Host Grooming Efficiency for Regulation of Cat Flea (Siphonaptera: Pulicidae) Populations

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ABSTRACT Grooming efficiency was studied by infesting domestic short-hair cats, *Felis catus* L., with known numbers of cat fleas, *Ctenocephalides felis felis* Bouché, then collecting the cat feces and extracting the fleas to determine how many had been groomed off, varying the infestation level. Some hosts were found to be significantly more efficient at grooming fleas than others, with the best groomer removing 17.6% of its flea burden daily, compared with only 4.1% removed by the poorest groomer. Cats were more efficient at grooming fleas at infestations of <50 fleas and >150 fleas. Mean on-host flea longevity was 7.8 d.

KEY WORDS *Ctenocephalides felis*, ectoparasite, host grooming

CERTAIN ANIMALS ARE better hosts for fleas than others, either because of grooming ability, physiology, or coat characteristics (Bradley 1983, Chandy and Prasad 1987). Individual dogs vary in their degree of flea tolerance, with some animals more actively searching for fleas on their coats and biting or scratching to remove them. In fact, excessive grooming is one criterion for identifying asymptomatic flea-infested cats, *Felis catus* L. (Scheidt 1988). Whiteley (1987) advanced the theory that animals showing flea allergy dermatitis symptoms have a selective advantage in that fleas abandon more pruritic hosts, lowering their flea numbers.

Marshall (1981) reported that a direct relationship existed between the host's ability to groom and incidence and intensity of ectoparasitism. Host age was shown to influence the number of cat fleas, *Ctenocephalides felis* Bouché, infesting the host, with more cat fleas on younger cats than on older ones, which the authors attributed to the host's experience regarding grooming effectiveness and frequency (Osbrink and Rust 1985). Wade and Georgi (1988) demonstrated that some cats were able to remove 50% of their flea burden in a week by grooming.

Fleas have evolved distinctive morphological characteristics, particularly elaborate spines and setae (Traub 1972), to reduce the effectiveness of host grooming. Structures such as the ctenidia permit the ectoparasite to anchor itself within host pelage or plumage and to resist the host's grooming efforts (Humphries 1967). Studies have demonstrated that anatomical features such as helmets, ctenidia, head shape, and even modifications of shape and size of spines and setae can be correlated with particular characteristics of the host's coat (Traub 1985). Thus fleas are particularly adapted morphologically to thwart grooming efforts of their hosts.

Grooming is considered to be 1 of the 2 most significant host-induced mortality factors for ectoparasites in general (Marshall 1981). It is defined as "an innate behavior to clean the hair and skin of dirt, grease, and other foreign materials, including ectoparasites . . . " (Kim 1985). Kern (1993) found that cats spent an average of 20.5% of their time budget in grooming, whereas Rust (1992) estimated that test cats spent 5% of their time grooming. An activity that occupies significant portions of an animal's time must have adaptive significance. This study was conducted to identify factors which affect the grooming competence of different animals and to determine the significance of host grooming as a mortality factor for fleas. Grooming efficiency was studied by infesting domestic short-hair cats with known numbers of cat fleas, and then collecting the cat feces and extracting the fleas to determine how many had been groomed off at various intervals.

Materials and Methods

Fleas. Mixed-sex cat fleas were obtained from a colony maintained at the USDA–ARS Center for Medical, Agricultural and Veterinary Entomology in Gainesville, FL (Hinkle et al. 1992).

In conducting the research described in this report, the investigators adhered to "The Guide for the Care and Use of Laboratory Animals," as promulgated by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council. The facilities are fully accredited by the American Association of Laboratory Animal Care.

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Hosts. Four domestic short-hair cats (designated A–D) were infested with known numbers of cat fleas within 5 d of emergence from the cocoon. The infestation was allowed to establish for 24 h, permitting the fleas to feed, mate, and begin oviposition before manipulation of populations. During testing, each cat was allowed to roam freely ≈8 h/d in the procedure room (2.5 by 2.5 m), but was otherwise housed in a stainless steel cage (Hinkle et al. 1992). The animal was isolated from the cat colony for the entire interval of testing to avoid contamination by additional fleas.

Combing Method. To reduce flea infestations, cats were combed with a standard flea comb, 13 tines per centimeter (Twinco, Cranbury, NJ), in a semisystematic fashion starting with the head, working back and under the body. As the comb became matted with hair, the mat and entangled fleas were removed and dropped into a bucket of soapy water (0.1 ml liquid detergent in 0.8 liter water), and swirled to submerge and drown the fleas. Based on computations of numbers remaining on the animal, specific numbers were removed to produce on-animal populations within the desired ranges. Once the combing interval was ended, the hair mats were transferred to a petri dish containing 75% isopropanol and the fleas were removed by forceps. Fleas were then sorted, counted, and their sex determined.

Recovery from Feces. To determine how quickly materials move through the feline gastrointestinal tract, ≈6–8 Styrofoam particles (<2 mm diameter) were placed in the food dish along with a small amount of food immediately after the animal was infested with fleas. The fleas groomed off following infestation were thus incorporated, along with the styrofoam, in the next fecal bolus (which exited ≈24 h after ingestion). This permitted identification of the point at which the new infestation was initiated. All feces were removed from the litter box daily and frozen in labeled plastic bags. Feces were processed by diluting them in warm water and agitating them until the boluses broke up. Generally the flea carcasses floated, although those entangled in the hair had to be separated manually. The styrofoam particles floated and were apparent by their color. Fleas were sorted by sex, counted, preserved in 75% isopropanol, and labelled by date and animal.

Data Analysis. Data were transformed by arcsine transformation and analyzed with the SAS general linear models procedure (SAS Institute 1988) using the Tukey Studentized range test for the individual variables and interactions between them. Sex ratios of the on-host population and fleas in fecal samples were compared by t-test.

Results and Discussion

Sex ratios of fleas in the feces did not vary significantly from the corresponding sex ratios on the host, indicating that host grooming was equally effective in removing both sexes (Table 1). Thus, neither sex was being selectively reduced.

Table 1. Comparison of sex ratios on the animal with those of fleas groomed off by host

Location	n	Mean % ♀	SE
On-animal	39	59.6	1.67
In feces	39	60.5	2.91

Considering the various factors and their interactions, only 2 variables, the animal itself and the infestation level, were found to be significant factors (Table 2). Individual animals varied in their ability to remove fleas, as shown by differing flea numbers in their feces (Table 3). The daily mean of fleas groomed off ranged from 4.1 to 17.6%. Only the cat removing 17.6%/d was significantly (P = 0.05) different from the percentages of the other 3 animals. The poorest groomer removed only 4.1% of its flea population each day, resulting in only 22% being removed per week, whereas the most successful groomer (by eliminating 17.6%/d) removed >68% during the same period.

The results confirmed the animal technicians' observations that numbers of flea eggs produced on cat A were low. With this level of loss from grooming, it was not surprising that the flea population on this animal had to be replenished more frequently than on other animals in the colony. Rust (1994) similarly conjectured that less efficient grooming by certain hosts made them better hosts for flea colony maintenance. It appears that animals experiencing allergy to fleas may be stimulated to more intense grooming. Silverman et al. (1981) observed this same phenomenon in their colony cats, noting that some animals seemed to be more meticulous groomers than others, resulting in lower egg production from these cats.

Interestingly, grooming efficiency is higher at low infestations (<50 fleas per animal) and at high levels (>150 fleas per animal) than for intermediate infestations (Table 4). Probably at high population densities, the irritation from flea bites stimulates intense grooming, resulting in a high proportion (9.2%) of fleas being removed. At low infestation levels, removal of even small numbers is a substantial proportion of the entire population, reflected in the daily 14.7% removal rate. At infestation rates between 50 and 150 fleas, the stimulus to groom appeared to be reduced, and numbers removed are only a small fraction (2.8%) of the total population.

None of the interactions were significant except for infestation level and age of fleas, which are not independent. We were unable to establish a sufficiently

Table 2. Factors affecting flea ingestion by host

Factor	F	df	P
Host animal	7.54	13	0.0005
Infestation level	9.64	12	0.0005
Age of fleas	2.19	2	0.1273
Host × infestation	1.72	4	0.1686
Host × age	0.62	1	0.4378
Infestation × age	8.29	2	0.0011
Host × infestation × age	2.42	1	0.1291

Table 3. Daily mean percentage of fleas groomed off and found in host's feces

Host	*n*	Mean
Cat A	18	17.6a
Cat B	7	12.1b
Cat C	7	5.2b
Cat D	19	4.1b

Means followed by the same letter are not significantly different at the 0.05 level (Tukey studentized range test).

high infestation level so that it would still be high when the fleas were a week old; inevitably the host removed them by grooming, leaving a low infestation level.

When grooming was eliminated as a mortality factor by containing fleas in microcells, 92.6% survived for 14 d (Thomas et al. 1996) and maximal longevity was 37 d (Osbrink and Rust 1984). When cats were declawed and wore Elizabethan collars, >72% of female fleas were able to persist on the host for 113 d (Dryden 1988). On the artificial rearing system, maximum longevity was 86 d (Table 5). However, estimation of the average on-host life span of the adult flea as between 4 and 6 wk (Baker 1984, Kwochka 1987) seems overly optimistic, unless the host is restrained from grooming. Silverman et al. (1981) noted that numbers of fleas on cats decreased over 90% in just 3 wk, as monitored by daily egg production. Similarly Wade and Georgi (1988) found that half the fleas were groomed off their experimental cats in 1 wk. Rust (1994) was unable to account for 8–47% of the fleas used in mark-recapture studies; these were assumed to have been removed by grooming.

The median lifespan of fleas on the poorest groomer in our study was 18 d and on the best groomer it was 5 d. In addition to the actual removal of fleas, flea host-grooming avoidance activity detracts from flea feeding and reproduction, further decreasing population success (Hinkle et al. 1991).

Few fleas were found in the cage bottoms, only 11 in 395 samples, and those displayed apparent grooming damage such as missing tarsi or heads. Dryden (1988) similarly found that of 35 fleas which were recovered off the animal in 300 collections, all were either dead or moribund. Wade and Georgi (1988) recovered 4.5% of the fleas with which they had infested their cats in the cage bottoms, but did not describe their conditions.

The concept that once fleas exceed a baseline on-animal population level they tend to leave the host (Kwochka 1987) is not supported by our research, as

Table 4. Mean percentage reduction in various levels of on-host flea populations per day attributable to host grooming

Infestation level	*n*	Mean ± SE
<50	21	14.7a ± 5.1
50–150	11	2.8b ± 0.9
>150	19	9.2a ± 2.1

Means followed by the same letter are not significantly different at the 0.05 level (Tukey studentized range test).

Table 5. Comparisons of average and maximal adult flea longevity and egg production per female per day for various rearing systems

Rearing system	Avg longevity, d	Max longevity, d	Avg eggs/♀/d	Max eggs/♀/d
Artifical cat[a]	15.3	86	4.2	7.9
Microcells[b]	11.8	37	13.5	22.3
On-host	7.8	—	21.3	38.4
Collared[c]	>113.0	>113	27.0	46.4

[a] Hinkle et al. 1992.
[b] Osbrink and Rust 1984.
[c] Dryden 1988.

upper levels of flea infestation in these studies were >300 fleas per animal. Similarly, the idea that environmental infestation occurs because of the host's scratching fleas off (Kwochka 1987) appears erroneous, based on our results. While flea transfer among animals can occur (Rust 1994), as far as can be determined, once a cat flea finds a host, it never leaves of its own volition.

Thus host grooming success depends upon the individual animal's grooming ability and the severity of the infestation. In the absence of reinfestation from the environment, adult on-host populations could be greatly reduced by host grooming (Rust 1994). Host grooming appears to be the most significant mortality factor acting on adult fleas once they have achieved a host.

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