Anticoagulant Rodenticide Exposure in an Urban Population of the San Joaquin Kit Fox

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Abstract: Concerned that San Joaquin kit foxes from urban areas may be exposed to commensal anticoagulants, the California Department of Fish and Game, Pesticide Investigations Unit, in conjunction with the Endangered Species Recovery Program's Urban Kit Fox Project, began monitoring San Joaquin kit foxes from the Bakersfield, CA population. Necropsies were performed and liver tissue samples collected from kit fox carcasses. Livers from archived kit foxes dating back to 1977 were also analyzed. A non-urban population of San Joaquin kit foxes from Lokern was used as a control. Other predators in the area, including coyotes and red foxes, were also analyzed for comparison. Between 1999 and 2007, tissue samples from 45 animals have been analyzed for residues of anticoagulant rodenticides. Anticoagulant compounds identified included brodifacoum, bromadiolone, pival, and chlorophacinone. Twenty-six of the 30 San Joaquin kit foxes from Bakersfield contained at least one anticoagulant, and the most commonly detected anticoagulant was brodifacoum. None of the 12 Lokern San Joaquin kit foxes contained anticoagulants. Other predators followed the same pattern: both red foxes from Bakersfield contained anticoagulant residues, but the coyote taken from Lokern did not.

Key Words: anticoagulants, brodifacoum, bromadiolone, chlorophacinone, diphacinone, kit fox, pival, rodenticide, *Vulpes macrotis*

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INTRODUCTION

Monitoring by the California Department of Fish and Game (DFG) Pesticide Investigations Unit has shown that a number of predatory avian and mammalian species that inhabit the urban landscape have been exposed to anticoagulant rodenticides, presumably as a result of secondary exposure (Hosea 2000). Species that had residues of anticoagulants were coyote *Canis latrans*, gray fox *Urocyon cinereoargenteus*, San Joaquin kit fox *Vulpes macrotis mutica*, raccoon *Procyon lotor*, fox squirrel *Sciurus niger*, bobcat *Lynx rufus*, red fox *Vulpes vulpes* , mountain lion *Felis concolor*, Heermann's kangaroo rat *Dipodomys heermanni*, golden eagle *Aquila chrysaetos*, great horned owl *Bubo virginianus*, barn owl *Tyto alba*, red-shouldered hawk *Buteo lineatus*, red-tailed hawk *Buteo jamaicensis*, Cooper's hawk *Accipter cooperii*, turkey vulture *Cathartes aura*, and wild turkey *Meleagris gallopavo*. The most frequently detected anticoagulant was brodifacoum. Anticoagulant rodenticides vary in terms of persistence in tissues, and brodifacoum, difethialone, and bromadiolone (second-generation anticoagulants) are the most persistent. In addition, as the second-generation anticoagulants may require several days to cause mortality, there is opportunity for rodents to ingest several doses and be available for predation while carrying high concentrations of anticoagulants.

A population of San Joaquin kit foxes *V. m. mutica* inhabits part of the City of Bakersfield in Kern County, California. This subspecies is currently federally listed as endangered and by the State of California as threatened. The proximity of this predator population to the urban environment puts kit foxes at elevated risk for secondary exposure to rodenticides used by homeowners and businesses. This urban population contributes to conservation and recovery efforts by contributing to the genetic diversity of the subspecies and serving as a source population for reintroduction efforts.

METHODS

San Joaquin kit fox carcasses were recovered by the Endangered Species Recovery Program (ESRP; California State University–Stanislaus) in an ongoing monitoring effort dating back to 1977. Approximately 10-20 carcasses were recovered per year from both urban (Bakersfield) and non-urban (Lokern) areas. The Lokern Natural Area is 40,000 acres of high-quality habitat located approximately 30 miles west of Bakersfield. The land is managed by a number of owners, including the California Department of Fish and Game and the Bureau of Land Management. The management objective is to maintain a functioning desert ecosystem for a number of sensitive species, including Kern mallow *Eremalche kernensis*, giant kangaroo rat *Dipodomys ingens*, Tipton kangaroo rat *Dipodomys nitratoides nitratoides*, San Joaquin antelope squirrel *Ammospermophilus nelsoni*, blunt-nosed leopard lizard *Gambelia sila*, and San Joaquin kit fox. Thirty San Joaquin kit fox liver samples from Bakersfield and 12 Lokern liver samples were analyzed. Two liver samples from red foxes recovered from Bakersfield, and one from a coyote recovered from Lokern, were also analyzed.

Liver tissue was homogenized by the DFG Pesticide Investigations Unit in Rancho Cordova, CA, and analyzed by DFG Water Pollution Control Laboratory in Rancho Cordova, CA, using high performance liquid chromatog-

Table 1. Anticoagulant residues in San Joaquin kit fox livers collected in Lokern (in ng/g fresh weight)**. ND = not detected.**

Individual	Brodifacoum	Bromadiolone	Chlorophacinone	Diphacinone	Warfarin	Pival
1	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND	ND
7	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND	ND
9	ND	ND	ND	ND	ND	ND
10	ND	ND	ND	ND	ND	ND
11	ND[1]	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
12	ND[1]	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
Detection limit	0.2	0.2	2	2	1	2

[1]Detection limit = 7 ng/g, fresh weight.
[2]Detection limit = 50 ng/g, fresh weight

Table 2. Anticoagulant residues in San Joaquin kit fox livers collected in Bakersfield (in ng/g fresh weight)**. ND = not detected.**

Individual	Brodifacoum	Bromadiolone	Chlorophacinone	Diphacinone	Warfarin	Pival
1	ND	13.3	ND	ND	ND	ND
2	0.678	ND	ND	ND	ND	ND
3	0.466	2.18	ND	ND	ND	ND
4	0.2	ND	ND	ND	ND	ND
5	0.2	1.17	ND	ND	ND	ND
6	1703	770	246	ND	ND	ND
7	ND	ND	ND	ND	ND	ND
8	66.4	3123	ND	ND	ND	ND
9	9855	131	ND	ND	ND	ND
10	5662	786	ND	ND	ND	ND
11	1248	902	ND	ND	ND	ND
12	4138	304	ND	ND	ND	ND
13	2818	79.2	ND	ND	ND	ND
14	2642	2477	ND	ND	ND	ND
15	8648	148	ND	ND	ND	ND
16	132	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
17	161	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
18	ND[1]	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
19	191	ND[1]	ND[2]	ND[2]	ND[1]	6.93
20	122	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
21	706	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
22	381	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
23	19	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
24	ND[1]	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
25	296	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
26	9	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
27	91	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
28	373	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
29	130	140	ND[2]	ND[2]	ND[1]	ND[2]
30	11,000	ND[1]	ND[2]	ND[2]	ND[1]	ND[2]
Detection limit	0.2	0.2	2	2	1	2

[1]Detection limit = 7 ng/g, fresh weight.
[2]Detection limit = 50 ng/g, fresh weight

Table 3. Anticoagulant residues in other predator livers collected in Bakersfield and Lokern (in ng/g fresh weight)**.**

Species	Location	Brodifacoum	Bromadiolone	Chlorophacinone	Diphacinone	Warfarin	Pival
Red fox	Bakersfield	3667	67.9	ND	ND	ND	ND
Red fox	Bakersfield	838	974	ND	ND	ND	ND
Coyote	Lokern	ND	ND	ND	ND	ND	ND
Detection limit		0.2	0.2	2	2	1	2

raphy with mass spectrometry analysis. Anticoagulants analyzed were brodifacoum, bromadiolone, chlorophacinone, diphacinone, pival, and warfarin. Detection limits varied among anticoagulants with generally lower detection levels in the later analyses as laboratory methods were refined (Table 1).

RESULTS

San Joaquin kit fox livers taken from Lokern contained no residues of anticoagulants (Table 1). Of the 30 livers tested from Bakersfield, 26 (87%) contained residues of brodifacoum, 13 (43%) contained residues of bromadiolone, one contained a residue of chlorophacinone, and one contained a residue of pival (Table 2). Anticoagulant residues, expressed as fresh weight, were as high as 11,000 ng/g for brodifacoum (mean of 1,960 ng/g for all samples with detections), 3,123 for bromadiolone (mean of 661 ng/g for all samples with detections), 246 ng/g for chlorophacinone, and 6.93 ng/g for pival. Livers of two red foxes *V. vulpes* from Bakersfield were also analyzed and both contained both brodifacoum and bromadiolone (Table 3). A coyote liver from Lokern contained no anticoagulant residues (Table 3).

DISCUSSION

Results from this study confirmed that San Joaquin kit foxes are exposed to anticoagulants in urban environments. Eighty-seven percent of San Joaquin kit foxes in Bakersfield had been exposed to anticoagulant rodenticides, compared to none taken at the control site. The most commonly detected rodenticides, brodifacoum and bromadiolone, are registered for use only against commensal rodents. This suggests that commensal rodents are likely the source of secondary exposure for San Joaquin kit foxes. Further study on the predation habits of San Joaquin kit foxes would be helpful to determine route of exposure.

There was a single detection of pival, a first-generation anticoagulant rodenticide. The detection was in a fox that died in 2002, when all registrations for pival had been inactive for a decade or more. This product is less persistent in animal tissues than the second-generation anticoagulants, making secondary poisoning less likely. It is possible that this exposure was due to a improper disposal of an old product.

It has been noted that the lower detection limits for second-generation anticoagulant rodenticides than for the first-generation products could partially explain the greater number of detections of the newer products. However, the data in this study do not support this, as the majority of detections of the second-generation products were well above the higher detection limits used for the older products. A total of 22 out of 26 detections for brodifacoum and 12 out of 13 detections for bromadiolone were above 2 ng/g (the detection limit for first-generation anticoagulants).

The U.S. Environmental Protection Agency issued a risk mitigation decision for 9 rodenticides in May 2008. This decision will prohibit the sale of second-generation anticoagulants to homeowners, beginning in 2011. There will be a need to continue sampling to determine the effectiveness of the regulation change in reducing exposure of San Joaquin kit foxes and other predators. This is particularly true, as it is not known whether misuse or proper use of these products has resulted in secondary exposure. It will also be important to monitor first-generation anticoagulant rodenticides, as the regulations will likely result in a more frequent use of the older products by homeowners.

The consequences of anticoagulant exposure to predators are not fully known. It is likely that impairment of normal clotting factors makes animals more susceptible to excessive bleeding from minor injuries. Several studies also indicate that sub-lethal concentrations of second-generation anticoagulants may cause mortality to embryos (Laas et al. 1985, Godfrey and Lyman 1980, Munday and Thompson 2003). Population impacts that jeopardize recovery efforts of San Joaquin kit foxes may occur as a result of widespread anticoagulant exposure.

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