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MESOSTIGMATA (ACARI) ASSOCIATED WITH A FUMEROLE IN HAWAII VOLCANOES NATIONAL PARK[1]

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Abstract. Examination of soil and vegetation samples from the Steaming Bluffs area of Hawaii Volcanoes National Park, Hawaii I, revealed 12 species of Mesostigmata in the families Ascidae, Laelapidae, Parholaspidae, Parasitidae, Phytoseiidae, Podocinidae and Rhodacaridae associated with a fumerole, or steam vent. Temperatures of samples yielding Mesostigmata ranged from 25 °C to 58 °C. Only 2 species, both in the family Ascidae, were recovered at temperatures greater than 46 °C. The greatest diversity of both acarine and plant material was in samples taken between 31 °C and 50 °C.

Examination of soil and vegetation samples from the east flank of Mauna Loa volcano in Hawaii Volcanoes National Park, as part of the International Biological Program, revealed 12 species of Mesostigmata associated with fumeroles or steam vents. These fumeroles are the result of rain water filtering down through the lava substrate, being converted to steam by volcanic heat and passing back to the surface via a vent or vents, generally within a larger fissure. The particular fissure sampled is located 1 km W of the park headquarters along Steaming Bluffs Trail. The fissure is 8.3 m in length with a maximum width of 3.2 m. The actual steam-emitting opening is located 1.6 m from the east end of the fissure, 1.7 m below the ground surface.

Eighty-one samples were removed from the fissure during the period 26 May–8 July, as illustrated in Fig 1. Each sample was 10 cm^2 and approximately 1.3 cm deep. The depth of the samples was in large part determined by the nature of the lava substrate. Samples were examined individually and then processed in Berlese funnels.

Temperature measurements were made with a Model 43 Yellow Springs telethermometer equipped with a flat YSI408 probe. Temperatures recorded within the fissure ranged from 25 °C to 72 °C. Temperatures at any given sample site appeared to remain stable as a result of a fairly constant flow of steam across the exposed surfaces.

Relative humidity measurements were made approximately 0.5 cm above the substrate at each sample site with a Honeywell humidity and temperature meter. Relative humidity in the area around the fissure at the time of measurements was 62% at 25.5 °C. Sample sites located at the periphery of the fissure had values ranging from 65% to 76%. The only exceptions to this occurred at sites 38, 43, 50 and 58, which were directly exposed to the flow of steam. Values at these sites ranged from 92% to 100%.

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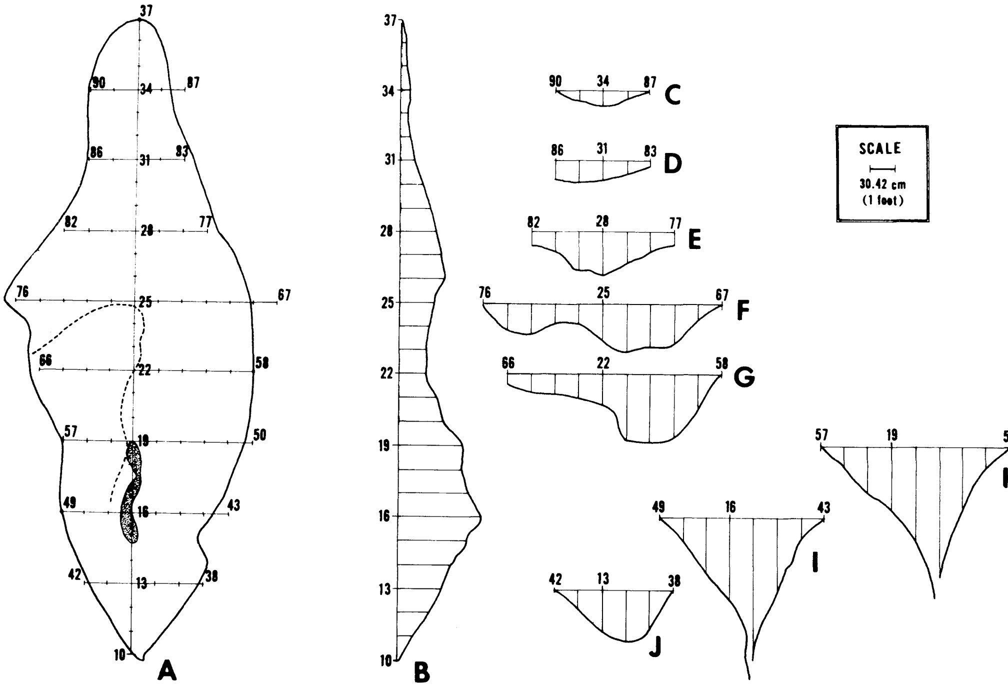

FIG. 1. Selected views of fumerole showing sample sites: A, top view of fumerole showing sample pattern; B, profile of fumerole along midline; C–J, cross profiles of fumerole at selected points along midline.

Sites within the fissure ranged from 92% to 100% at the actual vent opening. Due to the relatively constant flow of steam through the vent, it would appear that high relative humidity values may be anticipated at all times within the fissure and that, under normal circumstances, these values will be significantly higher than those for the surrounding area.

The autotrophic component of the fumerole consists of plants growing inside the fissure itself (major component) and plants outside of the fissure on the periphery, where their leaves and fronds overhang the fissure. These bordering plants contribute material to the fissure substrate when overhanging plant parts are killed by the steam and fall into the fissure. From this source a deposit of dead organic material has accumulated at the base of the fissure along the midline.

A number of plant species were located within the fissure. Various algae were present on the lava substrate within the fissure and in the soil both inside the fissure and immediately surrounding it. Identifications of algal species were not attempted. Slime molds were present along the edge of the fissure at sites 58, 68 and 77. Mosses, *Campylopus densifolius* and *Campylopus exasperatus,* were present toward the west end of the fissure in clumps on soil and exposed lava. Small clumps of another moss,

TABLE 1. Distribution of Mesostigmata within the fumerole as related to temperature. Number of samples containing given species, with total numbers of individuals collected given in parentheses.

TEMPERATURE (°C)	No. of samples	No. of samples with Mesostigmata	*Cheiroseius* sp. (undescribed)	*Cheiroseius* sp. nr. *necorniger*	*Asca spicata*	*Protogamasellus* sp. (undescribed)	*Pergamasus* sp.	*Typhlodromus neobakeri*	*Amblyseius mexicanus*	*Amblyseius* sp.	*Gamasiphis* sp.	*Holaspulus tenuipes*	*Hypoaspis queenslandicus*	*Podocinum sagax*
21–25	2	1							1 (1)		1 (2)	1 (1)		1 (1)
26–30	0	0												
31–35	10	7	4 (7)	2 (2)	1 (1)	1 (1)	2 (10)		1 (1)		3 (4)		1 (2)	
36–40	25	12	9 (31)	3 (4)			1 (2)	1 (1)	3 (3)	1 (1)	2 (2)		1 (1)	
41–45	24	11	11 (39)							1 (1)				
46–50	9	3	3 (7)	1 (2)										
51–55	2	0												
56–60	2	1	1 (1)											
60+	5	0												
No temp. data	2	1	1 (1)				1 (1)		1 (1)		1 (1)			

Racomitrium sp., were distributed throughout the fissure, being most prevalent in areas not exposed to the direct flow of steam. Three species of ferns were associated with the fissure. The sword fern, *Nephrolepis exaltata,* and the false staghorn fern, *Diacranopheris emarginata,* were found at the edge, forming a dense mass of vegetation, but not growing within the fissure. *Trichomanes humile* was found growing within the fissure as well as in association with *N. exaltata* and *D. emarginata.* The club moss, *Lycopodium cernuum,* was located in many areas of the fissure, but was most abundant in areas with high relative humidity near the edge of the fissure. A sedge, *Cyperus* sp., was found at the west end of the fissure and also in association with the ferns *N. exaltata* and *D. emarginata* at the edge. Two grasses, *Andropogon virginicus* and *Digitaria henryi,* were found in association with ferns near the periphery of the fissure and in the cooler areas within the fissure near the west end. *Waltheria americana* was present in cooler areas only slightly below ground surface. Two ohia trees, *Metrosideros polymorpha* (45–60 cm), were located in the fissure at sites 22 and 26. These individuals were smaller than specimens of the same species in the immediate vicinity of the fumerole. Both trees were in bloom at the time samples were taken. Observations made 4 and 8 years after the sampling did not show any substantial increase in the size of the 2 individuals of ohia. Additional specimens were noted within the fissure during the subsequent observations.

The dominant vegetation in the fissure consisted of the various ferns and grasses; mosses became prevalent in the intermediate temperatures, giving way to algae at temperatures greater than 50 °C. This distribution appears to be a stable rather than transient condition as indicated by observations of the fissure 4 and 8 years after

TABLE 2. Distribution of Mesostigmata within the fumerole as number of samples containing given species related to vegetation.

PLANT ASSOCIATIONS	No. of samples	No. of samples with Mesostigmata	*Cheiroseius* sp. (undescribed)	*Cheiroseius* sp. nr. *necorniger*	*Asca spicata*	*Protogamasellus* sp. (undescribed)	*Pergamasus* sp.	*Typhlodromus neobakeri*	*Amblyseius mexicanus*	*Amblyseius* sp.	*Gamasiphis* sp.	*Holaspulus tenuipes*	*Hypoaspis queenslandicus*	*Podocinum sagax*
No vegetation data	10	4	3					1	1	1	1		1	
No visible plant material	8	0												
Algae	19	4	4											
Algae-moss	2	0												
Algae-moss-ohia	1	1		1										
Algae-fern	1	1	1											
Algae-grass	2	1	1						1					
Moss	12	6	6				1	1	1		1			
Moss-fern	4	1		1										
Moss-grass	12	9	7	9		1				1			1	
Moss-fern-grass	3	3	2	1			2		3		3	1		1
Moss-ohia	1	1	1											
Grasses	6	5	5		1						2			

sampling. This pattern of distribution is spatially similar to the temporal succession pattern found in the invasion of new lava flows by plants. As observed by Smathers & Mueller-Dombois (1972), this invasion pattern tends to follow an algae–cryptogamic–seed plant succession.

For the purposes of this paper, 12 associations of vegetation are recognized, as set forth in TABLE 2 and 3. Ten samples lack vegetational data and 2 samples have vegetational data but lack temperature data. Samples at 8 sites with temperatures ranging from 39 °C to 72 °C did not contain any visible vegetation. Of the 81 samples, 69 are complete with regard to both temperature and vegetation. For analysis of mite populations related to temperature, 79 samples were used; and to relate mite populations to vegetation, 71 samples were used.

ACCOUNTS OF THE SPECIES

Twelve species of Mesostigmata were recovered, representing 7 families of free-living mites: 4 species of Ascidae, 3 of Phytoseiidae, and 1 each of Laelapidae, Parholaspidae, Parasitidae, Podocinidae and Rhodacaridae. Other arthropods taken in the fumerole, e.g., Collembola, Prostigmata and Cryptostigmata, will be reported on separately.

Family ASCIDAE

Cheiroseius sp. 1 (undescribed) was the most numerous and widely distributed species within the fissure. With a total of 91 individuals collected, this species ac-

TABLE 3. Occurrence of plant associations in samples taken within the fumerole, as related to temperature.

Plant associations	Temperature (°C) 21–25	26–30	31–35	36–40	41–45	46–50	51–60	61+	No temp. data	Total no. samples
No visible plant material				1	4	1		2		8
Algae				6	2	4	4	2		19
Algae-moss					1			1		2
Algae-moss-ohia				1						1
Algae-fern				1						1
Algae-grass				1	1					2
Moss			2	3	5	2				12
Moss-fern	1		2		1					4
Moss-grass			2	2	6	1				12
Moss-fern-grass	1		1						1	3
Moss-ohia				1						1
Grass			1	3	2	1				6
No vegetation data			2	6	2					10
Total number of samples	2	0	10	25	24	9	4	5	1	81

counted for 66% of the total Mesostigmata and was present in 29 of the 36 samples containing mites. *Cheiroseius* sp. 1 was collected at temperatures ranging from 32 °C to 58 °C and in all vegetational associations except algae-moss. Samples of moss and moss-grass associations yielded the greatest numbers of individuals (18 and 24, respectively), comprising 41% of individuals of this species collected. Seventy individuals were recovered at temperatures from 36 °C to 45 °C. Only a single female was recovered at 58 °C. The majority of moss and moss-grass associations occur between 36 °C and 45 °C with extremes of 31 °C and 50 °C.

Cheiroseius sp. nr *necorniger* (Oudemans) was represented by 8 individuals from 6 samples. This species was recovered from several vegetational associations, but always in an association with moss (TABLE 3). Temperature range was recorded as 33 °C to 48 °C. Three samples were taken from the midline of the fissure and included dead material from bordering plants as well as the recorded association. Also present in these samples was *Cheiroseius* sp. 1. The other 3 samples were taken along the south edge of the fissure near the surface.

Asca spicata Hurlbutt was represented by a single individual taken along with a specimen of *Cheiroseius* sp. 1 in grass at 36 °C.

Protogamasellus sp. (undescribed) was recovered from a moss-grass association near the outside of the fissure at 34 °C.

Family LAELAPIDAE

Hypoaspis queenslandicus (Womersley) was represented by 3 individuals in 2 samples with temperatures of 32 °C and 39 °C. One sample containing 2 mites was from a moss-grass-fern association along the south edge of the fissure. No vegetational data were available for the other sample.

Family Parholaspidae

Holaspulus tenuipes Berlese was represented by 2 specimens collected in a moss-grass-fern association at 25 °C.

Family Parasitidae

A single species of *Pergamasus* sp. *crassipes* group was found in 4 samples taken from 32 °C to 39 °C. Plant associations were moss and moss-grass-fern. One sample lacked vegetational data. Distribution of this species appeared to be restricted to the shallower portions of the fissure near either end. Specimens were not recovered at depths greater than 53 cm below the ground surface, even though vegetational associations and temperatures similar to those observed for this species were present at greater depths within the fissure.

Family Phytoseiidae

Typhlodromus neobakeri Prasad was represented by a single specimen taken in moss at 39 °C. *Cheiroseius* sp. 1 was also present in this sample.

Amblyseius mexicanus (Garman) was present in 6 collections: 5 were from algae-grass, moss and moss-fern-grass associations at temperatures ranging from 25 °C to 40 °C; 1 lacked both temperature and vegetation data.

Amblyseius sp. was represented by 2 individuals at temperatures of 39 °C and 41 °C. One was in moss-grass and the other lacked vegetational data.

Family Podocinidae

Podocinum sagax Berlese was represented by a single specimen in a moss-grass-fern association at 25 °C.

Family Rhodacaridae

Gamasiphis sp. (undescribed) was present in 7 samples with a total of 9 individuals recorded from 25 °C to 39 °C. Vegetational associations were moss-grass-fern, grasses and moss. Two samples lacked vegetational data. This species was collected from the thickly matted vegetation around the periphery of the fissure. None of the samples were from areas directly exposed to the flow of steam.

DISCUSSION

As shown in Table 1, the vast majority of collections containing mites were made at temperatures between 31 °C and 50 °C. These samples comprised 95% of the mites collected. Of the 7 families of Mesostigmata represented, only Ascidae species were found at temperatures greater than 40 °C. A single phytoseiid, *Amblyseius* sp., was recovered at 40 °C. Two species of Ascidae, *Cheiroseius* sp. 1 and *Cheiroseius* sp. nr *necorniger,* occurred at temperatures greater than 46 °C; 1 individual of *Cheiroseius* sp. 1 was collected at 58 °C. As shown in TABLE 3, the greatest diversity of plants was found within the 31 °C to 50 °C range. This temperature range also encompassed the greatest array of Mesostigmata.

The Mesostigmata associated with the fumerole are from soil- and litter-inhabiting groups which are widely distributed throughout the Hawaiian Is. All species other than the ascids *Cheiroseius* sp. 1, *Cheiroseius* sp. nr *necorniger* and *Protogamasellus* sp. have been collected elsewhere on Mauna Loa or other localities in the islands. These 3 ascid species were not taken outside the fumerole environment, despite repeated sampling of areas at ground level around the fissure and over 2 years of collecting along a transect on the southeastern slope of Mauna Loa. In a second fumerole ca 30 m away from the one reported on here and sampled concurrently with it, *Cheiroseius* sp. 1 and *C.* sp. nr *necorniger* were the most common mesostigmatic mites. It seems likely that these ascids are adapted for high temperature/high humidity environments and may well be restricted to fumeroles.

The situation with respect to fumeroles may be compared with arthropods in another specialized stress environment. Howarth (1973) has discovered a taxonomically diverse assemblage of troglobites in Hawaiian lava tubes. The generally accepted theory concerning troglobites holds that they are relicts of extinct surface populations which would otherwise be extinct. As pointed out by Howarth (1973), the relatively recent volcanic origin of the Hawaiian Is seems to preclude this mechanism for the origin of the Hawaiian cave fauna. Howarth suggests that the Hawaiian cave fauna is derived from speciating surface fauna invading the vacant niche of lava tubes rather than representing relicts of extinct surface populations. Fumeroles, like lava tubes, present microenvironments effectively isolated from surrounding areas. The distribution of *Cheiroseius* sp. 1 and *C.* sp. nr *necorniger* and the presence of other arthropod species at high temperatures suggest that adaptation to a highly specialized environment is in progress.

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