Treatment of Black-Tailed Prairie Dog Burrows with Deltamethrin to Control Fleas (Insecta: Siphonaptera) and Plague

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ABSTRACT Burrows within black-tailed prairie dog (*Cynomys ludovicianus*) colonies on the Rocky Mountain Arsenal National Wildlife Refuge, Colorado, were dusted with deltamethrin insecticide to reduce flea (Insecta: Siphonaptera) abundance. Flea populations were monitored pre- and posttreatment by combing prairie dogs and collecting fleas from burrows. A single application of deltamethrin significantly reduced populations of the plague vector *Oropsylla hirsuta*, and other flea species on prairie dogs and in prairie dog burrows for at least 84 d. A plague epizootic on the Rocky Mountain Arsenal National Wildlife Refuge caused high mortality of prairie dogs on some untreated colonies, but did not appear to affect nearby colonies dusted with deltamethrin.

KEY WORDS Deltadust, prairie dogs, insecticide, fleas, plague, epizootic

BLACK-TAILED PRAIRIE DOGS (*Cynomys ludovicianus* Ord) are a vital, dynamic component of the short grass prairie ecosystem (Miller et al. 1994). They provide a prey base for a variety of predators, including black-footed ferrets (*Mustela nigripes* [Audubon and Bachman]), badgers (*Taxidea taxus* [Schreber]), coyotes (*Canis latrans* Say), bald eagles (*Haliaeetus leucocephalus* L.), and ferruginous hawks (*Buteo regalis* [Gray]), as well as habitat infrastructure to a variety of wildlife species, such as burrowing owls (*Athene cunicularia* Molina) and mountain plovers (*Charadrius montanus* [Townsend]) through their feeding and burrowing activities. Prairie dogs are also considered major amplifying hosts for *Yersinia pestis* Yersin, the bacterium that causes plague, contributing to the spread of the disease among other species of small mammals (Barnes 1993). Mortality among infected prairie dogs can exceed 99%, and plague epizootics periodically eradicate prairie dog colonies across much of their range. Plague is most likely enzootic in small mammal populations residing within prairie dog colonies, a factor that severely limits the ability of prairie dogs to establish viable and self-sustaining populations. Recently, it has been proposed that *Y. pestis* poses a broad threat of disruption to ecosystems in western North America (Biggins and Kosoy 2001). Indeed, the majority of rodent species of conservation concern (Hafner et al. 1998) are within the portion of North America already invaded by *Y. pestis*.

Black-tailed and Gunnison's prairie dogs (*Cynomys gunnisoni* [Baird]) and their fleas have been identified as probable sources of infection for ≈14% of all human cases of plague in the United States since 1965 (Centers for Disease Control, unpublished data). Many of these cases involved hunters or other persons who had direct contact with blood or other tissues of infected prairie dogs, often as a result of skinning these animals. Other human cases were believed to have occurred after exposure to infectious flea bites from prairie dog fleas, particularly *Oropsylla hirsuta* (Baker) (formerly *Opisocrostis hirsutus*). Prairie dogs also can contribute to the risk of human plague by acting as amplification hosts, which promotes the spread of *Y. pestis* or infected fleas among other small mammal species, lagomorphs, and wild or domestic carnivores. Although infected prairie dogs pose some plague risk to humans, these risks may be greatly reduced by public education, routine surveillance of prairie dog colonies for epizootic plague activity, and the use of appropriate insecticides to reduce flea populations in colonies situated near human habitations.

At Rocky Mountain Arsenal National Wildlife Refuge, plague epizootics causing 95–99% prairie dog mortality have been documented since the mid-1970s, affecting as little as a few hectares to large scale epizootics of >1,000 ha (United States Fish and Wildlife Service, unpublished data). Prairie dogs are considered a high priority species at the site and are managed to provide nesting habitat for burrowing

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owls and other species, and wintering habitat for a variety of raptors, including the bald eagle.

Efforts to control plague during past epizootics have involved attempts to control fleas through application of insecticides, such as carbaryl or permethrin formulations, to prairie dog burrows. Barnes et al. (1972) reported 100% elimination of fleas in prairie dog colonies after application of 2% carbaryl dust. Treated burrows remained free of fleas for slightly more than 1 mo. Carbaryl has a relatively short half-life in burrows (Beard et al. 1992), requiring repetitive applications to maintain adequate control of fleas. However, flea populations in prairie dog burrows were reduced for at least 3 mo using a single application of permethrin dust (Pyraperm 455 Dust; Fairfield American Corporation, Rutherford, NJ) at an application rate of 4.0 g per burrow (Beard et al. 1992). In contrast, Karhu (1999) reported that flea counts on the prairie dogs in his study site returned to pretreatment levels within 10–18 d after application of permethrin dust. Although permethrin dust is reasonably effective, Pyraperm 455 is no longer being manufactured. Because of the high investment involved in applying insecticides in prairie dog colonies, any product proposed as an alternative to permethrin should effectively kill fleas with a single application and have a long residual effect, thereby enabling applicators to quickly achieve and maintain control throughout the transmission season. Deltadust (Aventis Environmental Health, Montvale, NJ) is a relatively new product that contains deltamethrin, a synthetic pyrethroid similar to permethrin, and is reportedly waterproof, providing insecticidal action for up to 8 mo after application. The purpose of this study was to assess efficacy, longevity, and cost of Deltadust to control fleas in prairie dog burrow systems.

Materials and Methods

Study Site Selection. Study site selection followed prairie dog town mapping efforts in May 2000, with sampling beginning in July 2000. One dusted and one nondusted site were selected, each with a minimum of 50 resident prairie dogs occupying approximately a 2- to 3-hectare portion of a prairie dog town. The dusted site was a 1.89-hectare area within a 5.47-hectare prairie dog town, and the nondusted site was a 2.73-hectare area within an 8.16-hectare prairie dog town. The two sites were separated by 1.34 km.

Collection and Processing of Fleas from Burrows. Fleas were collected by burrow swabbing (Gage 1999). A swab, consisting of a square piece of white diaper flannel ≈25–30 cm on a side, was held in an alligator clip attached to a flexible metal cable. The swab was pushed as far as possible (2–5 m) into the burrow, allowed to remain stationary for 30 s, then gently retrieved. Swabs with fleas were sealed in plastic bags for transport to the laboratory. Each burrow was swabbed three times. We attempted to sample a minimum of 75 burrows per sample effort (site/session). Upon arriving in the laboratory, the plastic bags containing the swabs were placed in a freezer (−4°C) and held overnight to kill the fleas. The following morning, all fleas were removed from the flags and placed in 2% saline for counting and identification (Hubbard 1947, Stark 1958, 1970, Furman and Catts 1982) under a dissecting microscope.

Prairie Dog Trapping and Processing Animals for Flea Collection. Prairie dogs were trapped with 90 single-door live traps placed near active burrows at both the dusted and nondusted sites. Traps were prebaited with sweet-mix (Purina, St. Louis, MO) for at least 3 d before each trapping session began. Traps were later rebaited with sweet-mix, opened at dawn of each trapping occasion, and checked by about noon on the same day. Traps with prairie dogs were labeled by burrow location (to facilitate later release), and moved to the processing area in which prairie dogs were ear tagged before flea sampling. Trapping was conducted for 2 d during each sampling period (pretreat, 10–11 July; 30 d, 9–10 August; 84 d, 3–4 October). Prairie dogs trapped on both days of the session were not sampled for fleas on the second day.

Sampling of fleas from prairie dogs at both the dusted and the nondusted sites involved combing (Heller 1991, Gage 1999, Karhu 1999) fleas from the animals after they were anesthetized with halothane or metafane. Anesthesia was accomplished by placing the trap with the prairie dog into a large plastic bag with a cotton ball soaked with the anesthetic. The prairie dog was monitored throughout this process for signs of consciousness and/or difficulty in breathing. After anesthetization, the prairie dog was held over a white plastic basin and vigorously combed with a small plastic comb to remove fleas. After each animal was combed, additional fleas were collected from the plastic bags used for anesthetizing these animals. All fleas collected from prairie dogs were counted, placed in 2% saline solution, and sent to the Centers for Disease Control Plague Lab in Fort Collins for species determination, as described above.

Application of Deltadust and Posttreatment Sampling. After pretreatment flea sampling was completed, the treatment site was dusted with Deltadust using pressurized, hand-held dusters that delivered 11–14 g of powder into the burrow opening. All burrows in the dusted-site prairie dog colony (5.47 ha) were treated. This was done to ensure that all burrows sampled had been treated. Only one treatment was performed on the treatment site. Seven days after treatment, both the dusted and nondusted sites were resampled for fleas using the burrow sampling protocol. No sampling from prairie dogs was conducted at the 7-d posttreatment period because of personnel and time constraints. Additional burrow and prairie dog flea sampling was conducted at 30- and 84-d intervals posttreatment.

Data Analyses. Raw data were counts of fleas for each burrow and prairie dog. Large numbers of prairie dogs and burrows had no fleas, resulting in skewed frequency distributions and heteroscedastic subsamples. Thus, data were transformed into counts of animals and burrows with fleas and without fleas for each time and treatment group, and the trend in counts over time was modeled statistically using lo-

Table 1. Species composition of fleas collected from dusted and nondusted sites at Rocky Mountain Arsenal National Wildlife Refuge

		O. hirsuta	*T. fotus*	*A. wagneri*	*E. wenmanni*	*F. ignota*
Burrows	Dusted	909	16	3	1	0
	Nondusted	728	6	0	0	1
Prairie Dogs	Dusted	240	0	0	0	0
	Nondusted	539	1	0	0	0
Total		2416	23	3	1	1

gistic regression (Steinberg and Colla 1998). The general model included parameters for time (day of sampling, treated as a continuous variable), treatment (dust versus no dust), and a time by treatment interaction. Likelihood ratio tests ($\% = 0.05$) were used to compare nested submodels with the general model, and to select the most parsimonious explanation of variation. Retention of an interaction term in a model required retention of the involved primary variables.

Results and Discussion

A total of 929 fleas was collected from 297 burrows at the dusted site and 735 fleas from 299 burrows at the nondusted site for all sample periods (Table 1). An additional 240 fleas were collected from 86 prairie dogs at the dusted site and 540 fleas from 134 prairie dogs at the nondusted site. Of the 780 fleas collected from prairie dogs, all were *O. hirsuta*, except for a single *Thrassis fotus* (typical host is the 13-lined ground squirrel, *Spermophilus tridecemlineatus*). Of the 1664 fleas collected from burrows, all were *O. hirsuta*, except for 23 *T. fotus*, 3 *Aetheca wagneri*, 1 *Epitedia wenmanni* (typical hosts for *A. wagneri* and *E. wenmanni* are mice, *Peromyscus sp.*), and 1 *Foxella ignota* (typical host is the pocket gopher, *Geomys bursarius*).

The number of fleas collected from burrows and animals on the dusted site declined after the pretreatment sampling (Fig. 1). Interactions terms were highly influential for both the burrow dataset (Table 2) and the combed animal dataset (Table 3), resulting in retention of the general model in both cases. The strong interactions provided added evidence that it was the application of insecticide that caused the difference between dusted and nondusted sites. If the rates of change in flea numbers at dusted and nondusted plots had been similar (i.e., parallel slopes), for example, the consistently greater abundance of fleas on the nondusted site would have been less convincing of insecticide effect. The most compelling argument for effect of insecticide was the combination of an increased frequency of prairie dogs with fleas on

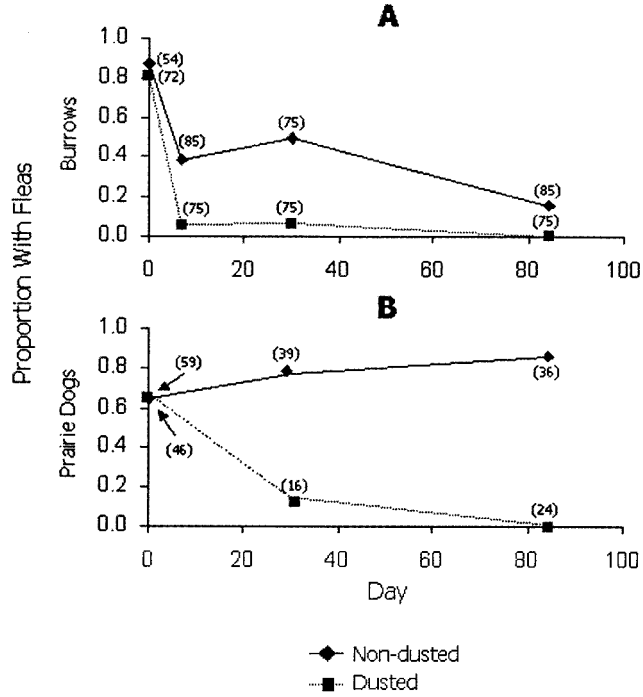

Fig. 1. Proportion of burrows and prairie dogs with fleas on a site dusted with Deltadust and a nondusted site. Samples were taken during d 0 (before dusting), and from burrows on d 7, 30, and 84 postdusting, and from prairie dogs on d 30 and 84 postdusting.

Table 2. Modeling flea occurrence in dusted and nondusted burrows of black-tailed prairie dogs through 84 d following application of deltamethrin powder

General and reduced models	ln(L)[a]	np[b]	Versus Model[c]	χ^2	P
1 Dust + Day + (Dust) (Day)	−278.942	4			
2 Remove (Dust) (Day)	−302.168	3	1	46.45	<0.001
3 Remove Day + (Dust) (Day)	−363.266	2	2	122.20	<0.001
4 Remove Dust + (Dust) (Day)	−323.168	2	2	42.00	<0.001

[a] ln(L) = Log likelihood.
[b] np = Number of parameters.
[c] The model identified in this column was compared via a likelihood ratio test with the model in the first column (same row), resulting in the χ^2 value and corresponding probability given in the last columns.

the nondusted plot, as fleas on prairie dogs in the dusted plot declined dramatically to zero (Fig. 1). Although some unnoticed disparity between the nonreplicated sites could have caused generally lower numbers of fleas on the dusted compared with the nondusted site, or could have caused the rate of change in frequencies of fleas to be different, it is less likely that such a nuisance variable would have resulted in simultaneous changes in both attributes in directions that mimic predicted effects of the insecticide.

Flea collections from burrows and those from the prairie dogs themselves at the nondusted site gave disparate results (Fig. 1). Using simple statistical models with time as the single predictor, frequencies of prairie dogs with fleas increased significantly (likelihood ratio $\chi^2 = 5.711$, df = 1, $P = 0.017$) over the 84-d period, as flea frequencies declined in the burrow samples (likelihood ratio $\chi^2 = 47.364$, df = 1, $P < 0.001$). Perhaps flea collection in burrows is influenced by weather conditions that could affect the location of fleas in the burrow systems. Tunnel lengths of black-tailed prairie dog burrow systems were 4.0–33.2 m in South Dakota (Sheets et al. 1971) and 4.7–29.3 m in Oklahoma (Wilcomb 1954), but our swabs could seldom be inserted >5 m. Perhaps declining surface temperatures during the late summer and early fall caused fleas to retreat to deeper portions of the systems.

Table 3. Modeling flea occurrence on black-tailed prairie dogs collected from dusted and nondusted burrows through 84 d following application of deltamethrin powder

General and reduced models	ln(L)[a]	np[b]	Versus Model[c]	χ^2	P
1 Dust + Day + (Dust) (Day)	−112.669	4			
2 Remove (Dust) (Day)	−133.389	3	1	41.44	<0.001
3 Remove Day + (Dust) (Day)	−135.241	2	2	3.70	0.054
4 Remove Dust + (Dust) (Day)	−147.110	2	2	27.44	<0.001

[a] ln(L) = Log likelihood.
[b] np = Number of parameters.
[c] The model identified in this column was compared via a likelihood ratio test with the model in the first column (same row), resulting in the χ^2 value and corresponding probability given in the last columns.

The apparent decline in the flea population sampled from burrows at the nondusted site could have been caused by removals from sampling. This phenomenon could also explain the steep initial decline compared with the more gentle slopes between later sample periods. Perhaps there were postremoval population recoveries in the upper reaches of the burrows because of migration of fleas, and samples were taken at different points in the oscillating population. A "removal" effect should be most dramatic immediately after each sampling, but immigration may have bolstered the population less after 7 d (the first resample), than after the lags of 23 or 54 d (the intervals between subsequent collections).

A total of 105 prairie dogs was captured and ear tagged at both sites during the pretreatment sampling period. Subsequent recapture rates were 45% (30 d) and 23% (84 d).

It appears that Deltadust, when applied in the manner described in this work, significantly reduces flea populations within prairie dog burrow systems and on prairie dogs. It also has a significant residual effect, with flea populations declining to nondetectable levels at d 84. By comparison, previous studies evaluating permethrin (Pyraperm) dust have reported low numbers of fleas after 84 d (Beard et al. 1992). Furthermore, Deltadust seemed to suppress an epizootic of plague at another area on Rocky Mountain Arsenal during the summer of 2000 (Seery, unpublished data). In that area, there were no losses of prairie dogs in ≈41 ha of colonies treated with Deltadust from 12 July to 26 October and monitored through January 2001. Prairie dog populations were decimated in untreated colonies immediately adjacent to the dusted areas.

Previous success rates in using permethrin to limit the spread of plague within prairie dog colonies appeared to be inversely related to elapsed time between discovery of plague and dusting of burrows. In some instances, application of permethrin within a few days of discovery of an epizootic has halted losses of prairie dogs (Seery, unpublished data). Rapid detection of plague and timely application of permethrin across large areas of habitat are in most cases impractical because of inaccessibility and shortages of personnel available for intensive monitoring and quick response. It is assumed that these observations also will be relevant to the use of deltamethrin for flea control in prairie dog colonies.

Conclusions

We believe that Deltadust represents an effective alternative to Pyraperm 455 for controlling flea populations in prairie dog colonies. Its relative effectiveness, ease of application, and safety should make it an important tool for managing plague epizootics in these animals. The long residual activity of Deltadust suggests that single applications may reduce fleas throughout most of the season of plague activity, which typically occurs during the warmest 4–5 mo of

the year. These advantages also suggest that Deltadust can be useful for conserving prairie dogs as a prey base for raptors and other carnivores, and reducing the risk of human plague in areas in which humans are living in close proximity to prairie dog colonies affected by plague epizootics.

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