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DO INFECTIONS LEAD TO HIGHER FEATHER MITE LOADS IN BIRDS? A TEST WITH MYCOPLASMAL CONJUNCTIVITIS IN HOUSE FINCHES (*HAEMORHOUS MEXICANUS*)

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Abstract.—Current evidence suggests that the health effect of avian feather mites is minimal. However, feather mites can still proliferate without effective preening, such as might occur during sickness. House Finches (*Haemorhous mexicanus*) are prone to infection by *Mycoplasma gallisepticum*, symptoms of which include conjunctivitis. Impaired vision and lethargy associated with the disease may limit preening ability. We examined trapping data from a 4-year study of *Mycoplasma* infection dynamics in House Finches in Atlanta, Georgia, to determine whether birds with conjunctivitis had higher feather mite loads. Abundance of feather mites (*Proctophyllodes* spp.) and conjunctivitis severity were visually scored on >800 House Finches of known age and sex. Feather mite abundance showed a distinct seasonal pattern: mite loads increased in July and remained high through January. Limiting the analyses to these months, we found that average mite scores were higher in birds with (n = 94) than in those without (n = 275) conjunctivitis, and mite loads increased with conjunctivitis severity. Although not significant, the mite scores in recaptured birds in relation to infection status support the other findings in the present study. Although these results from field-collected birds do not demonstrate cause and effect, they are consistent with prior studies in which feather mites increased in experimentally infected birds. The implications of this proliferation for the birds require further study, but given that feather mites consume oil and debris from feathers, their high numbers during illness could be beneficial. *Received 27 March 2013, accepted 13 September 2013.*

Key words: conjunctivitis, feather mites, *Haemorhous mexicanus*, House Finch, *Mycoplasma gallisepticum*, *Proctophyllodes* spp.

¿Conducen las Infecciones a una Carga Mayor de Ácaros en las Plumas de Aves? Una Evaluación Basada en Conjuntivitis por Micoplasma en *Haemorhous mexicanus*

Resumen.—Evidencia reciente sugiere que tener ácaros en las plumas tiene un efecto mínimo en la salud de las aves. Sin embargo, los ácaros de las plumas pueden proliferar en ausencia de un acicalamiento adecuado, como puede ocurrir durante la enfermedad. Los individuos de la especie *Haemorhous mexicanus* son susceptibles a infección por Mycoplasma gallisepticum, cuyos síntomas incluyen conjuntivitis. La visión disminuida y el letargo asociados con la enfermedad podrían limitar la habilidad de las aves para acicalarse. Examinamos datos de trampeo de un estudio de cuatro años sobre la dinámica de la infección por *Mycoplasma* en *H. mexicanus* en Atlanta, Georgia, para determinar si las aves con conjuntivitis presentaban cargas mayores de ácaros. La abundancia de ácaros en las plumas (*Proctophyllodes* spp.) y la severidad de la conjuntivitis fueron estimadas visualmente en más de 800 individuos de edad y sexo conocidos. La abundancia de ácaros mostró una clara tendencia estacional: la carga se incrementó en julio y se mantuvo alta hasta enero. Limitando los análisis a estos meses, encontramos que la carga promedio de ácaros fue mayor en aves con conjuntivitis (n = 94) que en aves sin conjuntivitis (n = 275), y también se incrementó con la severidad de la infección. Aunque no fue un patrón significativo, la carga de ácaros en aves recapturadas en relación con el estado de la infección sustenta los demás resultados del presente estudio. Aunque estos resultados obtenidos en campo no demuestran causa y efecto, concuerdan con estudios previos en los que las cargas de ácaros se incrementaron en aves infectadas experimentalmente. Las implicaciones de esta proliferación para las aves requiere de estudio, pero dado que los ácaros consumen aceites y residuos de las plumas, el incremento de sus números durante la enfermedad podría ser benéfico.

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Birds are host to a wide variety of ectoparasites, including feather mites, which are microscopic arthropods that feed on feather fragments, lipids, feather fungi, algae, and uropygial oil. Whether these organisms are actually parasites has often been debated in ornithological circles, no doubt because multiple contrasting studies have shown positive, negative, or no overall effects on health, survival, or other measures of fitness (e.g., Thompson et al. 1997, Blanco et al. 1999, Figuerola et al. 2003, Pap et al. 2005, Brown et al. 2006). Work with House Finches (*Haemorhous mexicanus*) has shown that feather mites are most abundant in larger birds with high fat stores (Hartup et al. 2004), suggesting a positive effect; other work with House Finches has suggested negative effects on plumage brightness (Thompson et al. 1997). A more recent analysis of data from >20,000 birds of 83 species showed that feather mites have no measurable effect on host body condition (Galván et al. 2012). Further adding to this discussion is recent evidence that variation in feather mite loads can be attributed to temporal variation in uropygial gland output (Haribal et al. 2011) and in uropygial gland size (Galván and Sanz 2006, Galván et al. 2008).

Regardless of their effect on the host, feather mites can increase without effective preening. Repeated observations by McClure (1989) of marked House Finches at a backyard feeding station showed that individuals became "infested" with feather mites when they could not preen effectively because of deformed bills. Similarly, in birds with natural or experimentally induced beak deformities, feather mites (and other ectoparasites) are higher than normal (Clayton 1991, Blanco et al. 1997, Clayton et al. 2005, Handel et al. 2010).

An important, but overlooked, contribution to the ongoing discussion of feather mites was from a California study of House Finches that showed how birds with avian pox infections (characterized by visible wart-like nodules on the legs, beak, or head region) were more likely to have feather mites and that the severity of pox infection was correlated with the abundance of mites (Thompson et al. 1997). The possible interpretations are that (1) poxvirus infections reduced the preening activity of the birds or (2) birds that had high feather mite loads were also more likely to become infected by pathogens. To our knowledge, no other studies have examined the concordance between feather mite abundance and a naturally occurring disease in birds.

Eastern House Finches are prone to another disease that can be even more debilitating than avian pox. Since the mid-1990s, the bacterial pathogen *Mycoplasma gallisepticum* has spread through the entire eastern range of the House Finch (Dhondt et al. 2005) and is now spreading into the western range (Ley et al. 2006). Infected birds typically develop mild to severe unilateral or bilateral conjunctivitis (Fig. 1). In the wild, birds with conjunctivitis experience reduced survival (Faustino et al. 2004). Infections also cause a range of sublethal effects, including elevated stress-induced corticosterone concentrations (Lindström et al. 2005), immune-cell redistribution (Davis et al. 2004), reductions in male plumage brightness (Hill et al. 2004), reduced nestling growth (Nolan et al. 2004), and, finally, reduced activity (lethargy) at bird feeders (Hotchkiss et al. 2005, Hawley et al. 2007) and under experimental conditions (Darbro et al. 2007). The lethargy associated with *Mycoplasma* infections has implications for the dynamics of feather mites living on House Finches. It is possible that infected birds would not preen effectively and, therefore, might show higher mite loads, similar to those seen with pox infections in western House Finches. This idea seems likely, given that reduced grooming behavior results from illness in most taxonomic groups (reviewed in Hart 1988).

Fig. 1. Juvenile House Finch with conjunctivitis caused by infection with *Mycoplasma gallisepticum*. (Photo taken by A.K.D. in Athens, Georgia, on 31 July 2012.).

We examined a 4-year data set of House Finch captures from a prior field study of *Mycoplasma* dynamics in Atlanta, Georgia (Altizer et al. 2004a), to test the hypothesis that infections lead to higher feather mite abundance. Prevalence of *Mycoplasma* is typically high in the southeastern United States (Altizer et al. 2004b) and undergoes a seasonal pattern of peaks in the fall and late winter. In the Atlanta study, House Finches were captured on a weekly basis in all months of the year and visually screened for conjunctivitis as well as feather mites. Because *Mycoplasma* infections were frequent in this population (Altizer et al. 2004a), this afforded us large sample sizes of diseased and nondiseased birds to use in statistical comparisons. We compared feather mite scores of House Finches with and without *Mycoplasma* infections (while accounting for possible age, sex, and size effects), and across varying levels of *Mycoplasma* severity. Our expectations were that average feather mite loads would be higher in House Finches with conjunctivitis than in those without, and that mite loads would be highest in individuals with the most severe infections. The results should prove useful in the ongoing discussion regarding the causes and consequences of feather mites in birds.

Methods

Capture of birds.—House Finches in the Atlanta study were trapped 2–3 days $week^{-1}$ (typically in the morning) at three backyard feeding stations in all months of the year between August 2001 and July 2005, using mist nets or cage traps (Davis 2005; locations were alternated on successive days). For further details of the trapping sites, see Altizer et al. (2004a) and Davis et al. (2004). Each bird was designated either after-hatch-year (AHY) or hatch-year (HY) on the basis of plumage characteristics, molt pattern, or time of year (i.e., all birds captured from January through April were classified as AHY), and sex, if possible, using plumage color (Pyle 1997). Birds were weighed to the nearest 0.1 g using a portable electronic balance, and the right tarsus length (an index of body size) was measured using digital calipers. The eyes were visually examined for conjunctivitis (see Fig. 1). Conjunctivitis severity was scored using a 4-point scale, where 0 represented no visible reddening or discharge, 1 represented a mild swelling, 2 represented moderate swelling and discharge (but the eye was not swollen shut), and 3 indicated that the eye was swollen shut (Altizer et al. 2004a, Sydenstricker et al. 2006, Davis 2010). Prior work has shown a strong correspondence (i.e., 90–100%) between infection with *M. gallisepticum* and the presence of conjunctivitis (Luttrell et al. 1998, Sydenstricker et al. 2006).

Finally, the wings of each bird were examined for the presence of feather mites (Fig. 2) by inspecting the outstretched wing against a lighted background and noting the number of primary and secondary flight feathers with mites as well as the number of mites per feather. Mites were not individually counted. Instead, mite loads were subjectively scored on a 4-point scale, where 0 represented no visible mites, 1 indicated that between 1 and 10 mites were visible and one or two feathers were affected, 2 meant that between 11 and 100 mites were present across 3–6 feathers, and 3 meant that nearly all feathers had heavy mite loads (hundreds per feather). This scoring system was similar to that used by McClure (1989) and Thompson et al. (1997), which was a scale of 0–4. We did not attempt to identify the species of feather mite in the Atlanta finches, although from microscopic examination it appeared to be in the *Proctophyllodes* genus (Atyeo and Braasch 1966). Studies of other eastern House Finch populations have also confirmed that they primarily harbor this mite genus (Hartup et al. 2004, Haribal et al. 2011).

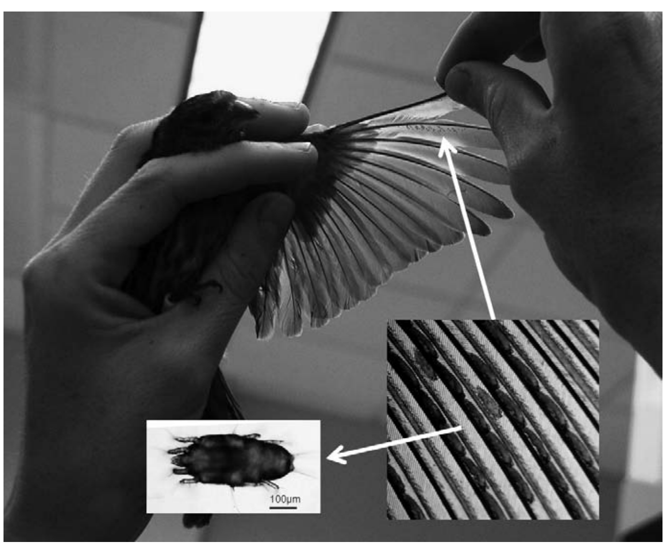

Fig. 2. Procedure for assessing feather mite abundance on House Finches. The outstretched wing was held against a lighted background, which allowed mites, if present, to be seen and scored. Mite abundance was subjectively scored on a scale of 0–3 (see text). Inset photographs show mites as seen under a dissecting microscope (presumed to be *Proctophyllodes* spp.).

Data analysis.—Feather mite loads of House Finches in this population showed a distinct seasonal pattern in which mite loads tended to be low from February through June (see below). Therefore, we confined all of our analyses below to the months when mites were abundant (July–January). We also limited all but one set of analyses (paired *t*-tests; see below) to initial captures only (i.e., no recaptures) of birds of known age and sex. We first looked for evidence that mites affect individual health by examining the relationship between mite presence (i.e., as a binomial variable) and body mass using a general linear model. Here, body mass was the response variable, while mites (present or not present), age, and sex were predictors, and tarsus length was a covariate. We included two-way interactions of age*mites and sex*mites in this model.

We used Poisson regression to explore the possible association of mite loads (scores) with age, sex, and conjunctivitis (as a dichotomous variable, yes or no), with tarsus length included as a covariate to account for possible size-based variation in mite loads (Rózsa 1997). Mite score was treated as a discrete variable and used as the dependent variable. We also included all two-way interactions (between categorical predictors) in the initial models, but they were removed if nonsignificant. To evaluate whether mite load was associated with increased severity of conjunctivitis, we used the sum of the left and right eye scores as an index of conjunctivitis severity (Sydenstricker et al. 2006). Summed eye scores varied from 0 to 6, but to ensure adequate sample sizes, we pooled birds with scores ≥3 to produce a single group of individuals that held the most severe cases. We used analysis of variance to compare mite scores of birds in these four categories of conjunctivitis severity.

As a final test, we compared individuals that were captured twice within the mite season (July–January) and that had changed conjunctivitis status between captures; 23 conjunctivitis-free birds had conjunctivitis upon recapture, whereas 10 others that were initially captured with conjunctivitis recovered. We used paired *t*-tests to compare mite scores at first capture to those at second capture for both scenarios. All tests were performed using the STATISTICA, version 6.1, software package (StatSoft, Tulsa, Oklahoma). Results are presented as means ± SD.

Results

Over the 4 years, a total of 1,615 individual House Finches were captured in Atlanta, along with 285 recaptures (1,900 total captures). Of these, there were 881 birds of known age and sex (Table 1). There was a distinct seasonal pattern to the mite loads: using all 1,900 records, a plot of average mite scores per month showed that mite loads increased in July and remained high through January (Fig. 3). Mite scores were generally low from February to June.

Table 1. Number of House Finches captured per month in all age–sex categories (using records from only known age–sex birds and no recaptures; AHY = after-hatch-year, HY = hatch-year, M = male, F = female) in Atlanta, Georgia. Trapping was initiated in August 2001 and continued through July 2005.

Month	AHY–M	AHY–F	HY–M	HY–F	Total
January	54	39	0	0	93
February	45	36	0	0	81
March	44	37	0	0	81
April	39	21	1	0	61
May	28	11	11	1	51
June	11	3	16	1	31
July	2	12	16	4	34
August	12	11	39	10	72
September	23	29	32	59	143
October	37	16	26	41	120
November	16	6	24	22	68
December	1	10	15	20	46
Total	312	231	180	158	881

House Finch body mass was independent of the presence of mites, the other two main effects (sex and age, $P > 0.05$ for all three), and both interaction terms ($P > 0.05$ for both terms). Body mass increased with tarsus length ($F = 43.21$, df = 1 and 556, $P < 0.0001$), as expected.

Poisson regression of mite scores yielded no support for inclusion of the sex*conjunctivitis or age*conjunctivitis interaction terms in the initial model ($P > 0.05$ for both). In the final model, there was no effect of sex on feather mite scores (Table 2), but a significant effect of age; mite scores were higher in HY (1.44 ± 0.93, n = 338) than in AHY birds (1.06 ± 0.81, n = 543; Fig. 4). The interaction effect of age*sex was not significant (Table 2). There was a significant effect of conjunctivitis (Table 2), with infected birds having higher mean feather mite scores (1.68 ± 0.84, n = 94) than those without

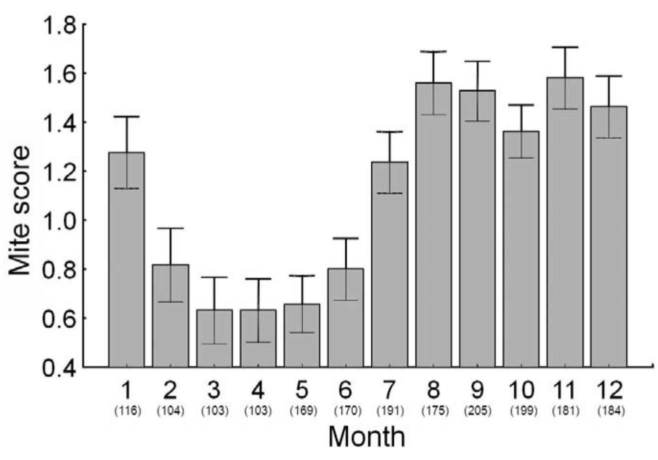

Fig. 3. Monthly prevalence of feather mite abundance (average mite score) on House Finches in Atlanta, Georgia, sampled from August 2001 through July 2005. Numbers in parentheses indicate sample sizes per month (note that this graph includes all initial and subsequent recaptures). Error bars represent 95% confidence intervals. January is represented by "1" and December by "12."

Table 2. Summary of a Poisson regression model that examined factors affecting feather mite scores (dependent variable) in the Atlanta House Finch population sampled between 2001 and 2005 (using only birds of known age and sex, and only dates within the period of mite abundance, July–January). Conjunctivitis was included as a binomial predictor (present or absent) in this model.

Predictor	df	Log-likelihood	Wald	χ^2	P
Age	1	–1,125.79	19.04	24.40	0.0000
Sex	1	–1,125.73	0.10	0.11	0.7361
Conjunctivitis	1	–1,118.60	14.20	14.26	0.0002
Tarsus length	1	–1,118.55	0.12	0.11	0.7397
Age * sex	1	–1,117.59	1.92	1.92	0.1657

conjunctivitis (1.38 ± 0.82, n = 275). The abundance of feather mites also increased with the severity of conjunctivitis ($F = 5.19$, df = 3 and 572, $P = 0.002$; Fig. 5). Tukey's post hoc tests indicated that birds with the most severe conjunctivitis had significantly higher mite scores than those with no conjunctivitis (Fig. 5), but all other comparisons were nonsignificant.

Mite scores of recaptured birds that changed from being free of conjunctivitis on first capture to having conjunctivitis at second capture were not different ($t = –1.41$, df = 21, $P = 0.170$; Fig. 6). Similarly, mite scores of birds that were initially captured with conjunctivitis but later captured without conjunctivitis also did not differ ($t = 0.55$, df = 8, $P = 0.591$). However, the patterns evident in both plots in Figure 6 are consistent with results detected at the population level: feather mite loads tended to increase if birds acquired *Mycoplasma* (left plot), and tended to decline once cleared of *Mycoplasma* (right plot).

Discussion

We undertook the present study to determine whether infections with Mycoplasma were associated with high feather mite loads in House Finches, because of a presumed disease-induced reduction

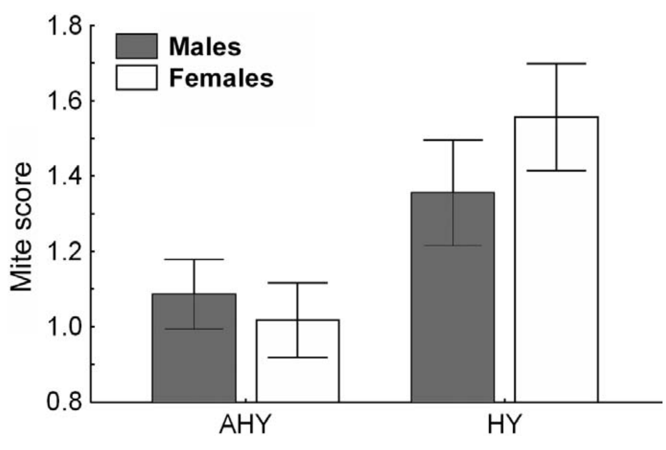

Fig. 4. Average feather mite score of adult (AHY = after-hatch-year) and young (HY = hatch-year) House Finches in Atlanta, Georgia, with males and females shown separately. Error bars represent 95% confidence intervals.

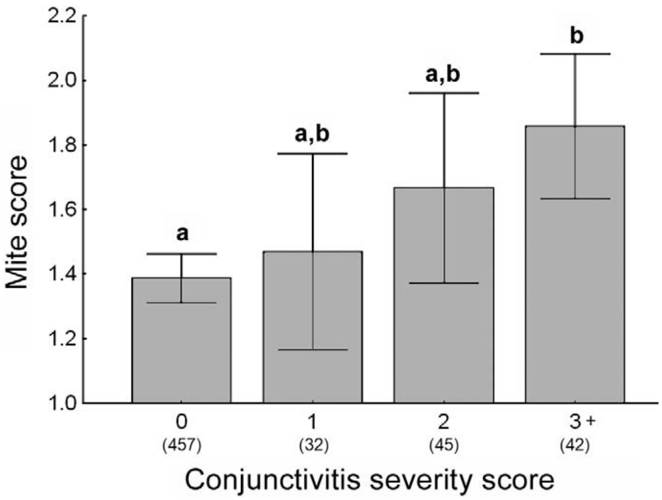

Fig. 5. Average feather mite score for House Finches captured between 2001 and 2005 in Atlanta, Georgia, compared across conjunctivitis severity scores. Conjunctivitis severity was the sum of the left and right eye scores. Birds with summed scores ≥3 were pooled for sample-size purposes (indicated in parentheses). Error bars represent 95% confidence intervals. Severity class scores that share letters (above error bar) do not differ significantly.

in preening behavior. Collectively, our results support this hypothesis: comparisons of mite scores of Mycoplasma-infected and noninfected House Finches showed higher feather mite abundance in infected birds, and mite scores tended to increase with increasing severity of conjunctivitis. Further, although the direct comparisons of individual birds before and after they were infected were not significant, the directions of changes in both plots (Fig. 6) were in the expected direction.

The patterns of *Mycoplasma* infection and feather mite abundance within the House Finch population we studied are consistent with those found in western House Finches infected with avian pox. Thompson et al. (1997) showed that individuals with visible pox lesions tended to have higher mite loads, which is similar to what we found with *Mycoplasma*. In both that study and ours, greater severity of disease equaled greater mite loads. Although pox infections differ substantially from *Mycoplasma*

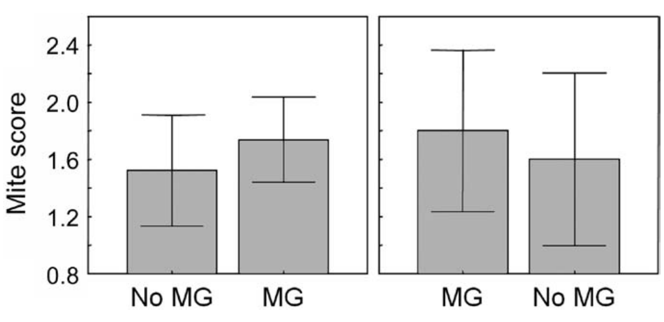

Fig. 6. Average feather mite score of House Finches that were captured twice in different states of *Mycoplasma* infection, going from uninfected to infected (left plot, $n = 23$) or from infected to uninfected (right plot, $n = 10$). Error bars represent 95% confidence intervals.

infections (pox is characterized by lesions of the legs, feet, wings, or head), the same explanation for the high mite loads of infected birds may hold true in both diseases: infections cause a reduction in grooming activity, leading to higher ectoparasite loads.

Although the results from the present study (of field-collected birds) are correlative in nature, there is experimental evidence that supports both our results and those of Thompson et al. (1997). Inoculation of breeding female House Martins (*Delichon urbica*) with either a virus (Marzal et al. 2007) or blood parasites (Marzal et al. 2008) resulted in increases in their ectoparasite load compared with control females. In addition, feather mites increased in captive House Finches that were experimentally infected with coccidia (Brawner 1997). The similarity in results from all of these studies, in which different pathogens were tested in each, is notable. The most parsimonious explanation for these experimental results is that preening activity (or effectiveness) is compromised during illness, a point that was raised by Marzal et al. (2007, 2008).

The experimental studies noted above, plus results from our field study, show that without effective preening, feather mites can over-proliferate in birds. By extension, this could mean that healthy birds typically endeavor to maintain low mite loads, and that high feather mite loads are undesirable. However, other studies have shown that feather mites can benefit hosts by consuming excess waxes, algae, and microorganisms within the feathers, thus keeping the plumage in good condition (Blanco et al. 2001, Galván and Sanz 2006, Galván et al. 2008). Moreover, feather mites have also recently been found to reduce the negative effects of pathogenic bacteria on eggshells (Soler et al. 2012). In fact, Blanco et al. (2001) argued that even in cases where mite abundance is high (such as when the host is ill), the cost of the mites to the host is still minimal, and that the mites may become abundant in such cases simply because of the accumulation of old oil and detritus on the feathers (i.e., from lack of preening). By this interpretation, high feather mite loads during illness are actually more a consequence of the buildup of feather oil from lack of preening, and that in such cases, the mites still perform a service to the host.

If there is any negative effect of feather mites, it may be felt during the deposition of pigment on molting feathers, although this idea is also not without debate. Multiple independent studies have demonstrated that feather mites can lead to poorly developed plumage color during molt in a variety of passerines, including House Finches (Thompson et al. 1997, Harper 1999, Figuerola et al. 2003). By contrast, Galván and Sanz (2006) reported the opposite result in Great Tits (*Parus major*), and Blanco et al. (1999) found no relationship between mite abundance and plumage brightness in Common Linnets (*Carduelis cannabina*). This discrepancy in findings among studies only serves to emphasize that there is still much to learn regarding the nature of the relationship between feather mites and their hosts, as well as the cost, if any, they have on the host.

In conclusion, results from this study showed that feather mites are not associated with measurable declines in House Finch body mass, which supports the idea that their outward effect on the host is minimal. We also showed that infected birds have higher average mite loads than uninfected birds and that the abundance of mites parallels the severity of infection. These results are consistent with prior experimental studies and collectively suggest that infections lead to reductions in preening activity. The implications for the proliferation of feather mites during illness are not clear, but this could be interpreted as a beneficial scenario to the host, because feather mites consume oil and debris from feathers, which would build up during times of reduced grooming.

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