Understanding Persistent and Recurrent Flea Problems

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New topical and systemic adulticides and insect growth regulators (IGRs) make controlling flea infestations much easier. But flea infestations can at times be persistent or reoccur, even after application of seemingly effective flea control products. While insecticide resistance may cause organophosphate- and pyrethroid-based flea products to fail, no one knows the extent of insecticide resistance to fipronil, imidacloprid, lufenuron, methoprene, pyriproxyfen, or selamectin in cat flea populations.[1-3] Even today, if a product containing fipronil, imidacloprid, lufenuron, methoprene, pyriproxyfen, or selamectin fails, some veterinarians cite resistance as the cause. But in my experience, true product failures are rare, and most problems stem from poor compliance, application or administration errors, and a lack of understanding of important biologic and epidemiologic parameters in the flea life cycle. This article will focus on the cat flea, *Ctenocephalides felis*, its biology, and its impact on control strategies.

Host associations

Surveys conducted in Virginia, California, Wisconsin, Florida, and Indiana demonstrate that *C. felis* is the most prevalent flea species on dogs and cats in the United States.[4] *Ctenocephalides canis*, *Pulex simulans*, and *Echidnophaga gallinacea* flea species also occasionally infest North American dogs and cats.

C. felis also infests a wide diversity of mammalian and avian hosts. In North America, hosts infested with *C. felis* include coyotes, red and gray foxes, bobcats, Florida panthers, cattle, skunks, several rodent species, raccoons, opossums, domestic rabbits, and ferrets.

A survey conducted in Northeastern Kansas demonstrated significant *C. felis* populations infesting urban wildlife.[5] Cat fleas were recovered from 61.5% (64/104) and 21.6% (24/111) of urban-trapped opossums and raccoons, respectively. Pet owners often blame their dogs' and cats' flea infestations on squirrels and rabbits because they see these animals during daylight hours. But squirrels and wild rabbits are rarely, if ever, hosts for *C. felis*. Pet owner don't often consider opossums and raccoons as sources because they rarely observe these nocturnal animals traveling through their yards. But when these flea-infested animals move through yards at night, they deposit flea eggs that can serve as an infestation source for dogs and cats.

In other regions of the world, a variety of animals may serve as *C. felis* reservoir hosts. In Hawaii, cat fleas infest up to 70% of the mongoose population.[4] Infested red foxes have been found in Germany and France.[4] Various rodent species have been reported harboring *C. felis* in Brazil, Saudi Arabia, Iraq, and Egypt. [4] Domestic rabbits, horses, cattle, sheep, goats, various poultry species, and koalas have also been reported infested with cat fleas.[4]

C. felis has extended its range into northern temperate climates despite its inability to survive exposure to temperatures below 30.2 F (–1 C) for more than five days in any life stage.[6] So *C. felis'* survival during winters in northern temperate climates is intriguing. Survival and maintenance of *C. felis* populations likely occurs through several

mechanisms: (1) Adults living on domestic and feral dogs and cats; (2) Adults living on urbanized small wild mammals (such as raccoons and opossums in North America); (3) Delayed development of immature stages in freeze-protected underground wildlife dens; and (4) Delayed pupae development and adult emergence in the home environment.

The unique host range and *C. felis' ability* to establish populations in human dwellings have allowed this flea to spread successfully throughout most inhabited areas of the world and to constantly reinfest our urban environments. Even if we restrict pets to an indoor environment or they rarely venture outdoors, fleas can find their way into our homes. I have consulted on many flea infestation cases where outside sources introduced fleas into a home. Outdoor flea infestations are common; they occur in crawl spaces, under porches, and in other community areas that animals frequent (such as parks, common latrine sites around apartments, and walking paths). Opossums, raccoons, and stray dogs and cats that use these areas can deposit flea eggs that establish *C. felis* infestations. Many times, fleas jump on a person's clothes and are then carried into a house, where they jump off and infest indoor pets. While determining the validity of an owner's assertion that the pets never go outside is difficult, even truly indoor pets can develop flea infestations.

Reproductive potential and larval development

Once a flea acquires a host, it initiates feeding within seconds to minutes, mates within eight to 24 hours,[7] and deposits eggs within 24 hours after taking its first blood meal.[8] During peak reproduction, which occurs within four to nine days of initiating feeding, females can reach reproductive levels of 40 to 50 eggs a day.[8] Reproduction continues at a slowly declining rate for the next 100 days.[8] Actual reproduction levels on a host will vary, depending on the amount of grooming activity—normal grooming can considerably decrease egg production.

The larva is the life stage most susceptible to environmental extremes. Larval development occurs in protected microhabitats that combine moderate temperatures, high relative humidity, and an adult flea fecal blood source.[4] Like most insects, the development rate is temperature-dependent. About 50% of the larvae formed cocoons within 34 days when reared at 55.4 F (13 C) and 75% relative humidity. At 89.6 F (32 C) 80% of the larvae formed cocoons within eight days.[9] In another study, two different cat flea strains were maintained at 75.9 F (24.4 C) and 78% relative humidity. In that study, 84% to 89% of eggs hatched and adult emergence from eggs ranged from 60% to 66%.[4] Given optimal conditions, flea populations can increase rapidly within two weeks. Interestingly, less than 60% of the larvae survive when reared at 95 F (35 C). Flea larvae simply will not develop in areas exposed to the hot sun.

Larvae are also susceptible to desiccation, with exposure to relative humidity less than 50% being lethal. Larvae were able to tolerate temperatures up to 80.6 F (27 C) if the relative humidity was greater than 50%.[9] Most areas in a home do not have the necessary humidity, and suitable outdoor sites are even more rare. Larvae only survived outdoors when relative humidity was greater than 50% for several consecutive days or their microhabitats provided higher relative humidity.[6] In addition larvae can be killed if the soil becomes moisture saturated after a heavy rainfall.[4] In summary, outdoor habitats that promote *C. felis* development provide a relative humidity greater than 50% and soil moisture of less than 20% and protect against temperatures above 95 F (35 C) and below

39.2 F (4 C). Larval nutritional requirements also will greatly limit the sites in and around structures suitable for *C. felis* development. During their development, the larvae must encounter and ingest adult flea feces, which contain partially digested blood. Without a dried blood source, it is doubtful that many, if any, larvae can mature.

As cited previously, *C. felis'* egg production capacity is remarkable. A cat infested with 15 fleas would, on average, have 10 female and five male fleas.[10] At peak reproduction, those 10 female fleas could produce 400 to 500 eggs daily. If the eggs were deposited in an area with optimal temperature and humidity and an abundance of flea feces, between 240 and 350 fleas could emerge daily within two to three weeks. A typical pet and home would become massively infested within a few weeks. Obviously, only a small percentage of eggs result in adult fleas in most homes. This massive death of developing stages, particularly the larvae, likely results from a combination of desiccation and starvation. But conditions that allow for only 10% to 20% survival of eggs to adult fleas can result in substantial infestation levels. Since *C. felis* can initiate egg production within 24 hours of infesting a pet, infrequent flea product application can allow rapid reinfestation. So continued administration of products that prevent flea reproduction becomes an important part of any flea control program.

Pupal development and flea emergence

After a short prepupal period, the mature larva transforms into a pupa, usually within a cocoon constructed of silk. The cocoon is ovoid, about 0.5 cm long, whitish, and loosely spun. The silk fibers are sticky, and debris from the environment usually coats the cocoon. Cocoons can exist in soil, on vegetation, in carpets, under furniture, and on animal bedding. The pupal stage is the immature stage most resistant to desiccation, with about 80% emerging as adults at 80.6 F (27 c) and 2% relative humidity.[11] Adult *C. felis* begin emerging eight days after pupal development starts. In one study, all fleas emerged by day 13 at 75.9 F (24.4 C) and 78% relative humidity.[12]

Once developed, the adult *C. felis* may rapidly emerge or remain quiescent in the cocoon for up to 140 days when held at 51.8 F (11 C) and 75% relative humidity. Researchers have observed delayed adult emergence (20 to 30 weeks) from eggs laid by *C. felis* in the fall.[13] The ability of the preemerged adult to survive for extended periods in the cocoon is especially important for species such as *C. felis,* which infest mobile hosts that may not return to a nest or burrow frequently. *C. felis* can complete development and emerge in as little as 13 days, or emergence may be delayed up to 174 days, depending on temperature and emergence stimuli (heat, carbon dioxide, physical pressure and movement of substrate). But under most household conditions, the fleas will complete their development and emerge within three to five weeks.

Adult fleas often resurge within days of treating carpets with insecticides.[14] Fleas may continue to emerge from cocoons for up to four weeks after insecticide and insect growth regulators are applied.[15] These resurgences involve pupae and preemerged adults in cocoons at the time of treatment, insecticide sprays do not kill these stages if the cocoons are spun at the base of a carpet.[16] While most residual insecticides exhibit activity for several weeks, this often causes a false sense of security. These residual compounds generally do not have a quick kill. So when a flea emerges from the cocoon, it may survive several hours before the residual insecticide kills it. This allows sufficient time for the fleas to find a dog or cat or to bite the pet owner. Continued flea emergence after

insecticides and insect growth regulators are applied is called the pupal window. We should tell owners about the pupal window and that they should reapply premise insecticides within one to two weeks to suppress this emerging adult population. Otherwise, they will assume that the control measures we recommended failed.

With the development of modern topical and systemic residual compounds, such as fipronil, imidacloprid, lufenuron, methoprene, permethrin, pyriproxyfen, and selamectin, a similar situation occurs. When these new topical or systemic insecticides and IGRs are administered, flea reproduction is markedly reduced if not completely halted. This reproductive inhibition occurs either because residual insecticides kill newly acquired fleas before the fleas produce eggs or IGRs or insecticides with ovicidal activity kill developing larvae within the egg. However, the premises are still infested because flea eggs, larvae, and pupae are still developing in the environment. The developmental periods of the eggs, larvae, and pupae and the emergence time for pre-emerged adults further delay population destruction. Fleas will continue to emerge until all flea life stages have developed and emerged. The lag period until flea populations are destroyed after topical or systemic therapy is termed the developmental window. Depending on climatic conditions, the developmental window may be as long as three months. If pet owners don't understand this process, they may confuse continued flea emergence with product failure.

Survival of newly emerging fleas

Once the flea emerges from the cocoon, it looks for a host. Pets attract newly emerged fleas by the various stimuli these hosts produce: body heat, movement, and exhaled carbon dioxide. And recently emerged unfed adult cat fleas exhibit positive phototaxis and negative geotaxis. These behaviors enhance the cat flea's success in host acquisition because newly emerged fleas move directly to the top of the carpet pile or to overhanging vegetation, where they are more likely to encounter a passing host.

The newly emerged cat flea can survive several days before requiring a blood meal, but reports of extended longevity have been greatly exaggerated. Survival of newly emerged fleas in the off-host environment depends greatly on temperature and humidity. In moisture-saturated air, 62% of adult cat fleas survived for 62 days, while in cool, dry air, only 10% survived for 20 days.[6] However, when fleas were maintained under ambient room conditions of 72.5 F (22.5 C) and 60% relative humidity, only 5% survived for 12 days.[12] Newly emerged fleas, which are located in carpets or outdoors, often bite people before finding their preferred host. While these fleas usually emerge from localized protected microenvironments, they often move away from these areas in response to stimuli. But if not stimulated, these fleas will not move away from their emergence site. Energy expenditure would reduce their longevity and decrease their chances of finding a host.

Veterinarians can help pet owners with flea-infested pets by implementing a safe and successful flea control program. In doing so, the veterinarian must consider issues of flea biology, the environment, the host, insecticide efficacy and safety, and pet owner concerns. Educating the pet owner on the biology and habitat of fleas, especially the concept of the development window, will help ensure client satisfaction.

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