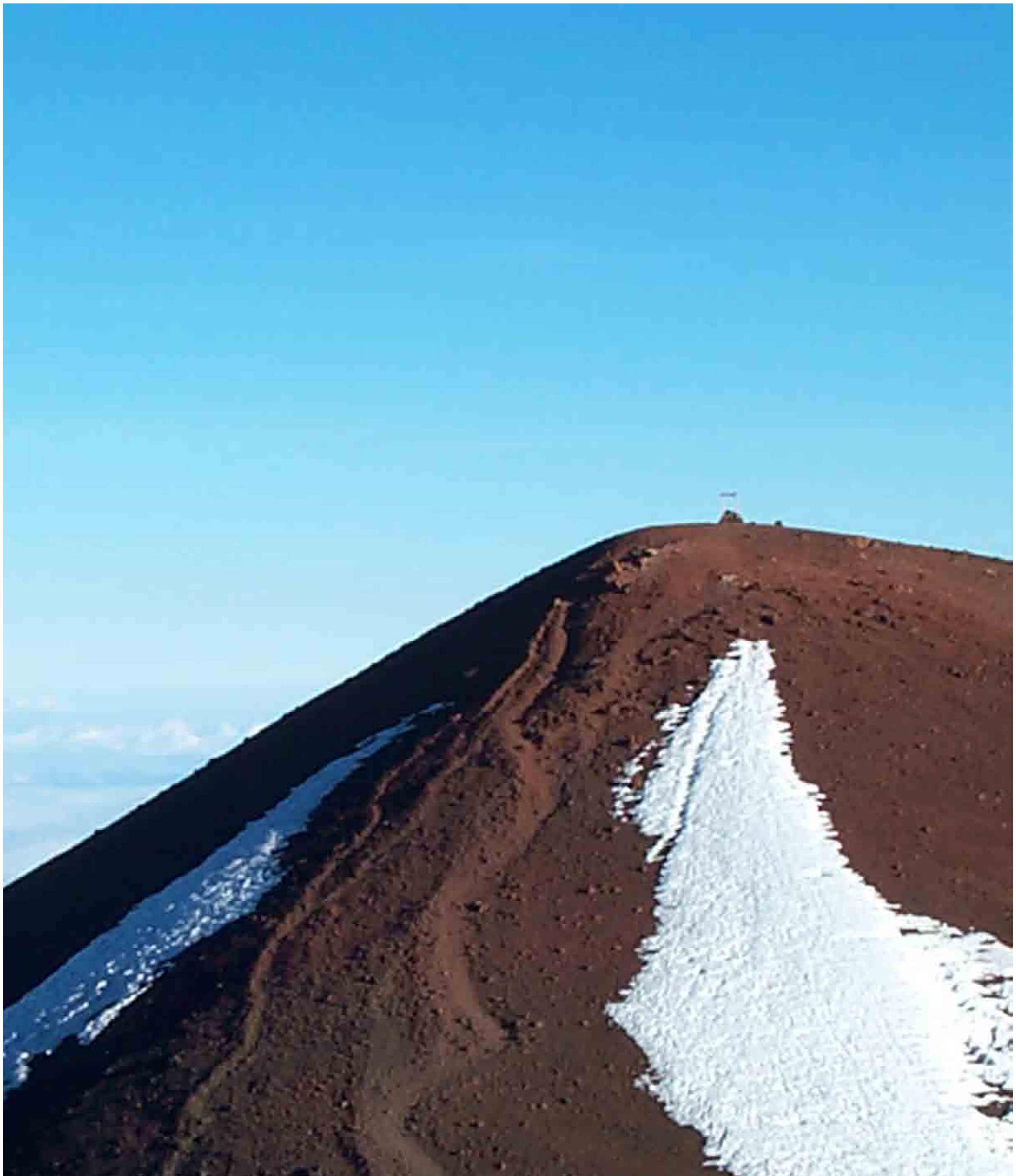

Results of 2004 Wēkiu Bug (*Nysius wekiuicola*) Surveys on Mauna Kea, Hawai‘i Island

Hawaii Biological Survey

Final Report **February 2005**

RESULTS OF 2004 WĒKIU BUG (*NYSIUS WEKIUICOLA*) SURVEYS ON MAUNA KEA, HAWAIʻI ISLAND

FINAL REPORT

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EXECUTIVE SUMMARY

In 2004, surveys for wēkiu bug distribution and abundance at the summit area of Mauna Kea occurred in April and July, while data loggers recording microhabitat parameters such as relative humidity and temperature were installed in July and December. This study builds upon research conducted by the Hawaii Biological Survey of the Bishop Museum that began in the early 1980s, resumed in 1997, and continued in 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.

This study began in April 2004 with three days of sampling for wēkiu bugs took at Pu‘u Hau Oki, and continued in July 2004 with more intensive sampling. Because it is such a vast area, previous information regarding the overall elevational range and distribution of the wēkiu bug throughout the entire alpine zone of Mauna Kea was largely lacking. Thus, wēkiu bug sampling efforts were concentrated in areas not previously sampled such as the remote cinder cone area of Red Hills. Areas surveyed during this study ranged from Pu‘u Kanakaleonui at 9,200 ft (2,800 m) to Pu‘u Hau Oki at 13,70 ft (4,177 m). A total of 55 baited shrimp pitfall traps were installed in April and July, with 10 wēkiu bug captures in April and only one in July. Seasonal activity differences are the likely explanation for so few wēkiu bugs being captured in the 50 traps installed during the July assessment as compared to 5 traps installed in April. Although attempted, a test of trapping efficiency with different types of pitfall traps failed in July because neither trap collected wēkiu bugs.

A total of 45 relative humidity and temperature data loggers were installed and are currently collecting data in a variety of locations throughout the Mauna Kea study area. A preliminary set of 8 data loggers were installed in July, with the remaining loggers installed in December 2004. In December 2004, data from the loggers installed in July were successfully downloaded and provided interesting new findings on the extreme conditions that wēkiu bugs must survive in areas of their most favored habitat. These findings provided valuable new information on wēkiu bug seasonal abundance, microhabitat climate data, as well as their overall range on Mauna Kea that will assist in conserving and managing this rare species.

INTRODUCTION

The Hawaii Biological Survey of the Bishop Museum was contracted by the Office of Mauna Kea Management (OMKM) to continue studies on the distribution and habitat use of the wēkiu bug (*Nysius wekiuicola* Ashlock and Gagné), which is endemic to Mauna Kea. The current study continues Bishop Museum wēkiu bug research that originated in the early 1980s (Howarth and Stone 1982), and continued again in the late 1990s (Howarth *et al.* 1999) and 2002 (Englund *et al.* 2002). 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 on wēkiu bug habitat using temperature and relative humidity loggers.

Wēkiu bug surveys for this study occurred primarily in July 2004, with three days of sampling occurring also in April 2004 and additional data logger installation occurring in December 2004. Previous Bishop Museum wēkiu bug studies were concentrated directly around the astronomical observatories (Gagné and Howarth 1982, Howarth and Stone 1982). Howarth et al. (1999) also examined areas in the Mauna Kea Science Reserve. Because it is such a vast area, previous information was available regarding the overall elevational range and distribution of the wēkiu bug throughout the entire alpine zone of Mauna Kea is still lacking. Thus, emphasis was placed on surveying previously unsampled and remote cinder cone areas during the current study. We also assessed the presence or absence of wēkiu bugs throughout the alpine zone. The results provided valuable new information on wēkiu bug seasonality, microhabitat climate data, and overall range on Mauna Kea that will assist in conserving and managing this rare species.

Areas surveyed during this study ranged from Pu'u Kanakaleonui at 9,200 ft (2,800 m) to the Pu'u Hau Kea Summit at 13,500 ft (4,115 m). To assess the effectiveness of various trapping methods on wēkiu bug capture rates, Pu'u Hau Kea was sampled again in July 2002 using capture methods used in previous studies.

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. Data were successfully downloaded from 6 of the 8 loggers initially installed in July 2004, with one logger malfunctioning and one missing. A total of 45 data loggers were installed and have been collecting temperature and relative humidity data since December 2004.

STUDY AREA

The overall study area has been thoroughly described in previous Bishop Museum reports and can be found in Howarth (et al. 1982), Howarth *et al.* (1999), and Englund *et al.* (2002). The study area 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). We defined study, cinder cones as non-vegetated, dormant volcanic cones in the alpine zone above 9,600 ft (2,925 m). Elevations sampled during the current study ranged from a maximum of 13,441 ft (4,098 m) at Puʻu Hau Kea to a low of 9,594 ft (2,925 m) at Puʻu Kanakaleonui. Unless otherwise stated, puʻu names were derived from USGS topographic quad maps. WGS 84 datum was used for recording GPS locations. Altitudes were determined using a combination of USGS 7.5 minute topographic quad maps and a handheld Suunto altimeter calibrated daily at Hale Pohaku.

Trap Placements in Study Area

A total of 55 pitfall traps, built and emplaced according to protocols discussed in the Methods section, were set in various cinder cone areas at elevations from 13,620 ft (4,152 m) to 9,594 ft (2,925 m), during April and July 2004 (Table 1). Sampled areas include Puʻu Pohaku, Puʻu Hau Oki Lake Waiau, Red Hill, Puʻu Kanakaleonui, and Puʻu Hau Kea. A comparative test of pitfall trapping efficiency between shrimp pitfall traps and ethylene glycol traps occurred at Puʻu Hau Kea, and traps were 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. A comparison of bug trapping efforts and trap distribution from the 2002 and current study is shown in Figure 1.

Data Logger Placement in Study Area

Loggers were placed in various cinder cone areas throughout the summit area (Table 2; Figures 2-4). In July 2004 an experimental test run of 8 data loggers, with paired surface and subsurface loggers, was installed at the very summit of Pu‘u Pohaku and Pu‘u Hau Kea. The remaining 6 loggers installed at the surface (Figure 3). Intensive logger placement occurred at Pu‘u Hau Kea because this area contains one of the last unimpacted, very high elevation cinder cone that maintains a core wēkiu bug population (Englund *et al.* 2002). A total of 9 pairs of loggers (18 total) were placed in a transect 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 Pu‘u Hau Kea cinder cone. Each logger pair consisted of one surface and one buried in the cinder to approximately 10-12 in (25-30 cm). These loggers will thoroughly describe conditions within the Pu‘u Hau Kea crater and outermost slopes, an area with some of the highest known wekiu bug densities on Mauna Kea (Englund *et al.* 2002). 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 2).

METHODS

Sampling methodology consisted of three techniques: visual surveys, baited shrimp pitfall traps, and ethylene glycol pitfall traps. 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 during the study. As in the 2002 Bishop Museum study, an efficiency test of the two main types of pitfall traps used for wēkiu bug surveys was conducted in July 2004, and the detailed protocol for this can also be found in Englund et al. (2002). A total of 5 glycol and 5 shrimp pitfall traps were placed at Pu‘u Hau Kea for 9 days in July 2004 (Table 1). Additionally, an analysis of beetle species bycatch collected and their potential impacts on wēkiu bugs was conducted.

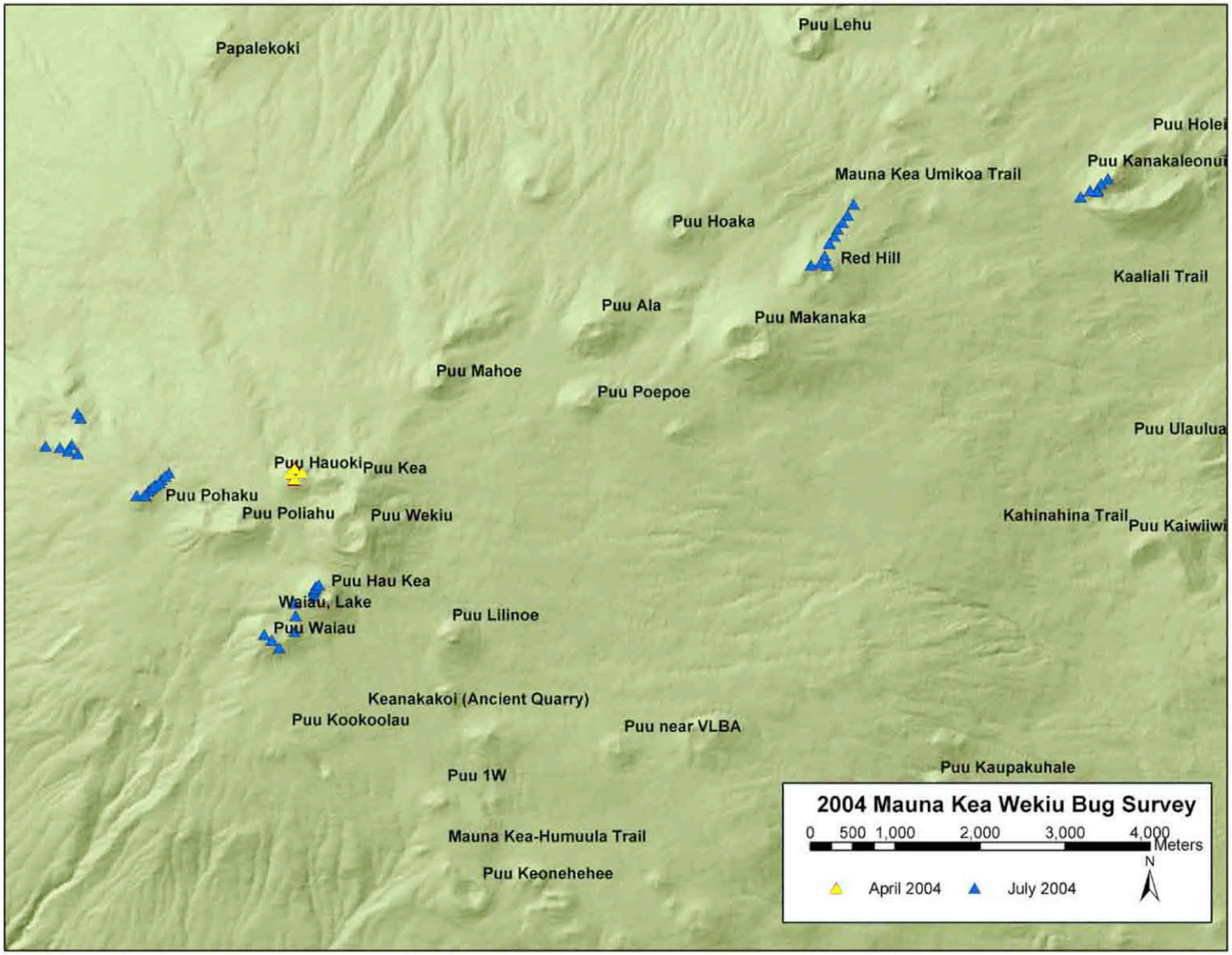

Figure 1. Overall study area and wēkiu bug sampling sites, and GPS waypoints at sample sites for 2004.

Table 1. Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in April and July 2004.

Cinder Cone	Trap #	2004 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Hau Oki	1	19–21 Apr	13,620 ft	19.82736°N 155.47537°W	shrimp
Pu‘u Hau Oki	2	19–21 Apr	13.605 ft	19.82734°N 155.47537°W	shrimp
Pu‘u Hau Oki	3	19–21 Apr	13,626 ft	19.82713°N 155.47526°W	shrimp
Pu‘u Hau Oki	4	19–21 Apr	13,649 ft	19.82693°N 155.47508°W	shrimp
Pu‘u Hau Oki	5	19–21 Apr	13,701 ft	19.82681°N 155.47488°W	shrimp
Pu‘u Hau Kea	1s	6–15 July	13,451 ft	19.81369°N 155.47339°W	shrimp
Pu‘u Hau Kea	2s	6–15 July	13,475 ft	19.81419°N 155.47335°W	shrimp
Pu‘u Hau Kea	3s	6–15 July	13,423 ft	19.81447°N 155.47332°W	shrimp
Pu‘u Hau Kea	4s	6–15 July	13,469 ft	19.81465°N 155.47316°W	shrimp
Pu‘u Hau Kea	5s	6–15 July	13,511 ft	19.81489°N 155.47283°W	shrimp
Pu‘u Hau Kea	1g	6–15 July	13,451 ft	19.81369°N 155.47339°W	glycol
Pu‘u Hau Kea	2g	6–15 July	13,475 ft	19.81419°N 155.47335°W	glycol
Pu‘u Hau Kea	3g	6–15 July	13,423 ft	19.81447°N 155.47332°W	glycol
Pu‘u Hau Kea	4g	6–15 July	13,469 ft	19.81465°N 155.47316°W	glycol
Pu‘u Hau Kea	5g	6–15 July	13,511 ft	19.81489°N 155.47283°W	glycol
Red Hill	1	7–10 July	11,023 ft	19.85516°N 155.41627°W	shrimp
Red Hill	2	7–10 July	11,079 ft	19.85402°N 155.41690°W	shrimp
Red Hill	3	7–10 July	11,156 ft	19.85324°N 155.41741°W	shrimp
Red Hill	4	7–10 July	11,246 ft	19.85254°N 155.41795°W	shrimp
Red Hill	5	7–10 July	11,334 ft	19.85179°N 155.41829°W	shrimp
Red Hill	6	7–10 July	11,451 ft	19.85104°N 155.41881°W	shrimp
Red Hill	7	7–10 July	11,701 ft	19.84971°N 155.41931°W	shrimp
Red Hill	8	7–10 July	11,880 ft	19.84895°N 155.41974°W	shrimp
Red Hill	9	7–10 July	11,845 ft	19.84871°N 155.41897°W	shrimp
Red Hill	10	7–10 July	11,957 ft	19.84874°N 155.42078°W	shrimp
Pu‘u Pohaku	1	8–13 July	13,084 ft	19.82675°N 155.48871°W	shrimp
Pu‘u Pohaku	2	8–13 July	13,103 ft	19.82640°N 155.48910°W	shrimp
Pu‘u Pohaku	3	8–13 July	13,113 ft	19.82605°N 155.48951°W	shrimp
Pu‘u Pohaku	4	8–13 July	13,132 ft	19.82568°N 155.48971°W	shrimp
Pu‘u Pohaku	5	8–13 July	13,149 ft	19.82548°N 155.49012°W	shrimp
Pu‘u Pohaku	6	8–13 July	13,165 ft	19.82530°N 155.49032°W	shrimp
Pu‘u Pohaku	7	8–13 July	13,207 ft	19.82504°N 155.49063°W	shrimp
Pu‘u Pohaku	8	8–13 July	13,251 ft	19.82485°N 155.49089°W	shrimp
Pu‘u Pohaku	9	8–13 July	13,252 ft	19.82435°N 155.49118°W	shrimp
Pu‘u Pohaku	10	8–13 July	13,249 ft	19.82438°N 155.49132°W	shrimp
Pu‘u Pohaku	11	8–13 July	13,287 ft	19.82434°N 155.49214°W	shrimp
Pu‘u Pohaku	12	8–13 July	12,888 ft	19.82877°N 155.49836°W	shrimp
Pu‘u Pohaku	13	8–13 July	12,875 ft	19.82906°N 155.49936°W	shrimp
Pu‘u Pohaku	14	8–13 July	12,857 ft	19.82942°N 155.50025°W	shrimp
Pu‘u Pohaku	15	8–13 July	12,827 ft	19.82958°N 155.50177°W	shrimp
Pu‘u Pohaku	16	8–13 July	12,883 ft	19.82974°N 155.49900°W	shrimp
Pu‘u Pohaku	17	8–13 July	12,812 ft	19.83253°N 155.49805°W	shrimp

Table 1. (cont.). Shrimp paste and ethylene glycol pitfall trap GPS locations (WGS 84) during wēkiu bug surveys conducted in April and July 2004.

Cinder Cone	Trap #	2004 Date Set	Trap Elevation	GPS Coordinates (WGS 84)	Trap Type
Pu‘u Pohaku	18	8–13 July	12,767 ft	19.83304°N 155.49842°W	shrimp
Lake Waiau	1	9–15 July	13,181 ft	19.80997°N 155.47541°W	shrimp
Lake Waiau	2	9–15 July	13,182 ft	19.80820°N 155.47703°W	shrimp
Lake Waiau	3	9–15 July	13,215 ft	19.80905°N 155.47783°W	shrimp
Lake Waiau	4	9–15 July	13,212 ft	19.80960°N 155.47864°W	shrimp
Lake Waiau	5	9–15 July	13,280 ft	19.81296°N 155.47546°W	shrimp
Lake Waiau	6	9–15 July	13,248 ft	19.81161°N 155.47529°W	shrimp
Pu‘u Kanakaleonui	1	10–13 July	9,722 ft	19.85790°N 155.38933°W	shrimp
Pu‘u Kanakaleonui	2	10–13 July	9,716 ft	19.85734°N 155.39005°W	shrimp
Pu‘u Kanakaleonui	3	10–13 July	9,722 ft	19.85672°N 155.39046°W	shrimp
Pu‘u Kanakaleonui	4	10–13 July	9,698 ft	19.85649°N 155.39044°W	shrimp
Pu‘u Kanakaleonui	5	10–13 July	9,663 ft	19.85663°N 155.39122°W	shrimp
Pu‘u Kanakaleonui	6	10–13 July	9,594 ft	19.85596°N 155.39223°W	shrimp
Total Pitfall Traps	55				

Temperature RH/Loggers

To obtain quantitative wēkiu bug microhabitat data, 8 HOBO® Pro RH/Temp (Model H08-032-08) data loggers were installed in July 2004. These loggers accurately measure and store temperature and relative humidity data for up to three years, with data needing to be downloaded at least once a year. A total of 45 loggers were placed throughout the Mauna Kea summit area during the week of 13–17 December 2004 and are currently recording data (Table 2, Figure 2).

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. Several types of protective cases were installed with the 8 loggers set in July. These included a pvc pipe cap with 4 large holes drilled for air circulation and one made from a plastic ziplock food storage container that was glued to the data logger with aquarium silicone sealant. 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 snow melt and provided air circulation. The plastic ziplock container allowed the temperature and humidity probes direct contact with the elements.

Table 2. Temperature/Relative Humidity data loggers placed on the Mauna Kea summit in 2004.

Date	#	Logger Serial #	Logger Placement	Depth Cm	Locality
12/14/04	1	789564	surface	0	Pu‘u Hau Kea
12/14/04	2	792689	subsurface	26	Pu‘u Hau Kea
12/14/04	3	792729	surface	0	Pu‘u Hau Kea
12/14/04	4	792733	subsurface	26	Pu‘u Hau Kea
12/14/04	5	792737	surface	0	Pu‘u Hau Kea
12/14/04	6	792703	subsurface	26	Pu‘u Hau Kea
12/14/04	7	792695	surface	0	Pu‘u Hau Kea
12/14/04	8	792727	subsurface	22	Pu‘u Hau Kea
12/14/04	9	792698	surface	0	Pu‘u Hau Kea
12/14/04	10	792709	subsurface	20	Pu‘u Hau Kea
12/14/04	11	792728	surface	0	Pu‘u Hau Kea
12/14/04	12	792691	subsurface	26	Pu‘u Hau Kea
12/14/04	13	792735	surface	0	Pu‘u Hau Kea
12/14/04	14	792688	subsurface	26	Pu‘u Hau Kea
12/14/04	15	792715	subsurface	26	Pu‘u Hau Kea
12/14/04	16	792710	surface	0	Pu‘u Hau Kea
12/14/04	17	792723	surface	0	Nr. trail to Lake Waiau
12/14/04	18	792807	subsurface	26	Nr. trail to Lake Waiau
12/15/04	19	792718	surface	0	Nr. trail to Lake Waiau
12/15/04	20	792690	surface	0	Pu‘u Hau Oki
12/15/04	21	792686	subsurface	26	Pu‘u Hau Oki
12/15/04	22	792702	surface	0	Pu‘u Hau Oki
12/15/04	23	Logger #7	subsurface	26	Pu‘u Hau Oki
12/15/04	24	792721	surface	0	Poi Bowl, upper
12/15/04	25	792731	surface	0	Poi Bowl, mid
12/15/04	26	792734	surface	0	Poi Bowl, lower
12/15/04	27	792696	surface	0	Pu‘u Wekiu
12/15/04	28	792738	surface	0	Pu‘u Wekiu
12/15/04	29	792730	surface	0	Pu‘u Wekiu
12/16/04	30	792713	surface	0	Pu‘u Poepoe
12/16/04	31	792736	subsurface	26	Pu‘u Poepoe
12/16/04	32	792743	surface	0	Pu‘u Poepoe
12/16/04	33	792687	surface	0	Pu‘u Poepoe
12/16/04	34	792732	subsurface	26	Pu‘u Poepoe
12/16/04	35	792701	surface	0	Pu‘u Mahoe
12/16/04	36	792692	subsurface	26	Pu‘u Mahoe
12/16/04	37	797240	surface	0	Pu‘u Mahoe
12/16/04	38	792714	subsurface	26	Pu‘u Mahoe
12/16/04	39	792717	surface	0	Pu‘u Mahoe

Table 2 (cont.). Temperature/Relative Humidity loggers placed on the Mauna Kea summit in 2004.

Date	#	Logger Serial #	Logger Placement	Depth Cm	Locality
12/17/04	40	792744	surface	0	Pu‘u Pohaku
12/17/04	41	792720	subsurface	26	Pu‘u Pohaku
12/17/04	42	792742	surface	0	Pu‘u Pohaku
12/17/04	43	792684	subsurface	26	Pu‘u Pohaku
12/17/04	44	789556	surface	0	Pu‘u Poliahu
12/17/04	45	Logger #4	surface	0	Pu‘u Poliahu

In July 2004, a test run of the 8 loggers began with 6 loggers placed just below the surface, and two loggers (one at summits of Pu‘u Hau Kea and one at Pu‘u Pohaku) buried at a depth of 10 in (25 cm). Flagging and wiring the loggers together was not attempted in July. In December 2004, paired loggers were placed just below the surface and covered with local substrate, and 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.

RESULTS AND DISSCUSION

In 2004, the study period included 3 field days in April, 10 field days in July, and five days for data logger installation in December. Table 2 summarizes trap locations by cinder cone, elevation, numbers of wēkiu bugs either observed or collected, and sampling effort or the amount of trap days for each sampled cinder cone. Total trap days are defined as the number of nights each shrimp or ethylene glycol pitfall trap was running. For both April and July 2004, a total of 15 wēkiu bugs were collected during 274 total trap days of both shrimp pitfall and ethylene glycol trapping (Table 2). During preliminary April sampling, 14 wēkiu bugs were collected either through shrimp traps or by direct hand collection (Table 3).

Seasonal factors and sampling in the summer appeared to have reduced wēkiu bug captures in July 2004. The only wēkiu bug collected during July sampling was one individual in the Mauna Kea Ice Age Natural Area Reserve (NAR) at the Pu‘u Pohaku cinder cone. This individual wēkiu bug was collected at 12,770 ft (3,893 m), with a substrate of 30% gravel and 70% cobble at the surface, 80% ash and 20% sand at a depth of 2 in

(5 cm), and 100% fine ash at 4 in (10 cm). Interestingly, the substrate was dry until the 4 in (10 cm) level, and thereafter the fine ash was moist. Other species in the pitfall trap with the wēkiu bug included staphylinid and coccinellid beetles (see Beetle section), and several species of muscid, sciarid, and linyphyid flies.

Ethylene Glycol versus Shrimp Paste Pitfall Trapping Test

Because of seasonal factors, wēkiu bugs were not collected either in shrimp paste pitfall or ethylene glycol during the July 2004 pitfall trapping test at the summit of Pu'u Hau Kea, with both sets of traps running for 9 nights. Clearly these inconclusive results indicate that a test of trapping efficiency will only be effective when wēkiu bug activity is great enough to allow some moderate level of catch, which appears to be earlier in the spring season such as June or earlier.

Table 3. 2004 Summary of sample effort and wēkiu bug captures from surveyed Mauna Kea cinder cones using both shrimp pitfall and ethylene glycol pitfall traps in April and July.

Cinder Cone	Highest Elevation	Total Traps	Wēkiu bugs in traps	Wēkiu bugs observed only[1]	Trap Dates	Total Trap Days[2]
Pu'u Hau Oki	13,701 ft	5	10	4	19-21 Apr	10
Pu'u Pohaku	13,252 ft	18	1	0	8-13 July	90
Pu'u Hau Kea	13,511 ft	10	0	0	6-15 July	90
Lake Waiau	13,248 ft	6	0	0	9-15 July	36
Red Hill	11,957 ft	10	0	0	7-10 July	30
Pu'u Kanakaleonui	9,716 ft	6	0	0	10-13 July	18
Totals		55	11	4		274

[1] Number of wēkiu bugs hand collected or observed while setting traps, but not collected in traps. [2]Trap days = total nights x total traps per cinder cone.

Photos of substrate and pitfall trap from Pu'u Pohaku (12,770 ft) where an individual wēkiu bug was collected in July 2004.

Table 4. Wēkiu bug capture data from surveyed Mauna Kea cinder cones using visual collections, shrimp pitfall, and ethylene glycol pitfall traps in April and July.

Cinder Cone	Trap #	Trap Elevation[1]	GPS Coordinates	Wēkiu #'s[2]	Trap Type
Puʻu Hau Oki	1	13,605 ft	19.82734°N, 155.47537°W	4	shrimp
Puʻu Hau Oki	3	13,649 ft	19.82693°N, 155.47508°W	3	shrimp
Puʻu Hau Oki	4	13,701 ft	19.82681°N, 155.47487°W	1	shrimp
Puʻu Hau Oki	5	13,594 ft	19.82663°N, 155.47565°W	2	shrimp
Puʻu Hau Oki	Vis	13,641 ft	19.82595°N, 155.47549°W	2	hand collect
Puʻu Hau Oki	Vis	13,636 ft	19.82603°N, 155.47548°W	2	hand collect
Puʻu Pohaku	16	12,883 ft	19.82974°N 155.49900°W	1	shrimp
Totals				15	

[1]Two mortalities in Puʻu Hau Oki trap #1 frozen to wick, water frozen in all traps.

Beetle Species Bycatch and Potential Impacts

Several new records of introduced beetle species collected during wēkiu bug trapping were made during this study. The following is a list of beetle species collected in July 2004 at various elevations on the summit, and a brief discussion of their potential impacts on wēkiu bugs.

STAPHYLINIDAE

Aleochara verna (Say) **New state record**

Status: Adventive.

Notes: Adults are known to be predators of the eggs, larvae and pupae of various Diptera, particularly several species of Anthomyiidae (Klimaszewski 1984). Larvae are ectoparasitoids of the pupae of cyclorraphous Diptera (Klimaszewski 1984). All life stages frequent microhabitats with suitable concentrations of hosts and prey, such as decaying plants, vertebrate dung and carrion (Klimaszewski 1984). *Aleachara verna* is native to North America (Klimaszewski 1984).

Material examined: **HAWAIʻI**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (15 BPBM).

Creophilus maxillosus (Linnaeus)

Status: Unknown (Newton 1997).

Notes: Adults and larvae occur on carrion of all kinds, but are most frequently reported from the vertebrate carcasses (Newton *et al.* 2000). Adults and larvae are primarily predators of insect larvae that occur in carrion, particularly Diptera (Newton *et al.* 2000). Additionally, adults will prey on certain other kinds of insects found in carrion and also likely ingest some of the nutrient rich fluid byproducts of the decaying carcass (Kramer 1955). *Creophilus maxillosus* is a widely distributed, at least partially synanthropic species, present throughout the Holarctic and northern Neotropical regions, and on numerous islands (Newton *et al.* 2000).

Material examined: **HAWAI'I**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11 Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (1 BPBM).

Tachyporus nitidulus (Fabricius) **New state record**

Status: Adventive.

Notes: Adults and larvae are generalized predators and mycophages that inhabit moist accumulations of organic debris (Campbell 1979). *Tachyporus nitidulus* is a widely distributed, Holarctic species known to be tolerant to high elevation conditions (Campbell 1979).

Material examined: **HAWAI'I**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (6 BPBM).

HYDROPHILIDAE

Sphaeridium scarabaeoides (Linnaeus)

Status: Introduced (Sweezy 1931).

Notes: Adults are terrestrial predators that typically dwell in the fecal deposits of domesticated ungulates (Smetana 1978). *Sphaeridium scarabaeoides* will occasionally also be found in other kinds of accumulations of decaying organic matter (Hansen 1995). This species is native to the Palaearctic region and was introduced to the Hawaiian Islands in 1909 to control pestiferous Diptera (Sweezy 1931).

Material examined: **HAWAIʻI**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (1 BPBM).

SCARABAEIDAE

Onthophagus nigriventris d'Orbigny

Status: Introduced (Nakao & Funasaki 1979).

Notes: This alien, coprophagous, dung beetle, was first released into the Hawaiian Islands in 1975, one of several species of Scarabaeidae introduced as biocontrol agents of the mammal dung-breeding fly *Haematobia irritans* (Linnaeus) (Diptera: Muscidae) (Nakao & Funasaki 1979). *Onthophagus nigriventris* is native to Australia (Nakao & Funasaki 1979).

Material examined: **HAWAIʻI**: Mauna Kea Ice Age NAR, near Pu'u Pohaku, 19°49.732'N, 155°29.427'W, 08 Jul 2004, Englund, Montgomery & Ramsdale leg., dead on ground in area of glacial till (1 BPBM).

DERMESTIDAE

Dermestes frischii Kugelann **New island record**

Status: Adventive (Beal 1991).

Notes: This cosmopolitan species is typically associated with vertebrate carcasses in the latter stages of decomposition (Beal 1991). Both adults and larvae are saprophagus, feeding directly on the animal remains.

Material examined: **HAWAIʻI**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (1BPBM).

CLERIDAE

Necrobia rufipes (DeGeer)

Status: Adventive (Blackburn & Sharp 1885).

Notes: A cosmopolitan species that is associated with vertebrate carcasses in natural situations (Simmons & Ellington 1925). Strongly synanthropic, this species also commonly infests stored products, including preserved meats, cheeses and copra, *Cocos nucifera* Linnaeus (Simmons & Ellington 1925). Adults and larvae of *Necrobia rufipes* engage saprophagy and will also prey on other insects, particularly Diptera larvae.

Material examined: **HAWAI'I**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (2 BPBM).

COCCINELLIDAE

Hippodamia convergens Guérin-Menéville

Status: Introduced (Funasaki *et al.* 1988).

Notes: This species is native to North America and was first introduced to the Hawaiian Islands in 1896 as a biocontrol agent of pest species of aphids (Hemiptera: Sternorrhyncha) (Funasaki *et al.* 1988). The adults and larvae are most commonly found on various species of vegetation, including several species of agricultural significance, where they are predators of Sternorrhyncha (Hagen 1962). However, *H. convergens* is also known to feed upon dead insects (Hagen 1962). Aggregations of adults of *H. convergens* occurring in high elevation, alpine habitats have been reported frequently (Hagen 1962).

Material examined: **HAWAI'I**: Mauna Kea Ice Age NAR, Pu'u Pohaku, 19.82485°N, 155.49089°W, 13186 ft., 11Jul 2004, Englund, Montgomery & Ramsdale leg., shrimp baited pitfall (1 BPBM).

Potential Impacts of Introduced Beetle Species

Hippodamia convergens, is alien beetle species which is both tolerant of high elevation conditions and known to feed on individual dead insects. This alien species could directly compete with wēkiu bugs for food resources.

The impact of the remaining species of Coleoptera on wēkiu bugs listed above is unclear. All of these species with the exception of *Onthophagus nigriventris*, are known to be attracted to invertebrate carrion, at least as presented by the volume and form of such carrion utilized as bait in the pitfall traps used during this survey. Therefore, the possibility exists that introduced beetle species are directly competing with wēkiu bugs for invertebrate carrion in the form of freshly dead aeolian drift which is a highly ephemeral resource that may be related to the amount of available snowpack.

The volume of rotting shrimp and shrimp paste used to bait an individual trap may more accurately mimic the vertebrate carcasses that are present in the summit area than it does the typical scenario of invertebrate carrion, *i.e.*, a single dead insect. This may serve to explain the capture in the baited traps of the three species of Staphylinidae, *Dermestes frischii* and *Necrobia rufipes*. It is unknown whether or not any of these beetle species would feed upon single, isolated individual dead insects, although their capture in traps from the same cinder cone (Pu'u Pohaku) as the individual wēkiu bug capture from July indicates their range definitely overlaps and potentially could compete for food resources.

Data Logger Results

In July 2004, 8 temperature/relative humidity data loggers were placed at Pu'u Hau Kea, Pu'u Wēkiu and Pu'u Pohaku. During the December 2004 field trip 7 of the loggers emplaced in July were recovered and data successfully download (Figs 5-26). One subsurface logger from the summit of Pu'u Hau Kea was lost, despite efforts that included using a metal detector (which did not work because of high mineral content of the substrate) to retrieve it. Because of the loss of this buried logger, we made greater efforts in December 2004 to flag and wire the loggers together to enhance the chances of future recovery. Currently, 45 loggers installed in December are now collecting data.

In July, we experimented with several types of protective housings for the loggers to determine which would be the best protection for the loggers in the hostile environment of the summit. We used several types of pvc pipe cases that snugly fit around the logger, and also a plastic ziploc type plastic food containers that were open on the bottom and glued to the top of the logger. Temperature recordings were unaffected by the both types of logger cases, but humidity may have been affected with the ziploc protective housing because it was open on the bottom. Concern had been expressed at 2004 wēkiu meetings regarding the effectiveness of the relative humidity portion of the data loggers. Some of this concern may have been justified, for example, when we retrieved the logger from the summit of Pu'u Wēkiu in a ziploc housing (open on the bottom) the humidity sensor had a layer of frozen water approximately 1/8 inch thick and it appeared from the data that the frozen sensor was recording humidity at a constant. This was in contrast to the data loggers with protective pvc pipe cases (protected and closed on the bottom, but with air holes) that had variable humidity, and the retrieved sensors appeared not to be frozen as was the case on Pu'u Wēkiu. An example illustrating the difference between a non-frozen humidity sensor (Fig. 6) and a frozen solid humidity sensor (Fig. 8) shows that humidity did not vary on a frozen sensor. It was apparent that in the warmer month of July 2004 the humidity sensor at Pu‘u Wēkiu was not frozen (Fig. 25), as distinct diel humidity fluctuations were observed, though these fluctuations were not observed in December of 2004 (Fig. 26) when the sensor was clearly frozen, as we observed upon pulling this data logger in December.

Table 5. Loggers installed in July 2004 and status of data downloads.

Cinder Cone/area	Date Installed	Date data Downloaded	Elevation	Logger Serial #	Placement
Pu‘u Hau Kea-summit	15 Jul 2004	14 Dec 2004	13,450 ft	S/N#754789 (#7)	surface
Pu‘u Hau Kea-summit	15 Jul 2004	logger lost	13,450 ft	#5	subsurface
Pu‘u Hau Kea-trail	15 Jul 2004	14 Dec 2004	13,180 ft	#10	surface
Lake Waiau-summit	15 Jul 2004	15 Dec 2004	13,160 ft	#6	surface
Pu‘u Pohaku-summit	13 Jul 2004	17 Dec 2004	13,170 ft	#3	subsurface
Pu‘u Pohaku-summit	13 Jul 2004	17 Dec 2004	13,170 ft	#4	surface
Pu‘u Pohaku-base[1]	13 Jul 2004	17 Dec 2004	13,050 ft	#9	surface
Pu‘u Wēkiu-summit	15 Jul 2004	15 Dec 2004	13,720 ft	#2	surface
Totals					

[1]This logger installed in exact position of where one wēkiu bug was collected.

To allow the data loggers to fully equilibrate to the new surroundings, data from the first full day of operation were not included in these in Figures 5-26. Overall temperatures and relative humidities for the period from July to December were plotted on Figures 5–11, with a general downward seasonal trend in temperature and highly variable humidities. Because of the great amount of data from July to December 2004 daily trends are somewhat difficult to see on the graphs. Thus, weekly fluctuations for both the summer (July) and winter (December) are shown in Figures 12-26. These data clearly indicate diel temperature fluctuations, but it is of interest that the one subsurface logger we were able to retrieve from Pu‘u Pohaku (Fig. 12-14) had more stable temperatures than the surface loggers, and completely stable humidity levels. Although wēkiu bugs may not be able to penetrate the surface as deeply (10 in or 26 cm) as this subsurface logger was buried, it does indicate the greater relative stability of the deeper subsurface environment as compared to the surface microhabitat.

One of the most interesting preliminary wēkiu bug microhabitat findings is that temperature and relative humidity at the surface fluctuates greatly, perhaps even more than was previously expected by researchers. For example, in July 2004 the surface temperature at the Pu‘u Pohaku cinder cone at 13,170 ft (4,015 m) went to nearly 25 °C on a daily basis (Fig. 15). Even more striking were summer diel fluctuations at the Puʻu Hau Kea summit of 13,450 ft (4,100 m) with daily surface temperatures exceeding 30 °C (Fig. 23). In December surface temperatures were greatly reduced at Puʻu Hau Kea, and sometimes did not exceed freezing for a period of several days (Fig. 24). The temperature fluctuations we found at Puʻu Hau Kea and Puʻu Pohaku are particularly important as both areas are prime wēkiu bug habitat. In fact, the data logger at Puʻu Hau Kea was placed in some of the best remaining wēkiu bug habitat available and this exact location still contains some of the highest bug densities (Englund *et al.* 2002).

From a management perspective, these findings indicate that the depth to which wēkiu bugs are able to penetrate the natural substrate must be one of the most important factors influencing their distribution. From our April and previous surveys it is known that wēkiu bugs can indeed be found at the surface of the substrate, particularly near the leading edge of a melting snowpack. Wēkiu bugs will exploit well-preserved aeolian drift (this study from April 2004; also see: Howarth and Stone 1982; Ashlock and Gagné 1983; Howarth et al. 1999) found at the snowpack's edge, but can also be found in areas totally lacking snowpack such as at Puʻu Pohaku in July 2004. The daily fluctuations of nearly 30 °C found at Puʻu Hau Kea has the implication that wēkiu bugs must require refugia within the substrate to avoid these daily extremes. Any disturbance to the natural substrate, such as paving or filling in the interstitial spaces would likely eliminate wēkiu bugs from that particular habitat. Clearly, future laboratory research examining diel movements should replicate natural substrates and environmental conditions to determine how far down into the substrate wēkiu bugs must go to avoid these extreme conditions. Of critical importance will also be determining how these insects overwinter in the substrate, and how far down into the substrate they either lay eggs or overwinter as adults. Replicating these extreme natural conditions in the lab, along with learning other basic life history parameters will shed light on proposed and future mitigation activities, and potentially could lead to habitat restoration leading to increased wēkiu bug populations.

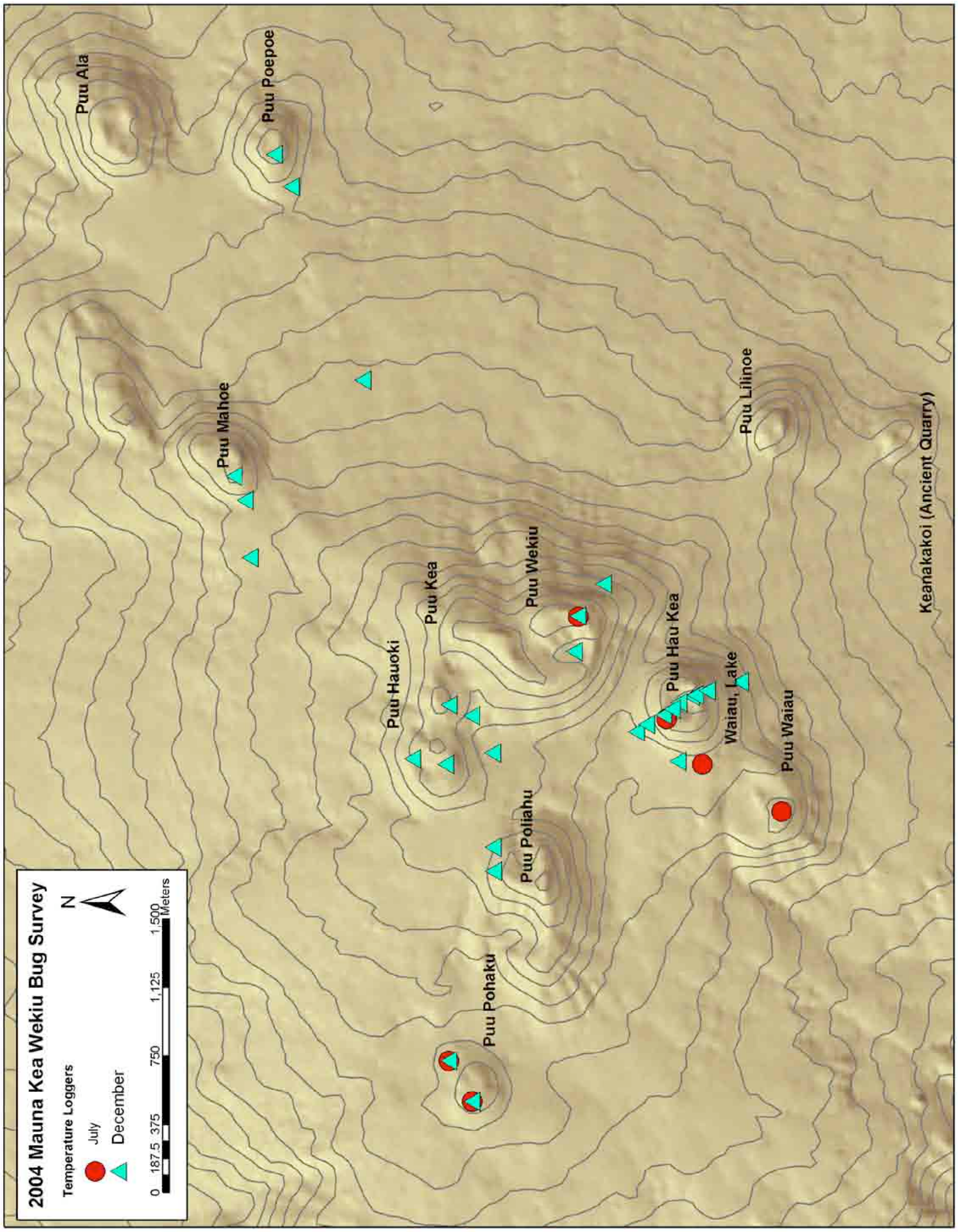

Figure 2. Temperature/Relative Humidity data loggers running at the summit of Mauna Kea.

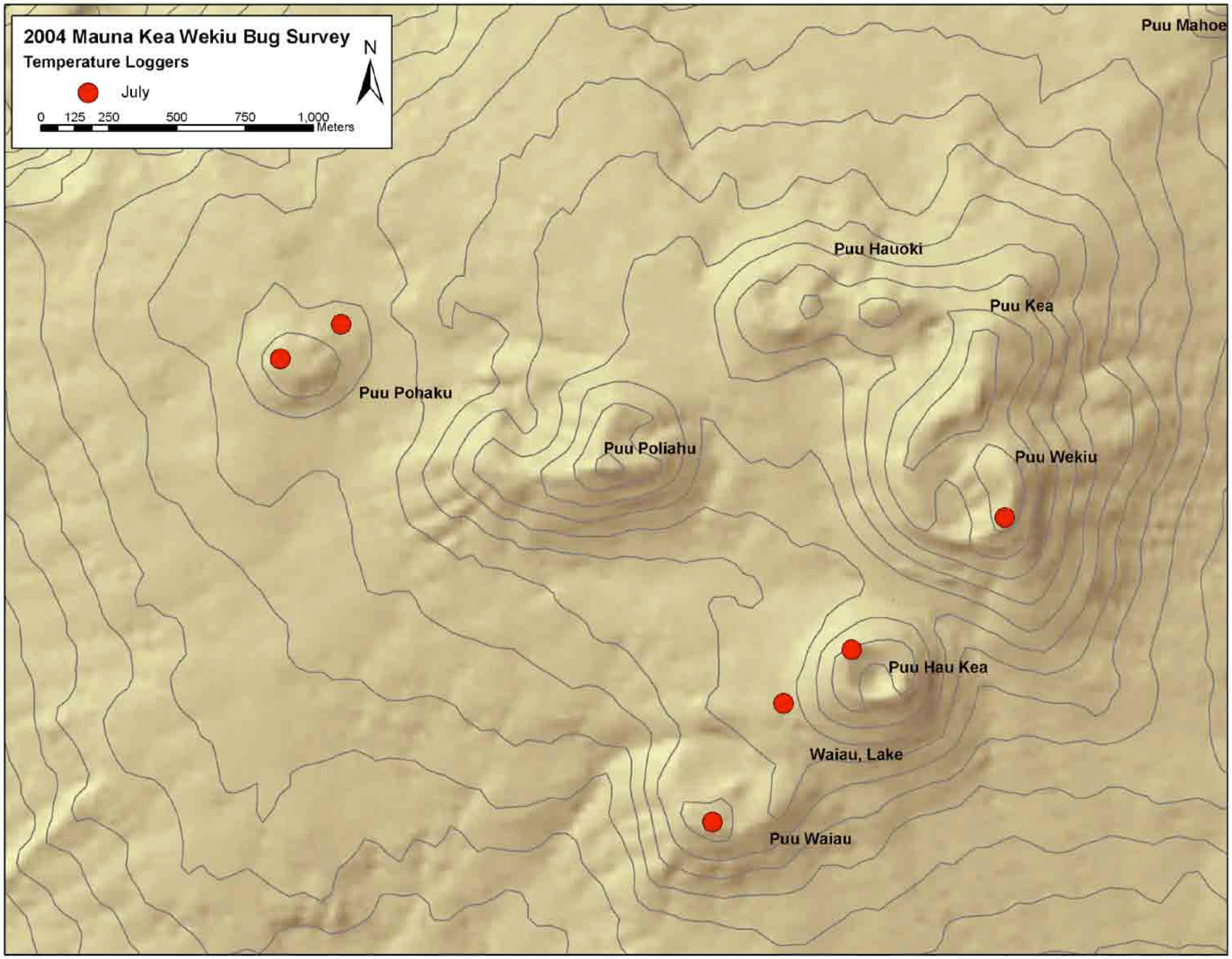

Figure 3. Temperature/Relative Humidity data loggers installed in July 2004, paired loggers (subsurface and surface installed) on Pu‘u Pohaku and Pu‘u Hau Kea.

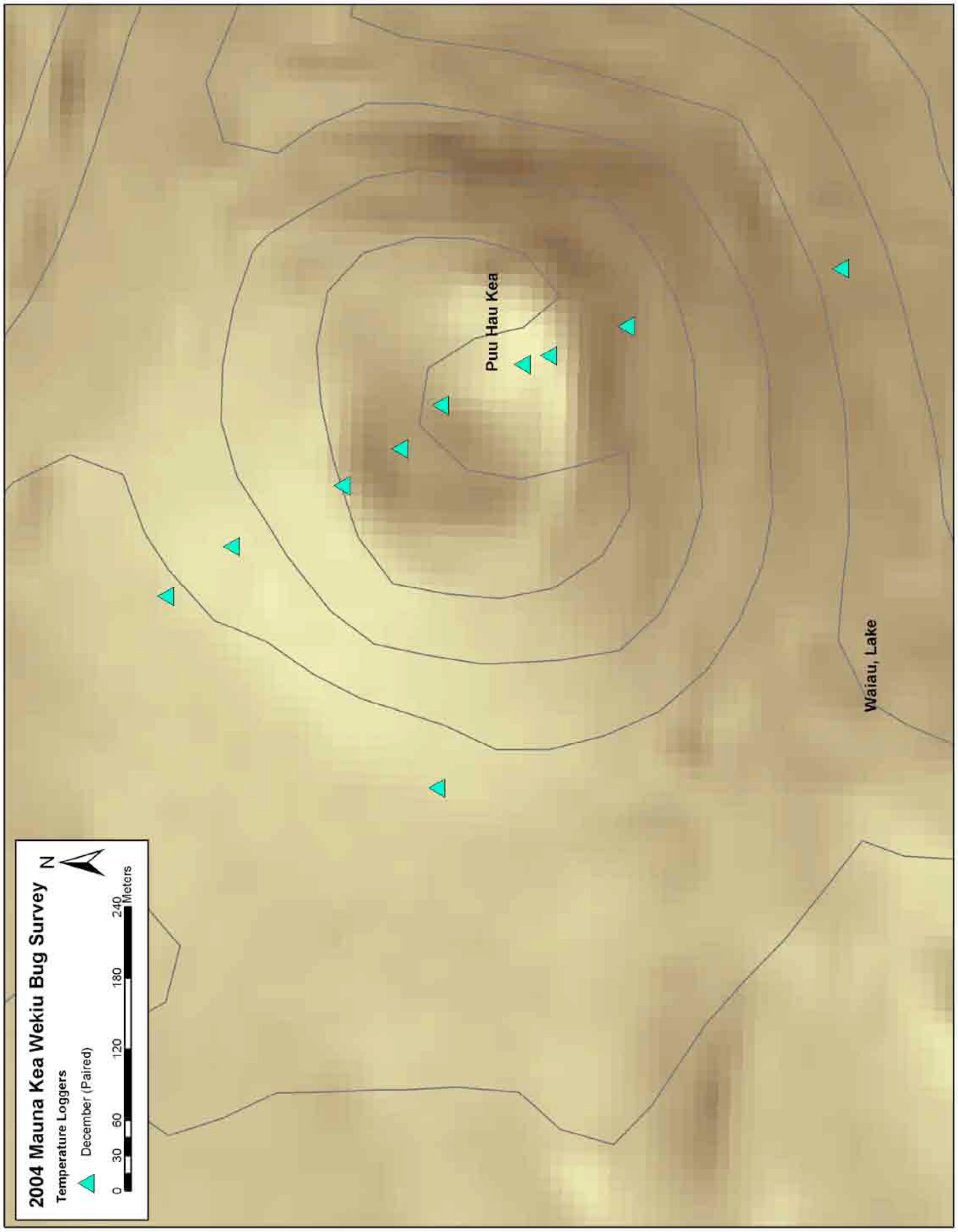

Figure 4. Temperature/Relative Humidity data loggers installed as part of an experimental paired logger (subsurface and surface) test on Pu'u Hau Kea.

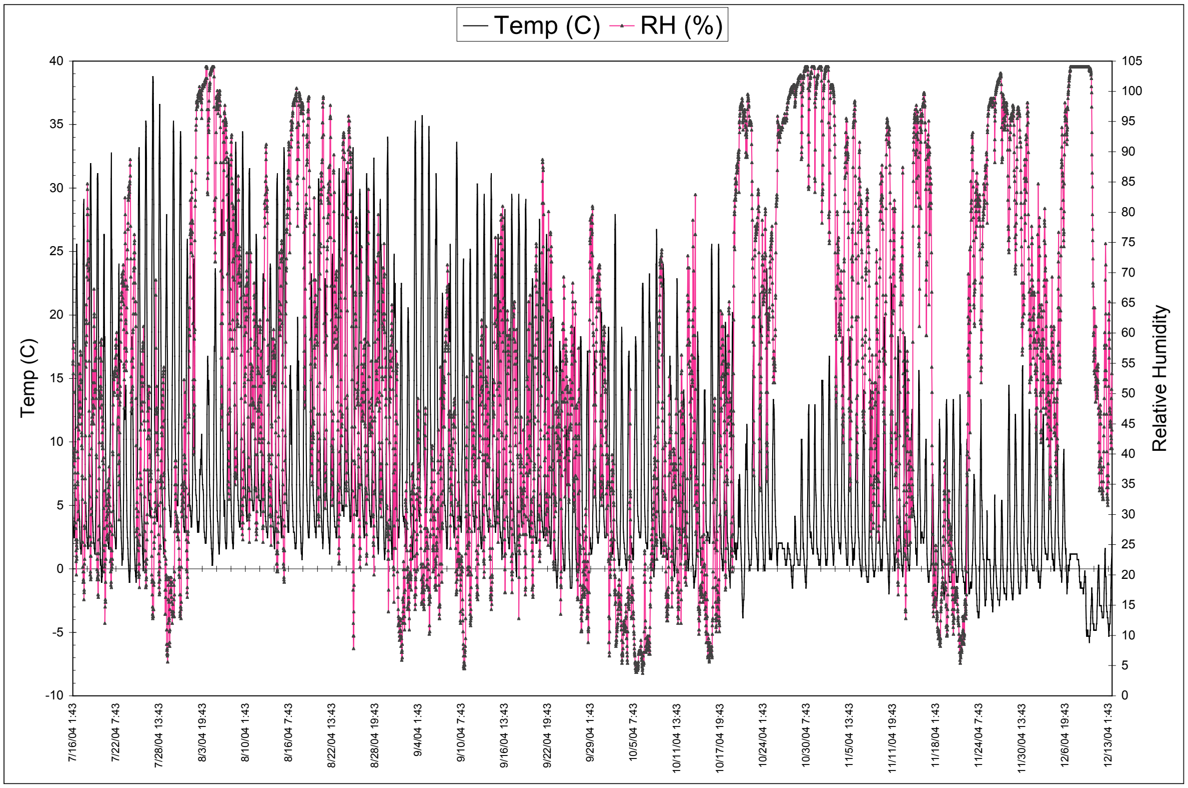

Figure 5. TEMP/RH Logger #7 S/N#754789 from Pu‘u Hau Kea summit (surface), from July-Dec 2004.

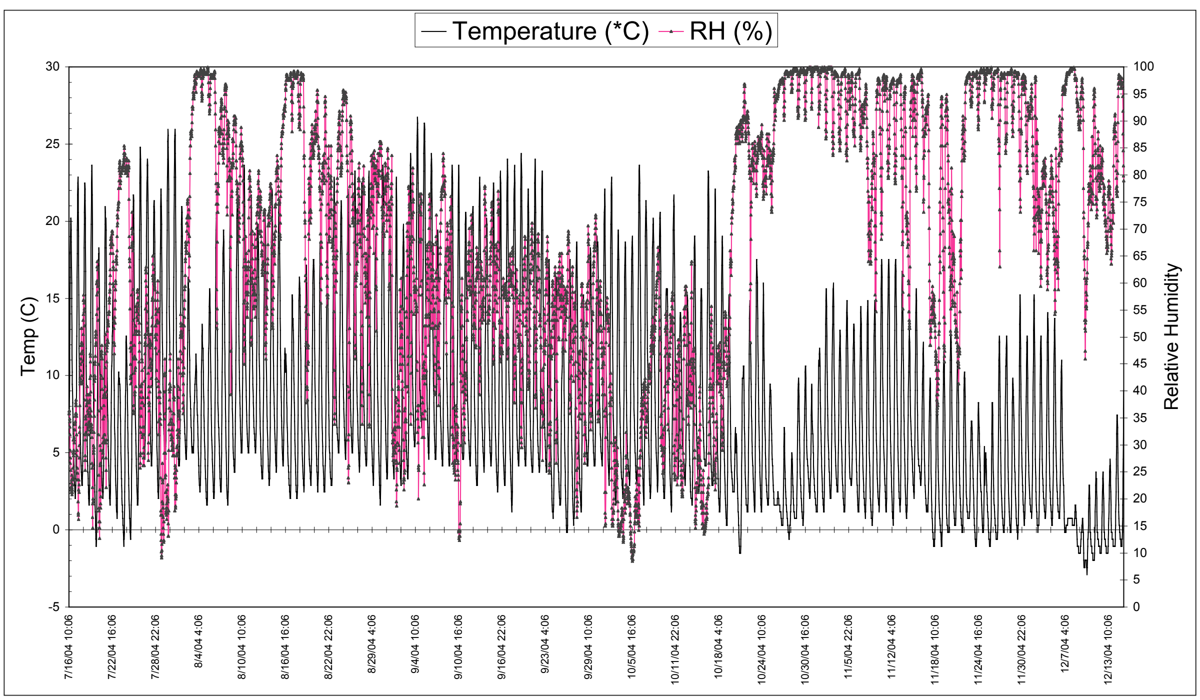

Figure 6. TEMP/RH Logger #10 S/N#754785 from base of Pu‘u Hau Kea nr. trail, from July-Dec 2004.

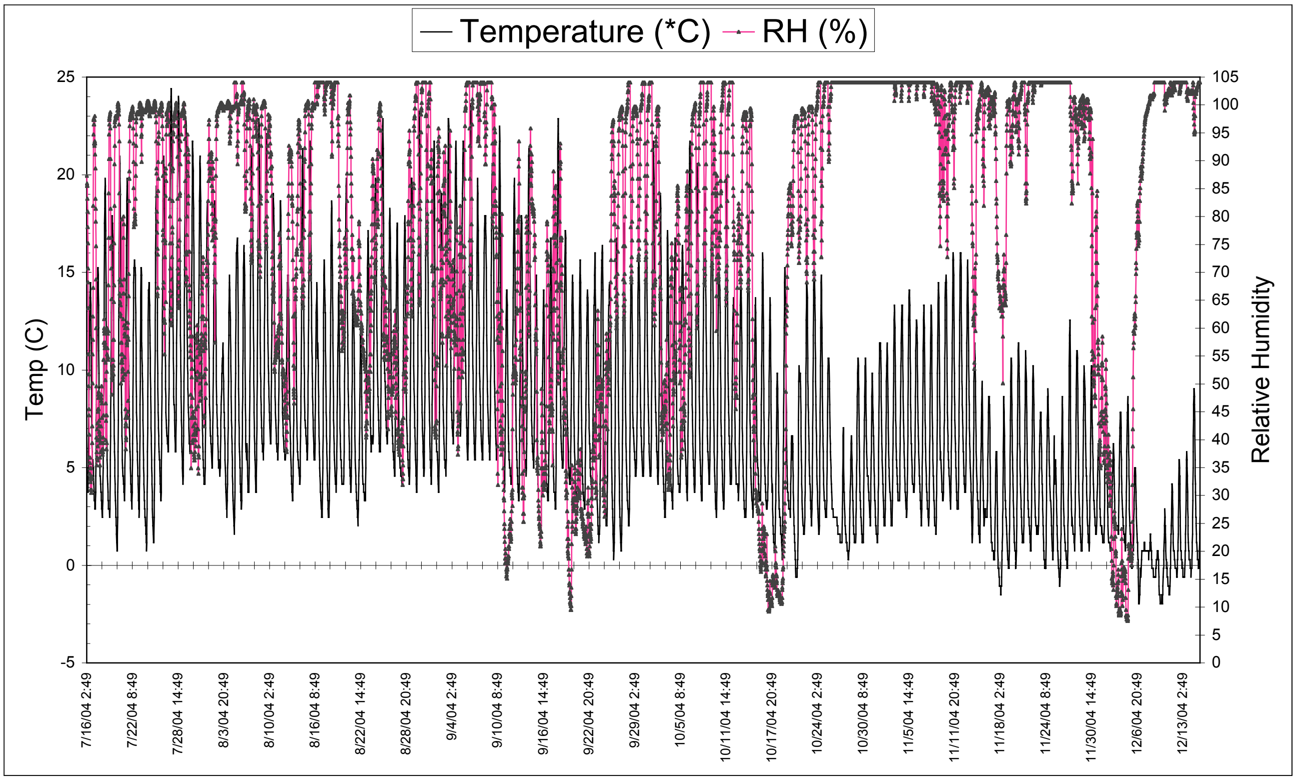

Figure 7. TEMP/RH Logger #6 S/N#754787 from Pu‘u (Lake) Waiau summit, from July-Dec 2004.

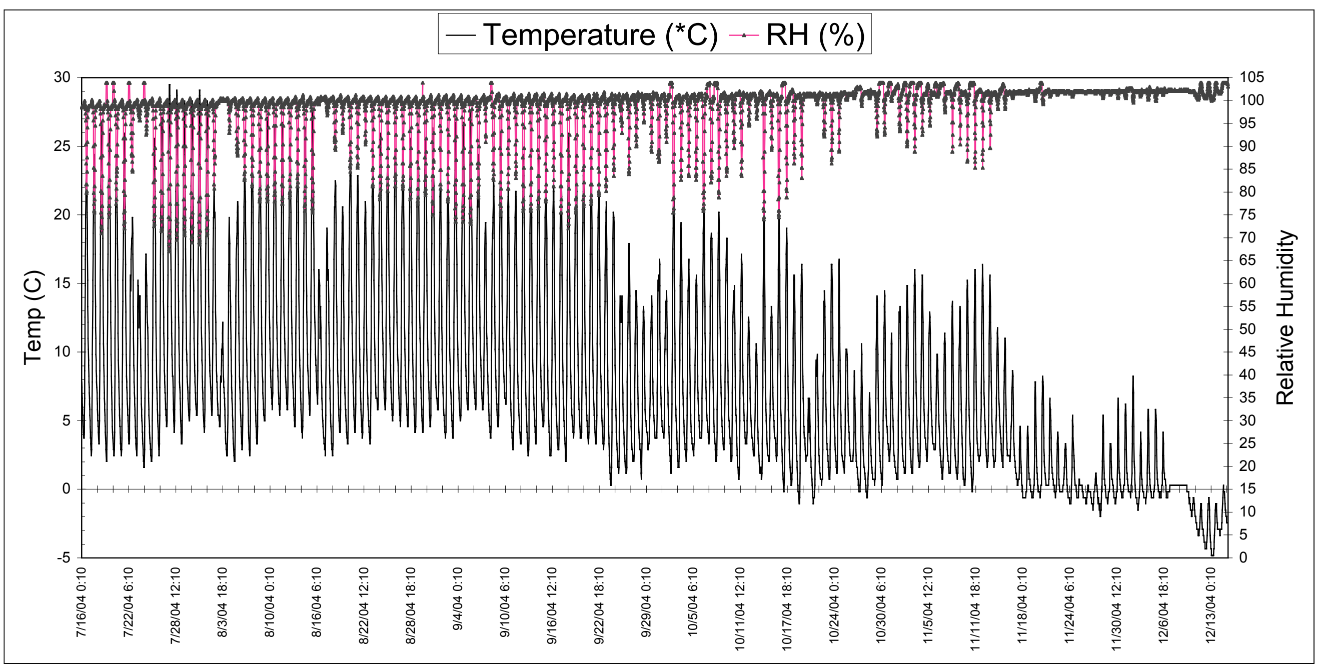

Figure 8. TEMP/RH Logger #2 S/N#754791 from Pu‘u Wēkiu summit from July-Dec 2004 (note: frozen humidity sensor, see text for details).

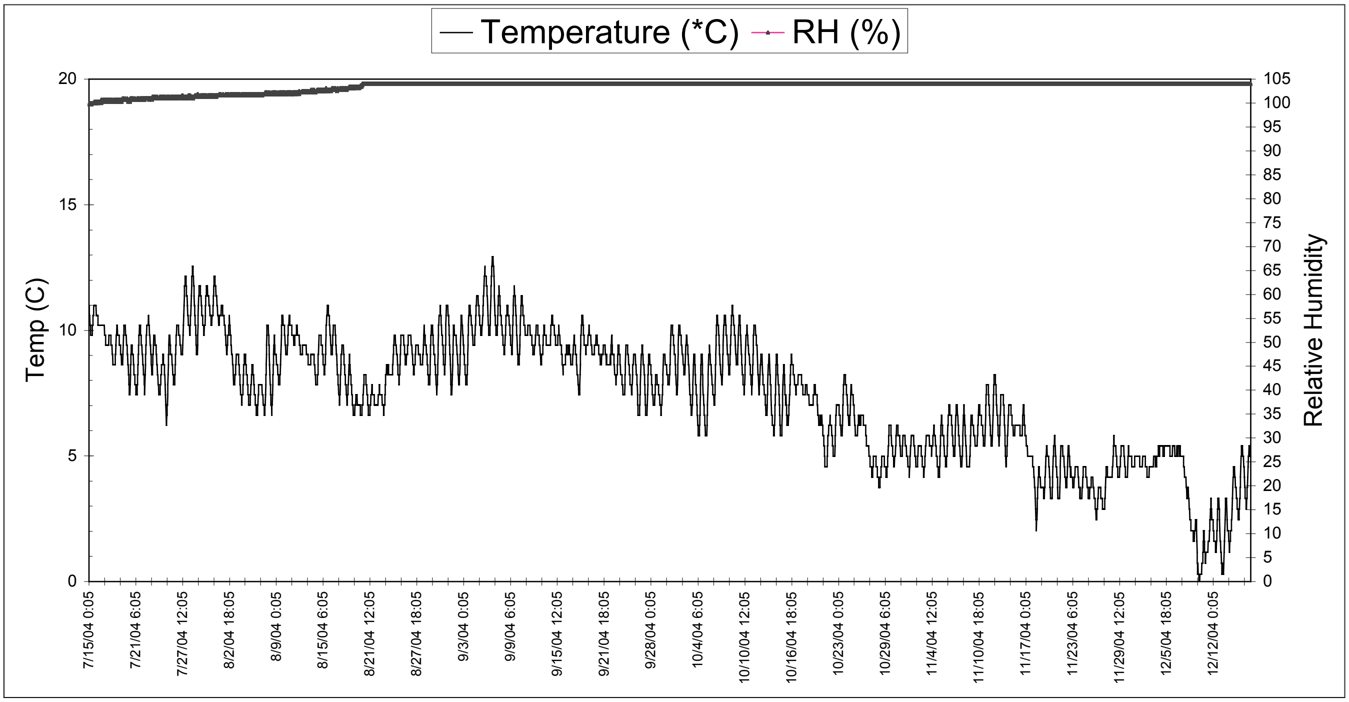

Figure 9. TEMP/RH Logger #3 S/N# S/N#754792 from Pu‘u Pohaku summit- SUBSURFACE, from July-Dec 2004.

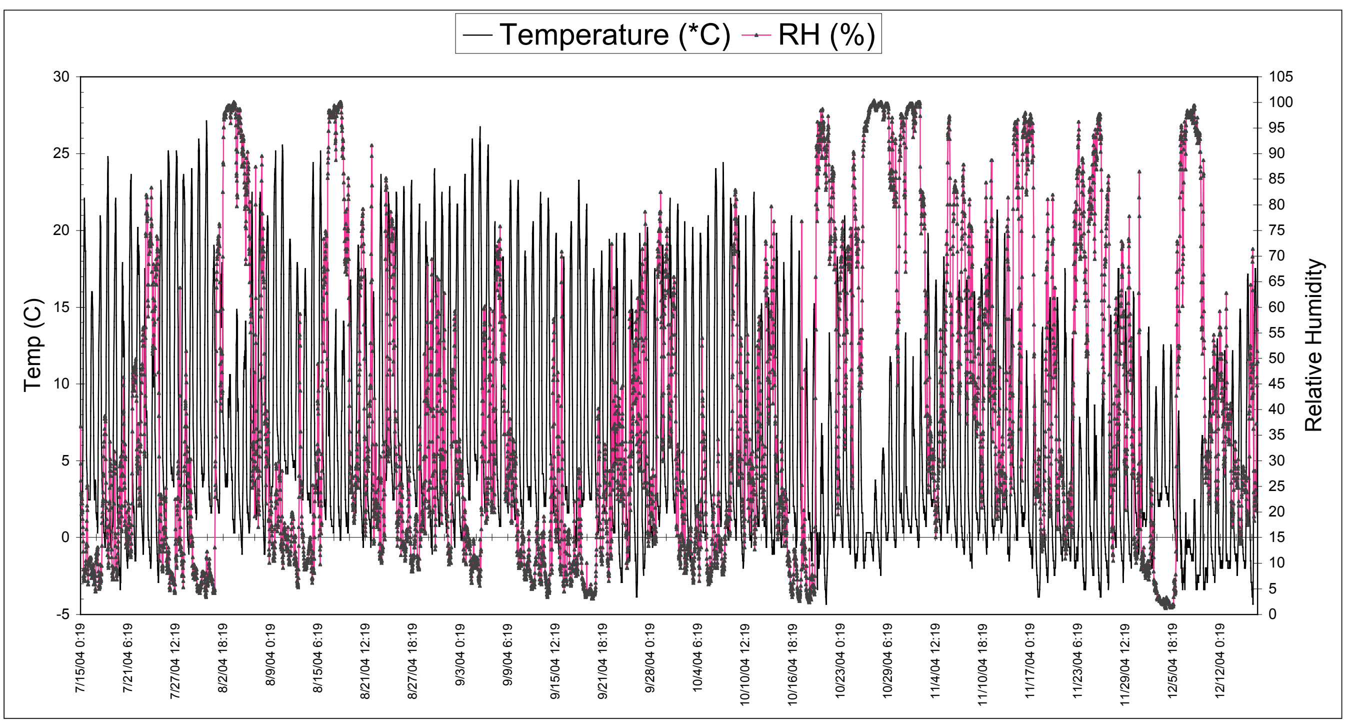

Figure 10. TEMP/RH Logger #4 S/N#754793 surface logger, from summit of Pu‘u Pohaku, from July-Dec 2004.

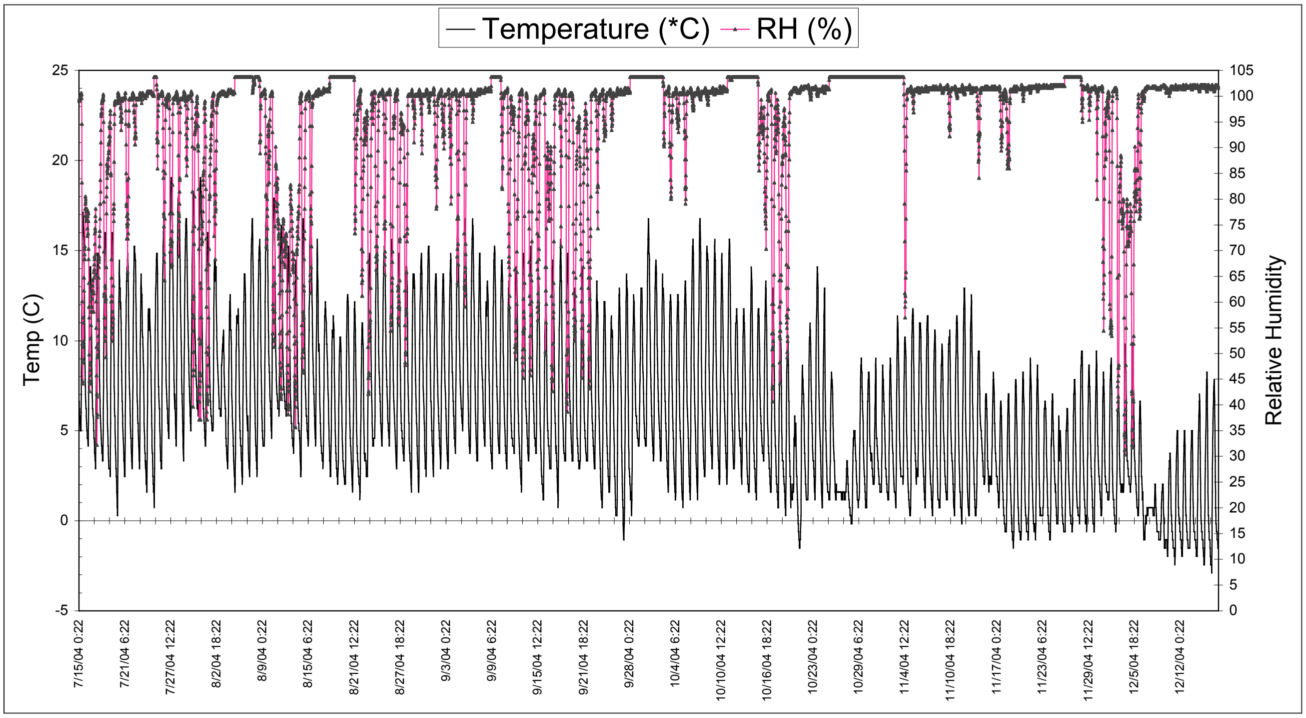

Figure 11. TEMP/RH Logger #9 S/N#754786 surface logger, from Pu‘u Pohaku base of cinder cone, at location of wēkiu bug capture, from July-Dec 2004.

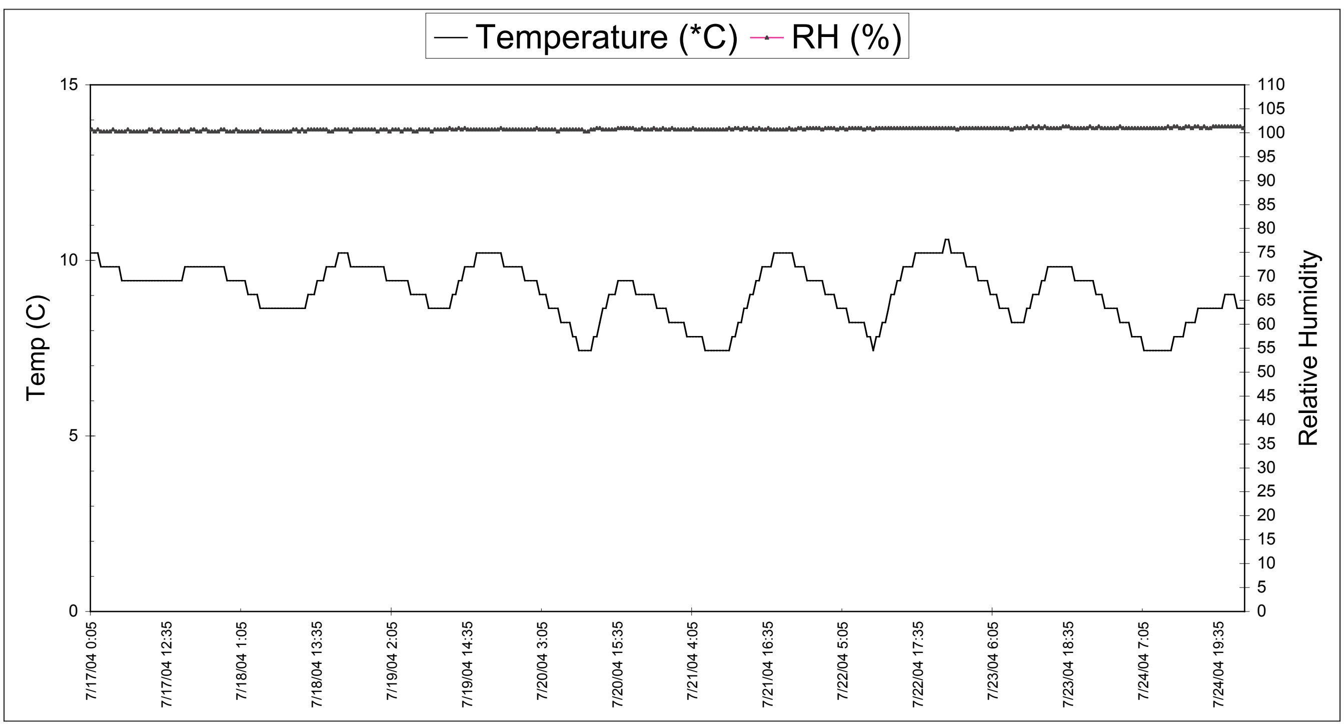

Figure 12. TEMP/RH Logger #3 S/N# S/N#754792 from Pu‘u Pohaku summit- SUBSURFACE, example of weekly fluctuations from 17-24 July 2004.

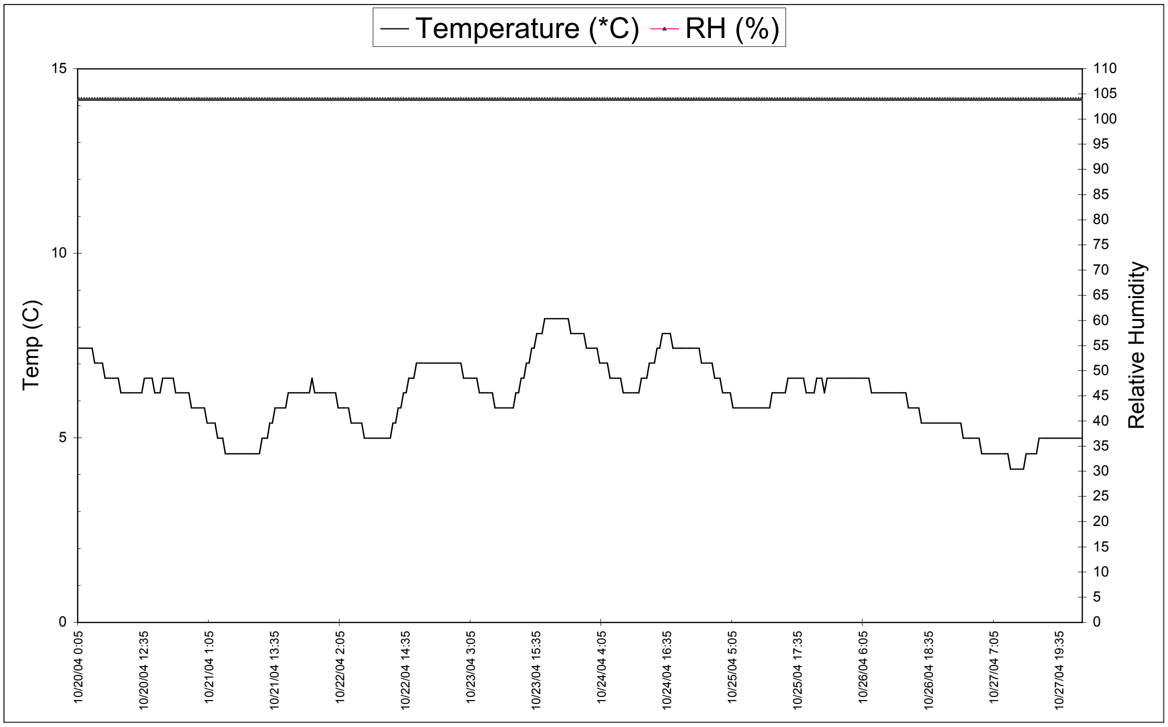

Figure 13. TEMP/RH Logger #3 S/N# S/N#754792 from Pu'u Pohaku summit- SUBSURFACE, example of weekly fluctuations from 20-27 Oct 2004.

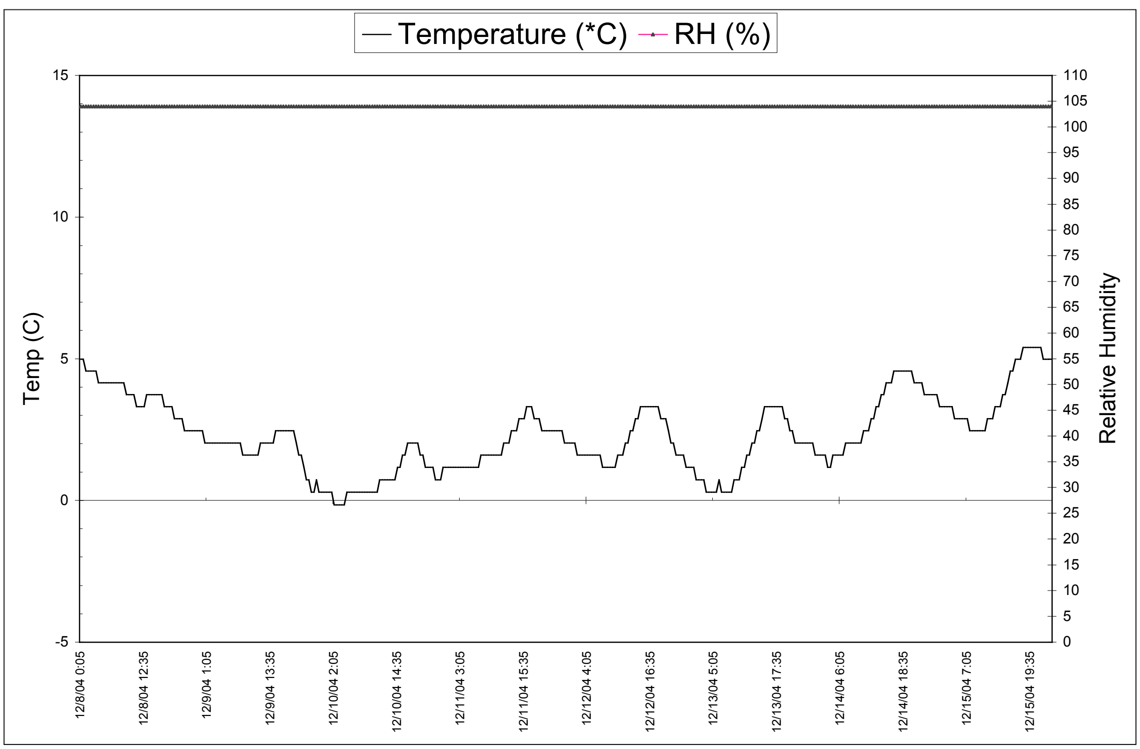

Figure 14. TEMP/RH Logger #3 S/N# S/N#754792 from Pu'u Pohaku summit- SUBSURFACE, example of weekly fluctuations from 8-15 Dec 2004.

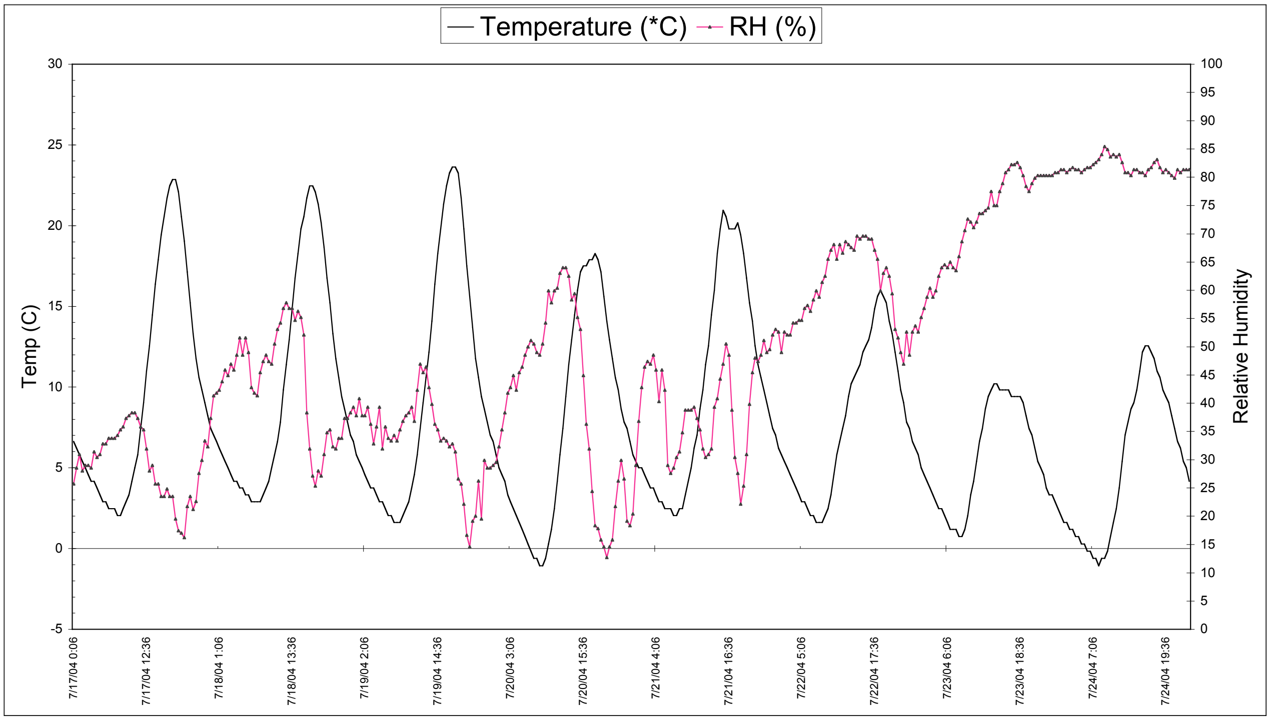

Figure 15. TEMP/RH Logger #4 S/N#754793 surface logger, from summit of Pu‘u Pohaku, example of weekly fluctuations from 17-24 July 2004.

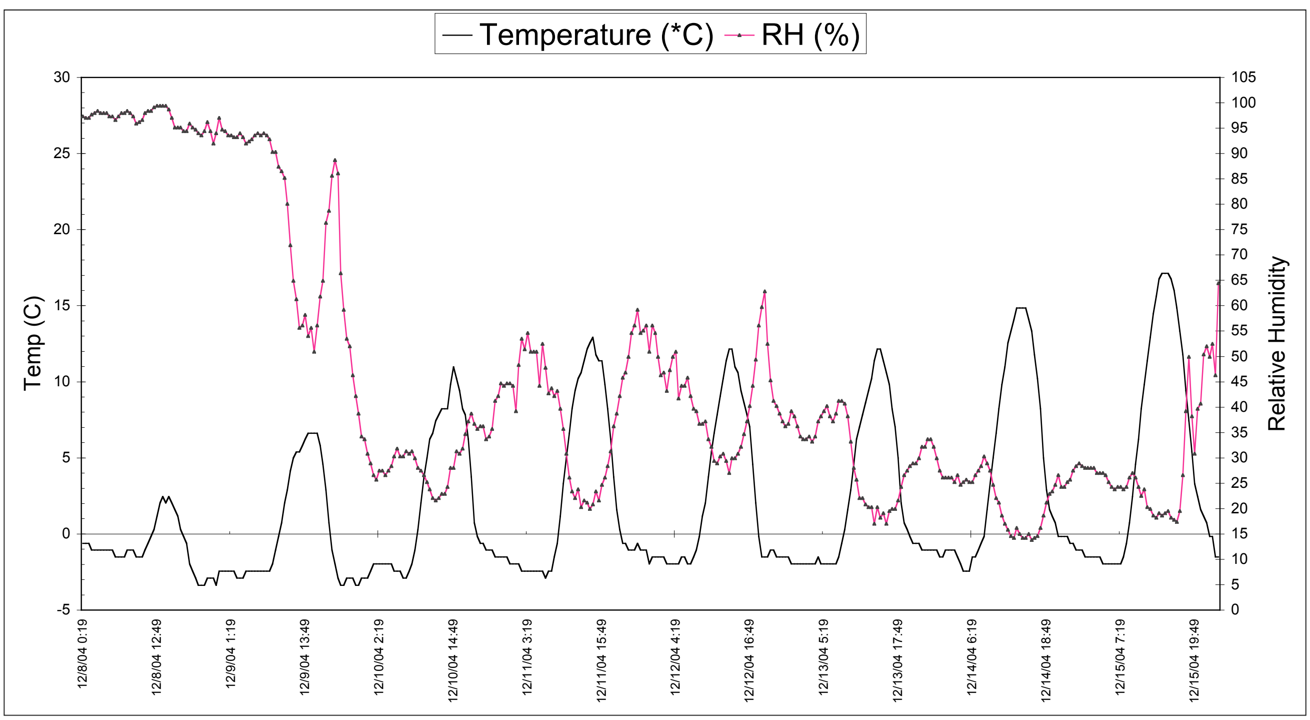

Figure 16. TEMP/RH Logger #4 S/N#754793 surface logger, from summit of Pu‘u Pohaku, example of weekly fluctuations from 8-15 Dec 2004.

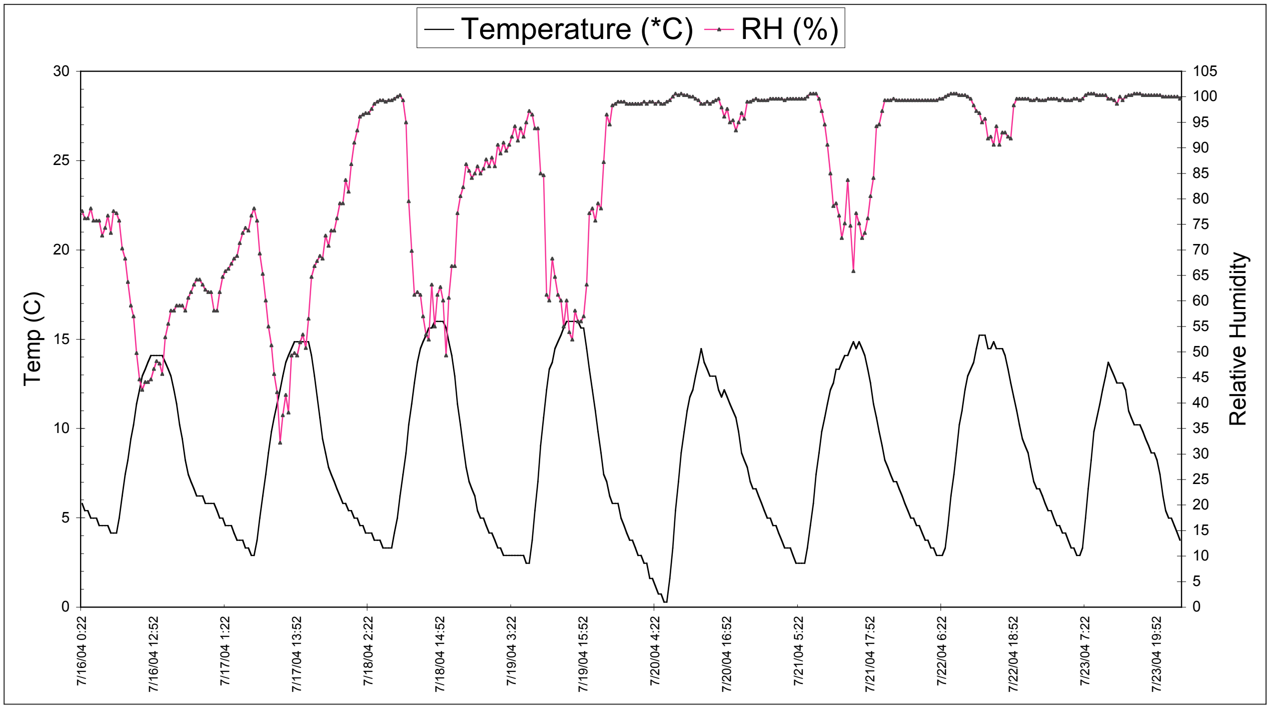

Figure 17. TEMP/RH Logger #9 S/N#754786 surface logger, from Pu'u Pohaku base of cinder cone, at location of July 2004 wēkiu bug capture, from 16-23 July 2004.

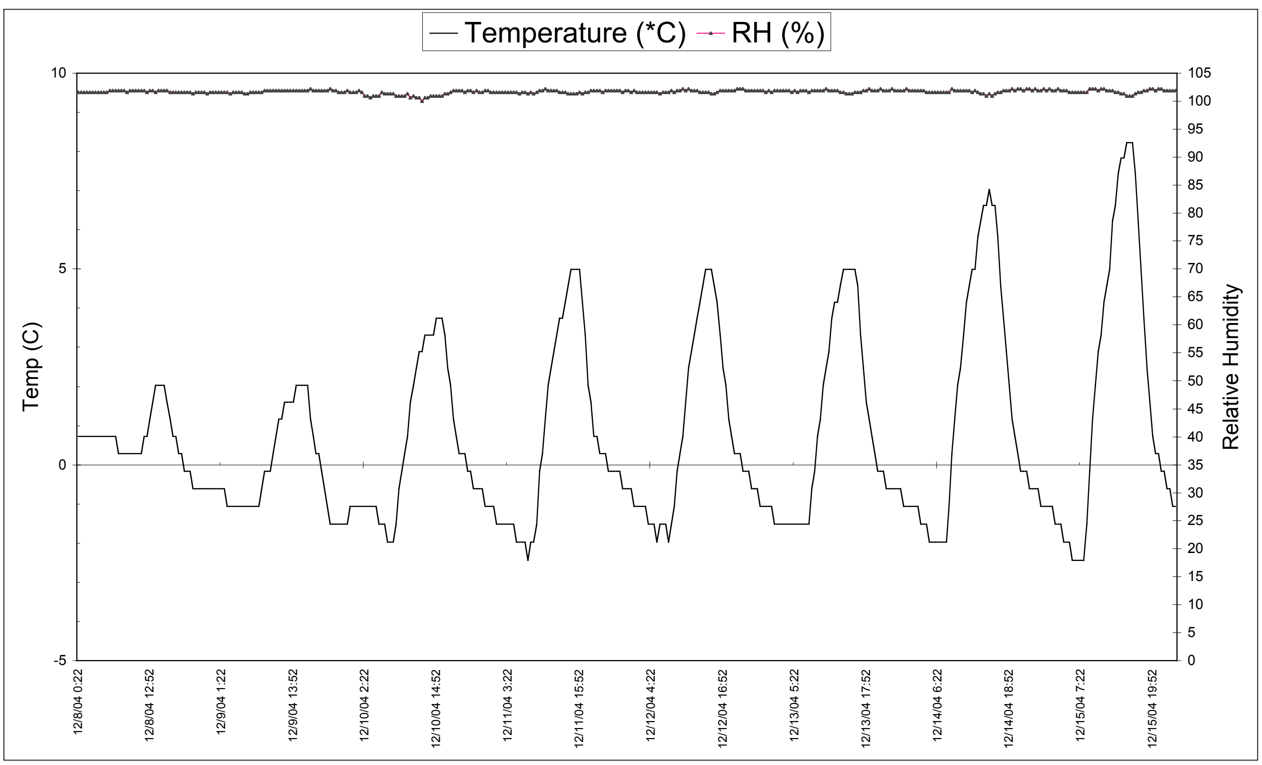

Figure 18. TEMP/RH Logger #9 S/N#754786 surface logger, from Pu'u Pohaku base of cinder cone, at location of July 2004 wēkiu bug capture, from 8- 15 Dec 2004.

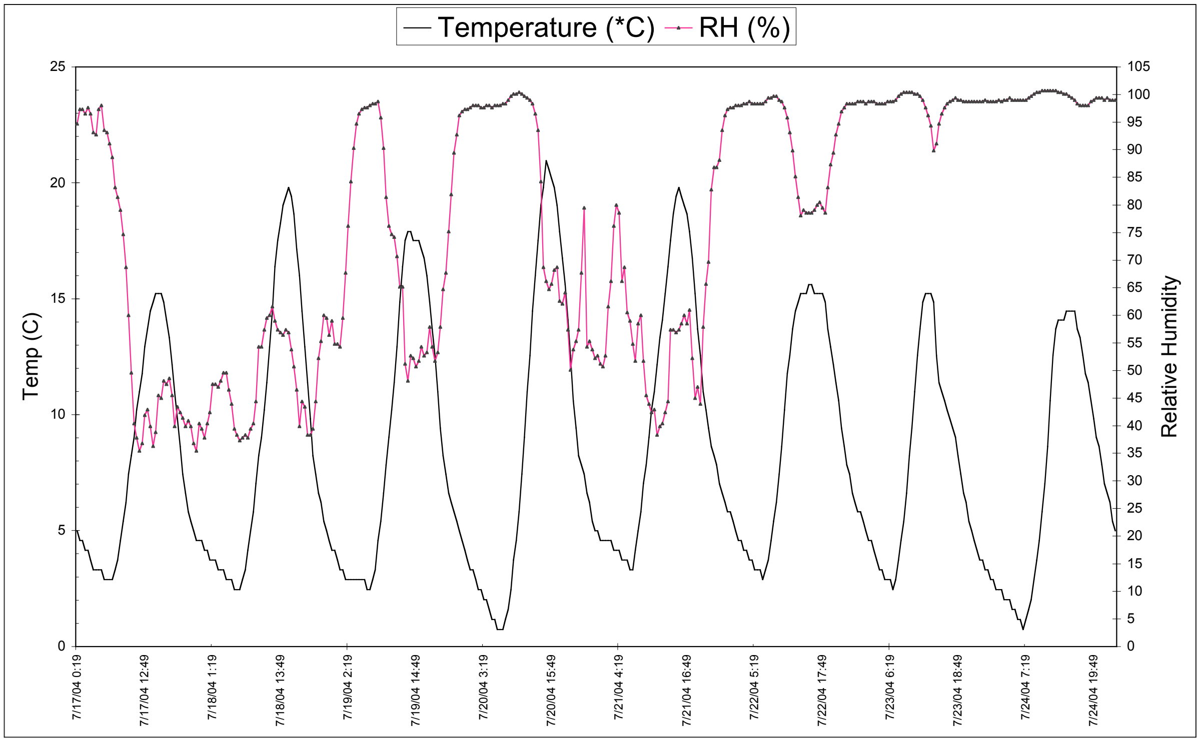

Figure 19. TEMP/RH Logger #6 S/N#754787 from Pu‘u (Lake) Waiau summit, from 17-24 July 2004.

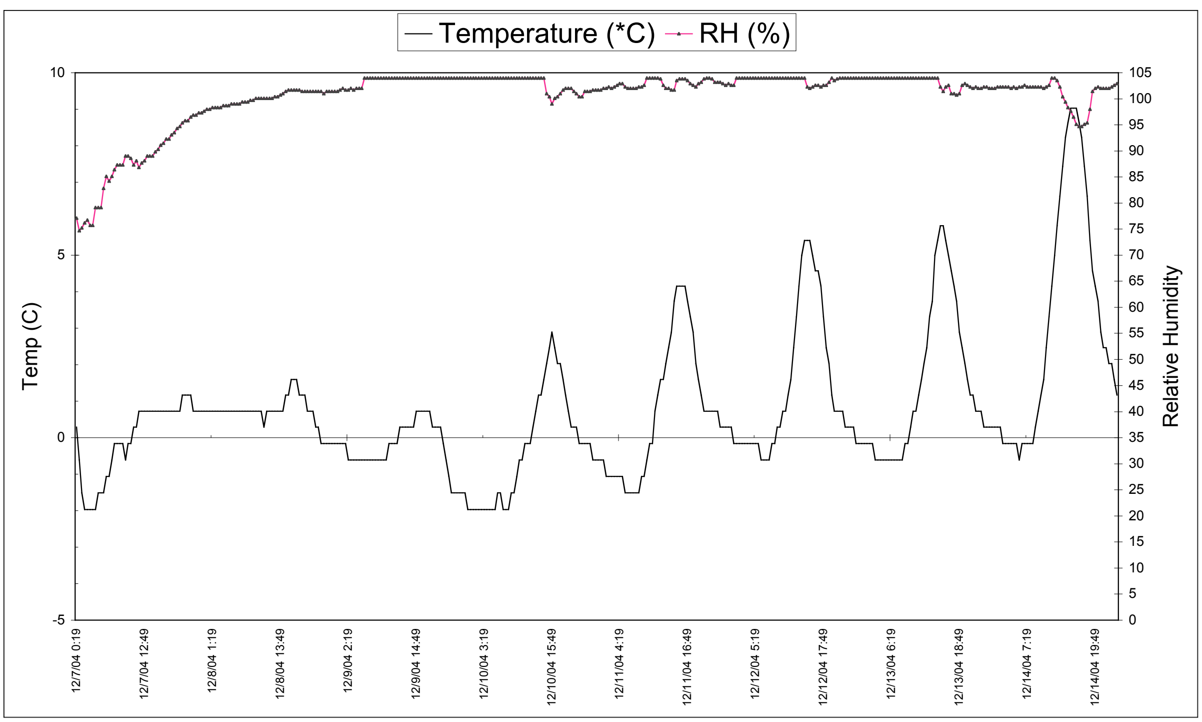

Figure 20. TEMP/RH Logger #6 S/N#754787 from Pu‘u (Lake) Waiau summit, from 7-14 Dec 2004.

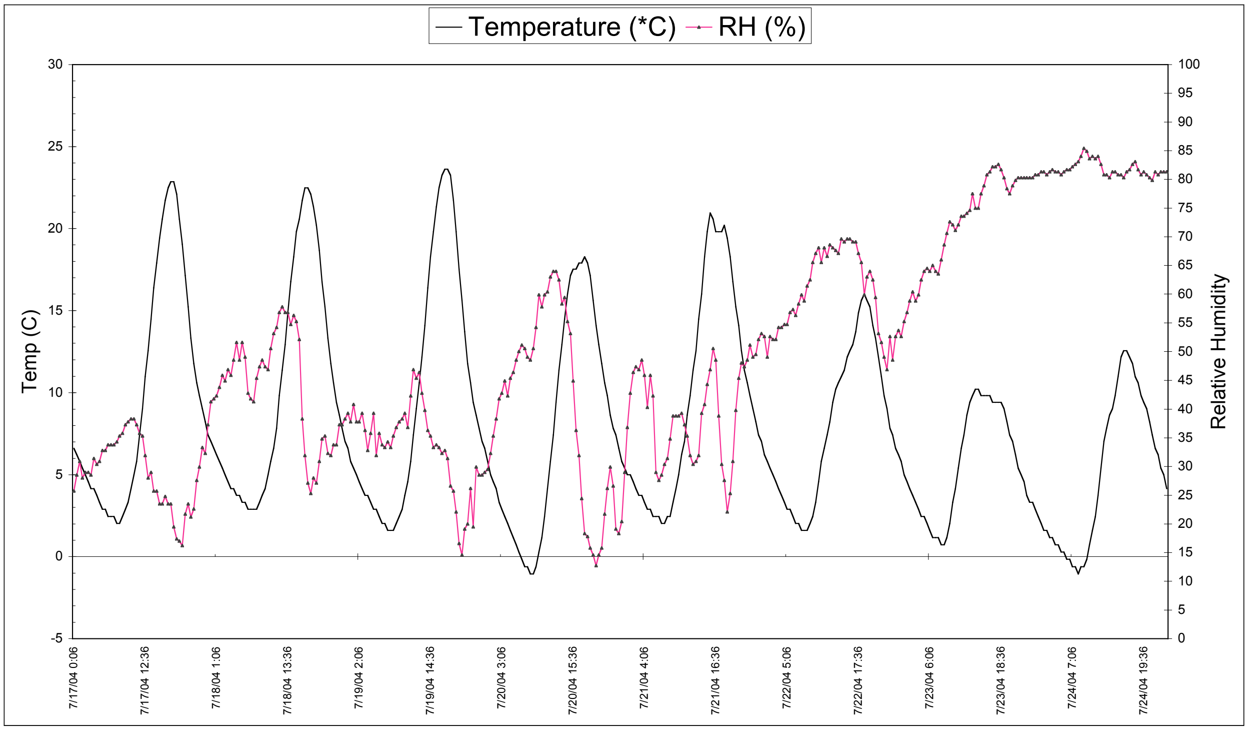

Figure 21. TEMP/RH Logger #10 S/N#754785 from base of Pu‘u Hau Kea nr. trail, example of weekly fluctuations from 17-24 July 2004.

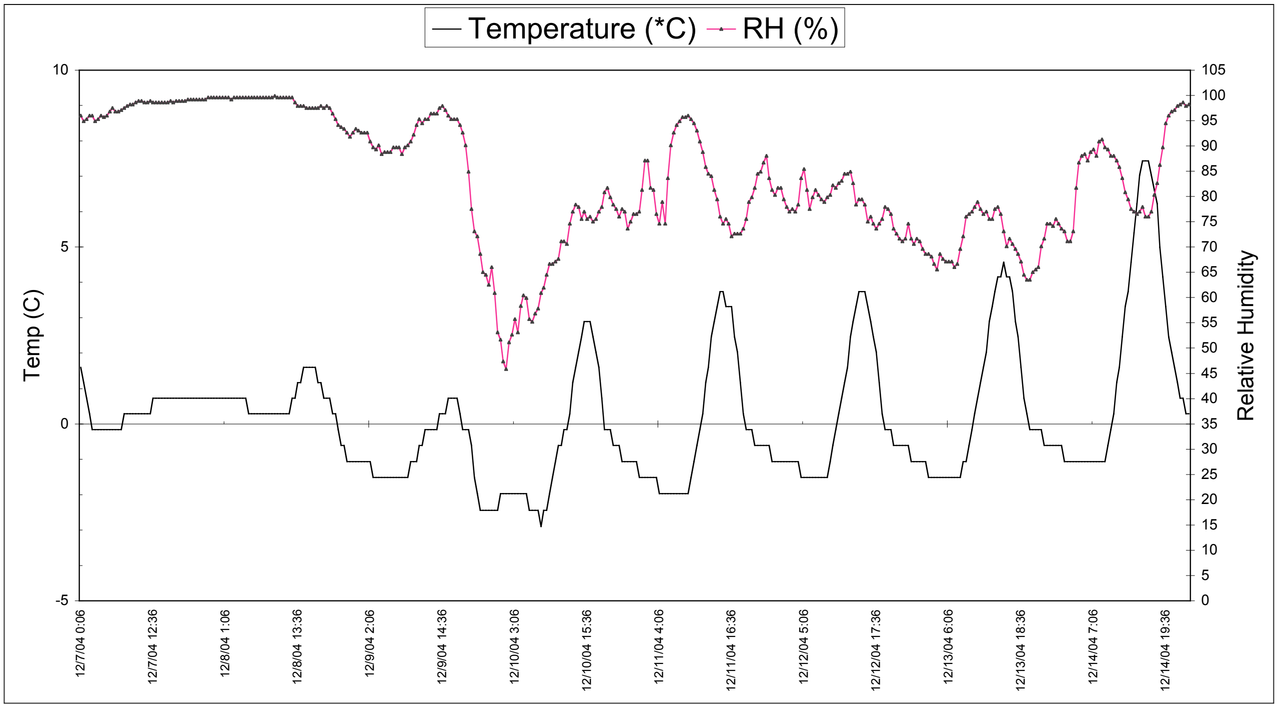

Figure 22. TEMP/RH Logger #10 S/N#754785 from base of Pu‘u Hau Kea nr. trail, example of weekly fluctuations from 7-14 Dec 2004.

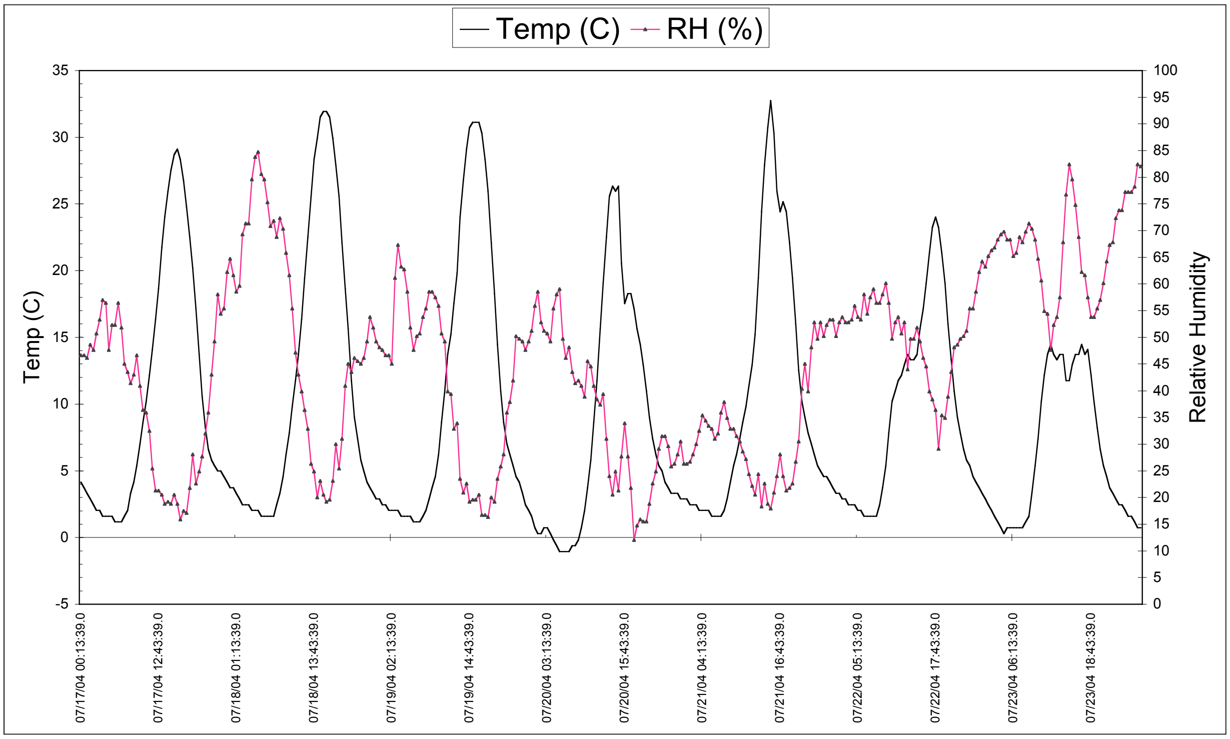

Figure 23. TEMP/RH Logger #7 S/N#754789 from Pu‘u Hau Kea summit (surface), from 17-24 July 2004.

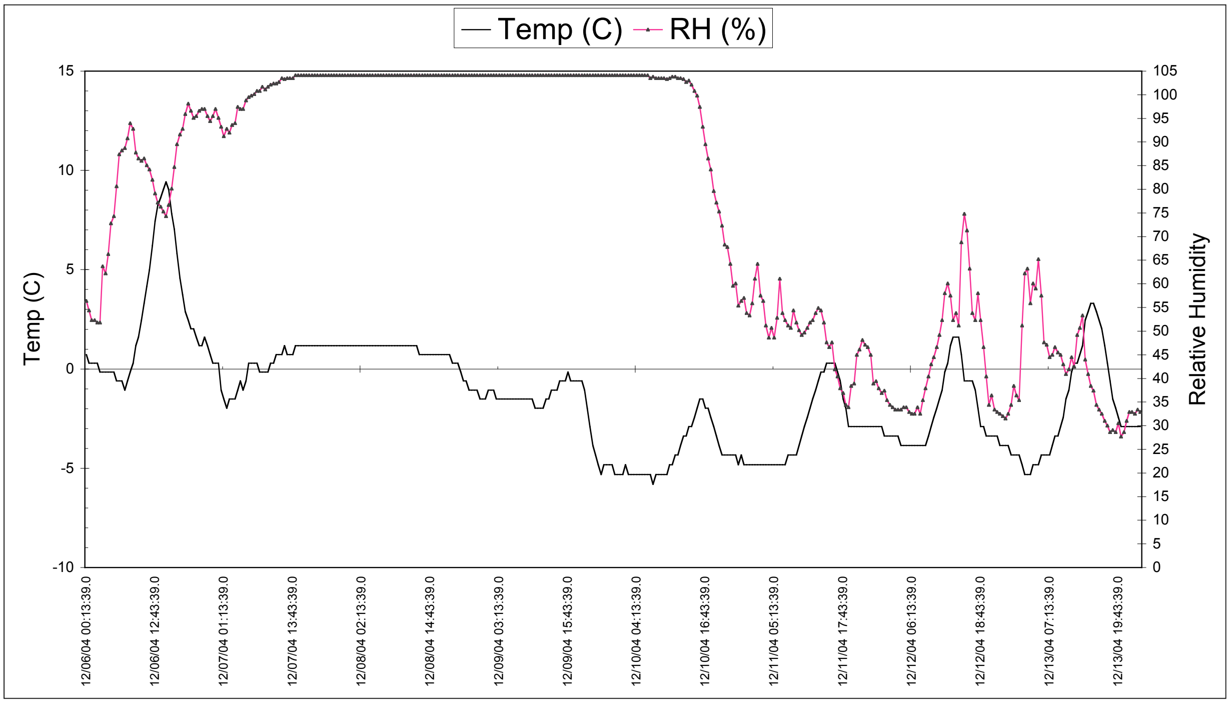

Figure 24. TEMP/RH Logger #7 S/N#754789 from Pu‘u Hau Kea summit (surface), from 6-13 Dec 2004.

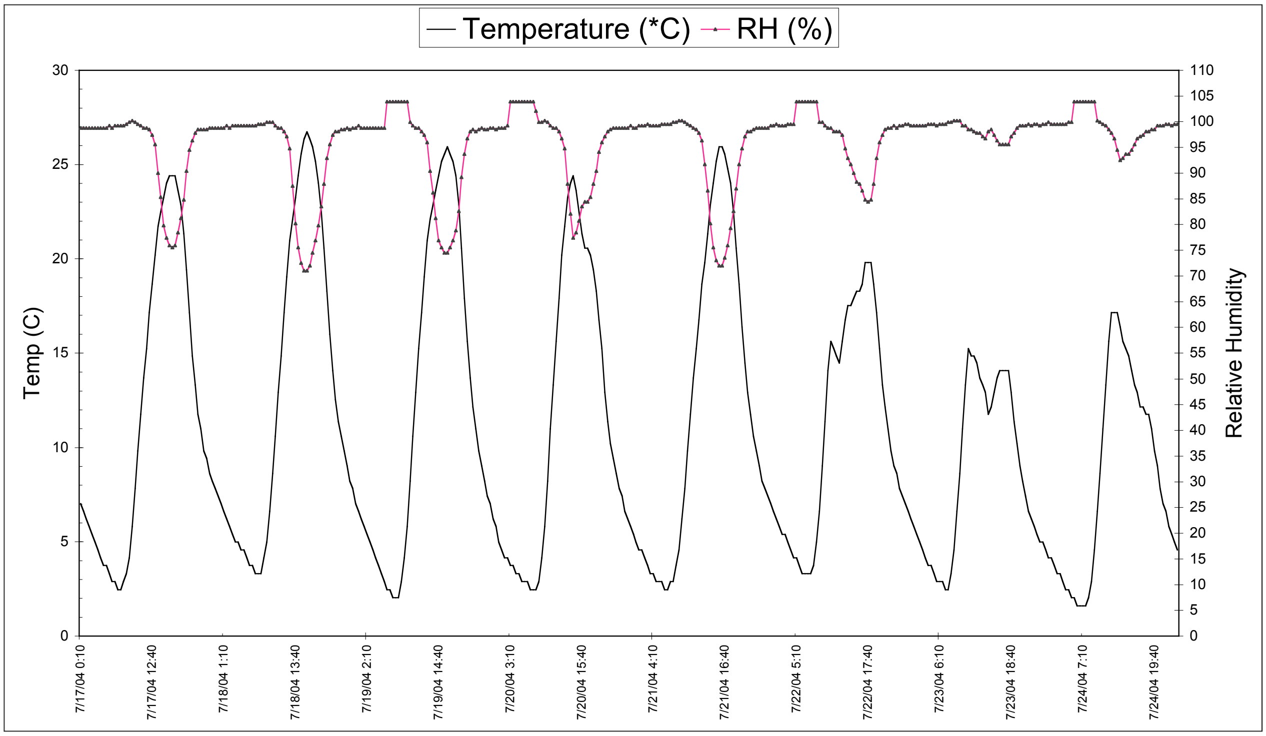

Figure 25. TEMP/RH Logger #2 S/N#754791 from Pu‘u Wēkiu summit from 17-24 July 2004 (note: frozen humidity sensor, see text for details).

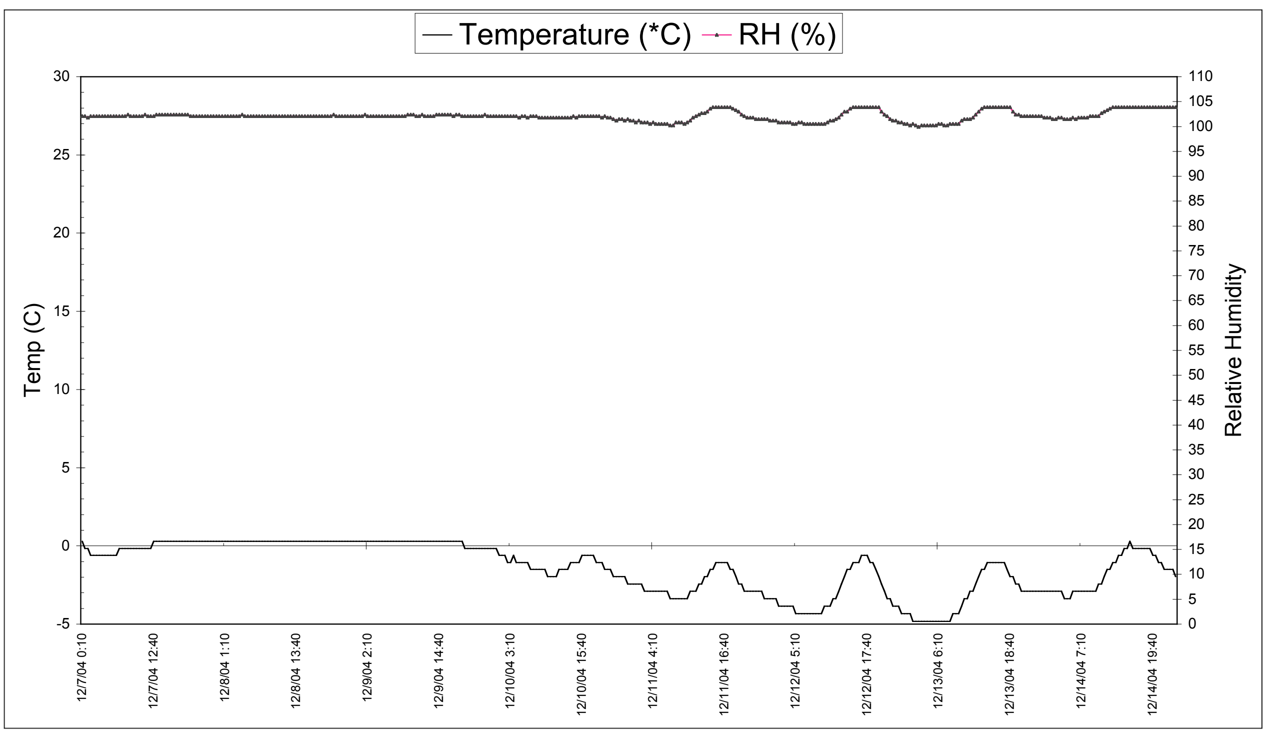

Figure 26. TEMP/RH Logger #2 S/N#754791 from Pu‘u Wēkiu summit from 7-14 Dec 2004 (note: frozen humidity sensor, see text for details).

Logger Substrate Photos

The following section contains photos taken at various temperature/relative humidity data logger stations. Paired loggers, or surface and subsurface loggers were placed in close proximity to each other (see Methods).

 Pu‘u Hau Kea Loggers #792729 and #792733	 Pu‘u Hau Kea Logger #792737	 Pu‘u Hau Kea Logger #792703
 Pu‘u Hau Kea Loggers #792728 and 792691	 Pu‘u Hau Kea Logger #792709	 Pu‘u Hau Kea Loggers #792698 and 792709

 Pu‘u Hau Kea Loggers #792695 and 792727	 Pu‘u Hau Kea Loggers #792735 and #792688	 Pu‘u Hau Kea Logger #792689
 Pu‘u Hau Oki Logger #792690	 Pu‘u Hau Oki Logger #792686	 Pu‘u Hau Oki Logger #7

 Poi Bowl, upper Logger #792721	 Poi Bowl, mid Logger #792731	 Poi Bowl, lower Logger #792734
 Pu‘u Wēkiu Logger #792696	 Pu‘u Wēkiu Logger #792738	 Pu‘u Poepoe Logger #792743

 Puʻu Poepoe Loggers #792713 and 792736	 Puʻu Mahoe Loggers #792701 and #792692	 Puʻu Poepoe, base Loggers #792687 and #792732
 Puʻu Mahoe Logger #792714	 Puʻu Mahoe Logger #792717	 Puʻu Pohaku Logger #792720

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