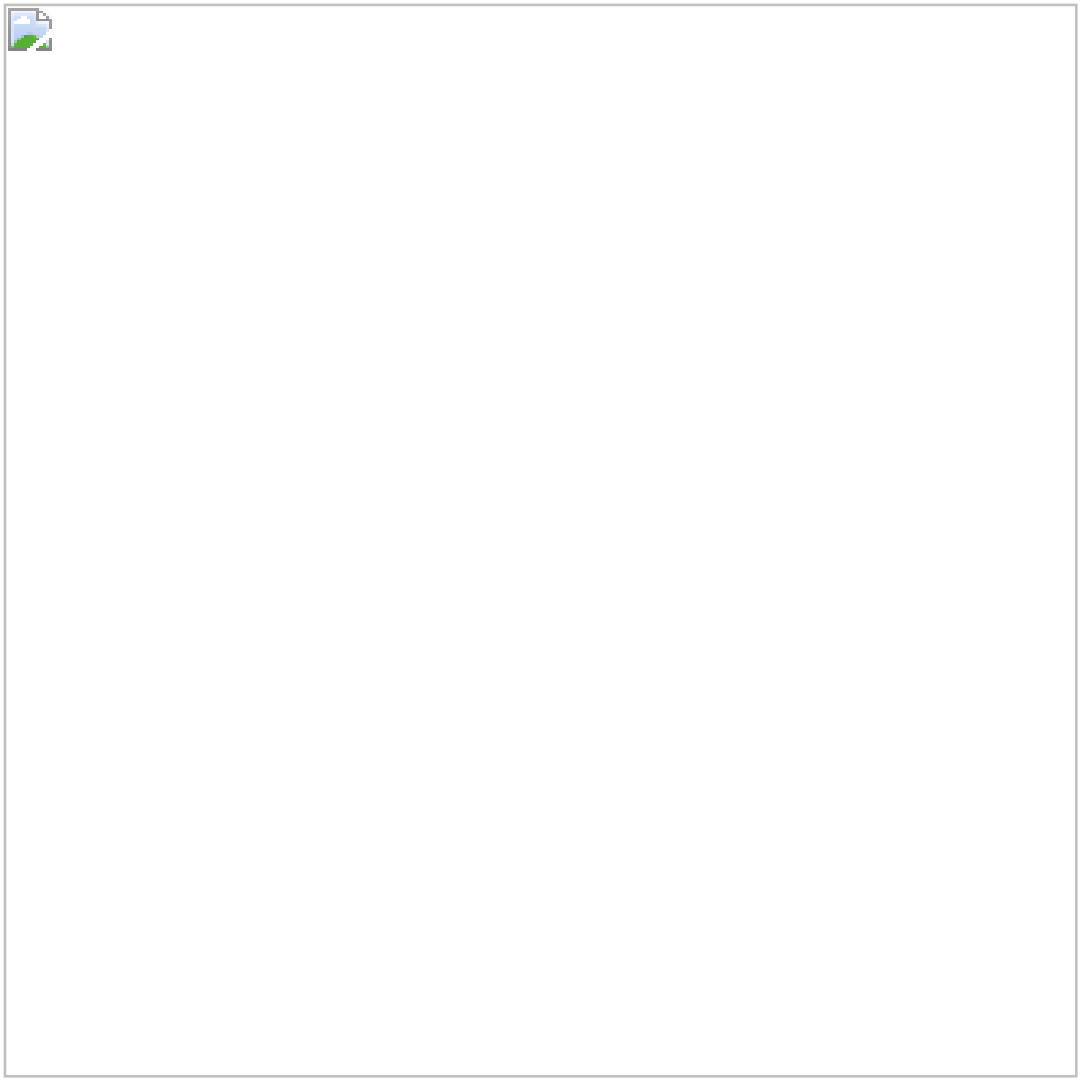

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MODES OF ECTOPARASITE REINFESTATIONS OF DEER MICE *(Peromyscus maniculatus)*

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Abstract: Modes of ectoparasite reinfestations were studied on ectoparasite-free deer mice *(Peromyscus maniculatus)* returned to their natural habitat on the Tule Lake National Wildlife Refuge, Siskiyou County, California, during the summer of 1977. The age of the host made no significant difference in the mode of reinfestation of lice, fleas, or mites. Flea reinfestation rates were related to the sex of the host, requiring 4 and 2 days, respectively, to reach control levels on male and female hosts. Mite populations reached the control level within 1 day, regardless of the sex of the host. No statistically significant louse reinfestations were noted within 8 days after the hosts were released. The percent of the host population reinfested with each ectoparsite followed the same patterns of reinfestation as the numbers of each parasite per host. It is suggested that the mode of ectoparasite reinfestation is a function of the behavior of the host relative to the lifestyle of the ectoparasite species.

INTRODUCTION

Ectoparasite loads on small mammals have been studied in diverse sections of the country. The ectoparasites of *Peromyscus* spp., one of the most ubiquitous and widely distributed of the small mammal genera in North America, have been studied in Minnesota,[1,6,7] New Mexico,[16] Florida,[14,23] the Great Salt Lake Desert[11] and California.[13] These studies are significant because some of these ectoparasites act as vectors, transmitting diseases of considerable economic and medical importance to domestic livestock and humans.[15,18,20] Although there is considerable information on the species of ectoparasites found on the various species of *Peromyscus*, limited data is available on the modes of infestion with ectoparasites and means by which ectoparasite infestation levels are maintained. It is unclear how these ectoparasites are transmitted from the environment to the host, or from host to host, and how fast this transmission can be accomplished. The present study was initiated to determine the rate at which ectoparasite reinfestation occurs when ectoparasite-free deer mice *(Peromyscus maniculatus)* are returned to their natural habitat.

METHODS

Study Area and Mouse-Trapping Handling Protocol

The deer mice used in this study were collected from 22 June to 14 August 1977, from the Tule Lake National Wildlife Refuge, Siskiyou County, California, at an elevation of 1,220 m. The study was conducted on a 30 m wide, 5 km long belt of relatively homogeneous vegetation which was bounded on one side by a 5 m wide irrigation ditch and on the other by the open water of Tule Lake Sump. The predominant vegetation was western ragweed *(Ambrosia psilostachya)*, stinging nettles, *(Urtica holosericea)*, thistles *(Cirsium* spp.), and annual grasses *(Stipa* spp. and *Festuca* spp.), growing on a sandy substrate.

Trapping protocol consisted of 200 stations, each with a single thoroughly cleaned Sherman live trap, 7.5 × 7.5 × 25.5 cm. The stations were placed at 10 m

intervals and the traps baited with rolled oats. Randomly selected groups of deer mice were either: a) killed and examined as discussed below for prevailing ectoparasite infestation levels (the control groups), or b) treated with Sevin® [1] insecticide dust (5% 1-naphthyl N-methylcarbamate) to kill any ectoparasites. Mice in the latter group were held in clean cages for 4 days, a duration of time determined by experimentation as sufficient for removal by grooming of the insecticide dust and the Sevin®-killed ectoparasites. The sex and age of these ectoparasite-free mice were determined and a small patch of hair was clipped in a distinctive manner to permit recognition of members of a given treatment group.

Host Recapture and Ectoparasite-Level Determinations

Groups of ectoparasite-free deer mice were released at the site of their initial capture and recaptured from 1 to 8 days later. Recaptured mice were killed and the pelt placed in individual polyethylene freezer bags to prevent the loss of ectoparasites or the transfer of parasites from one individual to another.[5] The pelt of each recaptured mouse was processed individually by the trypsin digestion procedure described by Cook,[6] except that the bovine pancreatic trypsin (lyophilized) was used in a buffered 0.3% solution instead of in the 3% concentration recommended by Cook. The ectoparasites recovered from individual mice were preserved in alcohol and subsequently mounted on slides for taxonomic identification and numerical determination. Statistical analysis utilized the Student's t-test evaluated at the $P = 0.05$ significance level.

RESULTS

A total of 1,060 deer mice was captured during 5,279 trap-nights (any malfunctioning traps and those capturing other species are excluded from the reported trap-nights), giving a 20.1% trapping success. One thousand thirty-one individuals were treated with Sevin® and released at their site of capture. Of these, 239 (105 males and 134 females) were recaptured — a 23.3% recapture success — and processed for ectoparasite evaluation. The ectoparasites from these mice consisted of fleas, lice, and mites. Fleas were identified as *Monopsyllus wagneri, Opisodasys keeni* and *Malareus telchinum*. Lice were of 2 genera: *Hoplopleura hesperomydis* and *Polyplax* spp. Mites were identified as *Androlaelaps fenilis, A. fahrenholzi, A. debilis* and *Hirstionyssus utahensis*.

Fleas

A statistical description of the flea reinfestation pattern is given in Table 1. Statistical analysis did not show any significant difference at any time in the numbers of fleas infesting adult and juvenile mice of a given sex. However, the numerical levels of fleas infesting males and females differed significantly. Flea infestation levels for male and female hosts in the control group averaged 3.4 and 1.2 fleas, respectively, per mouse. In addition, there was considerable difference between the sexes in the rate of flea reinfestation. Males reached their control level 4 days after their return to their natural habitat, whereas females reached their control level by day 2 (Figure 1). Flea numbers after day 1 (female) and day 3 (male) were not significantly different from control levels.

As a function of time after release, the percentage of the mouse population that became reinfested with fleas followed a pattern similar to that of the number of fleas per mouse. The percentage of flea-infested female mice reached the control level in 2 days; but it was 4 days before the percentage of flea-infested males reached the control level (Figure 3).

[1] Chacon Chemical Corp., 2600 Yates Ave., City of Commerce, California 90040, USA.

TABLE 1. Statistical description of flea infestation levels on the deer mouse *(Peromyscus maniculatus)* as a function of sex of host and time after returning the initially ectoparasite-free mammal to its natural habitat. Number of hosts examined is indicated by N, and the percentage of the host sample having at least one ectoparasite is given. Control levels are based upon the number of fleas on the host prior to treatment with the insecticide Sevin to render the host ectoparasite-free. Statistical comparison of ectoparasite levels on the treated and the control mice are given in Fig. 1.

	Male Hosts					Female Hosts					Male & Female Hosts				
Days After Release	N	$\bar{X}$	SE	Range	Percent Infested	N	$\bar{X}$	SE	Range	Percent Infested	N	$\bar{X}$	SE	Range	Percent Infested
Control	18	3.4	0.72	0-12	94.4	20	1.3	0.32	0-4	55.5	38	2.3	0.42	0-12	71.8
1	33	0.6	0.31	0-10	27.3	28	0.1	0.06	0-1	10.7	61	0.4	0.17	0-10	19.7
2	10	0.3	0.21	0-2	20.0	22	2.0	0.55	0-8	54.5	32	1.7	0.46	0-8	45.5
3	9	0.3	0.17	0-1	33.3	27	1.5	0.34	0-5	51.9	36	1.2	0.27	0-5	48.6
4	9	2.3	0.55	0-5	77.8	13	2.0	0.73	0-9	69.2	22	2.1	0.48	0-9	72.7
5	17	2.8	0.82	0-14	82.3	15	2.1	0.45	0-6	86.7	32	2.4	0.48	0-14	84.4
6	9	1.9	0.51	0-5	88.9	8	1.9	0.93	0-8	75.0	17	1.9	0.50	0-8	82.4
7	5	2.4	1.21	0-7	80.0	12	0.8	0.49	0-6	33.3	17	1.2	0.51	0-7	47.1
8	12	1.8	0.43	0-5	83.3	9	0.8	0.15	0-1	77.8	21	1.3	0.27	0-5	81.0

Lice

Thirty-nine percent of the 38 control mice were infested with lice, averaging 1.03 lice per mouse. Very few lice successfully reinfested the mice in the experimental group during the 8 days that reinfestation rates were monitored. The percentage of the treated mice that became reinfested varied from 0 to 12%, and the absolute number of lice per mouse was always significantly lower than the control level (Table 1, Figure 3).

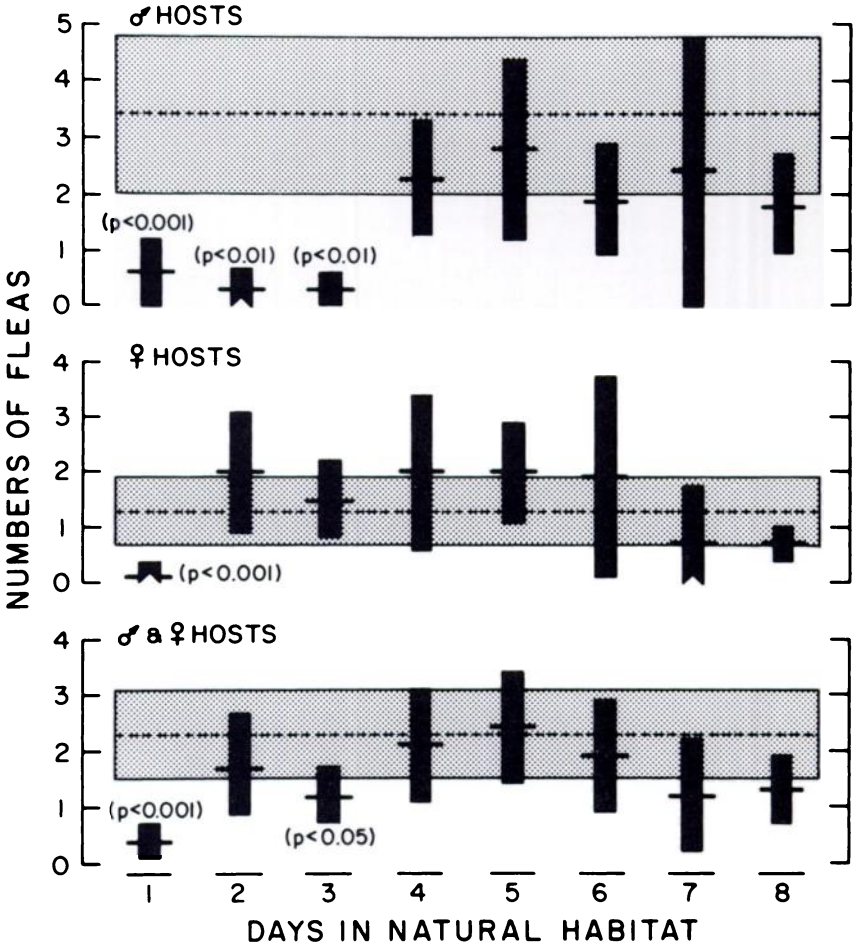

FIGURE 1. Flea infestation levels as a function of time after returning parasite-free deer mice to their natural habitat. Mean ectoparasite levels are indicated by horizontal lines, and two standard errors above and below the mean are shown by the solid rectangle. Statistical differences (Student's t-test) from the control host population are given in parenthesis. The mean for the control population and two standard errors above and below the mean are given by shaded horizontal rectangles. The sample size, range, and percent of population infested with fleas is presented in Table 1.

There was no significant difference between control and experimental groups in louse numbers due to age or sex of the host.

Mites

A statistical description of the mite reinfestation pattern is given in Table 2. All age and sex classes were grouped together, since there were no statistical differences among them. The rate of mite reinfestation was very rapid; a single day in their natural habitat was sufficient for these mice to be reinfested with mites at the levels shown by the control group. In fact, on day 2 these mice had significantly more mites than did the control group. By day 3 the mite numbers had regressed to control levels and subsequently the numbers fluctuated only slightly, never differing significantly from control levels (Figure 2).

The percentage of the Sevin®-treated mouse population that became reinfested with mites equaled the percentage of mite-infested individuals in the control group within a day after returning to their natural habitat. On days 2 and 3 a greater percentage of the treated mouse population was infested with mites than was noted in the control population. Subsequently, the percentage of the treated population infested with mites returned to the control level (Figure 3).

DISCUSSION

This study did not disclose any species of fleas,[2,8,13,17,21,22] lice, or mites[10,12,22] previously unreported as ectoparasites of the deer mouse. The mice in our population did not appear to be infested with as great a variety of louse species as have been found on deer mice in other sections of the country.[1,6,7,8,22] It is also notable that two of the species of flea *(M. wagneri* and *O. keeni)* occurring in our host population have been implicated in plague epidemics occurring about 25 km from our study area.[18,20] Regardless, the primary goal was to examine certain aspects of ectoparasite reinfestation phenomena in terms of the numbers and type of ectoparasites reinfesting individual hosts, and in terms of the percentage of the host population reinfested. There was a close correlation

TABLE 2. Statistical description of louse and mite levels (reinfestation of ectoparasite-free hosts) on the deer mouse *(Peromyscus maniculatus)* as a function of time after returning the host to its natural habitat. Number of hosts examined is indicated by N, and the percent of the host sample having at least one ectoparasite is given. Control levels are based upon the ectoparasite levels on the host prior to treatment with the insecticide Sevin to render the host parasite-free. Statistical comparison between ectoparasite levels on the treated mice and the control mice are given in Fig. 2.

		Lice				Mites			
Days After Release	N	$\bar{X}$	SE	Range	Percent Infested	$\bar{X}$	SE	Range	Percent Infested
Control	38	1.0	0.35	0-5	38.5	1.2	0.46	0-17	46.2
1	61	0.2	0.07	0-3	11.5	1.0	0.32	0-14	41.0
2	33	0.1	0.04	0-1	6.1	3.1	0.72	0-17	66.7
3	36	0.1	0.06	0-2	5.4	1.4	0.29	0-7	59.5
4	22	0.1	0.04	0-1	4.5	0.6	0.21	0-3	36.4
5	32	0.0			0.0	1.5	0.43	0-11	53.1
6	17	0.3	0.24	0-4	11.8	1.4	0.43	0-7	58.8
7	17	0.1	0.08	0-1	11.8	0.6	0.23	0-3	35.3
8	21	0.1	0.10	0-2	4.8	1.1	0.42	0-8	47.6

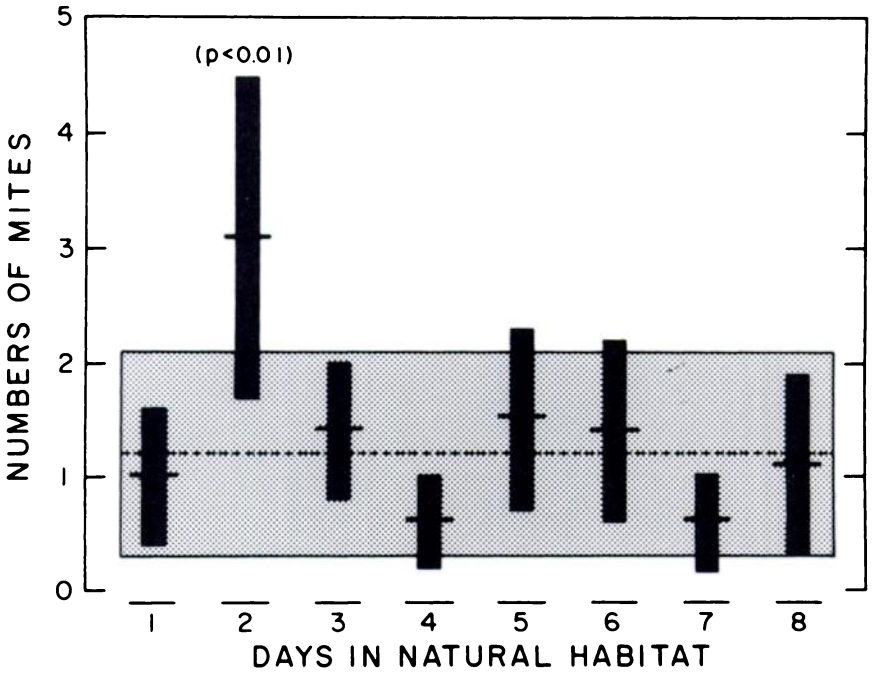

FIGURE 2. Mite infestation levels as a function of time after returning ectoparasite-free deer mice to their natural habitat. Mean ectoparasite levels are indicated by horizontal lines, and two standard errors above and below the mean are shown by the solid rectangles. Statistical comparisons (Student's t-test) with the control host population are given in parenthesis. The mean for the control populations is indicated by broken lines and two standard error above and below the mean are indicated by shaded horizontal rectangles. The sample size, range, and percent of the population infested with mites is presented in Table 2.

between individual and population ectoparasite loads as a function of the period of time during which reinfestation occurred. Essentially, the higher levels of population infestation with fleas, lice, and mites were associated closely with higher numbers of these ectoparasites per mouse. This may be a reflection of a more complex reinfestation mechanism than would occur as a direct function of the ectoparasite density on individual hosts and the resulting ectoparasite exchange rate between hosts. The sex-related differential rate of flea reinfestation found here suggests a more complex reinfestation mechanism incorporating host behavior as well as the lifestyle of the ectoparasite involved.

Fleas

The sex-related difference in flea numbers and reinfestation patterns may be a reflection of differences in the amount of time the host spends in the nest and in the amount of time spent in mutual grooming and self-grooming. Since fleas are not full-time residents on the host,[19] flea numbers may be related to sex-related differential behavior patterns of the mice; female deer mice

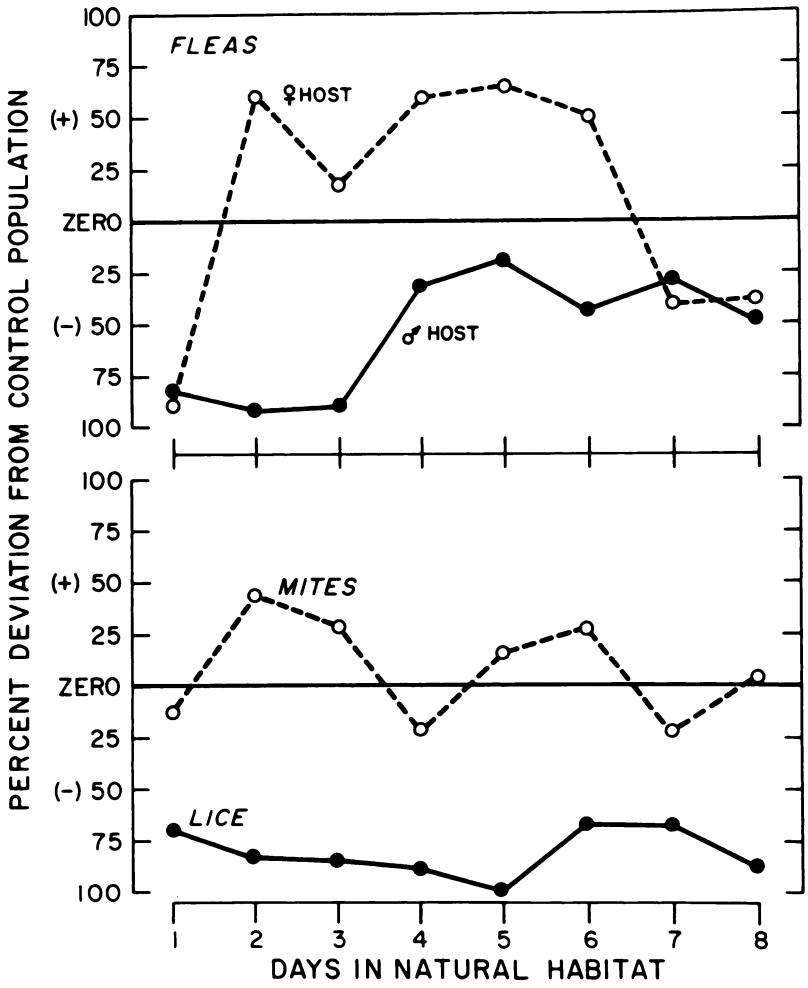

FIGURE 3. Ectoparasite infestation levels as a function of time after returning ectoparasite-free deer mice to their natural habitat. Infestation levels are expressed as + or − percent deviation from the percentage of infested individuals in the control population. See Tables 1 and 2 for numerical values of the ectoparasite load of the control and experimental groups.

spend more time in the nest (especially when they have a litter, and this study was conducted during the deer mouse reproductive period) than do the males.[9] Thus, females have a potentially greater degree of exposure to nest-dwelling fleas than do males and we offer this as a plausible explanation of why the former become reinfested more rapidly. However, female deer mice are less aggressive (potentially reducing the opportunity for host-to-host ectoparasite exchange) and have greater levels of grooming than do the males.[4] Both of

these female behavioral characteristics seem to contribute to maintenance of relatively low chronic levels of flea infestations. Indeed, females in the control population did show a much lower level of flea infestation (on both an individual and population basis) than did the males (Table 1). Regardless, potential effects of these latter two female behavioral patterns did not curtail the rate of flea reinfestation relative to that of the males (Fig. 1).

Lice

There was no significant difference in louse infestation levels related to the age or sex of the deer mice comprising the control population. This differs from several previous studies, wherein adult male deer mice were reported to have greater numbers of lice than adult females.[1,3,6,23] Lice are transferred primarily by direct contact between infected and susceptible individuals[19] and it may be that the mouse population studied here was high (or low) enough to maximize (or minimize) host-to-host interactions and thus to equalize the louse numbers per host. However, this study did not continue long enough to determine the reinfestation patterns of the lice; a longer study would facilitate evaluation of this density-dependent hypothesis. The lack of any appreciable degree of louse reinfestation may be due to the host specificity of the lice and their propensity for remaining on a single individual for their entire life span. Louse eggs deposited on the ectoparasite-free mice would require 17 days to hatch;[19] they would have been destroyed by the trypsin-digestion procedure[7] and thus would not have been noted during this study. Therefore, all that can be said is that lice apparently are not readily transmitted to new hosts and that more than 8 days are required for appreciable reinfestation under the host density studied here.

Mites

Mites are not as strictly parasitic as lice and spend part of their life cycle in vegetation and nest litter.[19] The rapid, one-day reinfestation of the mice with mites noted here may be due to the hosts acquiring mites from the vegetation while foraging or finding their way to a burrow immediately following their return to their natural habitat. Also, the rapidity of mite reinfestation, as well as the numerical increase above control levels noted on the second day, suggests that mites are opportunistic and are quick to utilize an ectoparasite-free host. The numerical overshoot noted is a common ecological phenomenon; as with most irrupting populations, the overshoot in mite numbers was subsequently reduced to normal maintenance levels. A plausible explanation for this is that host factors (such as grooming) and/or competition among the mites act to maintain mite numbers at a relatively constant level.

CONCLUSIONS

This study was not of sufficient duration to completely determine the pattern of louse reinfestation, since more than 8 days is needed before any appreciable reinfestation occurs at this host population density. Mites reinfest extremely rapidly (needing only 1 day to reach control levels), presumably because of their presence in vegetation and nest litter, as well as their potential for transferring from host-to-host. Fleas showed a sex-related difference in reinfestation rates (possibly due to sex-related behavior patterns); females reach control levels in 2 days, whereas males require 4 days to reach control levels.

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