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OCCURRENCE OF FEATHER MITES (PROCTOPHYLLODIDAE) AMONG BIRDS OF VENTURA COUNTY LOWLANDS, CALIFORNIA

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Abstract.—During 1977 through 1988, an examination of 90 species of birds, totalling 47,326 individuals in and near Camarillo, Ventura County, California, established the distribution and seasonality of feather mites (*Proctophyllodes* spp.) on these hosts. The House Finch (*Carpodacus mexicanus*) was the most abundant permanent resident examined and showed peak feather mite infestations in March and September. The White-crowned Sparrow (*Zonotrichia leucophrys*) was the most abundant winter resident studied, arriving in September or October with few evident mites which increased to a peak in March–April. Summer resident species were fewer in number with lighter mite loads. When all birds are considered the peak year of infestation at the park was 1982 whereas at the house it was 1983. Circadian movements at dusk and other factors controlling the distribution and numbers of the mites are discussed.

INCIDENCIA DE PIOJOS (PROCTOPHYLLODIDAE) EN AVES DEL CONDADO DE VENTURA, CALIFORNIA

Resumen.—Desde el 1977 hasta el 1988 se examinaron 90 especies de aves y un total de 47,326 individuos en y cerca de Camarillo (Condado de Ventura, California) y se estableció la distribución y estacionalidad de piojos (Proctophyllodidae) en sus huéspedes. *Carpodacus mexicanus* fue la especie residente más abundante y mostró picos de infección de piojos en marzo y septiembre. *Zonotrichia leucophrys* fue la especie residente más abundante en el invierno, llegando al área de estudio en septiembre u octubre con algunos piojos, los que aumentaron hasta alcanzar un pico en marzo–abril. Las especies residentes en el verano tuvieron 25% menos piojos. Las aves de parques tuvieron una infección máxima en el 1982, mientras que las especies caseras lo fueron en el 1983. En este trabajo son discutidos movimientos circadianos al oscurecer y otros factores que controlan la distribución y número de piojos.

World-wide collection of birds during the 18th and 19th centuries stimulated an early interest in their ectoparasites (Trousseart 1886). Feather mites were considered innocuous, however, and not listed as potential disease vectors until Boyd (1951). The shift in interest to mites as possible disease vectors stimulated Atyeo, his staff, and students to revise several genera (Atyeo and Braasch 1966, Orwig 1968). Earlier Dubinin published several papers (1950, 1951, 1952, 1953, 1956) in Russian which reported on his comprehensive studies of mites. In 1600 pages Dubinin addressed many of the problems of feather mite dispersion both on individual hosts and within species. Gaud (1957) from France also reported on feather mites. My study in Ventura County, California, from 1977 to the present, has focused on the interrelationships between mites and their hosts. The impact of annual bird populations, host migration, and seasonality upon mite infestations is examined. Mites infesting individual hosts were followed to determine how rapidly the parasite population could expand or decline.

LOCALITY AND METHODS

Birds were trapped and netted from July 1977 through December 1988 in and near Camarillo, Ventura County. The habitats included urban gardens and shade trees, nearby farmlands of truck crops, and citrus or avocado orchards in the lowlands. Upland studies centered in the coastal montane chaparral altered by over-grazing and burning, and in a residual Coastal Oak (*Quercus agrifolia*) grove.

Two Irl Rogers 8-celled traps and two 1-celled Potter traps (McClure 1984a) baited with mixed grain were operated for one day each week at my home in Camarillo (referred to as the house). Eight to ten, four panel mist nets, 6 to 12 meters long, were used one day each week at the Camarillo Oak Grove County Park and nearby chaparral pastures (designated as the park). This park is located 7 km east of the city of Camarillo.

All birds captured were banded with regulation U.S. Fish and Wildlife Service bands, sexed and aged where possible, weighed, measured, and examined for ectoparasites (McClure and Ratanaworabhan 1973, McClure 1984b). Feather mite infestations were classified by the number seen on the primary and secondary remiges of the right wing: None—no mites seen when the wing was extended against a brightly lighted background; Few—occasional mites scattered among the feathers; Medium—many mites present along the rachis of some feathers; and Many—nearly every feather supported hundreds of mites. Since the larvae and protonymphs are almost translucent and difficult to see, adult mite distribution formed the basis for the data of this paper. To reduce errors of interpretation only one person examined all birds.

RESULTS

During 862 trapping or netting days, 47,326 birds of 90 species were captured and examined. Of these, 18,921 (40%) had evident infestations of feather mites on their primary or secondary wing feathers. Forty-seven species were hosts for feather mites. In the following list of these species, the number of individuals infested with mites is listed before the number of birds examined.

California Quail (*Callipepla californica*) 2/40; Acorn Woodpecker (*Melanerpes formicivorus*) 4/30; Nuttall's Woodpecker (*Picoides nuttallii*) 18/38; Western Flycatcher (*Empidonax difficilis*) 1/39; Ash-throated Flycatcher (*Myiarchus cinerascens*) 3/14; Scrub Jay (*Aphelocoma coerulescens*) 52/311; Plain Titmouse (*Parus inornatus*) 6/22; House Wren (*Troglodytes aedon*) 1/51; Swainson's Thrush (*Catharus ustulatus*) 1/14; Hermit Thrush (*C. guttatus*) 48/360; American Robin (*Turdus migratorius*) 6/19; Wrentit (*Chamaea fasciata*) 5/181; Northern Mockingbird (*Mimus polyglottos*) 20/130; California Thrasher (*Toxostoma redivivum*) 4/75; Cedar Waxwing (*Bombycilla cedrorum*) 35/56; Loggerhead Shrike (*Lanius ludovicianus*) 5/18; European Starling (*Sturnus vulgarus*) 16/108; Warbling Vireo (*Vireo gilvus*) 1/8; Orange-crowned Warbler (*Vermivora celata*)

2/31; Yellow-rumped Warbler (*Dendroica coronata*) 31/607; Western Tanager (*Piranga ludoviciana*) 1/9; Black-headed Grosbeak (*Pheucticus melanocephalus*) 2/36; Blue Grosbeak (*Guiraca caerulea*) 1/5; Lazuli Bunting (*Passerina amoena*) 4/48; Green-tailed Towhee (*Pipilo chlorurus*) 1/1; Rufous-sided Towhee (*P. erythrophthalmus*) 126/507; Brown Towhee (*P. fuscus*) 296/986; Rufous-crowned Sparrow (*Aimophila ruficeps*) 5/106; Chipping Sparrow (*Spizella passerina*) 6%/16; Lark Sparrow (*Chondestes grammacus*) 68/154; Sage Sparrow (*Amphispiza belli*) 1/8; Savannah Sparrow (*Passerculus sandwichensis*) 13/31; Fox Sparrow (*Passerella iliaca*) 6/16; Song Sparrow (*Melospiza melodia*) 22/261; Lincoln's Sparrow (*M. lincolnii*) 3/67; White-throated Sparrow (*Zonotrichia albicollis*) 3/4; Golden-crowned Sparrow (*Z. atricapilla*) 132/491; White-crowned Sparrow (*Z. leucophrys*) 3668/9066; Dark-eyed Junco (*Junco hyemalis*) 146/707; Brewer's Blackbird (*Euphagus cyanocephalus*) 64/1461; Red-winged Blackbird (*Agelaius phoeniceus*) 5/48; Brown-headed Cowbird (*Molothrus ater*) 12/223; Northern Oriole (*Icterus galbula*) 7/84; House Finch (*Carpodacus mexicanus*) 13,655/20,600; Lesser Goldfinch (*Carduelis psaltria*) 16/153; American Goldfinch (*C. tristis*) 4/6; and House Sparrow (*Passer domesticus*) 393/5739.

The ratios given above represent total numbers. When the various segments and groups of these species are arranged seasonally, annually, or in other categories, the field data given in the tables and text will not necessarily agree with these totals. The 43 species lacking feather mites are not listed, but may be obtained from the author.

Table 1 summarizes the annual rate of mite infestations for 45 species at the park and 14 species at the house. When all species are considered, the peak year of infestation at the park was 1982, whereas at the house it was 1983. Removing data for the White-crowned Sparrow, infestation of the remaining species at the park peaked in 1979. No difference was found in the peak data for the house with or without the House Finch as all species had their heaviest infestations in 1983.

Based upon host residency (permanent, summer or winter) Tables 2, 3, and 4 show the monthly presence of mites over the 11 yr study period for each group, respectively. The range of monthly infestations for 24 resident species was 28.3% to 72.6%; for nine summer species, 12.03% to 28.6%; and for 11 winter species, from 20.0% to 56.5%. The average mite infestation for all 12 mo was 46.7% for the resident species, 22.6% for the summer species, and 35.9% for the winter species. The 11 yr average for the three groups was 43.7%.

Only five (Scrub Jay, Northern Mockingbird, Brown Towhee, Brewer's Blackbird, and House Finch) of the 24 permanent residents from either the house or park data were captured in large enough numbers for further analysis. Of these, the Scrub Jay population and the numbers examined were similar in each habitat, but the rate of infestation at the house was three times that at the park. The ratio of infestation was unchanged during peak mite activity in the fall months. Mockingbirds trapped at the house had the same ratio of mite infestation, three to one,

TABLE 1. The number of feather mite infestations per year as determined by examination of 47 species of birds captured at and near Camarillo, California. Figures are the number of infested birds over the number examined.

	1977	1978	1979	1980	1981
Camarillo Oak Grove Park					
California Quail		0/2	—	2/13	0/14
Acorn Woodpecker		0/1	1/3	2/17	—
Nuttall's Woodpecker		0/1	1/1	2/2	0/8
Western Flycatcher		—	0/2	0/6	1/7
Ash-throated Flycatcher		—	—	—	1/6
Scrub Jay		0/4	1/21	2/28	2/12
Plain Titmouse		0/1	2/7	0/3	0/5
House Wren		—	0/1	1/8	0/6
Swainson's Thrush		—	—	—	0/1
Hermit Thrush		0/6	6/36	7/95	0/57
American Robin		—	0/1	—	0/2
Wren Tit		—	0/13	1/109	0/9
Northern Mockingbird		0/4	0/16	0/14	0/15
California Thrasher		—	1/23	0/17	0/2
Cedar Waxwing		—	—	—	3/8
Loggerhead Shrike		—	1/1	—	1/7
European Starling		0/3	2/16	3/7	0/8
Warbling Vireo		—	—	0/1	0/3
Orange-crowned Warbler		—	0/3	0/7	0/5
Yellow-rumped Warbler		1/32	3/116	1/82	1/34
Western Tanager		—	—	0/1	1/1
Black-headed Grosbeak		—	—	0/5	0/5
Blue Grosbeak		—	—	—	0/1
Lazuli Bunting		—	—	—	3/18
Green-tailed Towhee		—	1/1	—	—
Rufous-sided Towhee		0/2	23/83	40/163	3/48
Brown Towhee		0/6	25/105	29/79	19/72
Rufous-crowned Sparrow		—	1/2	0/1	0/7
Chipping Sparrow		—	—	—	—
Lark Sparrow		—	—	—	8/69
Sage Sparrow		—	—	—	1/7
Savannah Sparrow		—	—	—	1/7
Fox Sparrow		—	1/3	0/2	0/3
Song Sparrow		—	0/6	3/10	2/24
Lincoln's Sparrow		—	—	0/6	1/11
White-throated Sparrow		—	1/2	—	—
Golden-crowned Sparrow		—	10/41	8/58	2/36
White-crowned Sparrow		0/2	16/52	40/119	39/119
Dark-eyed Junco		1/9	9/29	5/19	15/89
Brewer's Blackbird		—	0/37	1/26	0/32
Brown-headed Cowbird		—	—	—	—
Northern Oriole		—	1/13	1/16	3/20
House Finch		17/57	83/145	93/169	180/392
Lesser Goldfinch		1/9	1/18	0/16	3/39
American Goldfinch		—	—	—	0/1
Number of observations		5	41	50	47
Total birds examined		20/139	193/797	241/1099	290/1210
% Birds with infestations		14.4	24.2	21.9	24.0

TABLE 1. Extended.

1982	1983	1984	1985	1986	1987	Total
0/3	0/5	—	—	0/1	0/2	2/40
0/2	—	0/1	0/1	0/4	1/1	4/30
0/2	3/5	4/7	0/4	5/5	3/3	18/38
0/9	0/4	—	0/9	0/1	0/1	1/39
0/1	1/2	1/3	0/2	—	—	3/14
1/16	1/8	0/8	1/10	6/55	0/11	14/173
2/3	1/1	0/1	1/1	—	—	6/22
0/6	0/16	0/3	0/10	0/1	—	1/51
—	—	0/1	1/5	0/3	0/4	1/14
22/70	0/2	6/23	4/28	0/19	3/24	48/360
3/6	—	0/1	0/3	0/1	3/5	6/19
0/8	0/11	2/5	2/13	0/11	0/3	5/182
4/14	2/14	6/29	3/26	1/28	1/10	17/170
0/3	0/1	0/3	1/7	2/12	0/7	4/75
—	—	0/1	24/32	1/1	4/8	32/50
0/2	1/1	0/2	2/4	—	—	5/17
1/22	4/22	4/11	1/5	1/4	0/6	16/104
0/1	—	1/1	0/2	—	—	1/8
0/4	—	1/3	1/4	0/5	—	2/31
2/17	5/17	5/37	0/97	10/131	3/40	31/603
0/2	—	0/1	0/2	0/1	0/1	1/9
—	2/20	0/1	0/2	0/1	0/1	2/35
0/1	0/2	—	—	1/1	—	1/5
1/24	0/5	—	—	0/1	—	4/45
—	—	—	—	—	—	1/1
12/26	2/9	1/5	7/35	34/119	4/16	126/506
24/91	26/65	10/49	38/132	61/191	7/34	242/824
1/56	1/8	2/9	0/11	0/9	0/3	5/106
1/2	—	0/1	—	—	—	1/3
39/58	5/6	1/2	1/2	7/10	7/12	68/159
—	—	—	0/1	—	—	1/8
3/8	1/7	—	7/8	1/1	—	13/31
0/1	0/1	—	—	0/1	—	1/11
1/46	6/47	3/11	1/39	6/60	0/17	22/260
1/6	0/12	1/6	0/7	0/9	0/10	3/67
0/1	—	—	—	—	—	1/3
27/65	18/35	5/32	26/82	21/84	9/27	126/460
59/179	49/109	12/50	61/165	8/292	23/104	380/1191
13/108	20/42	20/64	39/113	15/144	11/90	148/707
1/37	5/30	0/19	3/66	8/56	1/10	19/313
—	0/1	—	—	2/7	0/3	2/11
2/18	0/2	0/3	2/9	0/3	0/1	9/85
348/487	66/73	43/64	119/189	365/522	60/142	1374/2240
12/63	0/2	—	0/2	0/1	—	17/150
4/4	0/1	—	—	—	—	4/6
49	31	37	45	46	23	374
584/1472	219/586	128/457	345/1128	628/1795	140/596	2788/9279
39.7	37.4	28.0	30.6	35.0	23.5	30.0

TABLE 1. Continued.

	1977	1978	1979	1980	1981
House in Camarillo					
Scrub Jay	0/4	0/16	3/10	2/18	2/16
Northern Mockingbird	—	—	0/1	—	0/3
Cedar Waxwing	—	—	—	—	—
White-throated Sparrow	—	—	—	—	—
White-crowned Sparrow	19/118	343/649	216/689	298/985	315/900
Gold-crowned Sparrow	—	—	0/3	0/1	1/2
Brown Towhee	2/4	5/13	7/17	7/17	8/14
Chipping Sparrow	—	2/4	3/4	0/1	0/3
Fox Sparrow	—	—	—	—	3/3
Brewer's Blackbird	0/17	0/62	3/133	6/143	0/120
Red-winged Blackbird	—	—	—	3/13	2/20
Brown-headed Cowbird	0/3	0/1	1/8	4/10	2/9
House Finch	128/246	603/947	1028/1512	1204/1858	1207/2139
House Sparrow	5/320	14/588	14/709	22/551	2/658
Number of observations	35	49	45	49	47
Total birds examined	154/712	967/1280	1275/3086	1546/3598	1542/3887
% Birds with infestations	21.6	42.4	41.3	43.0	40.0

even though the actual birds trapped were 13 at the house and 187 at the park.

Mite infestations were 33% greater in Brown Towhees trapped at the house than at the park, even though the species was more abundant in the park. Towhees are terrestrial in both habitats. During post-nesting dispersion (June–September), the towhee population rose rapidly but the rate of mite infestation remained the same.

Brewer's Blackbird was a year round resident at the house while at the park 80% of the year's occupancy was during the nesting season, April through August. The mite infestation at the park was one third greater than at the house for this species.

In Table 5 House Finch and White-crowned Sparrow data, which represented 91.4% of all mite infestations and 69% of all birds examined, are separated from those of the remaining species. The House Finch showed little difference between habitats; the frequency of mite infestations at the house and park were 66% and 60% respectively. Of the finches supporting evident mite populations, mite density peaked in March and September (Table 5). Fewest mites were seen in December, January, and May. Monthly infestation of the White-crowned Sparrow ranged from 21.5% in October to 58.2% in April with an 8 mo average of 40.5% (Table 5).

Infestation among the remaining 23 species of permanent residents (Table 5) ranged from 4.1% in August to 21.1% in February with a yearly average of 10.2%. Infestation of the 10 winter species ranged from 5.9% in November to 45.6% in April with an annual average of 18.1%.

TABLE 1. Extended.

1982	1983	1984	1985	1986	1987	Total
5/11	11/28	2/15	3/5	4/7	5/9	37/139
1/1	—	0/1	—	0/1	2/4	3/11
—	1/1	5/5	—	—	—	6/6
—	—	—	1/1	1/1	—	2/2
600/963	540/788	320/1113	410/939	145/317	76/394	3282/7855
2/2	0/4	0/12	3/7	—	—	6/31
11/22	9/10	1/21	4/13	2/7	0/6	55/144
—	—	—	—	—	0/1	5/13
2/2	—	—	—	—	—	5/5
3/56	10/121	5/139	4/151	10/112	5/93	46/1147
0/3	—	—	—	—	—	5/36
1/12	1/12	1/114	0/36	0/5	0/2	10/212
1333/1810	1428/1697	1450/2208	1209/1950	1222/1794	1344/2194	12,156/18,355
47/647	123/573	36/471	82/617	36/307	26/311	407/5752
45	43	46	46	45	38	488
2005/3529	2133/3234	1820/4099	1716/3719	1420/2551	1458/3014	16,026/33,709
56.8	65.6	44.4	46.1	55.7	48.4	47.5

Summer resident infestations ranged somewhere between these two groups: 12.3% in August to 28.6% in June with an annual average of 22.6%.

Table 6 reports the density (rated as none, few, medium, or many) of mites on House Finches by month for the 11 yr of the study. The difference between "medium" and "many" densities could have been affected by the diurnal activity of the mites so these categories were combined for clarity. The peaks for mite density were in March, August, September, and October.

To explore further the density of mites on individual House Finches, the results from repeatedly recapturing 346 birds are given in Table 7. The longest period between recaptures in this group was 240 d and the shortest was 1 week. There is no correlation between number of captures and time.

Fifty-seven percent of finches that had no mites when first captured had no mites on subsequent recaptures (Table 7) and only 4% had developed heavy (many) infestations. Finches with heavy infestations when first captured remained heavy at subsequent recaptures (51.7%) and lost their flight feather populations in only 10% of the recaptures. Finches with few or medium infestations fell between the extremes. The similarity in time lapse between captures (around 50 d) is such that time did not appear to be an important environmental factor. The average number of days between captures was a function of each bird's health and activity, not an element in the life cycle of the mites.

At irregular intervals samples of the mites were collected and sent to Dr. Atyeo for identification. *Proctophyllodes pinnatus* was the most abundant mite found on House Finches. *P. polyxenes* was found on White-

TABLE 2. The monthly distribution of feather mite infestations among 24 species of permanent resident birds in the Camarillo, California study area, based upon 368 d of observations from October 1977 to July 1987. Figures indicate the number of positive individuals/the number examined. P—park; H—house (see text).

	Area	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Species present at both locations								
Scrub Jay	H	1/1	2/5	1/3	0/6	1/8	0/5	0/13
	P	0/11	1/9	1/11	0/8	2/18	3/19	2/22
Northern Mockingbird	H	0/1	1/1	—	—	0/3	—	0/1
	P	1/11	2/13	3/17	1/8	1/10	1/19	0/10
Brown Towhee	H	0/5	2/5	5/7	8/12	8/11	13/27	5/17
	P	15/35	14/23	15/36	18/27	18/58	43/125	43/209
Brewer's Blackbird	H	2/16	0/3	3/23	5/35	8/72	6/175	6/344
	P	0/3	2/10	0/11	3/42	1/66	9/90	2/28
Brown-headed Cowbird	H	1/13	0/4	0/8	3/22	5/28	1/7	0/21
	P	—	—	—	1/6	1/2	0/2	—
House Finch	H	1166/2165	1595/2478	1885/2425	1166/1607	905/1520	1226/1812	1054/1658
	P	57/95	55/105	53/67	33/40	107/201	360/537	188/324
Percent infested	H	53.2	64.1	76.9	70.7	56.4	61.5	25.0
	P	46.5	46.3	50.7	42.7	36.6	52.5	39.6

TABLE 2. Continued.

	Area	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
Species captured in one location only								
House Sparrow	H	23/200	14/92	6/72	8/58	6/301	16/774	16/1133
California Quail	P	1/9	0/8	1/2	0/1	0/2	—	0/5
Acorn Woodpecker	P	1/1	0/1	0/2	1/1	1/4	—	0/4
Nuttall's Woodpecker	P	1/2	1/3	2/3	1/1	3/7	3/5	2/5
Plain Titmouse	P	—	0/2	1/1	—	1/2	0/2	1/6
House Wren	P	—	0/2	—	—	—	—	0/1
Wren Tit	P	1/9	0/4	—	0/3	0/6	1/16	1/27
California Thrasher	P	0/4	0/4	0/2	0/3	1/12	0/5	1/11
Loggerhead Shrike	P	—	—	—	—	0/1	0/1	1/6
European Starling	P	0/7	0/5	1/9	3/16	2/20	5/23	0/2
Orange-crowned Warbler	P	1/7	0/2	1/2	0/1	—	0/1	—
Western Tanager	P	—	—	—	0/1	—	—	0/1
Rufous-sided Towhee	P	8/43	4/16	6/12	6/11	8/19	7/42	17/96
Rufous-crowned Sparrow	P	2/3	0/2	0/1	0/4	0/8	1/24	0/15
Savannah Sparrow	P	2/2	—	0/1	8/10	—	—	0/2
Song Sparrow	P	2/8	4/11	2/19	1/26	2/46	3/38	0/19
Lincoln's Sparrow	P	1/8	0/5	2/9	0/11	0/2	0/3	0/5
Lesser Goldfinch	P	0/3	1/6	—	1/4	3/41	1/35	0/12
Percent infested		14.1	14.7	16.3	19.7	5.7	3.8	2.9

TABLE 2. Continued.

	Area	Aug.	Sep.	Oct.	Nov.	Dec.	Total	% Infested
Scrub Jay	H	9/21	15/55	8/7	1/3	0/1	34/138	27.5
	P	2/18	2/21	1/7	0/11	0/18	14/173	8.1
Northern Mockingbird	H	—	—	2/3	—	—	3/10	30.0
	P	0/15	3/16	5/17	0/16	0/18	17/170	10.0
Brown Towhee	H	11/35	0/11	2/5	1/5	0/3	55/143	38.5
	P	18/135	34/120	8/31	7/26	8/18	241/843	28.6
Brewer's Blackbird	H	1/239	5/109	5/62	2/40	5/30	45/1148	3.9
	P	1/25	1/24	0/15	0/4	0/1	19/319	5.9
Brown-headed Cowbird	H	0/5	—	—	0/2	0/102	10/212	4.7
	P	0/1	—	—	—	—	2/11	18.2
House Finch	H	656/868	722/917	536/755	460/736	785/1421	12,159/18,362	66.2
	P	161/280	163/247	86/140	51/122	32/80	1346/2238	60.1
Percent infested	H	58.0	67.9	66.2	59.0	50.7	61.5	
	P	38.4	47.4	47.6	32.4	29.6	43.7	

TABLE 2. Continued.

	Area	Aug.	Sep.	Oct.	Nov.	Dec.	Total	% Infested
House Sparrow	H	14/1338	53/770	82/415	69/297	87/286	393/5736	6.9
California Quail	P	0/5	0/1	0/1	0/4	0/2	2/40	5.0
Acorn Woodpecker	P	1/6	0/5	1/3	0/1	0/2	4/30	13.3
Nuttall's Woodpecker	P	3/2	1/3	2/4	0/3	—	18/38	47.4
Plain Titmouse	P	2/2	0/2	0/1	—	0/4	6/22	27.3
House Wren	P	0/12	0/17	0/7	1/5	0/4	1/51	1.9
Wren Tit	P	0/16	0/38	2/26	0/19	0/17	5/181	2.8
California Thrasher	P	1/9	1/12	0/5	0/1	0/7	4/75	5.3
Loggerhead Shrike	P	0/1	2/5	0/1	1/1	1/1	5/17	29.4
European Starling	P	0/3	4/9	0/6	1/4	0/1	16/105	15.2
Orange-crowned Warbler	P	0/2	0/8	0/4	0/3	0/1	2/31	6.9
Western Tanager	P	0/1	0/5	—	1/1	—	1/9	11.1
Rufous-sided Towhee	P	16/70	27/72	15/51	10/48	2/26	126/506	24.9
Rufous-crowned Sparrow	P	0/18	0/9	0/12	1/8	1/2	5/106	4.7
Savannah Sparrow	P	1/6	0/4	1/1	1/5	—	13/21	41.9
Song Sparrow	P	3/43	0/22	4/20	0/2	1/6	22/260	8.5
Lincoln's Sparrow	P	0/1	0/4	0/9	0/5	0/5	3/67	4.5
Lesser Goldfinch	P	1/4	6/19	0/4	2/15	1/8	16/151	10.6
Percent infested		2.7	9.5	18.7	20.4	28.7	8.6	

TABLE 3. The monthly distribution of feather mite infestations among nine summer resident birds examined at the park between 1977 and 1987. Figures indicate number of birds infested/number examined.

Species	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Total	% Infested
Western Flycatcher	0/2	0/3	0/9	1/1	—	0/5	0/15	0/4	1/39	2.6
Ash-throated Flycatcher	—	1/3	1/5	1/4	—	0/2	—	—	3/14	21.4
Black-headed Grosbeak	—	0/2	0/4	1/4	1/13	0/11	—	—	2/34	5.9
Blue Grosbeak	—	—	0/1	0/1	0/2	1/1	—	—	1/5	20.0
Lazuli Bunting	—	0/6	3/16	1/13	0/11	0/1	0/1	—	4/48	8.3
Lark Sparrow	6/9	6/7	12/16	14/26	19/40	7/40	4/16	—	68/154	44.2
Red-winged Blackbird	0/10	2/14	3/10	0/2	—	—	—	—	5/36	13.9
Northern Oriole	—	5/21	2/26	0/16	0/16	0/5	—	—	7/84	8.3
American Goldfinch	—	—	—	2/3	2/3	—	—	—	4/6	66.7
Total	6/21	14/56	21/87	20/70	22/85	8/65	4/32	0/4	95/420	22.6
Percent infested	28.5	25.0	24.1	28.6	25.9	12.3	12.5	0.0	22.6	

crowned Sparrows, Brown Towhees, Rufous-sided Towhees, Hermit Thrushes and Lark Sparrows. *P. occidentalis* occurred on Scrub Jays, *P. eggleston* on Brewer's Blackbirds, and *P. hylociclae* on Hermit Thrushes.

DISCUSSION

The opportunity to analyze the relationship between 47 species of birds and their mite infestations over 11 yr and two habitats led me to a closer analysis of Dubinin's (1951, 1953, 1956) findings. The stresses of host migration appear to affect the mite riders. Dubinin (1951, 1953, 1956) noted that in preparation for fall migration of some hosts, some species of feather mites decreased sexual activity, reduced egg laying, and entered diapause, all of which lowered the indigenous populations. Such physiological changes in the host as deposition of fat in the tissues and hormonal changes involved in molt could alert the mites to impending migration.

In the present study 10 of the winter residents listed were migrants arriving in October or later and about 20% of the birds were infested. Once these birds took up residence in the mild climate here, their mite population rose steadily to a peak in March or April as they were preparing to leave for northern habitats (Table 5). These observations were the reverse of those reported by Dubinin for western Russian migrants. It remains for someone in Canada to trap species from southern California to learn if the rigors of migration reduce the mite population by the time the birds reach their destinations.

At the house the White-crowned Sparrow and House Finch are contemporary during winter months. Mite infestations of House Finches

TABLE 4. The monthly distribution of feather mite infestations among eleven winter resident birds examined from 1977 through 1987. Figures indicate number of birds infested/number of birds examined. P—park; H—house (see text).

	Area	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total	% Infested
Species present at park and house												
Golden-crowned Sparrow	H	—	1/2	0/7	1/7	0/3	0/5	2/4	2/3	—	6/31	19.4
	P	0/1	6/29	7/35	15/66	22/117	33/111	27/75	16/26	—	126/460	27.4
White-crowned Sparrow	H	2/5	81/350	256/860	546/1444	472/1515	650/1432	924/1656	359/604	0/2	3290/7875	41.8
	P	1/2	10/67	25/115	50/169	84/300	92/304	76/152	40/82	—	378/1191	31.8
Percent infested	H	40.0	23.3	29.5	37.7	31.1	45.2	55.8	59.5	—	41.7	
	P	33.3	16.7	21.3	27.7	25.4	30.1	45.4	51.8	—	30.5	
Species captured in one location only												
Swainson's Thrush	P	—	0/5	—	—	—	—	—	0/1	1/8	1/14	7.1
Hermit Thrush	P	0/3	4/28	2/17	0/34	8/54	11/41	14/40	5/19	4/14	48/360	13.3
American Robin	P	—	0/1	—	0/1	0/4	1/1	1/2	2/6	2/4	6/19	31.6
Cedar Waxwing	P	—	—	0/8	—	6/8	6/11	19/25	3/3	—	35/56	62.5
Yellow-rumped Warbler	P	—	1/156	5/180	2/71	5/60	5/68	7/51	6/16	0/1	31/603	5.1
Chipping Sparrow	P	—	0/2	0/1	0/1	5/10	0/1	1/1	—	—	6/16	37.5
Fox Sparrow	P	—	1/4	1/2	2/4	—	1/2	1/4	—	—	6/16	37.5
White-throated Sparrow	P	—	—	—	—	—	1/2	1/1	1/1	—	3/4	75.0
Dark-eyed Junco	P	—	1/15	12/135	32/210	28/131	37/119	24/68	12/28	0/1	146/707	20.7
Percent infested		—	3.3	5.8	11.2	19.5	25.3	35.4	39.2	25.0	15.7	

TABLE 5. Summary of the occurrence of feather mite infestations in the Camarillo study areas, based on 11 yr of observations.

Month	23 Resident species		House Finch		9 Summer species		10 Winter species		White-crowned Sparrow		Total number	Percent based on numbers	Average percent infested[1]
	Numbers	% Infested	Numbers	% Infested	Numbers	% Infested	Numbers	% Infested	Numbers	% Infested			
Jan.	63/402	15.4	1223/2260	54.1	—	—	74/387	19.1	556/1815	30.6	1916/4864	39.4	29.8
Feb.	50/236	21.1	1656/2583	63.9	—	—	95/307	30.9	742/1737	42.7	2543/4863	52.3	39.7
Mar.	50/251	19.9	1941/2492	77.9	6/21	28.5	97/271	35.9	1000/1808	55.3	3094/4843	63.9	43.5
Apr.	67/341	19.6	1189/1647	72.8	14/56	25.0	47/103	45.6	399/686	58.2	1716/2833	60.6	44.2
May	72/741	9.7	1012/1721	58.8	21/87	24.1	5/25	20.0	—	—	1110/2574	43.1	27.5
Jun.	113/1438	7.8	1586/2349	67.5	20/70	28.6	—	—	—	—	1719/3857	44.6	34.4
Jul.	98/1987	4.9	1242/1982	62.7	22/85	25.9	—	—	—	—	1362/4054	33.6	31.2
Aug.	84/2033	4.1	817/1148	71.2	8/65	12.3	—	—	—	—	909/3246	28.0	29.2
Sep.	154/1361	11.3	885/1164	76.0	4/32	12.5	0/4	0.0	3/7	42.8	1046/2568	40.7	35.6
Oct.	138/727	19.0	622/895	69.5	0/4	0.0	50/282	17.7	91/424	21.5	901/2332	38.6	31.9
Nov.	98/529	18.5	511/858	59.5	—	—	27/455	5.9	281/975	28.8	917/2547	36.0	28.2
Dec.	106/562	18.9	817/1561	54.4	—	—	52/394	13.2	596/1613	36.9	1571/4130	38.0	30.9
Total	1086/10,612		13,555/20,600		95/420		414/2286		3668/9066		18,818/42,984	43.8	
% Infestation while hosts were present		10.2		65.7		22.6		18.1		40.5			31.4

[1] Based upon the percentage in each category (i.e., 15.4 + 54.1 + 19.1 + 30.6 ÷ 4 = 29.8).

TABLE 6. Mite density at the house by month as seen on House Finches at Camarillo, California over the period 1977–1987.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Totals
Number birds examined	2165	2478	2425	1607	1520	1812	1658	868	917	755	736	1421	18,362
Number with no evident mites	999	883	537	441	615	586	604	212	195	219	276	636	6203
Number with few infestations	927	1222	1237	860	794	1014	798	426	446	372	335	608	9039
Number with abundant (medium plus many infestations)	239	373	651	306	111	212	256	230	276	164	125	177	3120
% abundant infestations	20.5	23.4	34.5	26.2	12.3	17.3	24.3	35.1	38.2	30.6	27.2	22.5	25.7
% birds with abundant infestations	11.0	15.0	26.8	19.0	7.3	11.7	15.4	26.5	30.4	21.7	17.0	12.5	17.0

TABLE 7. The changes in feather mite populations on 346 House Finches and the time intervals involved.

Number of birds	Mite populations	Average interval between captures in days	Interval range in days
73	None to none	57	7/209
40	None to few	53	7/200
10	None to medium	64	11/189
5	None to many	39	7/56
28	Few to none	72	7/223
54	Few to few	38	7/180
16	Few to medium	38	7/125
14	Few to many	69	7/240
5	Medium to none	78	28/154
14	Medium to few	35	7/84
13	Medium to medium	34	7/196
16	Medium to many	33	7/154
6	Many to none	37	7/112
15	Many to few	63	7/213
7	Many to medium	39	7/127
30	Many to many	40	7/222
Summary			
346	Any infestation	50	7/240

were bimodal both in frequency of infestations (Fig. 1) and density of populations (Fig. 1). The mite population on White-crowned Sparrows might be bimodal as well, but the September figure was based on only four birds while the whole figure as well as that of the distribution of abundant populations is based upon infestation among more than 4000 birds.

Figure 2 compares the mite populations on House Finches in the park with those of the remaining 44 species. Here too the House Finch mite populations are bimodal whereas the bulk of infestations was few among other species, with a small peak in April.

The northward migration of South American birds reaches Ventura County which lies just far enough south (~34°N). The South American element was sparse in numbers. Less than 1000 individuals of nine species were examined during the 11 yr of the study. All were taken at the park and only the Lark Sparrow in some numbers. Although Garrett and Dunn (1981) indicate that in other parts of southern California the Lark Sparrow is a permanent resident with greatest numbers in the winter, they were trapped only during the summer in Ventura County. They had the highest rate of mite infestation among the summer residents, and May, June, and July were peak months of infestations.

Dubinin (1951, 1953, 1956) noted a correlation between mite movements and humidity. An increase in relative humidity led to a reduction in the concentration of mites on the wing as they transferred to feathers

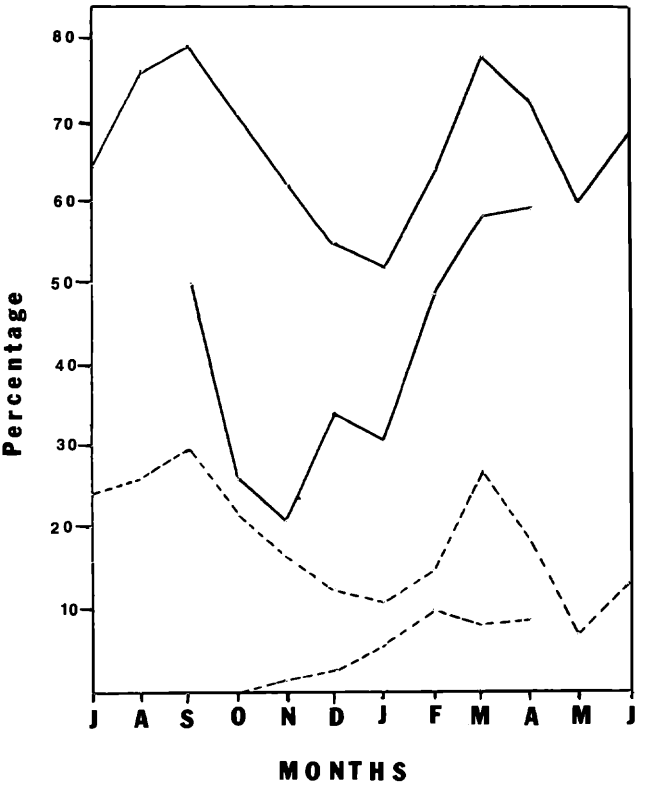

FIGURE 1. Seasonal variation in the percentage of birds infested with feather mites at the house. Solid line: Percentage of birds with any visible mites. Upper: House Finch. Lower: White-crowned Sparrow. Dashed line: Percentage of birds with heavy infestations of mites. Upper: House Finch. Lower: White-crowned Sparrow.

on, or closer to, the body. At Camarillo, a reverse of this pattern was seen. When the humidity dropped rapidly because of dry east winds blowing from the deserts or from wide spread brush fires (McClure, 1981) the mite population declined rapidly. In southern California, August through October, and, occasionally, early November, are the months in which these sudden changes in humidity occur most often. Low mite infestations correlated to these months (Tables 2, 3, 4). Possibly the mites may not have died, but moved to body sites where the humidity was higher during these climatic changes, but the return to normal numbers was slow, indicating actual mortality.

Because the wing of a small passerine in flight is almost undifferentiated for its entire length (Dubinin 1951), feather action upon the mite population may be almost homogeneous. Normally the mites are more abundant on the proximal half of secondary feathers and at the basal quarter

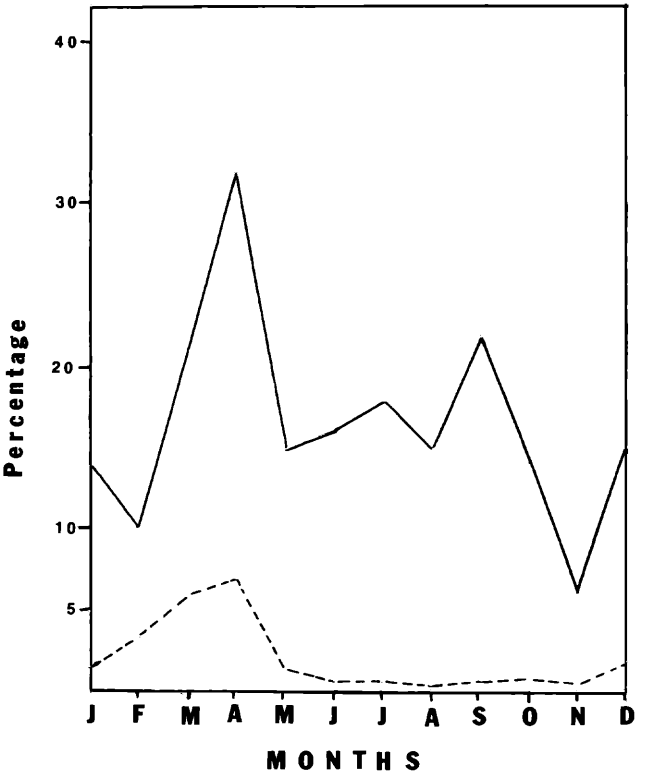

FIGURE 2. Monthly distribution of abundant infestations on House Finches and other species of hosts at the park. Solid line: Infestations on House Finches. Dashed line: Infestations on other species.

of the primaries. With peak invasion of these feathers, dense numbers of mites will extend distally almost to the terminus of each rachis. Even if such a feather load is lost by molt, it is not critical to the abundance of the parasites. The density relates to the time of day, temperature, humidity, and the activity of the host instead. The advent of a cloudy weather pattern brought movement onto the vanes while a day with hot wind caused them to cluster more closely to the rachis.

Post-juvenile and post-nuptial molt in the hosts are other stressful events for the mites. In many species molt is in progress or completed just prior to migration, either spring or fall. That of late summer is accompanied by increasing mite populations which peak in September. Dubinin suggests that the mites can quickly evacuate a feather about to fall as they have been alerted by movements abnormal to the usual flex in flying. This was observed repeatedly in House Finches in the present study. I found that primaries were deserted and secondaries occupied before the primary dropped, as well as the reverse.

Dubinin found that the mites on the flight feathers of the European Starling when subjected to cold (the birds were held in ice houses) retreated to body feathers. When returned to warmer temperature, the mites returned to their wing niches. Temperatures in the Camarillo area did not get low enough to produce this effect nor did the summer temperatures (usually around 35 C) reach significant heights.

Finally, circadian rhythms governing the mite population movements were not closely examined because of difficulties in housing wild species and examining them closely without upsetting the acarine activities and introducing other contributory variations. In September 1988, a situation arose in which birds trapped at sundown during peak mite population densities were held quietly until almost dark. During these few minutes there was a crepuscular rush from the protection of the rachis out onto the vanes. Birds captured earlier in the day and listed as having a few mites, recaptured at this crepuscular flush, were suddenly populated with at least a medium infestation. This evening emigration was noted on 40 House Finches caught at dusk over 6 weeks. No study was made to determine the parasite positions and numbers on the sleeping host during the night, nor when they retired to the rachis, presumably at dawn. The alacrity with which they changed numbers and position on the wing suggested that alternative explanations for reactions to humidity, time of year, temperature, etc. be considered.

CONCLUSION

Although many aspects of their bio-economics remain to be explored, the populations of proctophyllodid mites on birds form a complex ecosystem with many niches available and occupied. The presence and numbers of any species of mite on any species of bird are the result of a complex of host diurnal activity, feather structure, physiology, health, flight, and feeding habits. These are further complicated by the mite species present and its physiology, life stages, feeding habits, circadian rhythms, which are, in turn, affected by external temperatures, humidity, air movement, and light intensity.

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