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POSTER

Consumption of Rat Carcasses as a Pathway of Rodenticide Exposure of Wildlife in Southern California

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ABSTRACT: The high toxicity and effectiveness of anticoagulant rodenticides have led to their widespread use for controlling rodent pests; however, significant concerns remain about the potential exposure of non-target wildlife species at the urban-wildland interface. Such species can be exposed by consuming toxic baits directly, or indirectly, by scavenging rodenticide-killed prey (secondary exposure). To investigate opportunities for secondary exposure, we used Reconyx digital game cameras to quantify the fates of 20 rat carcasses placed in residential backyards in Orange County, California. We anchored rat carcasses to the ground and then followed their fates for seven days or until carcasses were removed. We also recorded yard characteristics (e.g., vegetation density, permeability of exterior barriers, presence of pets, water, and anthropogenic foods) to help explain variation in carcass removal rates between yards. Rats were discovered fairly quickly, with 35% of carcasses visited within 24 hours. Thirteen carcasses (65%) were removed within seven days, with Virginia opossums and corvids removing the most carcasses (9/13). Coyotes, free-roaming cats, striped skunks, and black rats also consumed rat carcasses, which, by the end of the trials, had attracted scavenging arthropods that then also appeared to be eaten. Yards from which carcasses were routinely removed had relatively low vegetation density; pets, water sources, and anthropogenic foods; and barrier types that permitted movement by wildlife into the yard. Our results improve our understanding of the routes by which native carnivores and scavengers are exposed to rodenticides in suburban settings and can be used to improve pest management practices.

KEY WORDS: carcasses, pest management, *Rattus*, rodenticides, scavenging, secondary rodenticide exposure, southern California, urban wildlife

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INTRODUCTION

Throughout human history, commensal rodents have had detrimental effects on human infrastructure, food storage, and public health (Stenseth et al. 2003). Anticoagulant rodenticides are the most widespread and effective method of controlling populations of commensal rodents, such as Norway and black rats (*Rattus norvegicus* and *R. rattus*, respectively) and house mice (*Mus musculus*) (Rattner et al. 2014). However, in areas of the U.S. where natural areas are juxtaposed with large urban and suburban populations where rodent control may be necessary, the potential for non-target poisoning of wildlife species is great. Indeed, mammalian predators such as coyotes (*Canis latrans*) (Riley et al. 2003), bobcats (*Lynx rufus*) (Serieys et al. 2015), and mountain lions (*Puma concolor*) (Riley et al. 2007) are exposed to rodenticides at the urban-wildland interface in southern California. It is expected that these carnivores are exposed secondarily or perhaps, tertiarily, by ingesting prey intoxicated by rodenticides, but the exact pathway of exposure in unclear. For example, mesopredators such as skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), and free-roaming cats (*Felis catus*), which could scavenge carcasses of commensal rodents, might themselves be consumed by these higher-level predators (e.g., Crooks and Soulé 1999).

To better understand how non-target wildlife species could be exposed to rodenticides secondarily, we investigated the removal rates of rat carcasses from residential backyards in suburban areas in Orange County, California. The objectives of our study were to determine the removal rates of rat carcasses from residential areas, and to identify the types of wildlife species that find and are capable of consuming carcasses, which would potentially expose them to rodenticides.

METHODS

Carcasses of domestic rats (*R. norvegicus domestica*) were placed in 20 residential yards throughout Orange County, California. Of the 20 areas sampled, 19 were in the backyards of Orange County Master Gardeners. Master Gardeners are residents who are trained by the University of California Cooperative Extension to educate their neighbors about regionally-appropriate gardening practices, including reducing water use, implementing safe pest management practices, and promoting the use of native plants. One additional carcass was placed in a community garden that had landscape features that were similar to those of the backyards of the Master Gardeners. Carcasses were only placed in each yard once to avoid pseudoreplication. Field work was conducted in February and March 2019.

A Reconyx PC800 infrared digital camera (Reconyx, Holmen, WI) was used to capture images of carcass visitation or removal. Rat carcasses were purchased frozen from an online pet food supplier (RodentPro.com) where they had not been exposed to any rodenticides. Carcasses with a darker brown pelage were chosen instead of the typical white morph to more closely resemble the natural coloration of commensal rats in the region. Carcasses were attached with a plastic zip-tie to a metal cable that was anchored in the ground. The anchoring process ensured that removing the carcass would require considerable effort to remove it, increasing the likelihood that details of removal events would be captured by the camera. Sites were sampled for a maximum of seven days, or until the rat carcass was completely removed. This period was chosen based on previous studies, (e.g., Erickson and Urban 2004), that have suggested that the effects of poisoning appear within three to seven days. In addition, carcasses were significantly decomposed and infested with arthropods by seven days of exposure, presumably reducing their palatability (Brakes 2003) and, potentially, the amount of rodenticide that would be present in the tissues if they had been poisoned.

After seven days, the cameras were retrieved, and the extent of carcass removal was noted. Qualitative yard characteristics such as barrier composition (fences, brick or block walls), vegetation density, presence of food and water sources, and the presence of pets were recorded for each yard. Sources of food and water consisted mostly of anthropogenic items such as bird feeders, bird baths, and swimming pools. Vegetation density was categorized as low, medium, or high, based on a visual assessment of the overall plant cover in the yard.

For each camera image, the time, date, species, and species behavior were recorded. Images were placed into three different categories (presence, interaction, removal) that reflected the amount of interaction between the carcass and visitors. Presence was defined as any animal that photographed in the same camera image as the carcass. Interaction was defined as an image showing any behavior that indicated the visitor was aware of the carcass (e.g., by sniffing or pawing at it). Removal was defined as a behavior or action in which the visitor physically removed the carcass or penetrated the body cavity, where it would have been exposed to rodenticide residues if they had been present. Images that were captured after the carcass had been completely removed were not included.

RESULTS AND DISCUSSION

In all, 95% (n = 19) of the 20 rat carcasses were discovered and interacted with by at least one vertebrate species over the seven-day period. Eight of the carcasses were completely removed, whereas five had signs of partial removal (65%; Figure 1). Seven carcasses (35%) were removed within the first 24 hours. Seven different species wholly or partially removed carcasses. Virginia opossums (five carcasses; three on Day 1, one each on Days 3 and 4) and coyotes (two carcasses, Day 1 and Day 5) completely removed carcasses by tearing them from their anchors. A striped skunk and domestic cat together also removed one carcass (Day 1 and 2), and a black rat (*R. rattus*) partially removed another (Day 7). Corvids [American crows (*Corvus brachy-rhynchos*) and common ravens (*C. corax*)] partially consumed four carcasses, two of the four on Day 1, and interacted with a fifth. A woodrat (*Neotoma macrotis*), fox squirrel (*Sciurus niger*), desert cottontail (*Sylvilagus audubonii*) and bobcat (*Lynx rufus*) also interacted with, but did not attempt to remove, rat carcasses. In two instances, both on Day 7, a crow and rat were observed eating insects (most likely larvae of blow-flies, Calliphoridae) that had infested the rat carcasses. Although it is not clear how much rodenticide the maggots would have been exposed to if the rat actually died from rodenticide poisoning, consumption of invertebrate scavengers represents another possible pathway of exposure of scavengers (Eason et al. 2002, Elliott et al. 2014, Alomar et al. 2018).

Figure 1. Kaplan-Meier survival curve showing the proportion of 20 rat carcasses remaining in backyards in Orange County, California, over the seven days of trials in February and March, 2019.

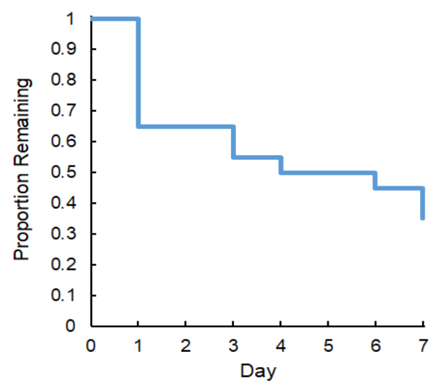

Table 1. Removal rates of rat carcasses as a function of backyard characteristics in Orange County, California, during February and March 2019. Carcasses removed by corvids were omitted from analyses of effects of barrier type because birds were not expected to perceive these structures as barriers.

Yard Characteristic (n)	# Carcasses Removed (%)
Vegetation density	
High (2)	1 (50)
Medium (10)	5 (50)
Low (8)	7 (88)
Anthropogenic food (8)	7 (88)
Water (13)	9 (69)
Pets (10)	6 (60)
Barrier type	
Solid (brick/wood/plastic; 12)	3 (25)
Chain-link (4)	3 (75)
Plastic slats (1)	1 (100)
None (3)	2 (66)

Even with a relatively small sample size, we found that yards with less vegetation and the presence of anthropogenic foods and water tended to be associated with higher removal rates (Table 1). It is possible that carcasses placed in yards with less vegetation were more easily discovered, and thus more likely to be removed. Yards with water and anthropogenic foods may have already had large populations of rats, which, in turn, could attract predators such as those that visited carcasses. For larger-bodied visitors such as coyotes and bobcats, fences and walls seemed to be significant barriers because we did not record any images of these species in yards with fences or walls. Fences that had more openings, such as chain-link or plastic slats, had higher removal rates than solid fences and walls (Table 1). The only mammal that was able to consistently overcome solid external barriers was the opossum, which accounted for all three carcass removals in yards with solid barriers. Although opossums are common scavengers in urban and rural areas of North America (e.g., DeVault et al. 2004, Olson et al. 2016), previous studies indicate that raccoons are the often most common scavengers of animal carcasses (Devault and Rhodes 2002, DeVault et al. 2003). Raccoons did not remove any of our carcasses, however, and do not appear to be as common in the suburban landscape of southern California as opossums, based on visitations to rodenticide bait stations (Burke et al. 2020) and their rarity in diet of coyotes (Shedden et al. 2020)

The high rates at which rat carcasses were discovered (95%) and removed (65%; 35% within the first 24 hours) suggests that carcass consumption could be a significant pathway for secondary rodenticide exposure in urban and suburban environments. Working in an agricultural setting, Brakes (2003) also reported a rapid rate of rat carcass removal (38%) within 24 hours. Likewise, in an intensively farmed region of Indiana, DeVault et al. (2011) found that rat carcasses were removed quickly within the first two days, which they attributed, in part, to the high local densities of raccoons and opossums. The high rates of carcass discovery and removal in both urban (see also Inger et al. 2016) and agricultural environments appear to contrast with the slower rates reported in more natural settings (DeVault et al. 2003). Because rodenticide use is likely to be higher in former areas as well, care should be taken to remove carcasses regularly in association with any rodenticide application to minimize their availability to scavengers, which could potentially expose higher-level predators to rodenticides.

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