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Influence of Poisoned Prey on Foraging Behavior of Ferruginous Hawks

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ABSTRACT.— We recorded 19 visits by ferruginous hawks (*Buteo regalis*) over 6 d at two black–tailed prairie dog (*Cynomys ludovicianus*) subcolonies poisoned with the rodenticide Rozol® Prairie Dog Bait (0.005% chlorophacinone active ingredient) and at an adjacent untreated subcolony. Before Rozol® application ferruginous hawks foraged in the untreated and treated subcolonies but after Rozol® application predation by ferruginous hawks was only observed in the treated subcolonies. We suggest that ferruginous hawks' preference for hunting in the treated subcolonies after Rozol® application was influenced by the availability of easy-to-capture prey, presumably due to Rozol® poisoning. The energetically beneficial behavior of favoring substandard prey may increase raptor encounters with rodenticide exposed animals if prey vulnerability has resulted from poisoning.

INTRODUCTION

Foraging decisions are a compromise between the energetic costs of searching for, capturing, and subduing prey plus the risks of injury from the defending prey and the nutritional and energetic benefits derived from feeding on the prey. Therefore, raptors may preferentially take substandard prey because these animals display decreased vigilance, a poor ability to escape, and reduced defenses compared to healthy conspecifics (Hoogland *et al.*, 2006; Genovart *et al.*, 2010). This behavioral adaptation has allowed raptors to efficiently exploit food resources, but the beneficial behavior of favoring substandard or dead prey also can be a detriment to a raptor, *i.e.*, when prey vulnerability results from poisoning (Chesser, 1979; Hunt *et al.*, 1992; Elliott *et al.*, 1997).

Ferruginous hawks (*Buteo regalis*, FEHA) that migrate through and winter in central and southern plains in the United States and eastern Mexico prey on black-tailed prairie dogs (*Cynomys ludovicianus*, BTPD; Plumpton and Andersen, 1997; Bak *et al.*, 2001). Black-tailed prairie dogs, however, are considered to be an agricultural pest and BTPD eradications often are promoted and conducted by county, state, and federal agencies (Lamb *et al.*, 2006; Miller *et al.*, 2007). Two first generation anticoagulant rodenticide products, Rozol® Prairie Dog Bait (0.005% chlorophacinone active ingredient; 2-[(p-chlorophenyl) phenylacetyl]-1,3-indandione, hereafter Rozol®) and Kaput-D® Prairie Dog Bait (0.005% diphacinone active ingredient; 2-diphenylacetyl-1,3-indandione,) are registered for BTPD control October 1–March 15 in 10 states. First generation anticoagulant rodenticides disrupt blood clotting that can lead to hemorrhaging and death in vertebrates (Pelfrene, 2001). Sublethal adverse effects can occur within 48 h of exposure but mortality may occur $\geq$1 wk after lethal exposure (Whisson and Salmon, 2009; Rattner *et al.*, 2011). Consequently, poisoned BTPDs (active, impaired, moribund, and dead) are available as prey for raptors (Vyas *et al.*, 2012).

While conducting a larger study to determine the hazards of Rozol® to wildlife, we hypothesized ferruginous hawk behavior would follow predictions of foraging theory, and they would prefer to hunt BTPDs in Rozol® treated areas because of the availability of easy-to-capture (poisoned) prey.

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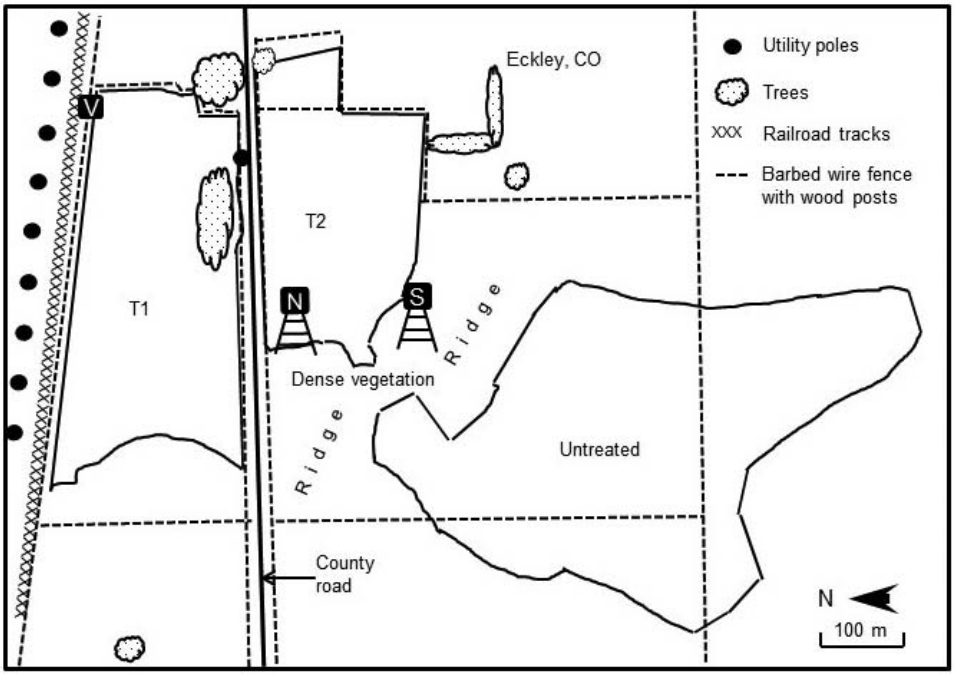

FIG. 1.—Map of the three black-tailed prairie dog (*Cynomys ludovicianus*) subcolonies at Eckley, Colorado, U.S.A. during January 2011. Subcolonies T1 and T2 were poisoned with Rozol® and the third colony (Untreated) did not receive Rozol® application. A ridge, dense vegetation, and a county road restricted black-tailed prairie dog movements among the subcolonies. Observations were conducted from N = north tower, S = south tower and V = vehicle

METHODS

STUDY SITE

The influence of Rozol® application on foraging behaviors of FEHAs was recorded at three subcolonies of a BTPD colony on a private pasture in Eckley, Colorado (40°6′45"N latitude and 102°29′22"W longitude; Fig. 1) in January–February, 2011. Two of the subcolonies (T1 and T2) were destined to be poisoned with Rozol®, and the third subcolony (untreated) did not receive Rozol® application. Subcolonies to be treated with Rozol® encompassed 16.3 ha and contained 1986 active BTPD burrows whereas the untreated subcolony was 16.8 ha and had 2032 active BTPD burrows.

SCAVENGER CARCASS-REMOVAL TRIAL

On the 4 d before Rozol® application and the 2 d of Rozol® application, a scavenger carcass-removal trial was conducted to document the loss of BTPD carcasses by scavengers from the three subcolonies. Twenty-two uncontaminated adult BTPD carcasses from the US Fish and Wildlife Service National Black-Footed Ferret Conservation Center, Wellington, Colorado were equally distributed to the treated and untreated subcolonies and four, eight, six, and four carcasses were randomly placed in the subcolonies on days 1–4 before Rozol®

application, respectively. Carcass locations were marked with a handheld GPS receiver (Garmin eTrex Summit® HC). On days 2–4 before Rozol® application and on the 2 d of Rozol® application, we conducted carcass searches to determine our carcass detection distance and scavenging activity. Our search patterns were alternated from north to south/south to north every other day to east to west/west to east. While conducting carcass searches, we opportunistically recorded FEHA activity in the subcolonies.

ROZOL® APPLICATION

Rozol® application was conducted on two consecutive days and hereafter, the 2 d are considered as day 0 of the study. Subcolonies T1 and T2 were poisoned with 112.6 kg of Rozol® according to the product label by certified pesticide applicators from the Yuma County Pest Control District as part of an ongoing BTPD control program. Black-tailed prairie dog movements among the subcolonies were restricted by a ridge, dense vegetation, and an unpaved, graded, secondary road, therefore the three subcolonies were considered independent of each other with respect to Rozol® treatment. The proximity of the treated and untreated subcolonies minimized spatiotemporal variability between the subcolonies and simplified determination of foraging preferences by the raptors.

DATA COLLECTION

Black-tailed prairie dog activity and FEHA foraging behavior were documented between 0930 and 1600 h on days 8–11 and 16 and 17 post Rozol® application. Observations were initiated 1 wk after Rozol® application based on the time course of adverse effects for chlorophacinone (Whisson and Salmon, 2009; Vyas *et al.*, 2012) and no observations were made on days 12–15 and after day 17 post application because of weather conditions that restricted above ground BTPD activity. Data were collected using binoculars (Nikon Monarch 3 8x42 ATB) and video cameras (Panasonic SDR-H80, JVC GZ-MG630, and Sony DCR-SR47) from two tower blinds (approximately 3.7 m high) and from a stationary vehicle at the northeast corner of the colony (Fig. 1). Three observers simultaneously monitored the three subcolonies to ensure visual coverage of the study area: one observer in each of the two towers and one observer in the stationary vehicle. Each tower provided a 360° view but the north tower primarily was used for observing the two treated subcolonies, whereas the south tower allowed scanning of the untreated subcolony. The vehicle facilitated observations on a small area in T1 that was blocked from view from the towers by trees. Observers in the tower blinds were rotated daily to reduce observer bias.

BLACK-TAILED PRAIRIE DOG ACTIVITY

The numbers of BTPDs active above ground in the three subcolonies were counted hourly from blinds to document their potential availability as prey for FEHAs. Changes in BTPD numbers over time in the subcolonies were analyzed by the Mann-Kendall test (https://www.researchgate.net/file.PostFileLoader.html?id=55bba3666225ff21e88b4569&assetKey=AS%3A273823084023809%401442295918401).

FERRUGINOUS HAWK FORAGING

Ferruginous hawk presence and duration of activity in the subcolonies were documented. Because FEHAs were not marked, after the FEHA had flown out of the three subcolonies and was out of our sight, it was not possible to reliably determine if the next conspecific that

was sighted was the same individual as the one observed earlier. Therefore, the FEHA count represents the number of FEHA visits to the colony. The amount of time a FEHA spent in the subcolonies (soaring, perched on trees and utility poles, and fence posts within and along the perimeter of the study area, perched on the ground at prey, and perched on the ground without prey) was documented from the first sighting to the last observation of that raptor. We used 'at prey' instead of the amount of a time a raptor spent consuming the prey because the raptors did not continuously feed while standing on the prey item and at times, other birds landed close to the bird that was in control of the food, challenging and displacing the feeding bird. Therefore, 'at prey' includes raptors feeding, standing over the prey, standing close to an unclaimed food item, or standing close to the raptor in control of the prey. We used 'perched on ground without prey' to describe FEHAs that perched on the ground where no above ground BTPD activity was observed within ~90 m of the hawks. Ferruginous hawks observed soaring in and out of the subcolonies without landing were allotted 1 min of time. The amount of time FEHAs spent in untreated and treated subcolonies was compared by the Tukey-Duckworth Procedure (http://www.ohio.edu/plantbio/staff/mccarthy/quantmet/lectures/Nonparm.pdf).

Predations by FEHAs were documented from the blinds and through discovery of preyed upon BTPDs during carcass searches conducted at the end of the daily observation period after the FEHAs had departed from the study area. Carcass searches involved walking transects approximately 4 m apart. Transect spacing was based on the mean distance of detection during the scavenger carcass-removal trial.

RESULTS

SCAVENGER CARCASS-REMOVAL TRIAL

Eighteen of 22 BTPD carcasses placed in the three subcolonies were removed during the night within 24 h of placement, presumably by mammalian scavengers. Two BTPD carcasses were removed within 48 hr of placement and two carcasses were not scavenged for at least 3 d. On day 2 before Rozol® application, two BTPD carcasses placed in the untreated subcolony and one placed in the treated colony were found partially scavenged before being removed by scavenger the following night. One of the carcasses in the untreated subcolony attracted a FEHA within 4 h of placement. Although we did not witness raptors at the two other partially scavenged BTPD carcasses, since raptors could not carry off the BTPD prey and fed at the site of carcass placement, the discovery of partially scavenged carcasses served as evidence of raptor foraging. We suspect FEHAs scavenged these two carcasses because five opportunistic sightings of FEHAs were recorded on that day. Opportunistic counts of FEHA ranged 1–5 sightings per day and the greatest number of FEHA sightings occurred on day 2 before Rozol® application. No other signs of predation or scavenging were observed during carcass removal trial. Ferruginous hawks were seen on all days during the scavenger carcass-removal trial and on the Rozol® application days.

BLACK-TAILED PRAIRIE DOG ACTIVITY

The numbers of BTPDs in the untreated subcolony showed no significant trend over time (Mann-Kendall 2-tailed $S = -7$; $P > 0.05$). However, a significant declining trend was detected in the numbers of BTPDs over time in the treated subcolonies (Mann-Kendall 2-tailed $S = -13$; $P < 0.05$).

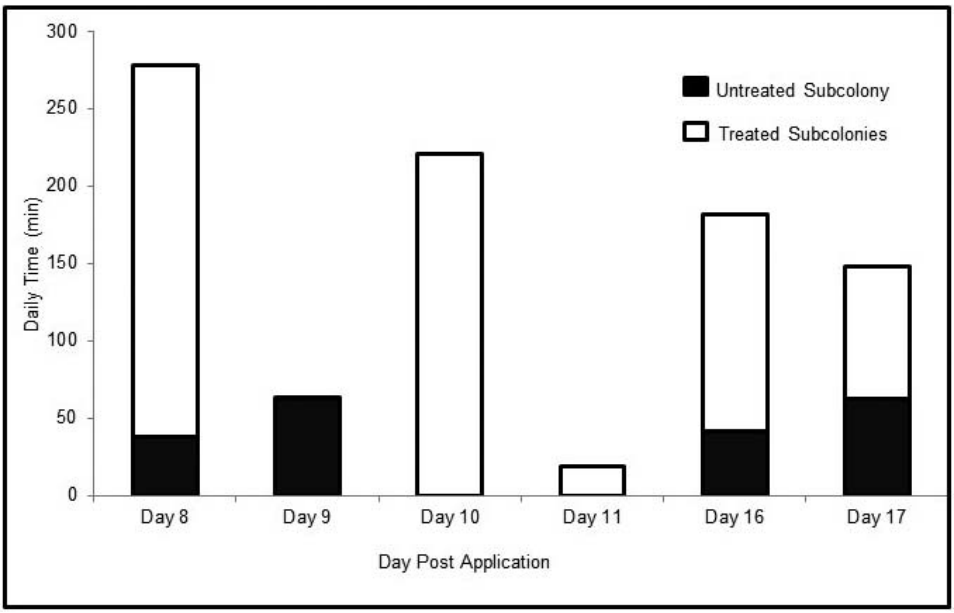

FIG. 2.—Amount of time that ferruginous hawks (*Buteo regalis*) spent in the untreated and Rozol® treated subcolonies of a black-tailed prairie dog (*Cynomys ludovicianus*) colony at Eckley, Colorado, U.S.A. during six observation days in January–February 2011

FERRUGINOUS HAWK FORAGING

We recorded 19 visits by FEHAs at the three subcolonies after Rozol® application. Ferruginous hawks spent 911 min in the three subcolonies over the six observation days: 203 min in the untreated subcolony and 708 min in the treated subcolonies (Fig. 2). The amounts of time FEHAs spent in the untreated and treated subcolonies were not significantly different (Tukey-Duckworth $C = 6$, $P > 0.05$). While in the treated subcolonies, FEHAs spent 310 min (daily range 0 min–194 min) at prey. Ferruginous hawks also perched on the ground without prey (no BTPDs active above ground observed within ~90 m of the FEHA) for 72 min (daily range 0 min–32 min) and 175 min (daily range 0 min–90 min) in the untreated and treated subcolonies, respectively.

Four predations by FEHAs were observed on days 10, 16 and 17 post application. Two predations occurred on day 10 post application and one predation was observed on days 16 and 17 post application. Predations were only observed in the treated subcolonies even though FEHAs spent time in the untreated subcolony. Ferruginous hawks spent time in the treated subcolonies on 6 d whereas they spent time in the untreated colony on 4 d. All preyed upon animals were BTPDs. No other evidence (*i.e.*, fur, blood, partial carcass) of predation or scavenging was found during carcass searches in the treated and untreated subcolonies. We also did not see failed hunting attempts by FEHAs. On days 10 and 16 post application, FEHAs that captured prey attracted two and one additional FEHAs, respectively. Three aggressions by FEHAs on conspecifics resulted in displacement of the feeding birds whereas two encounters were unsuccessful. Aggressive behaviors were similar to those described by Bechard and Schmutz (1995) and included lunging at a nearby bird, swooping

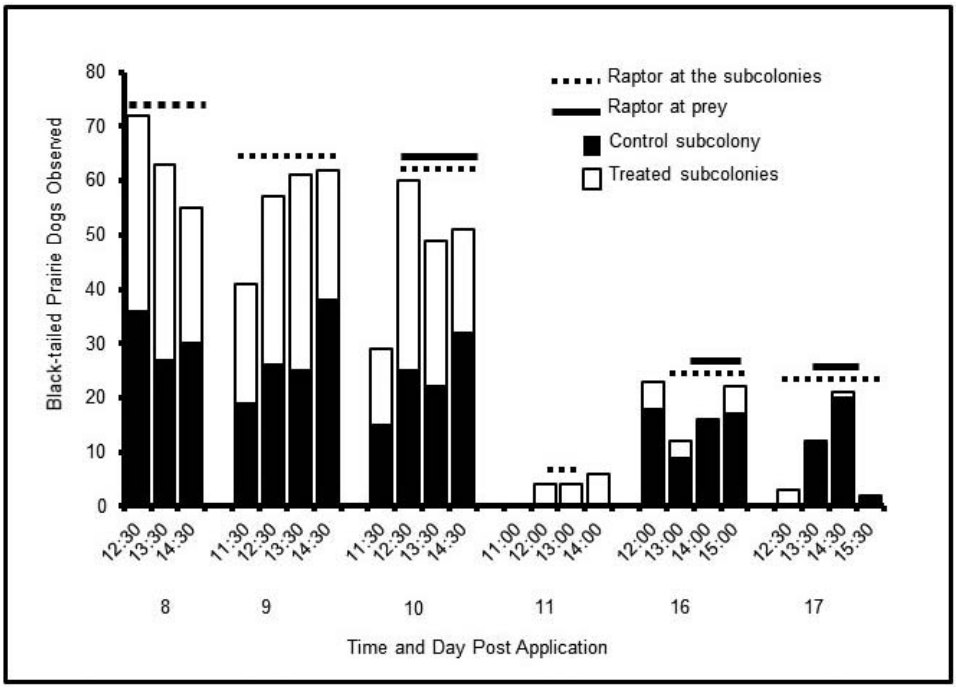

FIG. 3.—Number of black-tailed prairie dogs (*Cynomys ludovicianus*) observed above ground in the untreated and treated subcolonies after Rozol® application at Eckley, Colorado, U.S.A. during six observation days in January–February 2011. The dashed lines above the prairie dog counts show when at least one ferruginous hawk (*Buteo regalis*) was present in the untreated or treated subcolonies. The solid lines depict when at least one ferruginous hawk was at prey. Black-tailed prairie dogs were available to ferruginous hawks as prey in the untreated and treated subcolonies and ferruginous hawks were observed in all three colonies but all predations occurred in the treated subcolonies

low over a bird at prey, chasing the intruding bird on foot, snapping beaks, erecting feathers, lifting wings, and cupping wings to shelter the prey from other birds.

DISCUSSION

Foraging theory postulates that raptors should hunt such that they minimize their energy expenditure and maximize their net energy intake (Pyke *et al.*, 1977). The decision to forage in a particular area is based on prey availability and accessibility (Bechard, 1982; Preston, 1990) and the decision to prey on a particular animal is influenced by its vulnerability (Temple, 1987; Hoogland *et al.*, 2006). Black-tailed prairie dogs are large (700–1500 g, Hoogland and Foltz, 1982), colonial, diurnal rodents that provide FEHAs a concentrated food source in winter when other food is scarce. Black-tailed prairie dogs at our subcolonies were available as potential prey in the untreated and treated subcolonies while FEHAs foraged in the subcolonies (Fig. 3). A significant downward trend was detected in the numbers of BTPDs for the treated subcolonies over time but not for the numbers of BTPDs in the untreated subcolony. Because the proximity of the three subcolonies minimized

geographic and meteorological variations among the subcolonies, the decline in the numbers of BTPDs in treated subcolonies is attributed to chlorophacinone toxicity.

Surface BTPD availability is affected by meteorological factors including temperature, wind velocity, and precipitation (Tileston and Lechleitner, 1966; Lehmer *et al.*, 2003). Day 11 post application experienced fog and freezing rain and although no BTPDs were observed in the untreated subcolony, 14 BTPDs foraged above ground in the treated subcolonies. Captive BTPDs that were provided an ad libitum Rozol® diet suffered signs similar to diarrhea until the diet was supplemented with hay (Vyas, unpubl. data). The BTPDs in the treated subcolonies may have surfaced on day 11 post application to forage on vegetation despite unfavorable weather because of chlorophacinone's physiological effects.

Prey accessibility is affected by vegetation cover and perch availability. Visual obstruction of prey by vegetation in the three subcolonies was negligible because of grazing by BTPDs (Agnew *et al.*, 1986; Winter *et al.*, 2002) and plant winter dormancy and senescence. Elevated perch availability (trees, utility poles, fence posts) differed between the untreated and treated subcolonies. The two treated subcolonies had tall perches (telephone and utility poles and trees) along their perimeters and had ~2519 m of barbed wire fencing with wood fence posts. The control subcolony lacked tall perches and had ~597 m of the fencing (Fig. 1). However, FEHAs readily hunt perched on the ground or from soaring flight, therefore are not restricted in their foraging by a paucity of elevated perches (Wakeley, 1978; Janes, 1985; Bechard and Schmutz, 1995). During the scavenger carcass-removal trial, FEHAs foraged on the BTPD carcasses placed by us in the untreated subcolony despite the lack of trees and utility poles. After Rozol® application, FEHAs captured prey in the treated subcolonies from soaring flights and did not use the available elevated perches to initiate their hunts.

When more than one prey is available and accessible, raptors may select individuals based on their vulnerability (ease of capture) and the costs (energetics and risk of injury from the defending prey) of capturing healthy conspecifics (Temple, 1987; Ille, 1991; Taylor, 2009). Black-tailed prairie dogs in a Rozol® poisoned colony can exhibit a spectrum of vulnerabilities to predation, ranging from overtly healthy to dead animals for at least 4 wk after Rozol® application (Vyas *et al.*, 2012). Healthy BTPDs, when threatened, give alarm calls, run to their burrows, and if captured, attempt escape by biting the raptor's feet whereas Rozol® poisoned BTPDs are easily captured because of lethargy and reduced alertness (Vyas *et al.*, 2012).

Ferruginous hawks at our study site appeared to optimize their foraging before and after Rozol® application by taking easy-to-capture prey. During the scavenger carcass-removal trial, raptors fed only on the BTPD carcasses placed as part of the trial in the three subcolonies. No signs of predation were found although live BTPDs also were available above ground. After Rozol® application, FEHAs captured prey only in the treated subcolonies even though >80% of the above ground BTPDs in the three subcolonies were available in the untreated subcolony (Fig. 3). Additionally, after Rozol® application, FEHAs captured all prey in the treated subcolonies using high altitude soaring-flight, a hunting method used for vulnerable prey (Wakeley, 1978). Therefore, we suspect that after Rozol® application, FEHAs were drawn to the BTPDs in the Rozol® treated subcolonies because the animals were easy-to-capture, presumably due to Rozol® poisoning.

Before and after Rozol® application, FEHAs appeared to follow predictions of foraging theory by hunting easy-to-capture prey. Ferruginous hawks are designated as one of the Birds of Conservation Concern in the United States (U.S. Fish and Wildlife Service, 2008) and as Threatened in Canada (Committee on the Status of Endangered Wildlife in Canada, 2008).

Although our observations are limited by our small sample size on a single species at a single BTPD colony, our findings offer information towards conservation of FEHAs. First, the importance of BTPDs to FEHAs in winter, compounded with the FEHAs' preference for easy-to-capture prey, suggests a potentially greater risk of secondary poisoning for FEHAs if the prey vulnerability has resulted from poisoning. Second, in an effort to reduce the risks to raptors, the current Rozol® and Kaput-D® Prairie Dog Bait labels require rodenticide applicators to conduct follow-up visits to the poisoned colonies at one to two day intervals to remove above ground poisoned BTPDs (http://www.liphatech.com/uploads/files/pdf/US/Labels/Rozol/ENG_RZ_PrairieDogBait_Label.pdf; http://www.kaputproducts.com/wp-content/uploads/2013/07/72500-22-50lbKaput-D-Prairie-Dog-Label.pdf). However, many applicators consider the follow-up visits to be laborious and unrealistic (Vyas, 2013). Our observations of FEHAs hunting easy-to-capture prey by foraging in Rozol® treated areas supported the importance of the risk mitigation requirements on the pesticides' labels. Lastly, documentation of FEHAs' preference for vulnerable prey can improve rodenticide exposure encounter estimates in ecological risk assessments. An understanding of how foraging behavior modulates exposure to poisoned prey can aid risk assessments and guide hazard mitigation strategies.

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