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Kui'a Natural Area Reserves on Kaua'i Island, Hawaiian
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Mite (Acari) Communities Associated with 'Ōhi'a, *Metrosideros polymorpha* (Myrtaceae), at Hono O Nā Pali and Kui'a Natural Area Reserves on Kaua'i Island, Hawaiian Islands¹

Sabina F. Swift and M. Lee Goff²

Abstract: Native 'Ōhi'a trees (*Metrosideros polymorpha*) were sampled for mites at two natural area reserves on Kaua'i Island, Kui'a and Hono O Nā Pali. Ninety samples of leaves, flowers, bark, leaf litter, and soil under the 'Ōhi'a canopies were taken. Mites were extracted with use of Berlese-Tullgren funnels. One hundred sixty-four species were found, with the suborder Prostigmata having the greatest number of species (74), followed by Mesostigmata (43), Oribatida (43), and Astigmata with the least (4). Leaf litter, leaf litter with soil, and bark have the most species, composed of predaceous mesostigmatic and prostigmatic mites, but a certain amount of overlap of mite species between the leaf litter and soil habitats was observed. The predominance of Collembola in the soil and litter samples indicates a stable food source for the predaceous mites, partly explaining the high number of mites in those habitats. Oribatid mites were collected from leaves, but the species composition differs from that on flowers and litter. Preliminary residency status of identified taxa shows 12% endemic, 17% adventive, and 71% of unknown status.

MITES OR ACARI are one of the largest and most biologically diverse groups of the arachnids, rivaling insects in the extent to which they have successfully colonized aquatic and terrestrial habitats (Evans 1992). Mites are an important part of the Hawaiian ecosystems. Although approximately 630 species have already been named and reported (Nishida 1997, Swift and Norton 1998), mites remain one of the most poorly known arthropod groups in the Islands. Studies of Acari associated with particular plants, soils, and litter habitats are relatively uncommon in the Hawaiian Islands. Although sampling of litter from an area or location to determine its mite fauna has been done, there has been little

systematic collecting from specific plant hosts or habitats. In the early 1970s, the International Biological Program (IBP), through the Bishop Museum, sampled mites in soil and litter in an elevational transect of 'Ōhi'a forest east of Mauna Loa Trail on Hawai'i Island. From these collections, work by Radovsky and Tenorio (1981) on the soil Mesostigmata (Parasitiformes) and Collembola gave an indication of the diversity of soil and litter fauna living under the canopies of the native 'Ōhi'a. Gagné (1979) sampled arthropods including mites from 'Ōhi'a and Koa canopies with pyrethrum fogging. Unfortunately, the mites recovered from the canopy-sampling technique on 'Ōhi'a and Koa and most mites collected from the Maunaloa Trail transect currently remain unstudied.

'Ōhi'a, *Metrosideros polymorpha* (Gaud.) (Myrtaceae), is a dominant native Hawaiian tree found from sea level on wetter slopes up to 2590 m elevation. It is distributed on the six largest islands in areas with annual average rainfall ranging from 75 cm to 11.5 m (Corn and Heisy 1973). 'Ōhi'a was the subject of intensive research for over 20 yr because of periodic breakdown of stands known as "'Ōhi'a rainforest dieback" (Mueller-Dombois 1985).

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Although the effects of arthropods (e.g., wood borers) were studied extensively, the possibility of mites as a causal organism for 'Ōhi'a dieback was never considered. This study seeks to identify mite species associated with 'Ōhi'a and to expand the general knowledge of arthropods associated with this native tree. It is well known that sustainable management of any forest requires reliable knowledge of arthropod species and their ecological roles in the forest ecosystem.

Because of the current incomplete state of acarine systematics in many parts of the world, there has been a reluctance to designate residency for mite species described from Hawai'i (Goff 1987, Swift and Norton 1998). The preliminary designations for species associated with 'Ōhi'a in this report are for the primary purpose of assessments of the conservation status of the natural area reserves. For the purposes of this report, endemic refers to taxa found only in the Hawaiian Islands; adventive refers to those taxa that are immigrant species but not intentionally introduced; and introduced refers to those taxa intentionally brought in for use in biological control programs. A "?" for status of a species in the Appendix indicates an identification only to genus level and status is unknown. Undescribed species from the Hawaiian Islands and species identified as "near" a previously described species (e.g., *Neocypholaelaps* nr. *lindquisti* Prasad, 1968) are considered here to be endemic until shown otherwise.

MATERIALS AND METHODS

Sampling Sites

KUI'A NATURAL AREA RESERVE: Kui'a Natural Area Reserve (Figure 1) occupies 662 ha in the Waimea District of Kaua'i Island (Department of Land and Natural Resources, State of Hawai'i 1989b). Elevation ranges from 600 to 1170 m. Rainfall averages 102–203 cm annually, with December being the wettest month and June the driest (Giambelluca et al. 1986). Gradual to moderate mountain slopes cut by intermittent streams in drier sections of northeastern Kōke'e are the

reserve's main features. The lowland section has dry and semiwet shrublands with 'Ōhi'a and Koa forests, and rare plants.

Kui'a Reserve lies partially within the Nā Pali Kona Forest Reserve and adjacent to Kōke'e State Park. The reserve is traversed by Nu'alolo Trail; north of the reserve is the Awa'awapuhi Trail, and south is Miloli'i Ridge. Outside the reserve's eastern boundary are Kōke'e Lodge, Kōke'e Natural History Museum, and cabins of Kōke'e State Park, accessed by the two-lane Highway 55.

The *Metrosideros/Acacia koa* mixed forests in the higher half of the reserve along the Nu'alolo Trail are over 9 m in height. Trees in the lower elevation consist of younger and shorter stands (1.5–4 m) of *Metrosideros*. Samples of accessible leaves and flowers were taken from these lower stands of 'Ōhi'a.

Three sampling sites along Nu'alolo Trail were marked: top (1100 m), middle (975 m), and bottom (750 m). Samples were taken from these three sites during the duration of the study. Samples were collected on 27 November 1990 and 29 April 1991.

HONO O NĀ PALI NATURAL AREA RESERVE: The Hono O Nā Pali Natural Area Reserve (Figure 1) occupies 1275 ha in the Hanalei District (Department of Land and Natural Resources, State of Hawai'i 1989a). It stretches from sea level along the Nā Pali coast crossing Kalalau Trail and rises south to the highest point at Pihea (1285 m) to the northern edge of Alaka'i Swamp. In the drier coastal lowlands, annual rainfall averages 203 cm, increasing to more than 406 cm in the upland rain forests (Giambelluca et al. 1986). Along the coast, the reserve encompasses parts of Hanakāpī'ai and Hanakoa Streams and all of Waiahuakua Stream. These intermittent and continuous streams and riparian and ridgeline lowland and montane semiwet and wet forests are the main features of the reserve. Rare plants, rare stream animals, and rare forest bird habitats are prevalent in the reserve.

Upper Hono O Nā Pali Reserve is composed of an eroded plateau with a series of ridges with 'Ōhi'a/mixed and 'Ōhi'a/Uluhe montane wet forest. Along the upper southwest corner of the reserve boundary

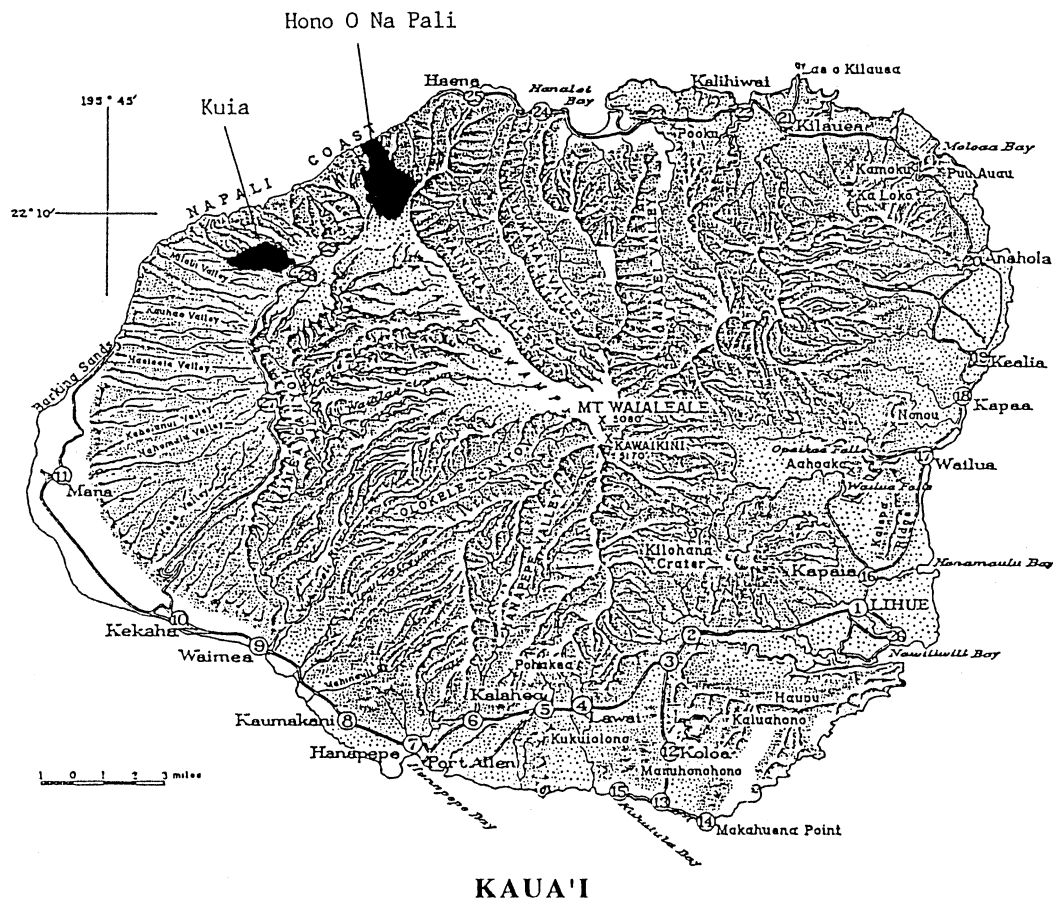


FIGURE 1. Topographic map of Kaua'i Island showing locations of Kui'a and Hono O Nā Pali Natural Area Reserves.

where samples from habitats were collected, the 'Ōhi'a trees were mixed with Lapalapa (*Cheirodendron platyphyllum* subsp. *kauaiense*), 'Ōlapa (*Cheirodendron trigynum*), Kāwa'u (*Ilex anomala*), Kōlea (*Myrsine lessertiana* and *M. alyxifolia*), and 'Ohe (*Tetraplasandra* spp.). The mixed shrub layer contained species of 'Ōhelo kau lā'au (*Vaccinium calycinum*), patches of Uluhe (*Dicranopteris linearis*), tree fern (*Cibotium*), Naupaka (*Scaevola procera*), *Styphelia*, and *Dodonaea*. Trunks and twigs of 'Ōhi'a were well covered with epiphytic mosses and liverworts. Diverse ground cover of mosses, ferns, and a thick layer of leaf litter on spongy humus dominates the forest floor. No signs of animal disturbance were observed.

The coastal section of Hono O Nā Pali Reserve is traversed by Kalalau Trail with sparse 'Ōhi'a communities. These trees were growing either below or above the trail and thus barely accessible for sampling. During the one-time sampling of the coastal Hono O Nā Pali Reserve, it had not rained for over 2 weeks, rendering the area extremely dry.

The upper Hono O Nā Pali Reserve was sampled on 19 November 1990, 18 February 1991, and 13 July 1991. The coastal section of the reserve was sampled on 4 September 1991.

Sampling and Extraction Techniques

A total of 90 samples of flowers, leaves, bark, bark with moss, litter, litter with soil, and soil

TABLE 1

Number of Habitat Samples Collected from Hono O Nā Pali and Kui'a Natural Area Reserves

Sample Type	Hono O Nā Pali ^a	Kui'a ^{a,b}
Flower	3	3
Leaves	14	10
Bark	6	14
Bark with moss	8	1
Leaf litter	9	10
Leaf litter with soil	9	3
Soil	0	5
Total	49	41

^a Three collections from upper elevation on Pihea, and one collection from coastal area along Kalalau Trail.

^b Two collections along Nu'alolo Trail.

was taken (Table 1). A litter sample consisted of leaves and small twigs lying on top of the mineral soil showing signs of decomposition. A soil sample was the mineral soil under the litter scooped to desired depth. Each litter sample was taken with a lightweight plastic trowel, approximately three trowelsful (approximately three to four cups [700–950 cm³] dry weight). When mineral soil was inadvertently included in the litter during sampling, the category became "litter with soil." At Hono O Nā Pali, moss and liverwort growth on trunks and twigs of 'Ōhi'a was predominant, making it difficult to sample bark without moss or liverworts. Few flower samples were taken because they were located 4 to 10 m up in the canopy. Flowering season was also a factor in the low number of flower samples. Leaves were picked off singly from tree branches. Efforts to standardize leaf samples at 20–30 leaves per sample were maintained during sampling. Samples were individually bagged in half-gallon (1893 cm³) plastic bags and labeled. Plastic bags were left open in the canvas carrier to provide a continuous supply of oxygen to the live microorganisms in the bag and to reduce condensation inside the bag, deemed lethal to the tiny mites. Closing the bags was unnecessary because most mites, unlike ants and spring-tails, will not wander off from the substrate. Samples were transported the same day to the Acarology Laboratory at the University of

Hawai'i at Mānoa for extraction. Mites were extracted using Tullgren-Berlese funnels (Krantz 1978).

Extracted mites in 70% ethyl alcohol were sorted to suborders. Samples of each morphospecies were mounted on microslides with Hoyer's mounting medium, then later dried in an oven for 2 weeks at 45–50°C and sealed with Glyptal electric paint before examination. A phase-contrast microscope (Wild) was used in mite identification. Voucher specimens were kept at the J. Linsley Gressitt Center for Research in Entomology of the Bishop Museum, and the Acarology Laboratory, University of Hawai'i at Mānoa.

RESULTS AND DISCUSSION

Acarine Population, Composition, and Densities

The suborders Mesostigmata (Gamasida), Prostigmata (Actinedida), Astigmata (Acari-dida), and Oribatida (Cryptostigmata) were all represented at Kui'a and Hono O Nā Pali Natural Area Reserves. Approximately 33,400 mites were extracted from 90 habitat samples. Of the mite total, 67% (22,500) were Oribatida, 23% (7,711) Prostigmata, 19% (2,568) Mesostigmata, and 2% (592) Astigmata. Of the 164 species found, 74 were of the suborder Prostigmata, 43 were Mesostigmata, 4 were Astigmata, and 43 were Oribatida (Appendix). Immatures composed 35–40% of the entire mite collection.

MESOSTIGMATA: (Figure 2). A large and cosmopolitan suborder, mites in this group have adapted successfully to a remarkably wide range of habitats. Many are free-living predators in the soil, in litter, or on plants, where they prey on other small invertebrates (Krantz and Ainscough 1990). Many species are parasites of mammals, birds, reptiles, or invertebrates (Strandtmann and Wharton 1958, Yunker 1973, Treat 1975). Mesostigmatic mites are generally well sclerotized. They range in size from 200 to 2500 μm.

A total of 43 species of mesostigmatic mites was recorded on flowers, leaves, bark, leaf litter, leaf litter and soil, and soil. Most species were found in leaf litter, bark, and the combination of leaf litter with soil (Table 2)

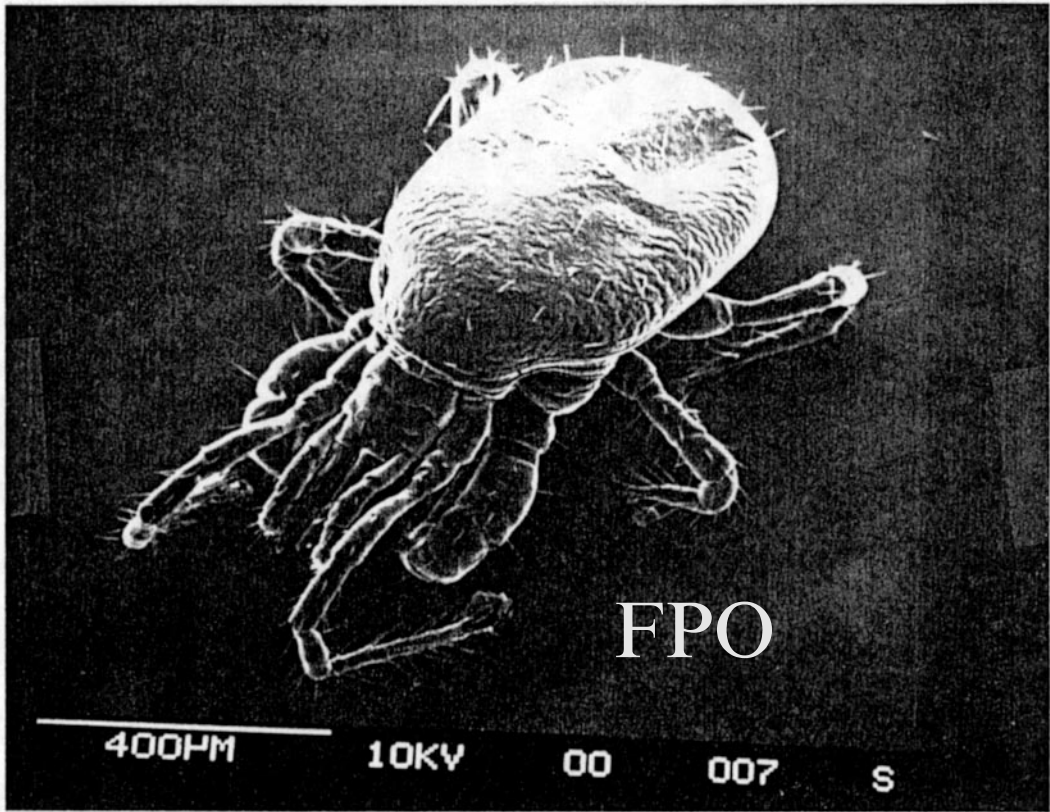


FIGURE 2. Suborder Mesostigmata, *Pergamasus* sp., family Parasitidae. SEM photomicrograph by S.F.S.

in both reserves. *Gamasiphis*, undescribed sp. (Ologamasidae), *Gamasholaspis gamasoides* (Parholaspididae), and *Veigaia planicola* (Veigaiidae) were the predominant species in both reserves. In Kui'a, *Athiesella*, undescribed sp. (Rhodacaridae), was numerous in all the samples, but was not found at Hono O Nā Pali. Radovsky and Tenorio (1981) reported the ubiquitous distribution of this species in soil on the lower half of Mauna Loa transect in Hawai'i Island. In Kui'a, this species was more frequently represented in litter and bark than in soil. *Gamasolaelaps whartoni* (Veigaiidae) was found only on Hono O Nā Pali in litter and litter with soil. The family Veigaiidae was well represented with seven species in Hono O Nā Pali: one species in the genus *Gamasolaelaps* (*G. whartoni*) and six species in the genus *Veigaia* (*V. planicola*, *V. cervina*, *V.*

uncata, and *Veigaia* species 1, 2, and 3. In Kui'a, *V. planicola* and *V. uncata* were the two species represented.

Mesostigmatic mite species found in different 'Ōhi'a habitats were mostly predaceous (except species in the genus *Neocypholaelaps*, family Ameroseiidae), feeding on small arthropods like Collembola and other small mites. Their presence and abundance in bark, soil, and litter indicate the availability of food (prey) in these habitats as well as the optimum temperature and moisture they require for survival.

PROSTIGMATA: (Figure 3). Among the Acari, prostigmatic mites exhibit the greatest biological and morphological diversity. Members of this group are delicate, small, and, unlike the mesostigmatic mites, almost free of sclerotization. They are free-living

TABLE 2
Number of Mite Families, Genera, and Species for Each Sample Habitat at Hono O Nā Pali and
Kui'a Natural Area Reserves

Habitat	Major Taxa	Hono O Nā Pali			Kui'a		
		Family	Genus	Species	Family	Genus	Species
Flower	Mesostigmata	4	4	5	2	3	3
	Prostigmata	5	5	5	5	5	5
	Astigmata	1	1	1	1	2	2
	Oribatida	1	1	1	0	0	0
Leaf	Mesostigmata	3	6	10	3	3	3
	Prostigmata	8	13	15	8	8	12
	Astigmata	1	1	1	1	2	2
	Oribatida ^a	7	7	7	5	5	5
Bark	Mesostigmata	6	14	15	6	9	10
	Prostigmata	10	17	24	12	20	28
	Astigmata	1	1	1	1	2	2
	Oribatida	7	7	7	7	7	7
Bark with moss	Mesostigmata	6	10	14	6	7	7
	Prostigmata	12	18	25	8	10	14
	Astigmata	1	1	1	1	1	1
	Oribatida	13	13	13	10	10	10
Leaf litter	Mesostigmata	9	12	16	9	13	16
	Prostigmata	15	26	34	15	22	30
	Astigmata	2	3	3	1	3	3
	Oribatida	22	23	23	15	15	15
Leaf litter with soil	Mesostigmata	9	13	22	9	12	17
	Prostigmata	13	22	29	12	15	17
	Astigmata	1	2	2	1	2	2
	Oribatida	12	12	12	9	12	12
Soil ^a	Mesostigmata	0	0	0	7	10	11
	Prostigmata	0	0	0	11	12	13
	Astigmata	0	0	0	1	2	2
	Oribatida	0	0	0	10	10	10

^a Soil samples taken at Hono O Nā Pali mixed with leaf litter.

predators, fungivores/algaevores, and obligate plant feeders. A few species are parasitic on vertebrates and invertebrates and are vectors of diseases like scrub typhus.

This group was represented by 74 species in both reserves. Leaf litter habitat had the greatest number of species at both Hono O Nā Pali and Kui'a (34 and 30, respectively), followed by bark habitat (24 and 28, respectively). Predaceous species such as *Spinibdella tbori* (Bdellidae), *Eupodes hawaiiensis* and *Eupodes sigmoidensis* (Eupodidae), *Rhagidia longi-*

sensilla (Rhagidiidae), *Ereynetes* sp. (Ereynetidae), and three species in the superfamily Raphignathoidea, *Neognathus spectabilis* (Caligonellidae), *Favognathus distinctus* and *F. picatus* (Cryptognathidae), and *Raphignathus* sp. (Raphignathidae) were widespread along Nu'alolo Trail and Hono O Nā Pali. Although raphignathoid mites are primarily predaceous, the *Favognathus* species are most likely nonpredaceous; instead they feed on fungal hyphae and other microorganisms in their habitat (Swift 1996). An undescribed

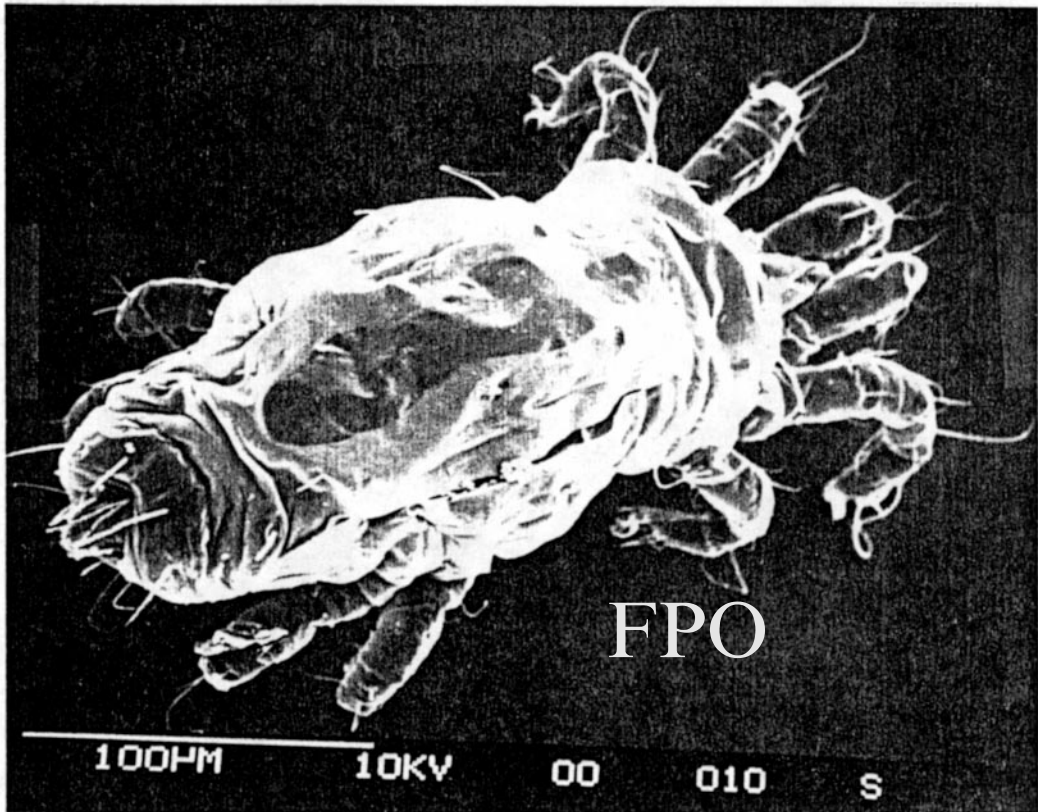


FIGURE 3. Suborder Prostigmata, *Stigmaeus*, undescribed sp., family Stigmaeidae. SEM photomicrograph by S.F.S.

species of *Spinibdella* (Bdellidae) (one specimen) was found on 'Ōhi'a bark at 1100 m. The species diversity of the families Cunaxidae, Eupodidae, Stigmaeidae, and Tydeidae was unexpectedly high (see Appendix).

ASTIGMATA: *Tyrophagus putrescentiae* (Acaridae) was the most widespread of the Astigmata. The species was represented on all sample habitats in the Nu'alolo Trail transect and the upper fringe of Hono O Nā Pali, but not in the low coastal area. The absence of this species and the entire group in the low coastal area was probably a sampling artifact because few samples were taken along Kalalau Trail. It was also very dry when samples were collected, suggesting that conditions were unfavorable for the mite group, although Astigmata represents one-third of the mite fauna in California desert soil (Wallwork

1972). Three other astigmatic species collected from the reserves were *Suidasia pontifica* (Acaridae), *Rhizoglyphus* sp. (Acaridae), and *Glycyphagus* sp. (Glycyphagidae).

The hypopus stage (phoretic deutonymph), which represents an adaptation unique to astigmatic mites (O'Connor 1982), was the most common stage collected in the samples. Attempts to identify them were not made in the study.

ORIBATIDA: (Figure 4). Often called "beetle mites" because of their usually rounded shape and dark, hard, and shiny exoskeleton, oribatid mites are usually the most abundant and diverse arthropods in temperate forest soils and subtropical environments (Swift and Norton 1998). High densities surpassing 100,000/m² are commonly reported (Norton 1994). Arboreal

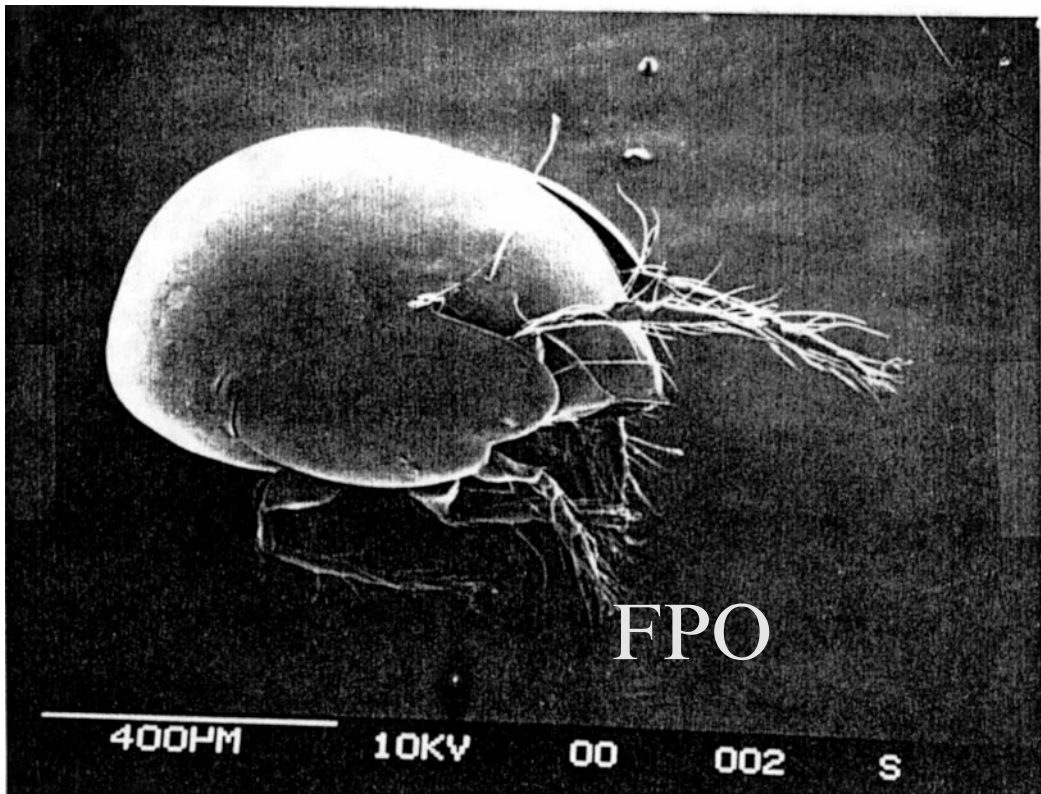


FIGURE 4. Suborder Oribatida, *Galumna* sp., family Galumnatidae. SEM photomicrograph by S.F.S.

forms of oribatid mites are found on tree bark, flowers, leaves, mosses, liverworts, lichens, and algae. Adult oribatid mite size ranges from 150 μm to 1.5 mm. Luxton (1972) categorized oribatid mites by feeding habits as macrophytophages (those that feed strictly on higher plant material after some decomposition has taken place); microphytophages (those that feed on certain soil microflora such as fungi, algae, and bacteria); and panphytophages (those that utilize both microbial and higher plant materials). The latter includes perhaps the majority of oribatid mites.

Thirty-three families and 43 species of Oribatida were recorded on the Kui'a transect and on both coastal and upper elevations of Hono O Nā Pali. Numerous species in families such as Galumnatidae and Scheloriobatidae are reported only to generic level.

Several species known only from the natural area reserves of Kaua'i were found on leaves and flowers of 'Ōhi'a. *Adhaesozetes* sp. (Adhaesozetidae) and *Campbellobates* sp. (Campbellobatidae) were reported from 'Ōhi'a leaves at Hono O Nā Pali (Swift and Norton 1998). An undescribed genus in the family Oribatulidae was recorded from flowers (Swift and Norton 1998). The family Phthiracaridae had three species, *Atropacarus* (*A.*) *striculus*, *Phthiracarus* *anonymus*, and *P. curiosus*, recorded for Kaua'i and the Hawaiian Islands by Niedbala (1998). *Phthiracarus curiosus* Niedbala, 1998, an endemic species, was collected from Kui'a (Niedbala 1998). A definite introduction from along the Atlantic and Gulf coastal plains of southeastern North America is the unusually unsclerotized *Nehypochthonius porosus* Norton & Metz, 1980, found for the first time in Kaua'i (Hono O

Nā Pali) and in five other islands (O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i) (Swift and Norton 1998).

Distribution Trends

Mites were widely distributed on both reserves. Different species were collected, possibly related to elevation, at the three sites along Nu'alolo Trail on Kui'a Reserve. Three distribution groups could be distinguished as follows: group I, composed of species distributed throughout the transect; group II, distributed from 975 to 1100 m; and group III, distributed from 762 to 974 m. In the Mesostigmata, *Gamasiphis*, undescribed sp., and *Athiesella*, undescribed sp., were two of five species found along the Nu'alolo transect. *Podocinum pacificum* (Podocinidae) and *Pseudoparasitus annectans* (Laelapidae) were two species distributed above 975 m in soil and leaf litter. These two species were not found at Hono O Nā Pali Reserve. *Asca aphidoides* (Ascidae), *Veigaia uncata* (Veigaiidae), *Amblyseius* sp. 1 (Phytoseiidae), and *Pseudoparasitus trincisus* (Laelapidae) were in the group III category found in the lower elevations of Nu'alolo Trail.

In the Prostigmata, *Eupodes sigmoidensis* and *E. hawaiiensis*, *Spinibdella thori*, and *Ereynetes* sp. were four of nine species that were widespread along the transect. Found in high elevations (group III) were two species of Cunaxidae (*Cunaxa* nr. *veracruzana* and *Neocunaxoides* sp. 2) and three species of Eupodiidae (*Eupodes*, undescribed sp., *Eupodes* sp. 8, and *Cocceupodes* nr. *triscutatus*). Two mite species in the supercohort Endeostigmata, *Oehserchestes* sp. (*Oehserchestidae*) and *Bimichaelia* sp. 1 (*Bimichaeliidae*), were collected in leaf litter and soil at Kui'a Reserve.

Habitats

Leaf litter, litter with soil, and bark habitats had the most diverse mite fauna in the reserves. The remarkable species diversity from leaf litter was not unexpected. The presence of tremendous number of microhabitats, availability of optimum environmental requirements, and decomposing plant parts and

other debris provide ideal growth environment both for mites and for the microflora that serve as mite food. The large, sclerotized, predatory mesostigmatic mites such as *Pergamasus* sp., *Veigaia* spp., and *Pseudoparasitus* spp. generally move freely chasing after prey animals in the upper litter layer. The Veigaiidae, which are common in woodland and forest soils, probably feed extensively on oribatid mites (Wallwork 1957) and Collembola. The smaller and more delicate Prostigmata in the families Cunaxidae, Bdellidae, and Stigmaeidae occur in the lower litter layer near the mineral soil where most members in the suborder flourish (Wallwork 1972). The large number of predaceous Mesostigmata and Prostigmata can be partly explained by the presence of large population of prey available in the form of Collembola and other mites, particularly immature Oribatida (which make up approximately 30–40% of the prey).

The inner bark of trees provides habitats for a great variety of burrowing insects and their mite associates. In a review of food habits and host relationships of mites found under bark, Lindquist (1970) reported symbiotic relationships between insects and mites. In view of this, the presence of scolytid beetles occasionally seen in the bark samples raises the question of whether the beetles have any relationship to Acari groups found in 'Ōhi'a bark. Lindquist also observed that coexistent congeneric species have different habits and are not directly competitive within the bark habitat. Perhaps this is also true of mite groups found in other habitats, when several species of the same family are found in the same microhabitat. In a study on apples, the mite fauna found on bark at the base of the trunk is apparently richer than on any other part of the tree (Garman 1948). A large portion of the fauna were oribatid mites, which could be partly explained by their movement from the soil and litter layer during the winter season or during adverse environmental conditions. Fauna of soil and bark crevices overlaps to some extent, as observed in pseudoscorpions (Wallwork 1970).

Leaves and flowers had the least number of mite associates. They also harbor an entirely different mite group. Phytophagous Prostig-

mata species such as *Tuckerella* sp. (Tuckerellidae) and *Brevipalpus* sp. (Tenuipalpidae) fed on living plant parts. The family Ameroseiidae, with two species in the genus *Neocyphoblaelaps*, was reported only from leaves and flowers of 'Ōhi'a. Members of this genus are known to live in flowers feeding on pollen and nectar using bees and butterflies for phoretic transport (Eickwort 1994). It is also possible that these mites use Hawaiian native birds feeding on nectars and pollen of 'Ōhi'a flowers to move from flower to flower. *Tyrophagus putrescentiae*, *Asca pineta*, four cunaxid species (*Cunaxa* sp., *Cunaxoides* sp., *Neocunaxoides andre*, and *Dactyloscirus inermis*), three stigmatid species (*Eryngiopus* sp. 1, *Stigmaeus* sp. 2, *Stigmaeus* sp. 3), two tydeid species (*Lorryia* sp. 1, *Tydeus* sp. 2), and nine families in the Oribatida (Haplochthoniidae, Malaconothridae, Nothridae, Adhaesozetidae, Campbellobatidae, Oribatulidae, Scheloriibatidae, Ceratozetidae, and Galumnatidae) were some of the taxa collected from leaves and flowers. The predaceous cunaxid and stigmatid species probably feed on small insects and their immatures and other small mites. The oribatid mite families collected from leaves and flowers were examples of arboreal panphytophagous Oribatida, which feed on microflora found in plant parts and also on higher plant materials (Luxton 1972, Walter and Behan-Pelletier 1999).

Residency Status/Endemism

Typically, island biotas exhibit a high degree of endemism resulting from isolation and geologic history. In Hawai'i, well over 90% of plants and terrestrial arthropods are endemic (Simon et al. 1984). Currently, this level does not appear to be reflected in the acarine fauna. Of the 164 mite species associated with 'Ōhi'a, 19 are endemic (12%) and 28 adventive (17%). However, there are 117 species (71%) for which we are currently unable to determine their status.

CONCLUSIONS

The mite fauna associated with 'Ōhi'a trees in the two Kaua'i natural area reserves was

clearly a rich one, both in number of species and number of individuals. The numbers are comparable to numbers of mites found on cultivated apples. In a study of mite associates in an apple orchard in southwestern Quebec, 71 species were collected from bark, leaves, and litter (Forest et al. 1982). On 'Ōhi'a, 127 species were determined from bark, leaves, and litter. In Wisconsin, apple foliage is home to 31 mostly predaceous mite species (Oatman 1963); on 'Ōhi'a, 33 species were found on foliage, not all of them predaceous. The species composition, however, was quite different in the two studies.

A certain amount of overlap exists between litter and mineral soil mite populations. Litter and mineral soil layers represent two distinct microhabitats for the soil fauna, and although there is appreciable faunal movement between the two, the presence of an association of mite species characteristic of each suggests that some habitat separation is occurring (Wallwork 1972). A closer look at the vertical distribution of certain focal taxa is necessary to clear up this uncertainty and establish the vertical distribution pattern for Hawaiian rain forest soil and litter fauna. Although there appeared to be a distribution trend among some mite groups on the Kui'a Reserve transect, distribution overlap among taxa was also prevalent. Perhaps factors such as relative humidity and temperature that accompany elevation changes did not have any limiting effect or the elevation difference in the study was not enough to allow recognition of differences in the mite faunal communities.

Factors that influence the distribution of predatory Mesostigmata and Prostigmata are basically unknown in the Islands. The distribution of prey animals as food sources is definitely important for these mites to survive in particular habitats. The predominance of Collembola probably plays an important role as preferred food in the maintenance of communities of predaceous mites inhabiting the forest floor. From a sample of 'Ōhi'a litter with soil collected along the Pihea Trail on Kaua'i, the Collembola-Acari composition showed 67% Collembola and 25% Acari (S.F.S., unpubl. data). It is probable that distribution of predaceous mites is governed

more by the distribution of prey animals than by the type of organic material or ground vegetation in the particular habitat.

Another dominant tree in Hawaiian forest communities, Koa (*Acacia koa*), together with 'Ōhi'a, provides the essential matrix of the natural forest ecosystems in the Hawaiian Islands (Mueller-Dombois 1981). Can we expect similar mite species diversity on Koa trees? How do the findings from these two reserves compare with data from reserves in other islands? Knowledge of Acari diversity is crucial as loss of hosts and habitats speeds up their decimation and possible extinction. Although we doubt that their loss will have an immediate impact on 'Ōhi'a communities or any ecosystem in general, distinguishing endemic mites is becoming even more difficult because of the continuous and frequent introduction of arthropods to the Islands.

Findings from this study show that future monitoring of Hawaiian ecosystems should include the acarine fauna, which can contribute substantially to our knowledge of both fauna and ecosystems that could be used in conservation assessments of forest reserves.

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Appendix

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kūi'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve			Habitat ^b				Ecological Note ^c
Suborder MESOSTIGMATA									
Superfamily Ascoidea									
Family Ascidae									
<i>Asca aphidoides</i> (Linnaeus, 1758)	Adv	H	K	li	ls	b			Mi
<i>Asca pimeta</i> De Leon, 1967	Adv	H	K		ls	b	s	le	f
<i>Blattisocius</i> sp. 1	?	H		li		b	bm	le	f
<i>Blattisocius</i> sp. 2	?	H				b		le	f
<i>Cheiroseius</i> sp.	?	H			ls	b	bm		
<i>Gamaselodes bicolor</i> complex	Adv	H	K	li	ls	b	bm	s	

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kui'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve			Habitat ^b			Ecological Note ^c		
<i>Lasioseius sugawarai</i> Ehara, 1964	Adv	H			bm			Pr, Mi		
<i>Lasioseius</i> nr. <i>sugawarai</i> Ehara, 1964	End?	H			bm	le		Pr, Mi		
<i>Lasioseius</i> sp. 2	?	H			bm	le		Pr, Mi		
<i>Lasioseius</i> sp. 3	?	H			bm	le		Pr, Mi		
Superfamily Dermanyssoidea										
Family Laelapidae										
<i>Hypoaspis</i> (<i>Geolaelaps</i>) <i>queenslandica</i> (Womersley, 1956)	Adv	H			b			Pr, Mi		
<i>Pseudoparasitus</i> (<i>Gymnolaelaps</i>) <i>annectans</i> (Womersley, 1955)	Adv		K	ls	bm			Pr, Mi		
<i>Pseudoparasitus trincisus</i> (Hunter, 1966)	Adv	H	K	li	ls	b		Pr, Mi		
Superfamily Eviphiidoidea										
Family Parholaspididae										
<i>Gamasbolaspis gamasoides</i> (Berlese, 1904)	Adv	H	K	li	ls	b	bm	s	Pr	
<i>Holaspina</i> sp. 1	?	H					bm		Pr	
<i>Holaspina</i> sp. 2	?	H			ls				Pr	
<i>Holaspina</i> sp. 3	?	H			ls	b	bm		Pr	
<i>Parbolaspulus</i> (<i>Parbolaspidellus</i>) <i>maunaloaensis</i> Tenorio & Marshall, 1977	End		K			b			Pr	
Superfamily Parasitoidea										
Family Parasitidae										
<i>Pergamasus</i> sp.	?	H	K		ls			s	Pr	
<i>Vulgarogamasus</i> sp. 1	?	H	K	li	ls	b			Pr	
<i>Vulgarogamasus</i> sp. 2	?	H	K	li	ls			s	Pr	
<i>Vulgarogamasus</i> sp. 3	?	H	K	li	ls				Pr	
<i>Vulgarogamasus</i> sp. 4	?	H			ls				Pr	
Family Veigaiidae										
<i>Veigaia cervia</i> (Kramer, 1987)	Adv	H			ls				Pr	
<i>Veigaia planicola</i> (Berlese, 1892)	Adv	H	K	li	ls	b	bm	s	Pr	
<i>Veigaia uncata</i> Farrier, 1957	Adv	H	K	li	ls				Pr	
<i>Veigaia</i> sp. 1	?	H			ls				Pr	
<i>Veigaia</i> sp. 2	?	H			ls				Pr	
<i>Veigaia</i> sp. 3	?	H			ls				Pr	
<i>Gamasolaelaps whartoni</i> (Farrier, 1957)	Adv	H		li	ls				Pr	
Family Ameroseiidae										
<i>Neocypholaelaps</i> nr. <i>lindquisti</i> Prasad, 1968	End?	H						le	f	Mi
<i>Neocypholaelaps</i> sp.	?	H	K					le	f	Mi
Family Phytoseiidae										
<i>Amblyseius ovatus</i> (Garman, 1958)	Adv	H		li		b				Pr
<i>Amblyseius</i> nr. <i>ovatus</i> (Garman, 1958)	End?	H	K	li	ls		bm	le	f	Pr
<i>Amblyseius</i> sp. 1	?		K	li						Pr
<i>Phytoseius</i> nr. <i>hawaiiensis</i> Prasad, 1968	End?		K	li						Pr
<i>Phytoseius</i> sp.	?	H						le		Pr
<i>Typhlodromus</i> nr. <i>haramotoi</i> Prasad, 1968	End?	H				b				Pr
Family Podocinidae										
<i>Podocinum pacificum</i> (Berlese, 1896)	Adv		K	li	ls			s		Pr
<i>Podocinum sagax</i> (Berlese, 1882)	Adv	H	K	li	ls			s		Pr

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and
Kui'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve			Habitat ^b					Ecological Note ^c	
Superfamily Polyaspidioidea											
Family Polyaspididae											
Unidentified genus	?	H	K	li			s			?	
Superfamily Rhodacaroidae											
Family Ologamasidae											
<i>Gamasipbis</i> , undescribed sp.	End	H	K	li	ls	b	bm	s		Pr	
Family Rhodacaridae											
<i>Athiesella</i> , undescribed sp.	End		K	li	ls	b	bm	s		Pr	
<i>Rhodacarus</i> sp.	?	H		li			bm			Pr	
Superfamily Uropodoidea											
Family Uropodidae											
<i>Fuscuropada</i> sp.	?	H	K		ls					Sa, Pr	
Suborder PROSTIGMATA											
Superfamily Anystoidea											
Family Anystidae											
Anystinae, unknown genus	?		K	li		b		s	le	f	Pr
Erythracarinae, unknown genus	?	H	K	li	ls	b			le	f	Pr
Superfamily Bdelloidea											
Family Bdellidae											
<i>Bdella nipoensis</i> Swift & Goff, 1987	End	H		li	ls	b	bm				Pr
<i>Cyta kauaiensis</i> Swift & Goff, 1987	End	H		li	ls						Pr
<i>Spimbella thori</i> (Meyer & Ryke, 1959)	Adv	H	K	li	ls	b	bm	s	le		Pr
<i>Spimbella</i> , undescribed sp.	End		K			b					Pr
Family Cunaxidae											
<i>Cunaxa</i> nr. <i>veracruzana</i> Baker & Hoffmann, 1948	End?	H	K			b	bm				Pr
<i>Cunaxa</i> sp.	?	H		li		b	bm		le		Pr
<i>Cunaxoides</i> sp.	?	H	K	li		b	bm		le		Pr
<i>Dactyloscirus inermis</i> (Baker & Hoffmann, 1948)	Adv	H		li	ls		bm		le		Pr
<i>Neocunaxoides andre</i> (Baker & Hoffmann, 1948)	Adv	H	K	li	ls	b	bm		le		Pr
<i>Neocunaxoides</i> sp. 1	?	H					bm				Pr
<i>Neocunaxoides</i> sp. 2	?	H	K	li			bm				Pr
<i>Pseudobonzia</i> sp.	?	H		li	ls						Pr
<i>Pseudocunaxa</i> sp.	?	H			ls						Pr
Superfamily Cheyletoidea											
Family Cheyletidae											
<i>Eucheyletia</i> sp.	?	H							f		Pr
Superfamily Eupodoidea											
Family Eupodidae											
<i>Cocceupodes triscutatus</i> Strandtmann & Prasse, 1977	Adv		K		ls						Pr
<i>Cocceupodes</i> nr. <i>triscutatus</i> Strandtmann & Prasse, 1977	End?	H	K	li	ls	b		s			Pr
<i>Eupodes hawaiiensis</i> (Strandtmann & Goff, 1978)	End	H	K	li		b	bm		le		Pr
<i>Eupodes sigmoidensis</i> (Strandtmann & Goff, 1978)	Adv	H	K	li	ls	b	bm	s	le		Pr
<i>Eupodes</i> , undescribed sp.	End	H		li	ls		bm				Pr
<i>Eupodes</i> sp. 2	?	H			ls						Pr
<i>Eupodes</i> sp. 3	?	H			ls						Pr

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kūi'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve			Habitat ^b			Ecological Note ^c			
<i>Eupodes</i> sp. 4	?	H	K	ls						Pr	
<i>Eupodes</i> sp. 5	?	H		ls						Pr	
<i>Eupodes</i> sp. 6	?		K	li						Pr	
<i>Eupodes</i> sp. 7	?		K		b					Pr	
<i>Eupodes</i> sp. 8	?		K	li						Pr	
<i>Protereunetes</i> sp.	?	H	K	li						Pr	
Family Rhagidiidae											
<i>Coccorhagidia</i> nr. <i>clavifrons</i> (G. Canestrini, 1886)	End?		K	ls						Pr	
<i>Rhagidia longisensilla</i> Shiba, 1969	Adv		K	li	ls		s			Pr	
<i>Rhagidia</i> sp.	?	H		li		bm				Pr	
Superfamily Erythraeoidea											
Family Erythraeidae											
<i>Hauptmannia</i> sp.	?	H				bm				Pa	
Superfamily Pygmephoroidea											
Family Pygmephoridae											
<i>Bakerdania</i> sp.	?	H	K	li	ls		s			?	
Family Scutacaridae											
<i>Imparipes</i> sp.	?	H	K	li	ls		s			?	
Superfamily Raphignathoidea											
Family Caligonellidae											
<i>Neognathus spectabilis</i> (Summers & Schlinger, 1955)	Adv		K			b				Pr	
Family Cryptognathidae											
<i>Favognathus distinctus</i> Swift, 1996	End	H	K	li		b	bm	s		Mi	
<i>Favognathus pictus</i> (Summers & Chaudhri, 1965)	Adv	H	K	li			bm			Mi	
Family Raphignathidae											
<i>Raphignathus</i> sp.	?		K	li		b		s		Pr	
Family Stigmaeidae											
<i>Agistemus</i> sp.	?	H	K			b	bm			Pr	
<i>Eryngiopus</i> sp. 1	?	H			ls	b		le		Pr	
<i>Eryngiopus</i> sp. 2	?	H			ls					Pr	
<i>Eustigmaeus segnis</i> group	?	H	K	li		b		s		Pr	
<i>Ledermuelleriopsis plumosus</i> Willmann, 1951	Adv		K	li		b				Pr	
<i>Stigmaeus</i> sp. 2	?	H		li		b	bm	le		Pr	
<i>Stigmaeus</i> sp. 3	?	H	K	li	ls	b		le		Pr	
<i>Stigmaeus</i> sp. 4	?		K			b				Pr	
Superfamily Tarsonemoidea											
Family Tarsonemidae											
<i>Hemitarsonemus</i> sp.	?	H	K	li	ls	b	bm			Ph?	
<i>Heterotarsonemus</i> sp.	?	H	K	li	ls					Ph?	
Family Tenuipalpidae											
<i>Brevipalpus</i> sp.	?	H	K						f	Ph	
Superfamily Tetranychoidae											
Family Tuckerellidae											
<i>Tuckerella</i> sp.	?	H	K					le	f	Ph	
Superfamily Tydeoidea											
Family Ereynetidae											
<i>Ereynetes</i> sp.	?	H	K	li	ls	b	bm	s	le	f	Pa?
Family Paratydeidae											
<i>Neotydeus?</i> sp.	?		K			b				Mi	

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kui'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve		Habitat ^b				Ecological Note ^c
Family Tydeidae								
<i>Tydaecolus</i> sp.	?	H		li		b		Pr?
<i>Lorryia</i> sp. 1	?	H	K	li			le	Pr?
<i>Lorryia</i> sp. 2	?	H	K	li				Pr?
<i>Lorryia</i> sp. 3	?	H			ls			Pr?
<i>Tydeus</i> sp. 1	?		K			b		Pr?
<i>Tydeus</i> sp. 2	?	H	K	li	ls	b	bm le	Pr?
<i>Tydeus</i> sp. 3	?		K	li		b		Pr?
<i>Tydeus</i> sp. 4	?	H		li				Pr?
<i>Tydeus</i> sp. 5	?		K			b		Pr?
<i>Tydeus</i> sp. 6	?	H	K	li		b	bm	Pr?
<i>Tydeus</i> sp. 7	?	H				b		Pr?
<i>Tydeus</i> sp. 8	?	H				b		Pr?
<i>Tydeus</i> sp. 9	?	H	K			b		Pr?
Supercohort ENDEOSTIGMATA								
Family Alicorhagiidae								
<i>Alicorhagia</i> sp.	?	H		li				Mi
Family Bimichaeliidae								
<i>Bimichaelia</i> sp. 1	?		K	li	ls			Mi
<i>Bimichaelia</i> sp. 2	?	H			ls		bm	Mi
<i>Bimichaelia</i> sp. 3	?	H			ls			Mi
Genus A sp. 1	?	H			ls			Mi
Genus A sp. 2	?	H					bm	Mi
Family Nanorchestidae								
<i>Nanorchestes</i> sp.	?	H		li	ls		bm	Mi
Family Oehserchestidae								
<i>Oehserchestes</i> sp.	?		K				s	Mi
Suborder ASTIGMATA								
Superfamily Acaroidea								
Family Acaridae								
<i>Rhizoglyphus</i> sp.	?	H	K	li	ls		s	Sa, Mi
<i>Suidasia pontifica</i> (Oudemans, 1905)	Adv		K	li		b	le f	Sa, Mi
<i>Tyrophagus putrescentiae</i> (Schrank, 1781)	Adv	H	K	li	ls	b	bm s le f	Sa, Mi
Family Glycyphagidae								
<i>Glycyphagus</i> sp.	?	H		li				Sa, Mi
Suborder ORIBATIDA								
Superfamily Ctenacaroidea								
Family Aphelacaridae								
<i>Aphelacarus</i> sp.	?	H		li			bm	Sa, Mi
Superfamily Hypochthonoidea								
Family Hypochthoniidae								
<i>Eohypochthonius</i> sp.	?	H			ls			Sa, Mi
Superfamily Protoplophoroidea								
Family Haplochthoniidae								
<i>Haplochthonius</i> sp.	?	H	K	li			le	Sa, Mi
Family Cosmochthoniidae								
<i>Cosmochthonius</i> spp.	?		K	li		b		Sa, Mi
Superfamily Brachychthonoidea								
Family Brachychthoniidae								
<i>Liobchthonius</i> sp.	?		K		ls			Sa, Mi
<i>Sellnickochthonius</i> nr. <i>zelawaiensis</i> (Sellnick, 1928)	End?	H	K		ls		bm s	Sa, Mi

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kūi'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve	Habitat ^b	Ecological Note ^c
Superfamily Atopochthonioidea				
Family Pterochthoniidae				
<i>Pterochthonius angelus</i> (Berlese, 1910)	Adv	H	li ls	Sa, Mi
Superfamily Phthiracaroidae				
Family Phthiracaridae				
<i>Atropacarus (A.) striculus</i> (C. L. Koch, 1836)	Adv	K	ls	Sa, Mi
<i>Phthiracarus anonymus</i> (Grandjean, 1933)	Adv	K	ls	Sa, Mi
<i>Phthiracarus curiosus</i> Niedbala, 1998	End	K	ls	Sa, Mi
Superfamily Euphthiracaroidae				
Family Euphthiracaridae				
<i>Microtritia</i> sp.	?	K	li	Sa, Mi
Family Oribotritiidae				
<i>Oribotritia</i> sp.	?	H K	li	Sa, Mi
Superfamily Epilohmannioidea				
Family Epilohmanniidae				
<i>Epilohmannia</i> sp.	?	K	li s	Sa, Mi
Superfamily Nehypochthonioidea				
Family Nehypochthoniidae				
<i>Nehypochthonius porosus</i> Norton & Metz, 1980	Adv	H	li	Sa, Mi
Superfamily Crotonioidea				
Family Camisiidae				
<i>Platynothrus</i> sp.	?	H K	li b bm s	Sa, Mi
Family Malaconothridae				
<i>Malaconothrus</i> sp.	?	H K	li b bm le	Sa, Mi
Family Nothridae				
<i>Nothrus</i> sp.	?	H K	li ls b bm s le	Sa, Mi
Family Trhypochthoniidae				
<i>Trhypochthoniellus</i> sp.	?	H	li	Sa, Mi
<i>Trhypochthonius</i> sp.	?	H	li b	Sa, Mi
Superfamily Nanhermannioidea				
Family Nanhermanniidae				
<i>Masthermannia</i> sp.	?	H	li	Sa, Mi
<i>Nanhermannia</i> sp.	?	H	li	Sa, Mi
Superfamily Hermannioidea				
Family Hermanniidae				
<i>Phyllhermannia</i> sp.?	?	H	li	Sa, Mi
Superfamily Liodoidea				
Family Liodiidae				
<i>Liodes</i> sp.	?	H	li	Sa, Mi
Superfamily Damaeoidea				
Family Damaeidae				
<i>Damaeus</i> sp.	?	H K	li ls b bm s	Sa, Mi
Superfamily Carabodoidea				
Family Carabodidae				
<i>Austrocarabodes</i> sp.	?	H	li ls	Sa, Mi
Superfamily Cepheidoidea				
Family Cepheidae				
" <i>Cepheus</i> " <i>pustulatus</i> , undescribed g.	End	K	li s	Sa, Mi
Superfamily Amerobelboidea				
Family Eremobelbidae				
<i>Eremobelba</i> sp.	?	H	li	Sa, Mi

Appendix (Continued)

Systematic Position, Status, and Ecological Notes of Mites Associated with 'Ōhi'a in Hono O Nā Pali (H) and Kui'a (K) Natural Area Reserves on Kaua'i Island

Taxa	Status ^a	Reserve			Habitat ^b				Ecological Note ^c	
Family Tectocepheidae										
<i>Tectocephus</i> sp.	?	H	K	li	bm				Sa, Mi	
Superfamily Oppioidea										
Family Oppiidae										
<i>Machuella</i> sp.	?	H	K	li	ls	bm				Sa, Mi
<i>Microppia</i> sp.	?		K	li					Sa, Mi	
<i>Multioppia</i> sp.	?		K		ls	s				Sa, Mi
Family Quadropiidae										
<i>Quadroppia</i> sp.	?	H			ls					Sa, Mi
Family Suctobelbidae										
<i>Suctobelbella</i> sp.	?	H		li	ls	bm				Sa, Mi
Superfamily Licneremaeoidea										
Family Adhaesozetidae										
<i>Adhaesozetes</i> sp.	?	H					le		Sa, Mi	
Superfamily Oripodoidea										
Family Campbellobatidae										
<i>Campbellobates acanthus hawaiiensis</i> Balogh, 1985	End	H					bm		Sa, Mi	
<i>Campbellobates</i> sp.	?	H						le	Sa, Mi	
Family Haplozetidae										
<i>Rostrozetes</i> sp.	?	H	K	li	ls					Sa, Mi
Family Oribatulidae										
Undescribed genus	End	H							f	Sa, Mi
Family Scheloribatidae										
<i>Scheloribates</i> spp.	?	H	K	li	ls	b	bm	s	le	Sa, Mi
Superfamily Ceratozetoidea										
Family Ceratozetidae										
<i>Ceratozetes</i> sp.	?	H	K				bm	s		Sa, Mi
<i>Fuscozetes</i> sp.	?	H	K	li					Sa, Mi	
Superfamily Achipterioidea										
Family Tegoribatidae										
<i>Tegoribates</i> sp.	?	H			li					Sa, Mi
Superfamily Galumnatoidea										
Family Galumnatidae										
<i>Galumna</i> spp.	?	H	K	li	ls	b	bm	s	le	Sa, Mi

^a Adv, adventive; End, endemic; ?, unknown.

^b b, bark; bm, bark with moss; f, flower; le, leaves; li, leaf litter; ls, leaf litter with soil; s, soil.

^c Mi, microphytophage (fungivore, lichenovore, pollinivore, and phycophage of Luxton [1972]); Pa, parasite; Ph, phytophage (feeding on living plant material); Pr, predator; Sa, saprophage (ingesting decaying plant or animal matter); ?, unknown ecological role.