26	792734	surface	0	4,096 m	Poi Bowl, lower	failed	19.82331°N 155.47493°W
12/15/04	27	792696	surface	0	4,183 m	Pu‘u Wekiu	failed	19.81909°N 155.46819°W
12/15/04	28	792738	surface	0	4,098 m	Pu‘u Wekiu	failed	19.81781°N 155.46652°W
12/15/04	29	792730	surface	0	4,128 m	Pu‘u Wekiu	5 June 2005	19.81927°N 155.46989°W
12/16/04	30	792713	surface	0	3,869 m	Pu‘u Poepoe	Failed	19.83411°N 155.44531°W
12/16/04	31	792736	subsurface	26	3,869 m	Pu‘u Poepoe	4 June 2005	19.83411°N 155.44531°W
12/16/04	32	792743	surface	0	3,878 m	Pu‘u Poepoe	Failed	19.82972°N 155.45647°W
12/16/04	33	792687	surface	0	3,787 m	Pu‘u Poepoe	4 June 2005	19.83324°N 155.44690°W
12/16/04	34	792732	subsurface	26	3,787 m	Pu‘u Poepoe	4 June 2005	19.83324°N 155.44690°W
12/16/04	35	792701	surface	0	3,963 m	Pu‘u Mahoe	failed	19.83548°N 155.46242°W
12/16/04	36	792692	subsurface	26	3,963 m	Pu‘u Mahoe	4 June 2005	19.83548°N 155.46242°W
12/16/04	37	797240	surface	0	4,024 m	Pu‘u Mahoe	failed	19.83607°N 155.46123°W
12/16/04	38	792714	subsurface	26	4,024 m	Pu‘u Mahoe	failed	19.83607°N 155.46123°W
12/16/04	39	792717	surface	0	3,960 m	Pu‘u Mahoe	failed	19.83522°N 155.46527°W

Table 8 (cont.). Temperature/Relative Humidity data loggers placed on the Mauna Kea summit in December 2004, and status of data being successfully downloaded in June 2005.

Install Date	#	Logger Serial #	Logger Placement	Depth Cm	Elevation	Locality	Data Downloaded?	GPS Coordinates (WGS 84)
12/17/04	40	792744	surface	0	3,963 m	Pu‘u Pohaku	failed	19.82548°N 155.49013°W
12/17/04	43	792720	subsurface	26	3,963 m	Pu‘u Pohaku	failed	19.82548°N 155.49013°W
12/17/04	42	792742	surface	0	4,020 m	Pu‘u Pohaku	8 June 2005	19.82485°N 155.49089°W
12/17/04	41	792684	subsurface	26	4,020 m	Pu‘u Pohaku	8 June 2005	19.82485°N 155.49089°W
12/17/04	44	789556	surface	0	4,073 m	Pu‘u Poliahu	Lost	19.82330°N 155.47957°W
12/17/04	45	754793	surface	0	4,175 m	Pu‘u Poliahu	5 June 2005	19.82292°N 155.48105°W

Table 9. Temperature/Relative Humidity data loggers on the Mauna Kea summit operating from December 2004, reinstalled in May/June 2005 with data downloaded in December 2005, with additional loggers also installed at new sites. Surface loggers at 0 cm, subsurface at 26 cm depth.

Date Installed	#	Logger Serial #	Logger Placement	Elevation	Locality	GPS Coordinates (WGS 84)
3 June 2005	1	789553	surface	3,902 m	Hau Kea (trail to Waiau)	19.81296°N 155.47545°W
3 June 2005	2	789453	surface	3,950 m	Pu'u Hau Kea (Keck side)	19.81616°N 155.47389°W
3 June 2005	3	789560	subsurface	3,950 m	Pu'u Hau Kea (Keck side)	19.81616°N 155.47389°W
3 June 2005	4	789559	surface	4,058 m	Pu'u Hau Kea	19.81575 °N 155.47351°W
3 June 2005	5	789545	subsurface	4,058 m	Pu'u Hau Kea	19.81575 °N 155.47351°W
3 June 2005	6	754788	surface	4,096 m	Pu'u Hau Kea	19.81496°N 155.47305°W
3 June 2005	7	789561	subsurface	4,096 m	Pu'u Hau Kea	19.81496°N 155.47305°W
3 June 2005	8	792694	surface	4,105 m	Pu'u Hau Kea	19.81443°N 155.47275°W
3 June 2005	9	754792	subsurface	4,105 m	Pu'u Hau Kea	19.81443°N 155.47275°W
3 June 2005	10	789549	surface	4,061 m	Pu'u Hau Kea (crater bottom)	19.81413°N 155.47243°W
3 June 2005	11	789562	subsurface	4,061 m	Pu'u Hau Kea (crater bottom)	19.81413°N 155.47243°W
3 June 2005	12	789544	surface	4,081 m	Pu'u Hau Kea	19.81342°N 155.47214°W
3 June 2005	13	754787	subsurface	4,081 m	Pu'u Hau Kea	19.81342°N 155.47214°W
3 June 2005	14	754782	surface	4,126 m	Pu'u Hau Kea	19.81331°N 155.47206°W
3 June 2005	15	792712	subsurface	4,126 m	Pu'u Hau Kea	19.81331°N 155.47206°W
3 June 2005	16	789552	surface	4,096 m	Pu'u Hau Kea	19.81269°N 155.47188°W
3 June 2005	17	792739	subsurface	4,096 m	Pu'u Hau Kea	19.81269°N 155.47188°W
3 June 2005	18	789565	surface	4,006 m	Pu'u Hau Kea (Hilo side)	19.81112°N 155.47139°W
3 June 2005	19	792706	subsurface	4,006 m	Pu'u Hau Kea (Hilo side)	19.81112°N 155.47139°W
7 May 2005	20	792680	Surface	3,989 m	Pu'u Lilinoe	19.81008°N 155.45908°W
7 May 2005	21	792705	subsurface	3,989 m	Pu'u Lilinoe	19.81008°N 155.45908°W
15 Dec 2005	22	792739	surface	3,843 m	Pu'u Lilinoe	19.80664°N 155.45836°W
15 Dec 2005	23	792694	surface	3,843 m	Pu'u Lilinoe	19.80664°N 155.45836°W
4 June 2005	24	754791	surface	4,143 m	Pu'u Hau Oki	19.82578°N 155.47539°W
4 June 2005	25	789597	subsurface	4,143 m	Pu'u Hau Oki	19.82578°N 155.47539°W
4 June 2005	26	729724	surface	4,139 m	Pu'u Hau Oki	19.82721°N 155.47528°W
4 June 2005	27	789558	subsurface	4,139 m	Pu'u Hau Oki	19.82721°N 155.47528°W
4 June 2005	28	789547	surface	4,097 m	Poi Bowl	19.82329°N 155.47491°W
4 June 2005	29	789554	surface	4,105 m	Poi Bowl	19.82433°N 155.47307°W
4 June 2005	30	789741	surface	4,167 m	Poi Bowl	19.82543°N 155.47256°W
15 Dec 2005	31	792691	surface	4,009 m	Pu'u Pohaku	19.82548°N 155.49011°W
15 Dec 2005	32	792691	subsurface	4,009 m	Pu'u Pohaku	19.82548°N 155.49011°W
15 Dec 2005	33	792736	surface	4,055 m	Pu'u Pohaku	19.82434°N 155.49211°W
15 Dec 2005	34	792730	subsurface	4,055 m	Pu'u Pohaku	19.82434°N 155.49211°W
15 Dec 2005	35	754790	surface	3,914 m	Horseshoe Crater	19.82953°N 155.50050°W
15 Dec 2005	36	789550	surface	3,924 m	Horseshoe Crater	19.83063°N 155.49815°W
15 Dec 2005	37	792695	surface	3,924 m	Horseshoe Crater	19.83063°N 155.49815°W

Table 9 (cont.). Temperature/Relative Humidity data loggers on the Mauna Kea summit operating from December 2004, reinstalled in May/June 2005 with data downloaded in December 2005, with additional loggers also installed at new sites. Surface loggers at 0 cm, subsurface at 26 cm depth.

Date Installed	#	Logger Serial #	Logger Placement	Elevation	Locality	GPS Coordinates (WGS 84)
13 Dec 2005	38	792697	subsurface	4,154 m	Pu‘u Poliahu	19.82298°N 155.48096°W
13 Dec 2005	39	792742	surface	4,154 m	Pu‘u Poliahu	19.82298°N 155.48096°W
13 Dec 2005	40	792728	subsurface	4,175 m	Pu‘u Poliahu	19.82101°N 155.48149°W
13 Dec 2005	41	792689	surface	4,175 m	Pu‘u Poliahu	19.82101°N 155.48149°W
15 Dec 2005	42	754792	surface	3,840 m	Pu‘u North of VLBA	19.80324°N 155.45889°W
15 Dec 2005	43	754791	surface	3,850 m	Pu‘u North of VLBA	19.80372°N 155.45930°W
14 Dec 2005	44	792744	surface	3,663 m	Pu‘u by J. Burns road sign	19.79351°N 155.45930°W
14 Dec 2005	45	792721	surface	3,702 m	Pu‘u by J. Burns road sign	19.79250°N 155.46034°W

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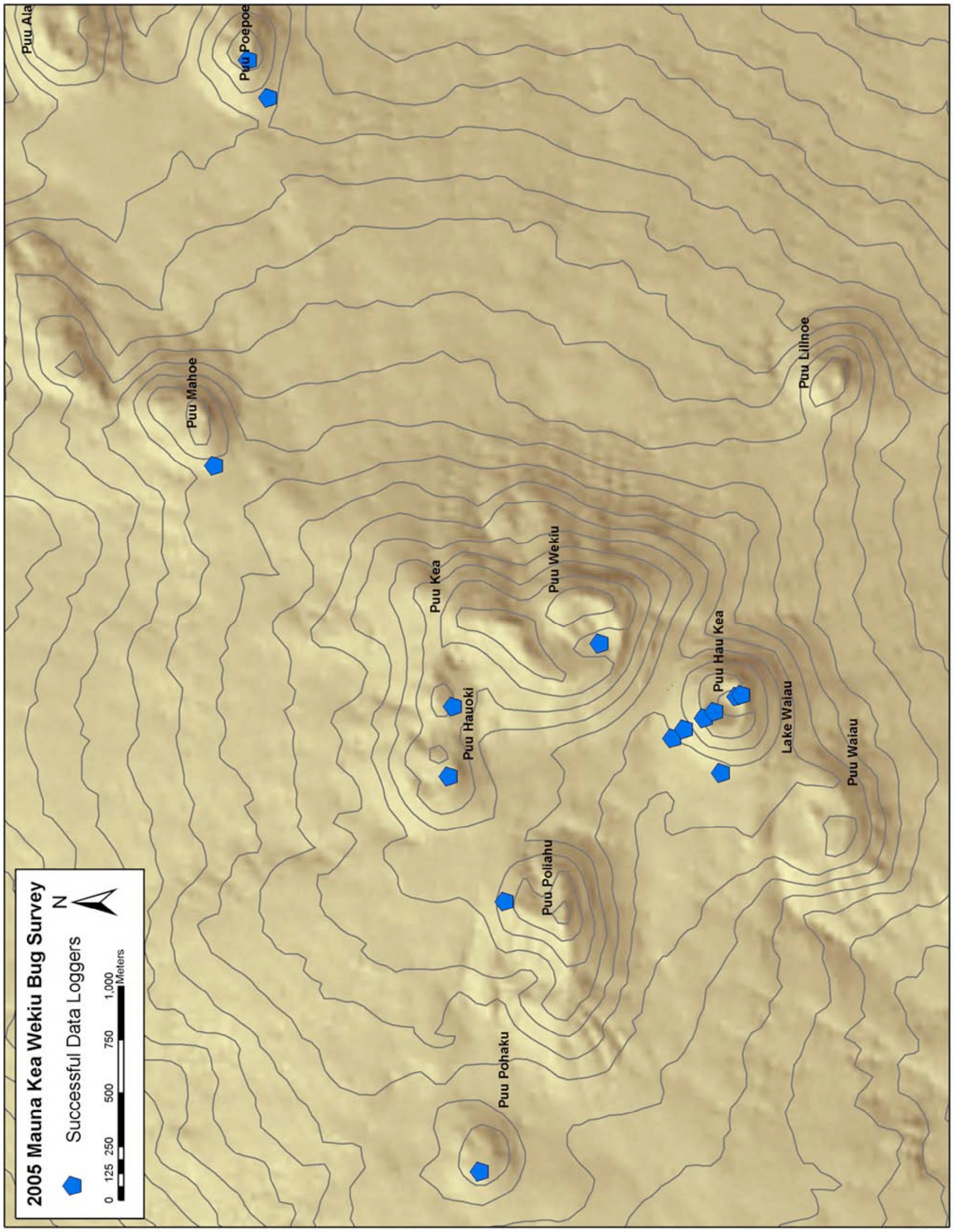

Figure 7. Temperature/Relative Humidity data loggers installed in December 2004, with data successfully downloaded in June 2005.

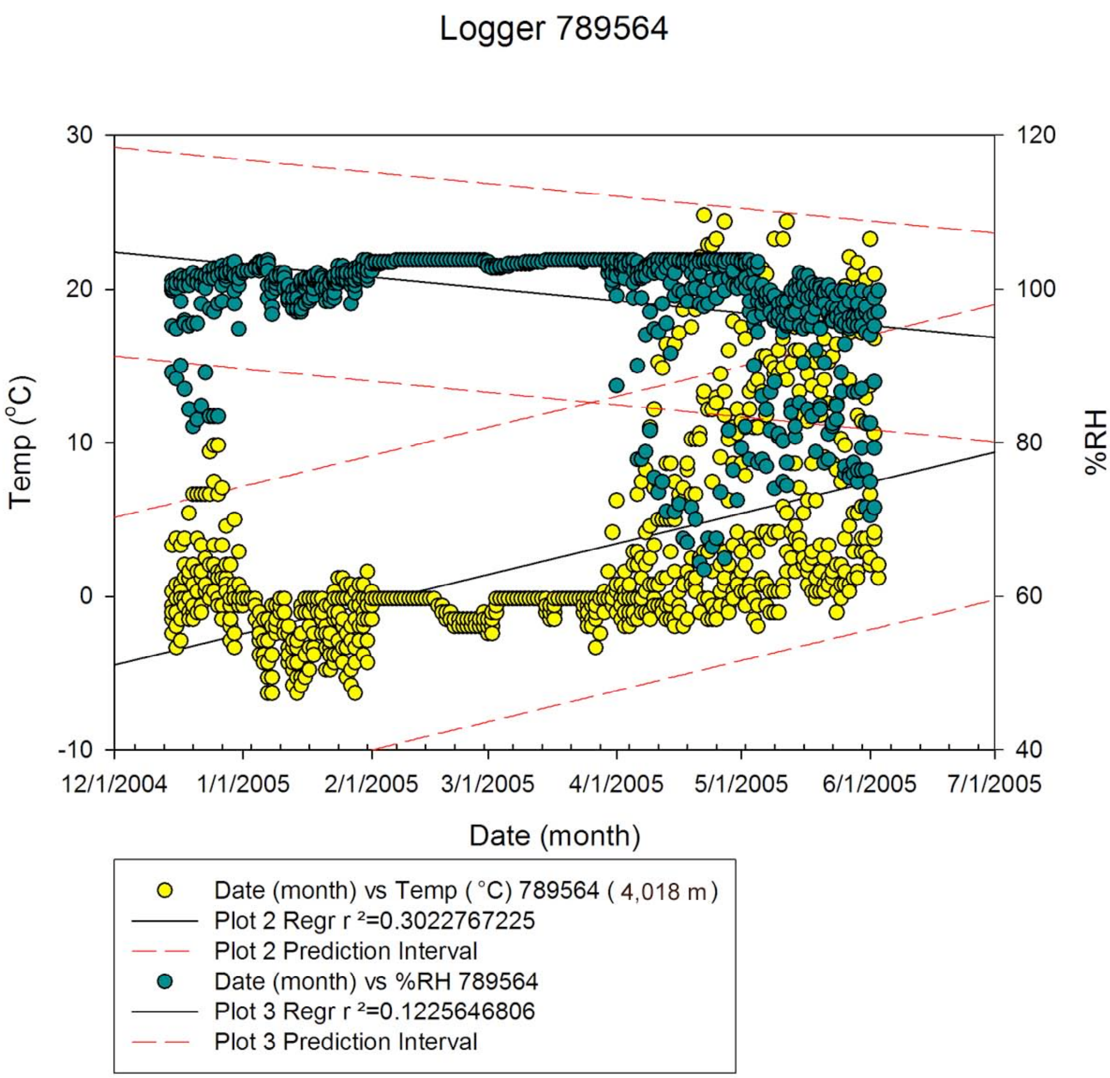

Figure 8. TEMP/RH Logger S/N#789564 from base (Keck side) of Pu'u Hau Kea -SURFACE, from Dec 2004-June 2005.

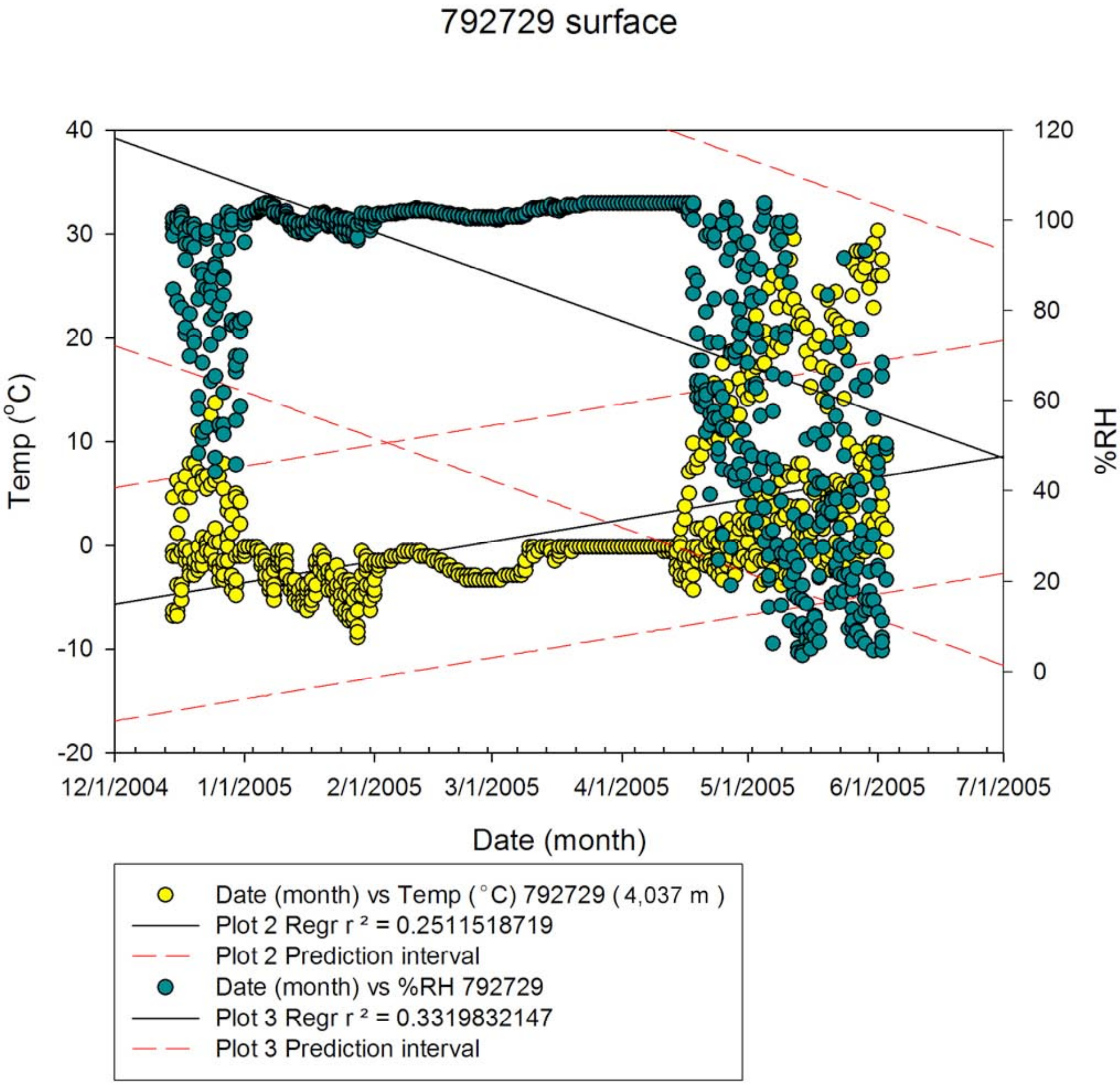

Figure 9. TEMP/RH Logger S/N#792729 midway (Keck side) Pu‘u Hau Kea SURFACE, Dec 2004-June 2005.

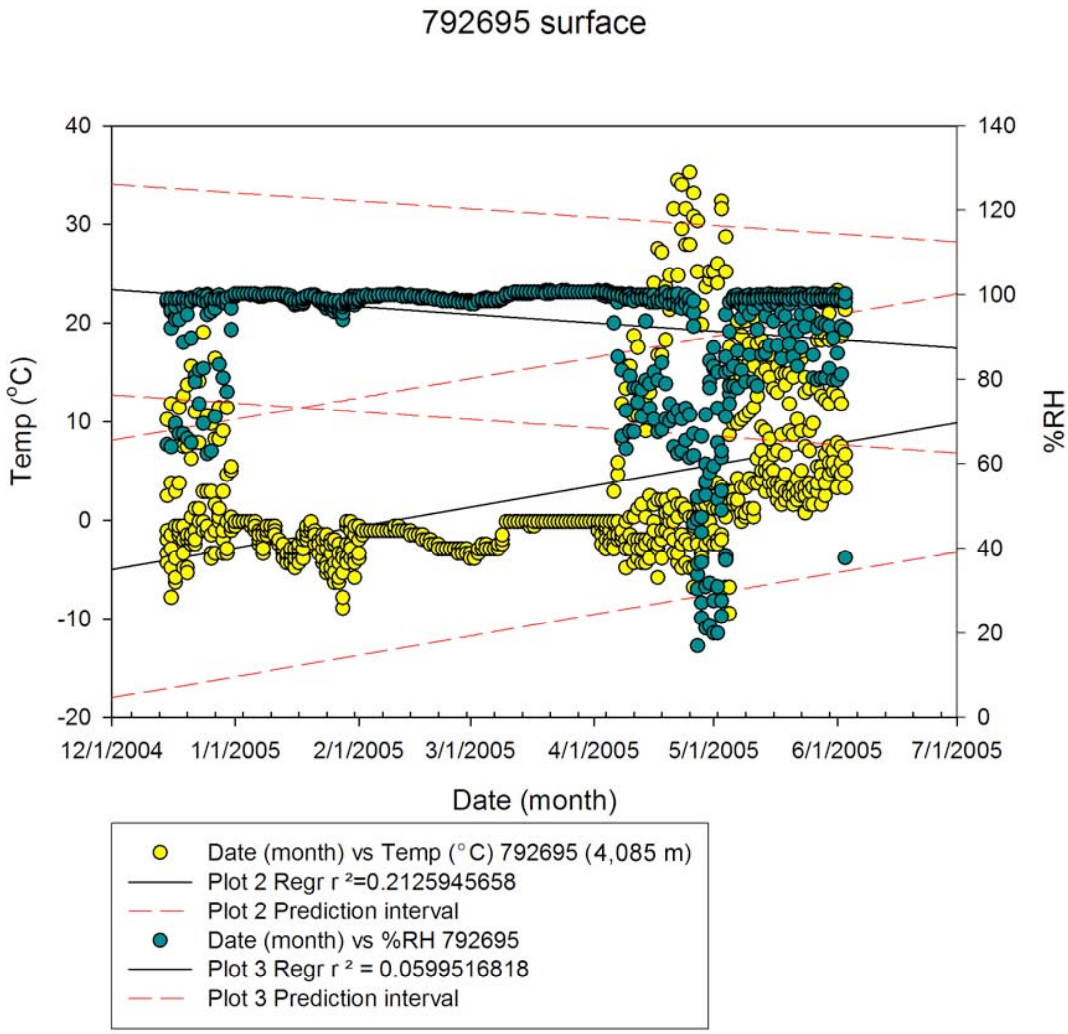

Figure 10. TEMP/RH Logger, S/N#792695, middle inside crater rim, Pu'u Hau Kea SURFACE, Dec 2004-June 2005.

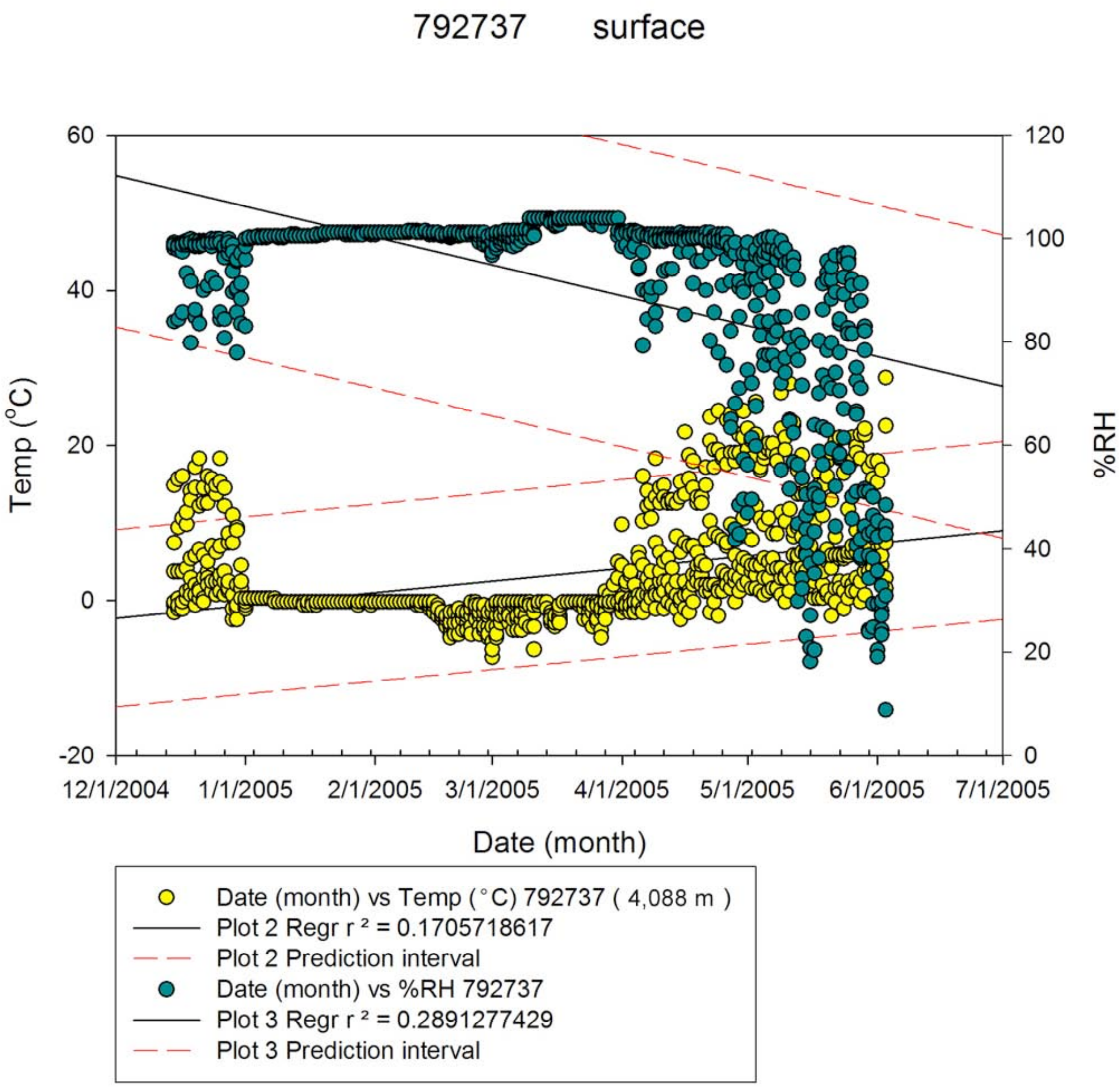

Figure 11. TEMP/RH Logger S/N#792737 uppermost rim Keck side, Pu'u Hau Kea SURFACE, Dec 2004-June 2005.

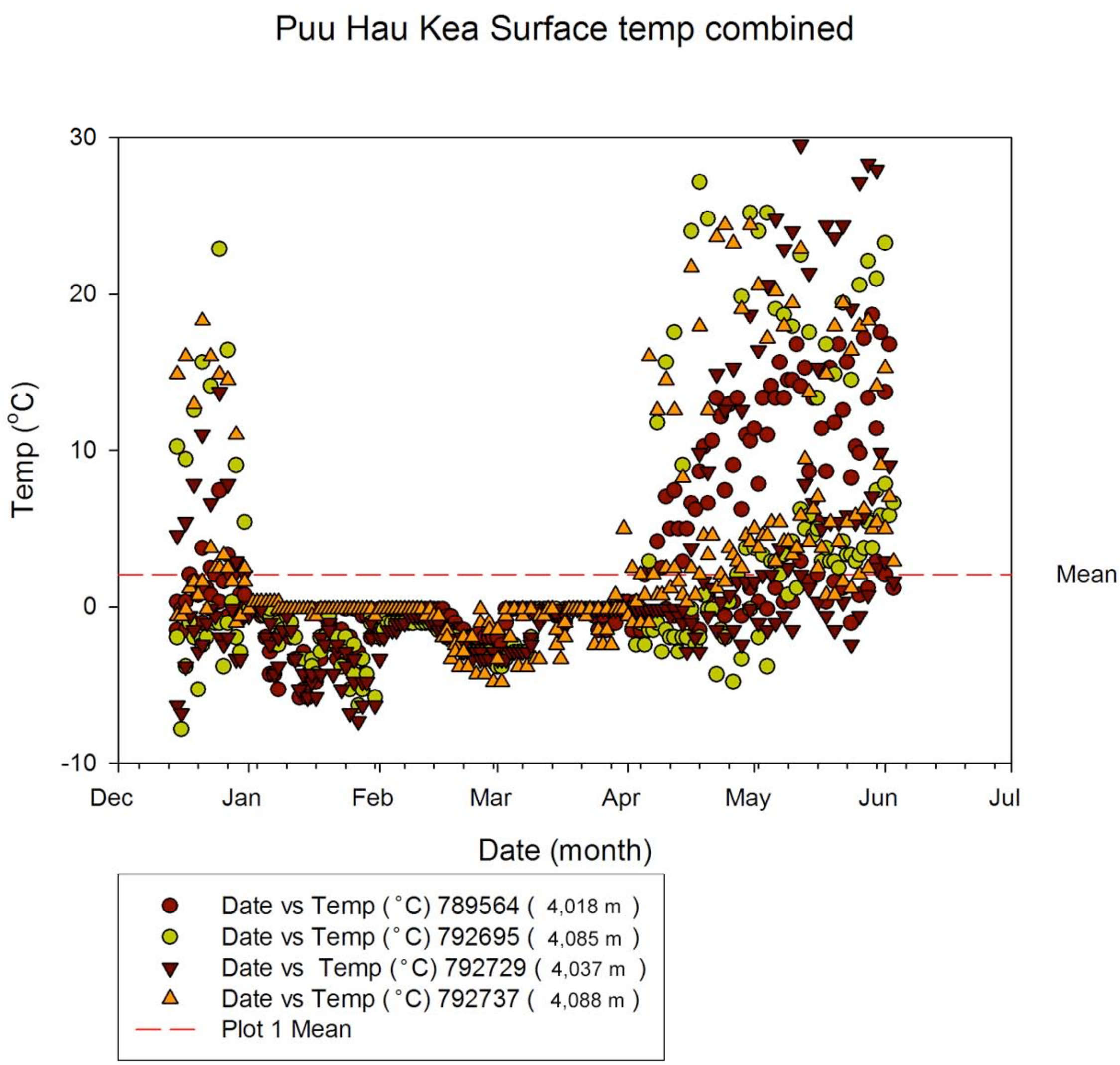

Figure 12. Pu'u Hau Kea combined SURFACE loggers temperature, Dec 2004-June 2005.

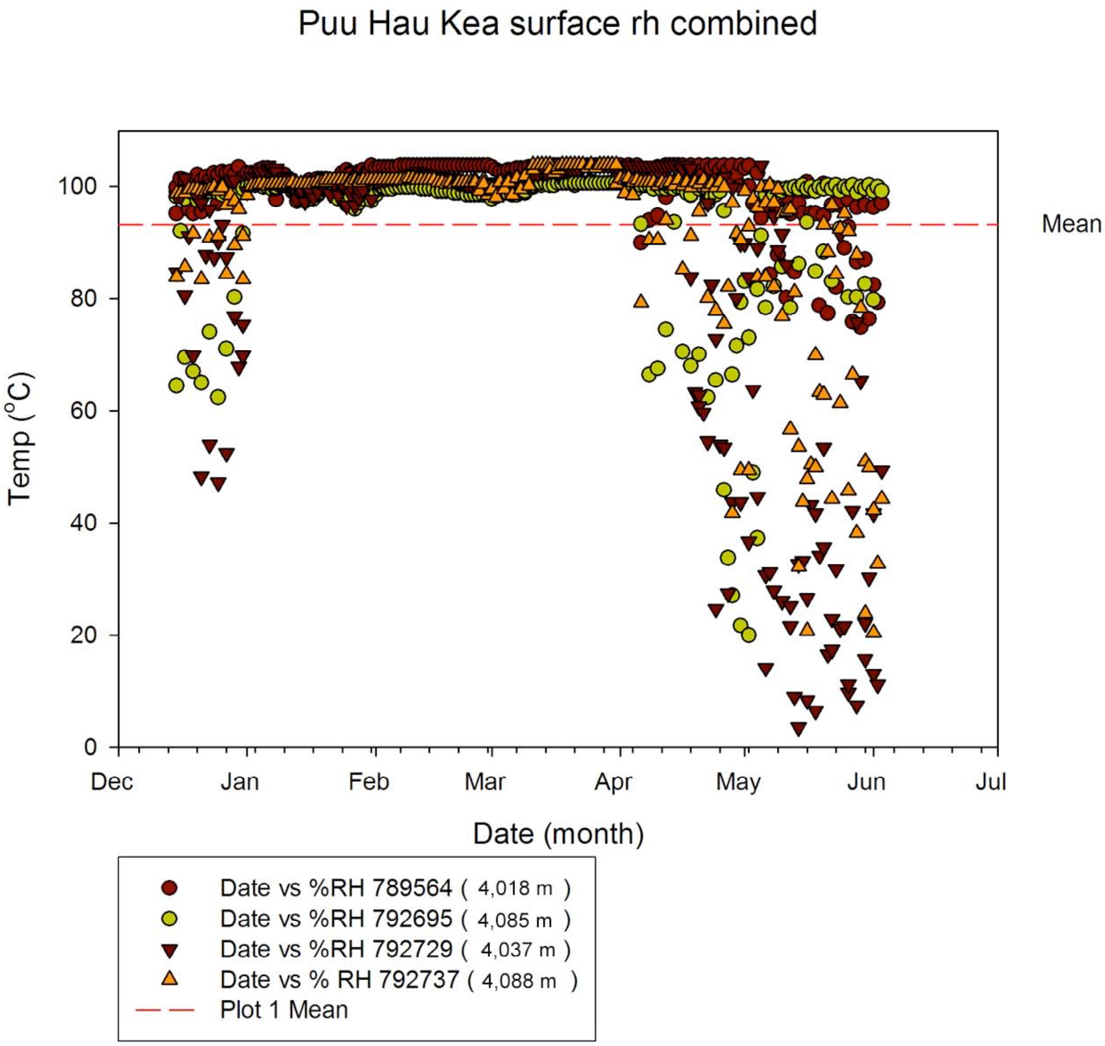

Figure 13. Pu'u Hau Kea combined SURFACE loggers relative humidity, Dec 2004-June 2005.

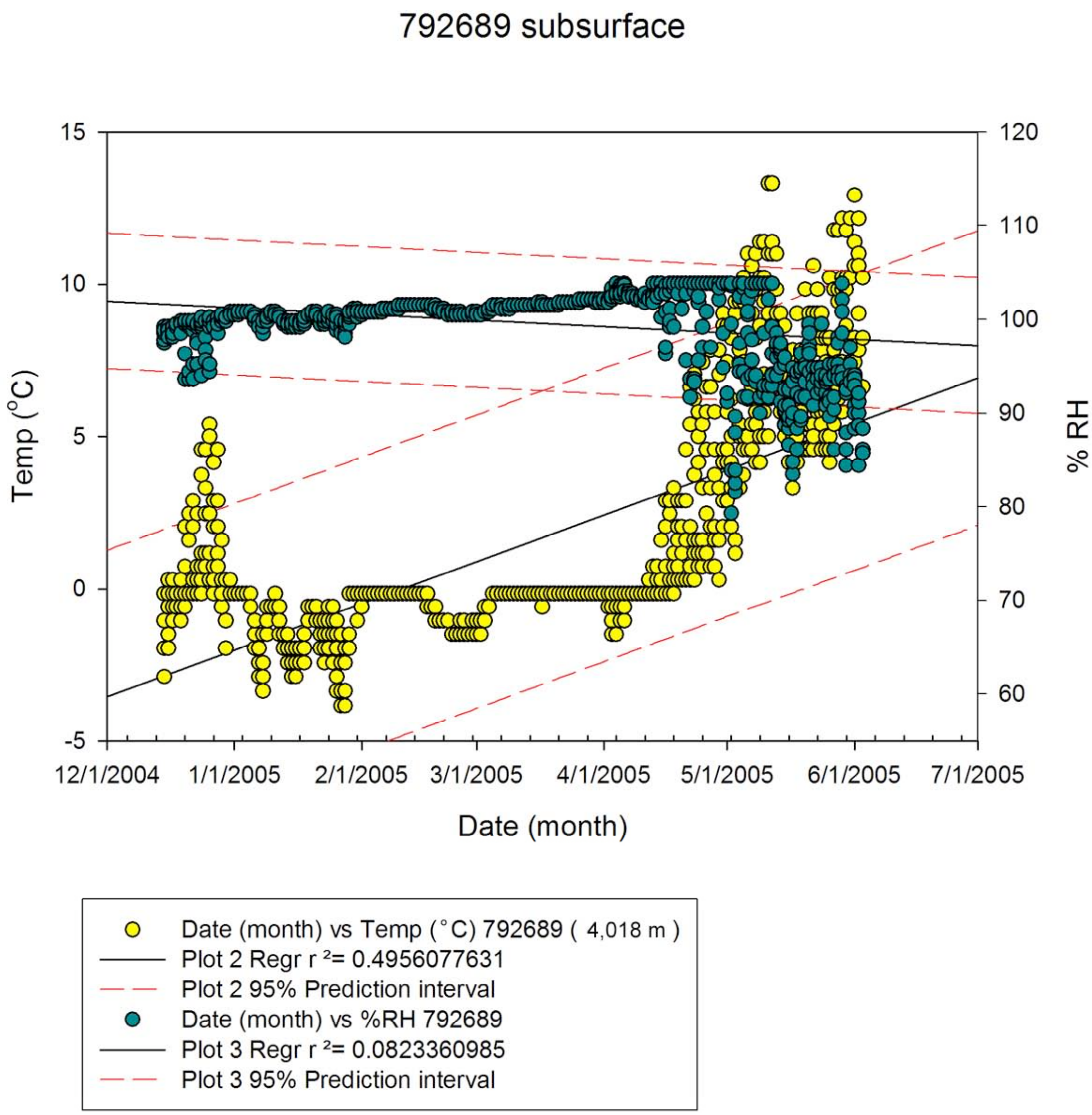

Figure 14. TEMP/RH Logger S/N#792689 from base (Keck side) of Pu‘u Hau Kea, SUBSURFACE, Dec-June 2005.

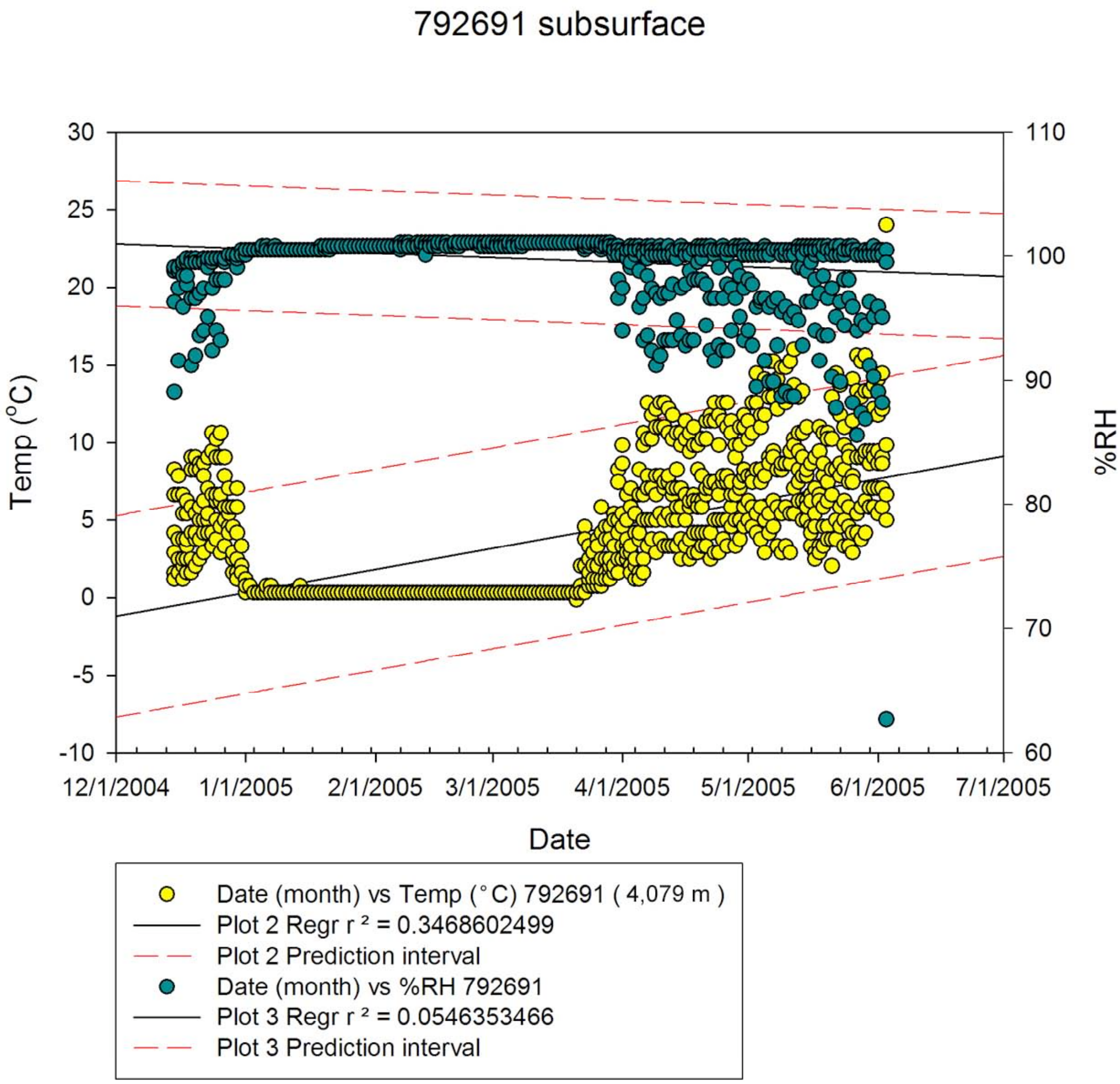

Figure 15. TEMP/RH Logger S/N#792691 inside crater, middle, nw slope, Pu'u Hau Kea, SUBSURFACE, Dec-June 2005.

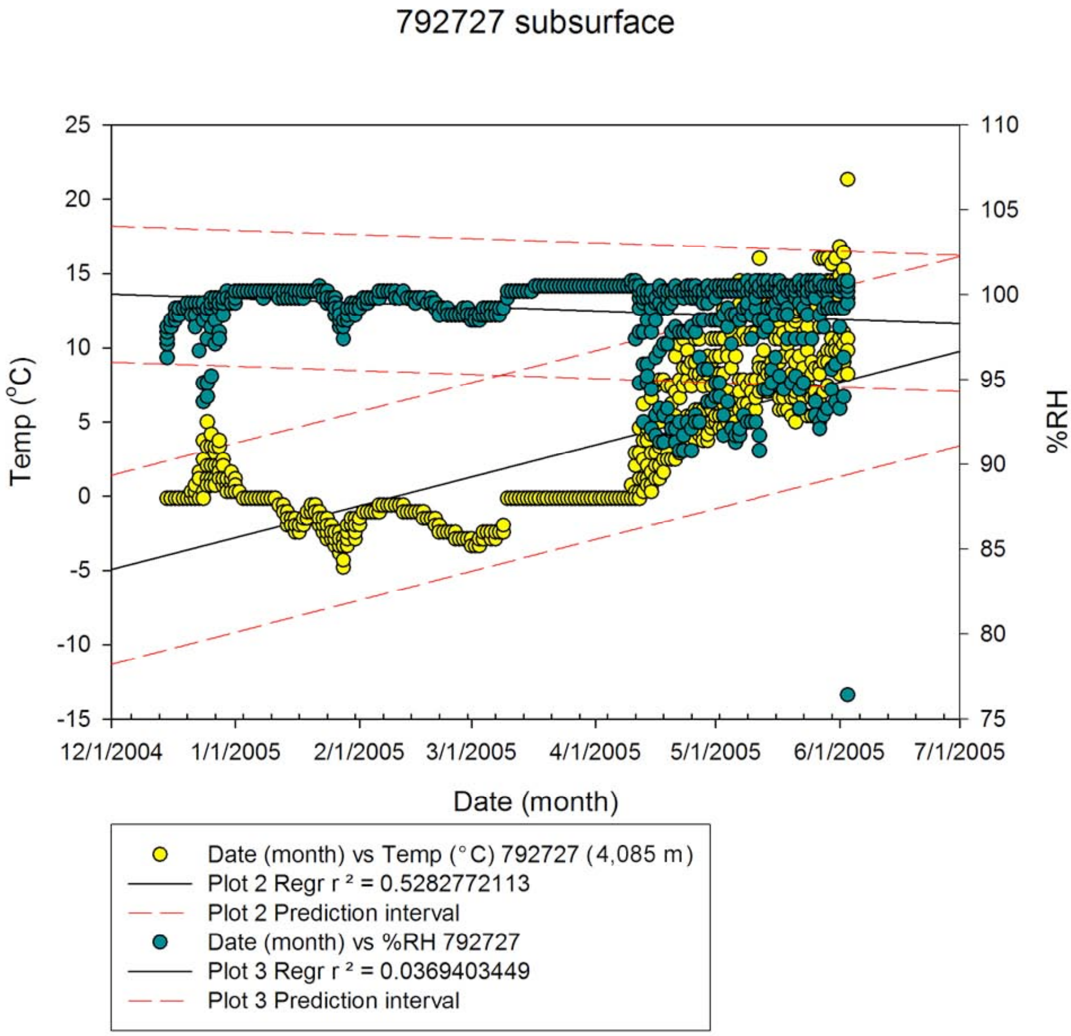

Figure 16. TEMP/RH Logger S/N#792727 middle inner rim, southeast side, Pu‘u Hau Kea, SUBSURFACE, Dec-June 2005.

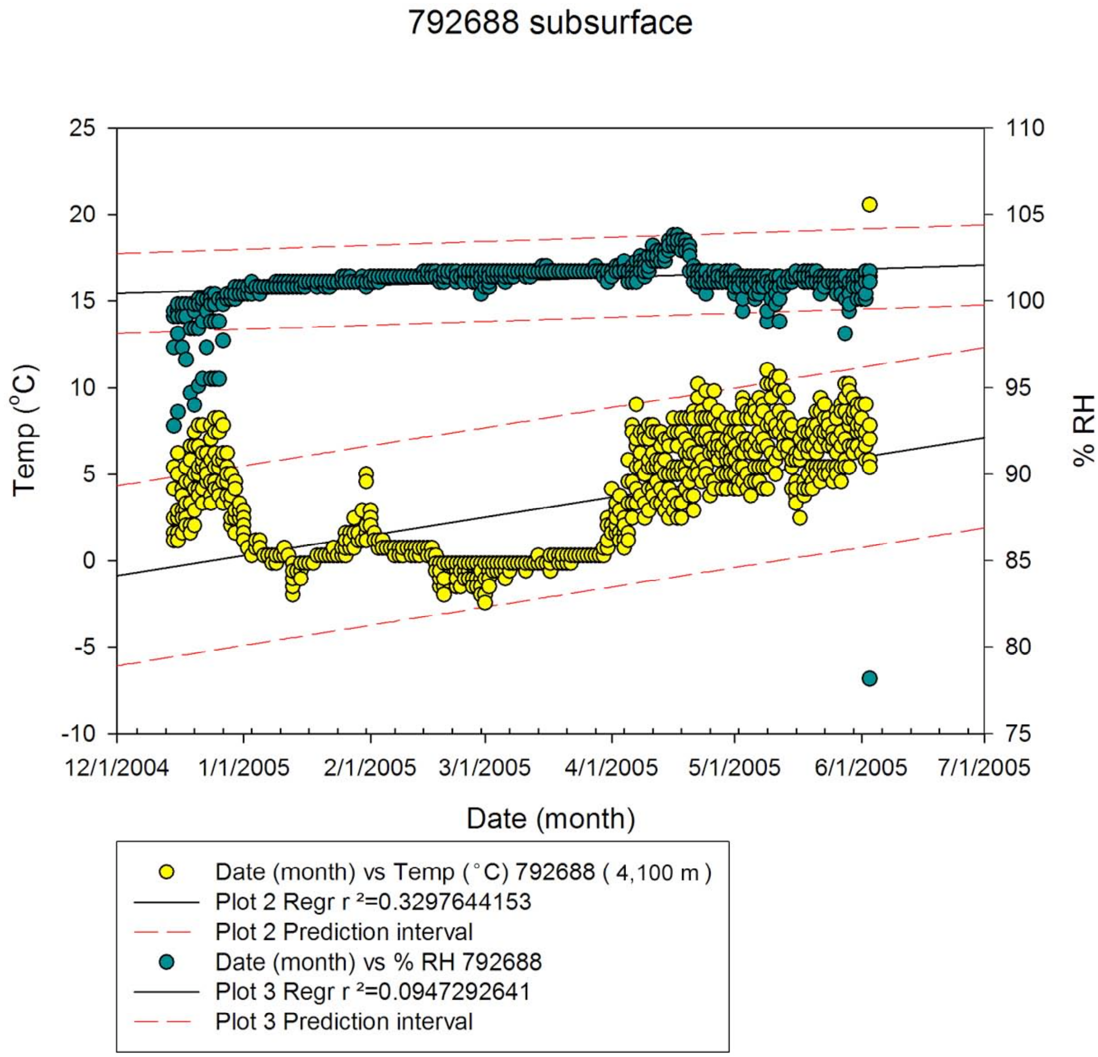

Figure 17. TEMP/RH Logger S/N#792688 upper rim (Hilo side opposite scopes), Pu'u Hau Kea SUBSURFACE, Dec-June 2005.

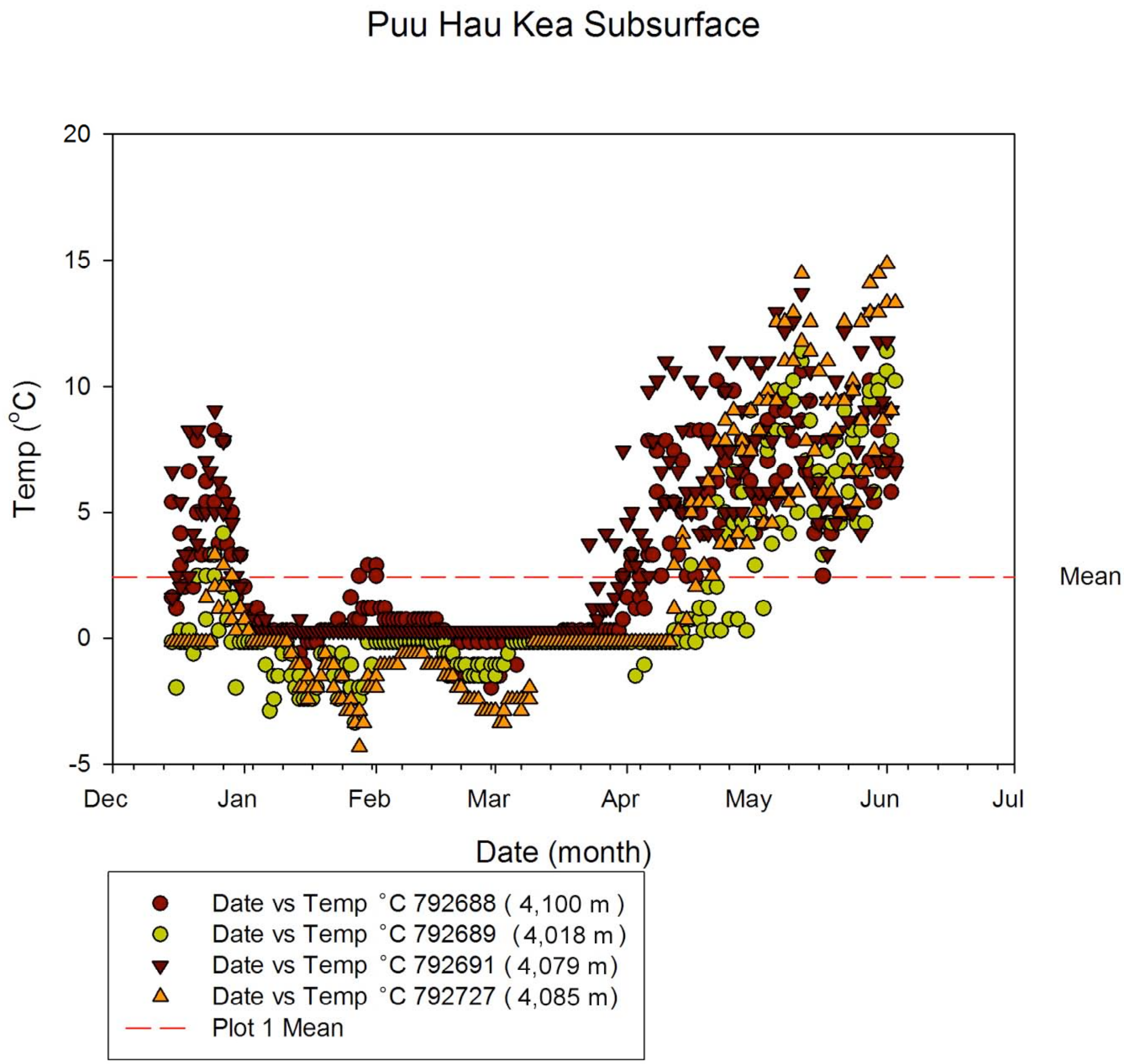

Figure 18. TEMP/RH Loggers Pu‘u Hau Kea combined SUBSURFACE loggers temperature, Dec 2004-June 2005.

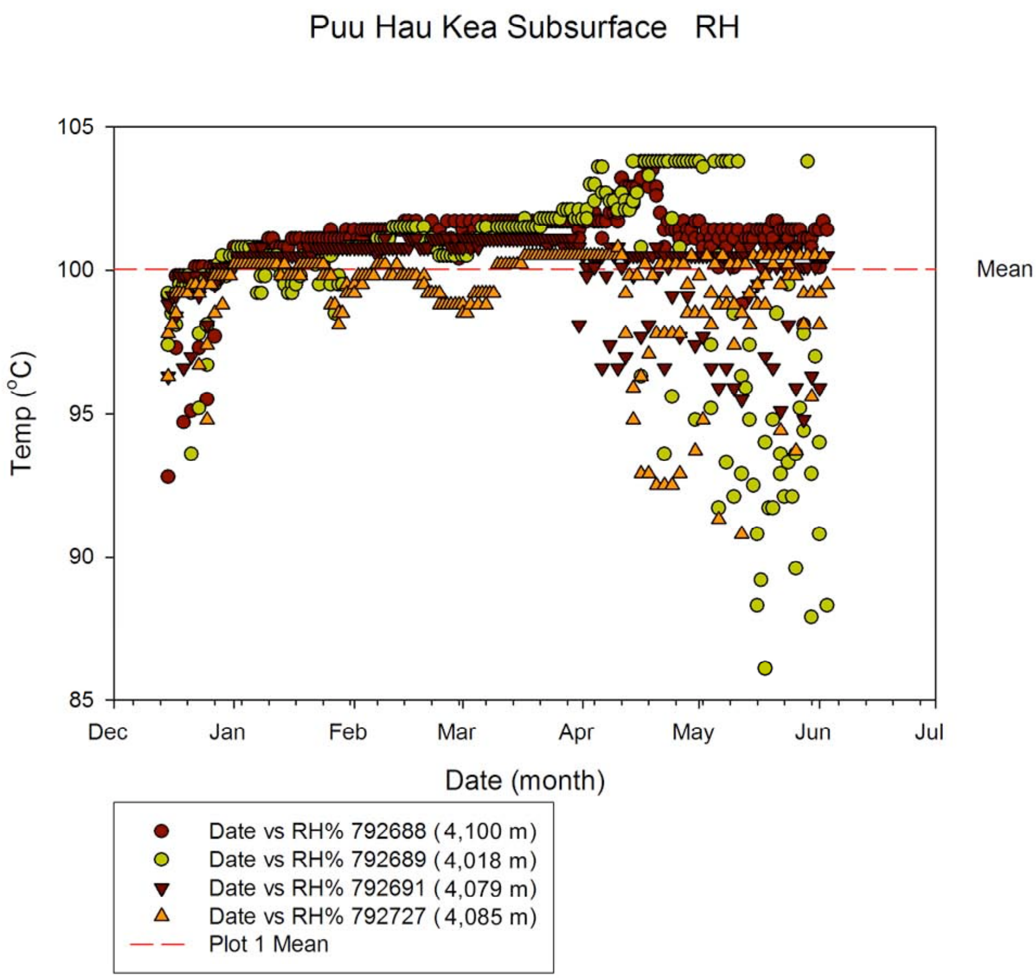

Figure 19. TEMP/RH Loggers Pu'u Hau Kea combined SUBSURFACE loggers relative humidity, Dec 2004-June 2005.

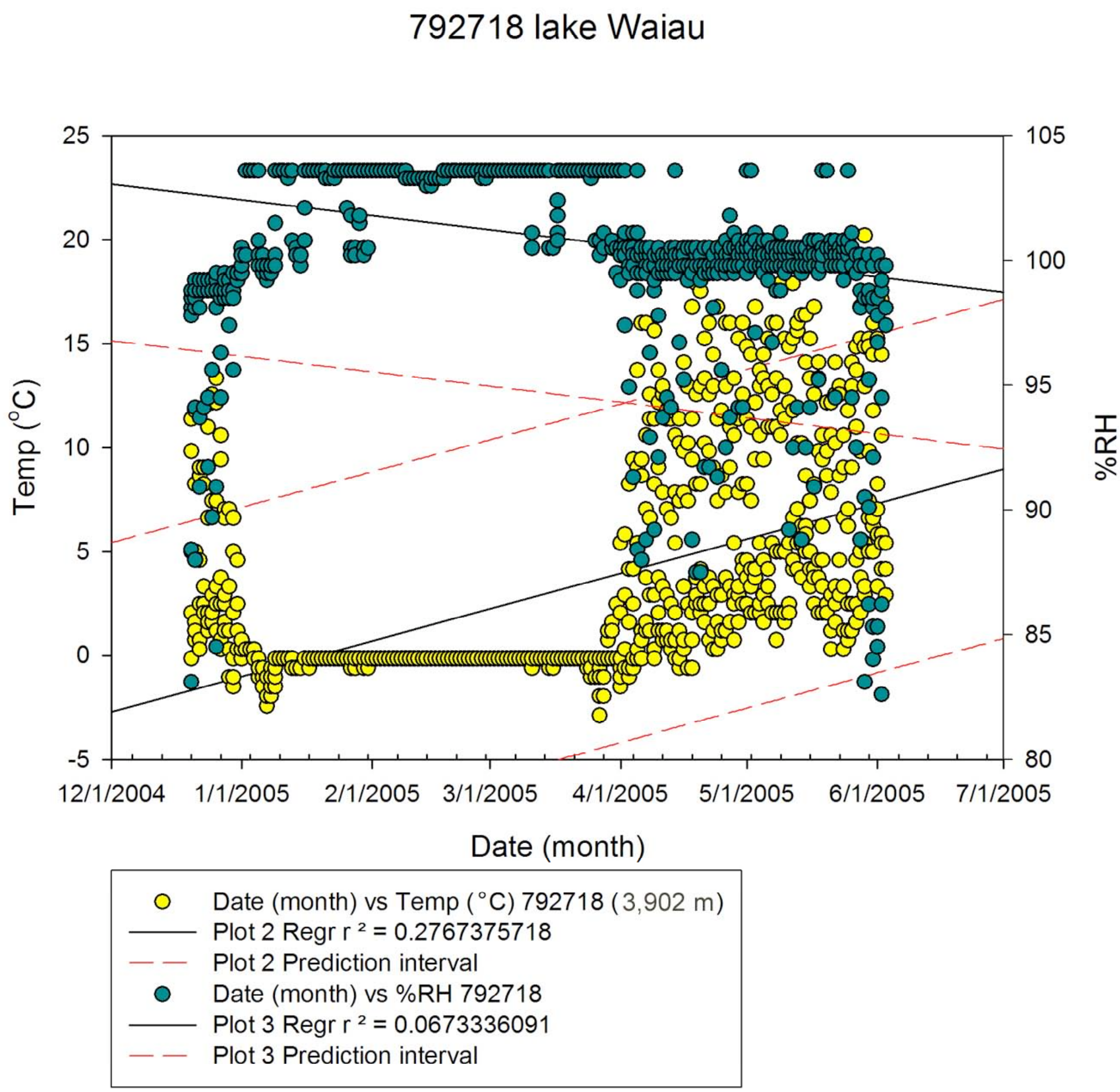

Figure 20. TEMP/RH Logger S/N#792718 on trail to Lake Waiau, SURFACE Dec. 2004- June 2005.

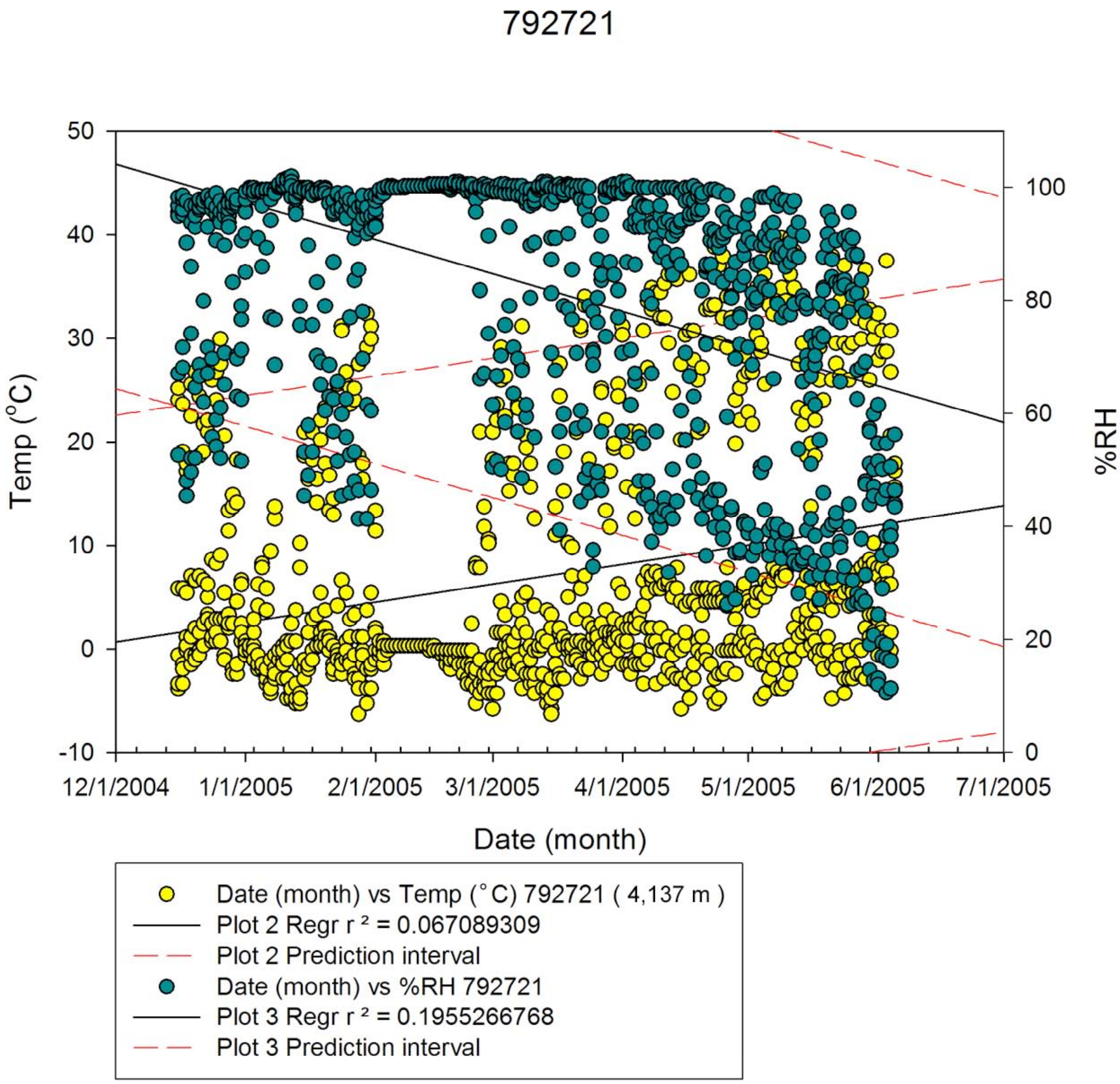

Figure 21. TEMP/RH Logger S/N#792721 Poi Bowl, SURFACE Dec. 2004- June 2005.

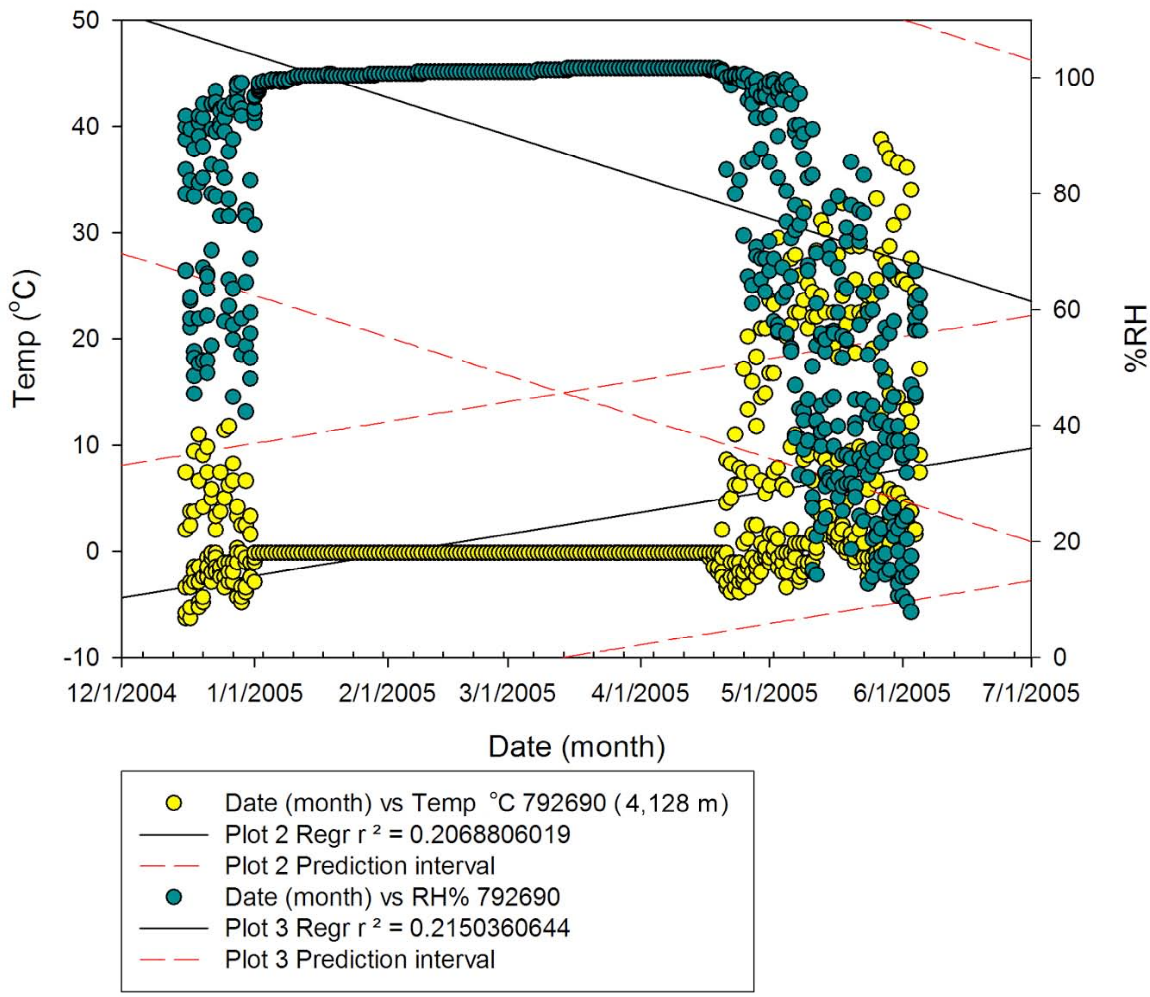

Figure 22. TEMP/RH Logger S/N#792721 Pu'u Hau Oki, SURFACE Dec. 2004- June 2005.

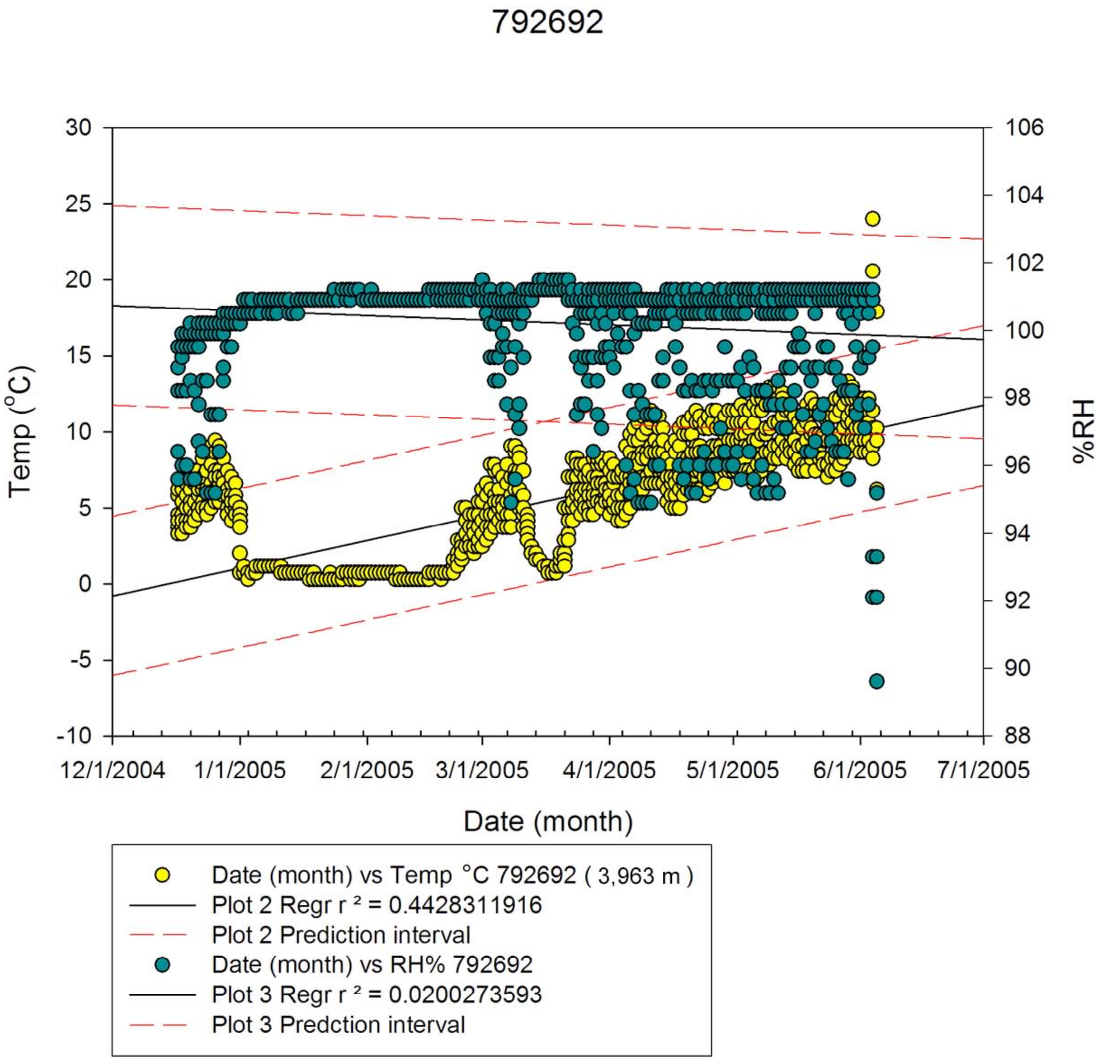

Figure 23. TEMP/RH Logger S/N#792692 Pu‘u Mahoe, SURFACE Dec. 2004- June 2005.

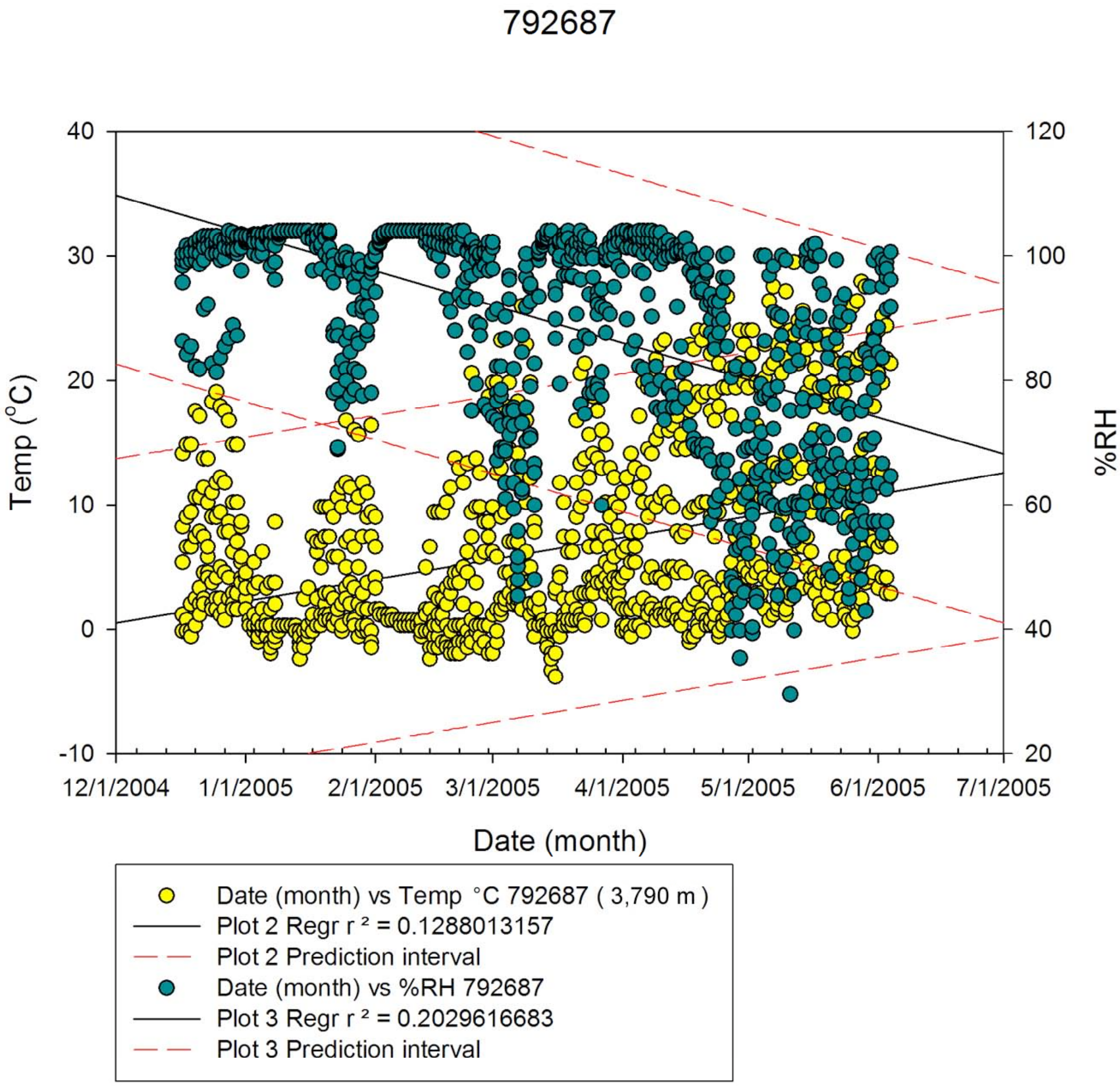

Figure 24. TEMP/RH Logger S/N#792687 very bottom of outside base of Pu‘u Poepoe, SURFACE Dec. 2004-June 2005.

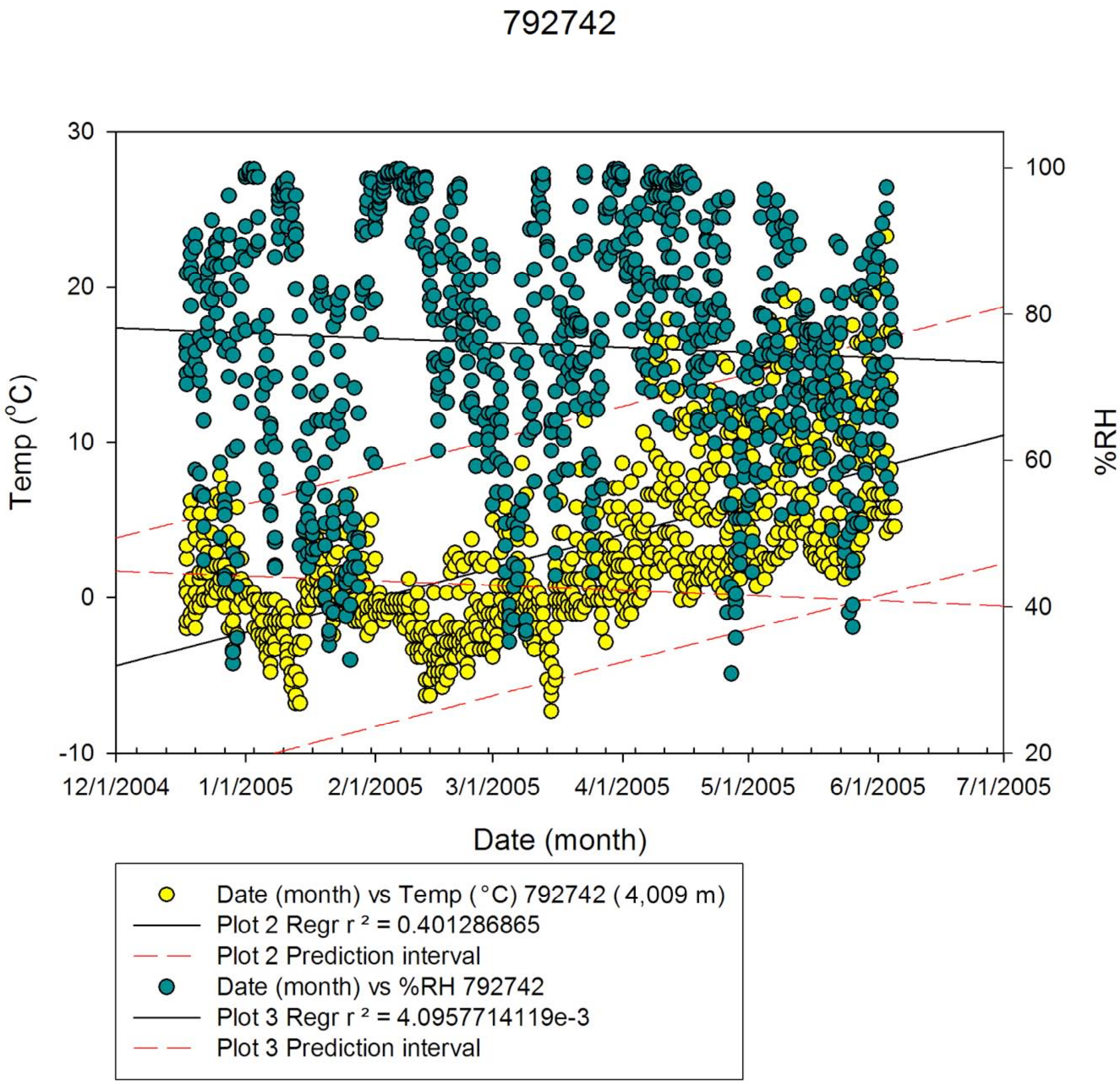

Figure 25. TEMP/RH Logger S/N#792742 summit of Pu‘u Pohaku (4,009 m), SURFACE Dec. 2004- June 2005.

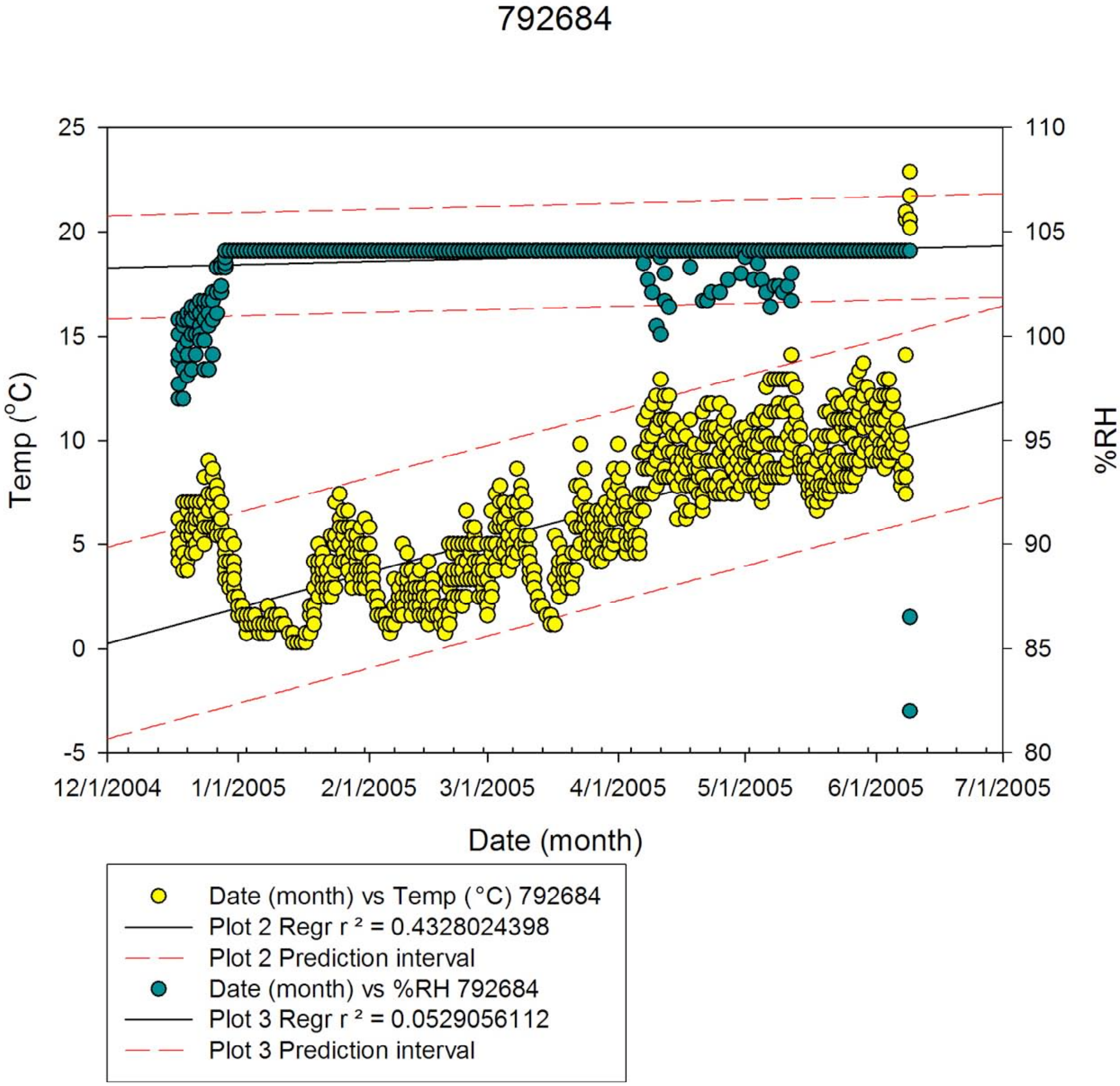

Figure 26. TEMP/RH Logger S/N#792684 summit of Pu‘u Pohaku (4,009 m), SUBSURFACE Dec. 2004-June 2005.

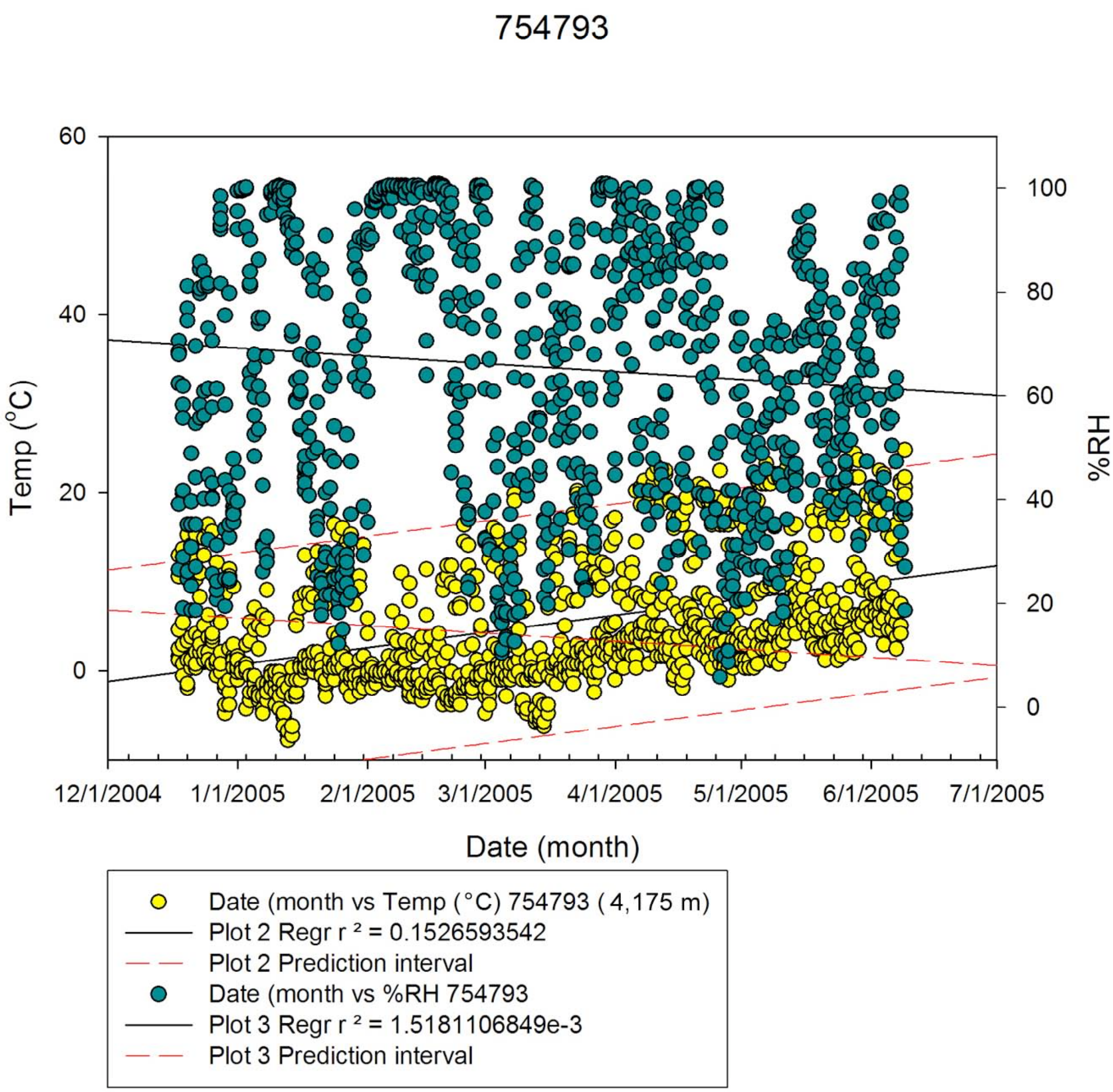

Figure 27. TEMP/RH Logger S/N#754793 summit of Pu'u Poliahu, SURFACE Dec. 2004- June 2005.

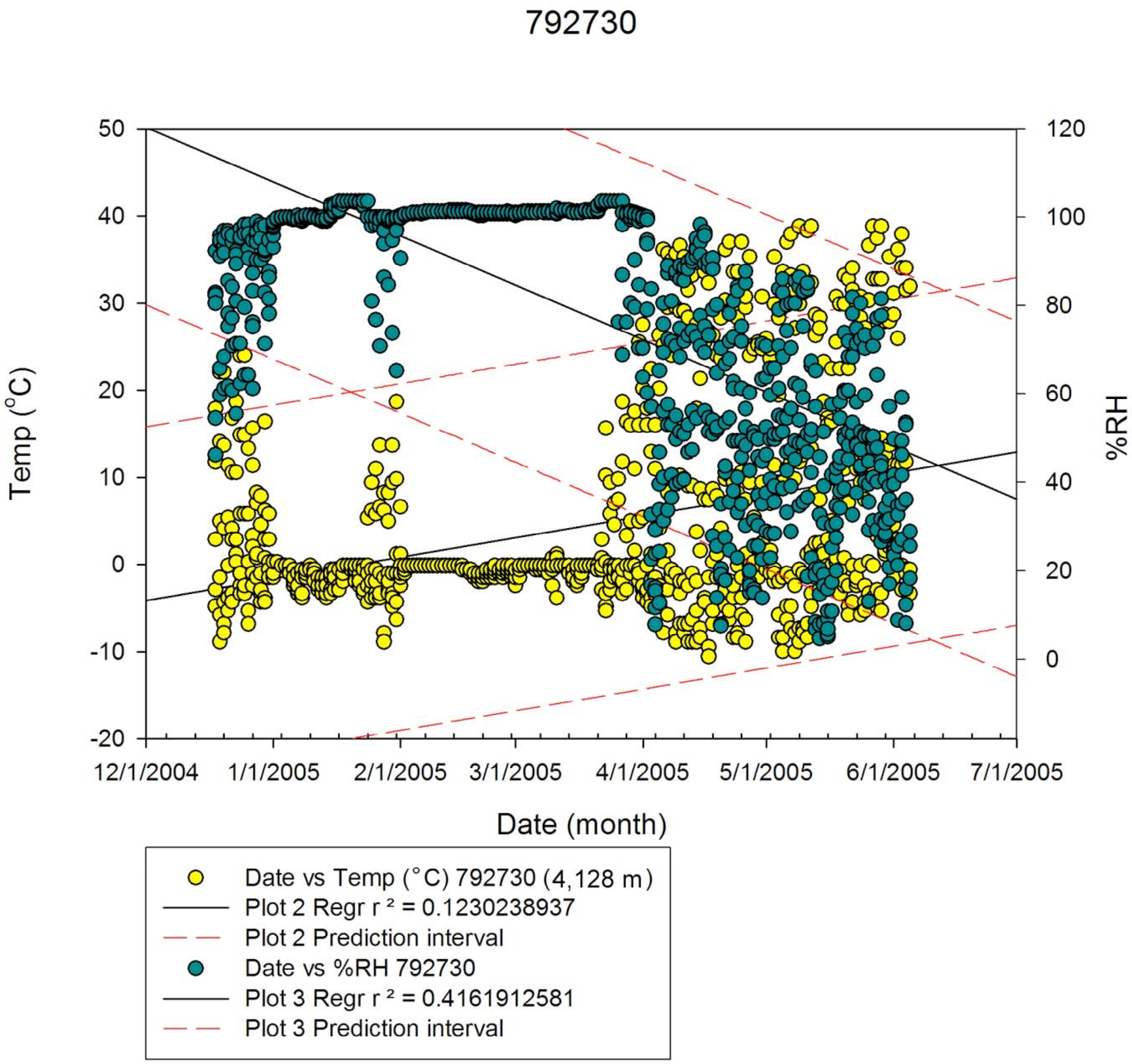

Figure 28. TEMP/RH Logger S/N#792730 inside crater of Pu‘u Wēkiu, SURFACE Dec. 2004-June 2005.

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