Journal of Arid Environments 189 (2021) 104476

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Short communication

Predation on desert tortoises (*Gopherus agassizii*) by desert canids

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ARTICLE INFO

Keywords:
Dietary analysis
Canis latrans
Mojave desert
Prey availability
Scat
Vulpes macrotis arsipus

ABSTRACT

Desert tortoises (*Gopherus agassizii*) are a long-lived reptile vulnerable to predation by many predators, including desert kit foxes (*Vulpes macrotis arsipus*) and coyotes (*Canis latrans*). From 2009 to 2014, we assessed canid food habits at a study site in the Mojave Desert in California, USA, by collecting and analyzing desert kit fox and coyote scats. These canids primarily consumed small mammals and invertebrates. Desert tortoise remains occurred at an overall low frequency (<3%), indicating the opportunistic use by these canids of desert tortoise as a prey or scavenged food item. When we analyzed the desert tortoise remains further, there was a significant difference between predator type and desert tortoise age class. Coyotes consumed more than twice as many adult than juvenile desert tortoises, while desert kit foxes only consumed juveniles. Desert kit foxes are a small canid, thus limited to smaller prey items (i.e., juvenile desert tortoises), while coyotes are larger and can optimize a wider size range.

Desert tortoises (*Gopherus agassizii*) are a long-lived, desert-adapted species that occur throughout the Mojave and Colorado Deserts in Arizona, California, Nevada, and Utah (U.S. Fish and Wildlife Service [USFWS] 1994). The slow growing reptiles are typically found in creosote bush (*Larrea tridentata*) scrub habitat that has a high diversity of perennial plant cover, sandy-gravel soils that are fragile enough to dig burrows in but dense enough to not collapse, and relatively sparse annual rainfall (<20 cm; Germano et al., 1994; USFWS, 1994). Although desert tortoise nests contain multiple eggs, few make it to adulthood due to natural (i.e., dehydration, extreme temperature, disease) and anthropogenic mortality factors associated with a harsh desert landscape (Bjurlin, 2001; Peterson 1994; USFWS 1994, 2011). Desert tortoises in California are listed as both federally and state threatened (California Department of Fish and Wildlife, 2019; USFWS, 2011) primarily due to mortality from anthropogenic events including vehicle strikes, wildfires, and substantial changes to their habitat from urbanization, livestock grazing, off-highway vehicle use, and renewable energy facility construction (Boarman, 2002; Tuma et al., 2016; USFWS 1994, 2011).

Desert tortoises, particularly hatchlings, are also susceptible to predation by a multitude of animals (Boarman, 2002; Germano, 1994; USFWS, 2011). Many mammalian and avian species, including coyotes (*Canis latrans*), desert kit foxes (*Vulpes macrotis arsipus*), American badgers (*Taxidea taxus*), common ravens (*Corvus corax*), and red-tailed hawks (*Buteo jamaicensis*), are known to prey upon desert tortoises or their carcasses (Boarman, 2002; USFWS, 2011). There have been multiple instances where hundreds of juvenile desert tortoise shells were found under known raven nests (Campbell, 1983; Woodman and Juarez, 1988) and desert tortoise nest sites were destroyed from what was inferred to be desert kit fox predation (Bjurlin and Bissonette, 2004). To a lesser degree, adult desert tortoises also are subject to predation. Carcasses have been found with wounds consistent with coyote predation (Peterson, 1994). However, it can be difficult to determine if a desert tortoise died directly due to predation or was scavenged after dying from other causes (Boarman, 2002).

Both coyotes and desert kit foxes are known to prey upon or consume desert tortoise remains to varying extents, but only recently have large scale dietary analyses of these two canid species been conducted in the Mojave Desert in California (Cypher et al., 2018; Kelly et al., 2019). From 2009 to 2014, Cypher et al. (2018) and Kelly et al. (2019) collected and conducted dietary analyses on thousands of coyote and desert kit fox scats from the western Mojave Desert. Generalist coyotes preferentially consumed lagomorphs and heteromyid rodents (Cypher et al., 2018) while the more specialized desert kit fox primarily ingested heteromyid rodents and invertebrates (Kelly et al., 2019).

The consumption of desert tortoises did occur, but was relatively infrequent when compared to other prey items (Cypher et al., 2018; Kelly et al., 2019). To further understand the extent to which these two canid species were preying on desert tortoises in this particular area, we compared the frequency of occurrence of desert tortoise remains

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https://doi.org/10.1016/j.jaridenv.2021.104476
Received 25 August 2020; Received in revised form 31 December 2020; Accepted 18 February 2021

between coyote and desert kit fox scats. We also determined the approximate age of each desert tortoise to assess whether specific age classes were targeted by each of the canids.

Our 1500-km^2 study site, as described by Cypher et al. (2018), was located in the Mojave Desert north of Barstow, California, USA (Fig. 1). The sparse vegetation structure consisted of Mojave Desert scrub vegetation and, typical of an arid desert environment, mean annual precipitation was only 13.4 cm (Turner 1994; U.S. Climate Data 2014). The majority of the study area was comprised of public lands managed by the U.S. Bureau of Land Management with interspersed private property (Cypher et al., 2018). Nearby relatively sparsely populated.

Towns included Barstow, Hinkley, and Harvard, California. From Fall 2009 to Summer 2014, we collected coyote and desert kit fox scats as part of an investigation of coyote predation on desert tortoises (Cypher et al., 2018). Years were defined as October to September and scats were collected during the fall (October–December), winter (January–March), spring (April–June), and summer (July–September) seasons. To locate scats, a crew of two people slowly (i.e., <15 kph) drove along the multitude of dirt roads within the research site for three consecutive days during each season. Each scat that we located was individually bagged and labeled with the date and location coordinates. We also opportunistically collected scats during prey transect surveys and camera station surveys (Cypher et al., 2018; Kelly et al., 2019). Only fresh scats were collected; any scats that were dry and bleached white were not used in our study.

To safely process and analyze the canid scats, we followed the techniques outlined by Cypher et al. (2018). We heated all scats in a drying oven for 24 h at 60 C to destroy any eggs and cysts of zoonotic parasites. After drying, we placed each scat inside a nylon pantyhose that was tied with an identification marker. We then put wrapped scats into a mesh laundry bag, washed them in a standard household washing machine, and dried them in a household dryer for 60–120 min. This process removed soluble material leaving undigested food item remains.

To analyze each scat, we spread the remaining undigested material from each scat on a paper towel and carefully sorted through to identify food items. Any desert tortoise remains were carefully removed from the rest of the scat and put aside for further examination to determine the relative age of the desert tortoise. The desert tortoise remains were classified as either juvenile (<10 y old) or adult (>10 y old) based on the size of the fragments and visible growth rings on scutes.

The frequency of occurrence (FOO) of desert tortoise (number of scats with desert tortoise divided by the total number of scats) was determined for all years combined (Cypher et al., 2018; Kelly et al., 2019). We also calculated the FOO of desert tortoise by age class (adult or juvenile). We compared the FOO by age class between coyote and desert kit fox scats using a Fisher Exact Probability Test with $\alpha = 0.05$.

During the five-year study, we collected and analyzed 3,246 coyote scats and 1,230 desert kit fox scats. Of the 4,476 scats, only 123 contained desert tortoise remains (116 from coyote and seven from desert kit fox) (Fig. 2). Out of the 123 scats, two coyote scats had evidence of more than one individual desert tortoise's remains. Both coyote scats had remains of a juvenile and adult desert tortoise. The total FOO of desert tortoise for both canids combined was 2.75%. The FOO of desert tortoise remains in coyote scats was 3.57% while in desert kit fox scats it was 0.57%.

Of the 118 occurrences of desert tortoise remains in coyote scats, 30.51% were juvenile, 66.95% were adult, and 2.54% were unconfirmed. Of the seven occurrences of desert tortoise remains in desert kit fox scats, 100% were juvenile desert tortoise. There was a significant difference ($p < 0.001$) between age classes of desert tortoise consumed by the two predators. Coyotes in our study consumed more than twice as many adult desert tortoises than juvenile desert tortoises, while desert kit foxes only consumed juvenile desert tortoises. Of the seven juvenile desert tortoise occurrences in kit fox scats, six were from winter and one from summer. Coyotes ingested desert tortoises every season and to varying extents. Of the 118 desert tortoise occurrences in coyote scats, 38 (26 adult, 11 juvenile, 1 unconfirmed) were from fall, 29 (18 adult, 11 juvenile) were from winter, 37 (29 adult, 7 juvenile, 1 unconfirmed) were from spring, and only 14 (6 adult, 7 juvenile, 1 unconfirmed) were from summer. There was also temporal fluctuation in the number of

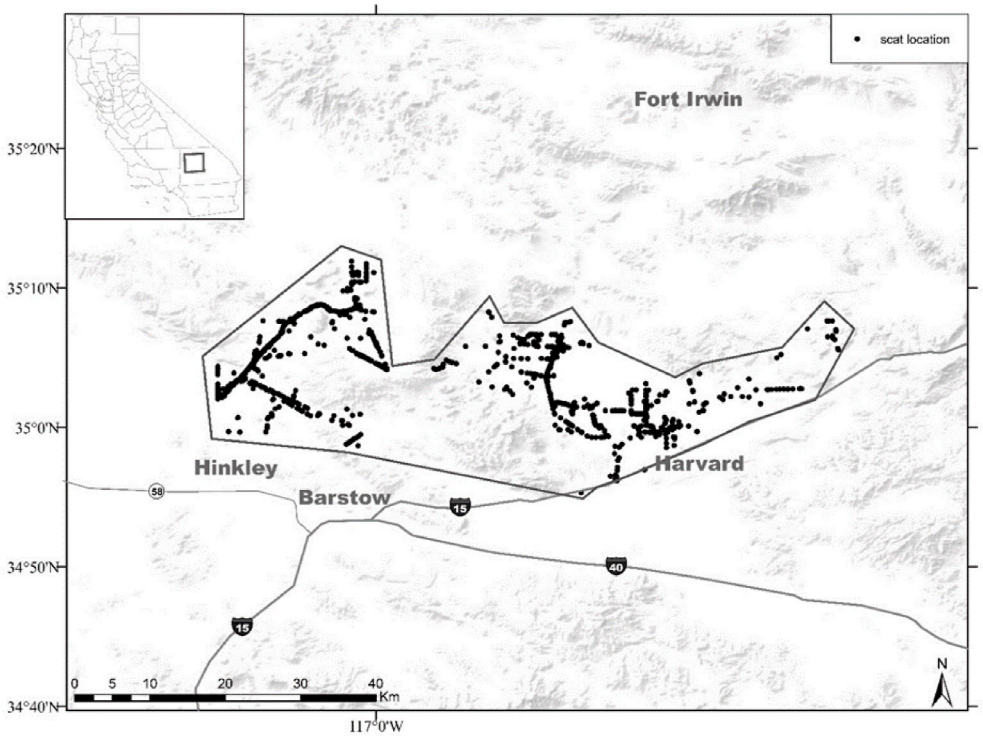

Fig. 1. Study area located in the Mojave Desert in California, United States. The black boundary is the specific study area and the black dots denote every location a coyote or desert kit fox scat or multiple scats were collected during the five-year project (2009–2014).

Fig. 2. Visual comparison of juvenile (left of ruler) and adult (right of ruler) desert tortoise remains found in desert kit fox and coyote scats.

scats with desert tortoise remains. The annual number of coyote scats with desert tortoise remains ranged from 17 to 37 (8-25 adult, 2–13 juvenile, 0–2 unconfirmed) while the annual number of kit fox scats with juvenile desert tortoise remains ranged from 0 to 4.

Both desert kit foxes and coyotes at our study site in the Mojave Desert in California consumed desert tortoise, although relatively infrequently. Overall, we identified 45 different food items in the desert kit fox scats (Kelly et al., 2019) and 50 different items in the coyote scats (Cypher et al., 2018). Out of the 4,476 scats analyzed, fewer than 3% contained desert tortoise remains. Thus, desert tortoise is not a primary food item for either coyotes or desert kit foxes and were most likely an incidental prey item or part of an opportunistic scavenging event. Due to the nature of fecal analysis, we could not determine whether occurrences of desert tortoise in scats was a result of predation or scavenging. As mentioned previously, desert tortoises can die from a number of natural and anthropogenic causes. Juvenile desert tortoises, particularly hatchlings, are probably easier to subdue and consume, and their remains in scats may have been a result of predation. Conversely, young desert tortoises do have a high mortality rate from natural and anthropogenic causes and could have been opportunistically found and scavenged upon.

Coyotes generally consumed adult desert tortoises while desert kit foxes specifically consumed younger desert tortoises. These results are consistent with desert tortoise mortality findings from other studies (Bjurlin and Bissonette, 2004; Peterson, 1994; USFWS, 1994). The preferential consumption of different desert tortoise age classes is likely, at least partially, a function of canid body size. Kit foxes are small and slim while coyotes are substantially larger (Bekoff, 1977; Grinnell et al., 1937). Because of their size, it is not easy for coyotes to gain access into a desert tortoise burrow to consume eggs and young desert tortoises, but their larger and more robust jaws may enable coyotes to prey on older desert tortoises outside of a burrow (Bjurlin, 2001; Peterson, 1994). Coyotes are also known scavengers and, when encountered, would likely have opportunistically consumed deceased desert tortoises of varying sizes.

Due to their relatively small size, it is unlikely that a desert kit fox would be able to kill or consume a healthy adult desert tortoise; however, desert kit foxes are known to enter desert tortoise natal burrows and prey upon the nests and young desert tortoises without even disturbing the soil around the burrow (Bjurlin and Bissonette, 2004; Karl, 1998). In our study, one of the seven desert kit fox scats that contained desert tortoise occurred during the summer. All others were found in the winter, after hatching concluded, indicating that the desert kit foxes in this area were consuming young desert tortoises and not developing embryos (Bjurlin, 2001). In winter, though, primary food items for desert kit fox were less available, dietary diversity of desert kit foxes was at its highest relative to the other seasons, and scavenging was more prominent and may have included deceased desert tortoises (Kelly et al., 2019). Even if desert kit foxes were preying on desert tortoises, it would seem doubtful that desert kit foxes had a detrimental impact on the desert tortoise population in this area.

Per expectations, the smaller kit fox consumed exclusively small desert tortoises (i.e., juveniles) while the larger coyote consumed a wider size range of desert tortoises (i.e., adults as well as juveniles). Assuming that each canid scat represented an individual desert tortoise, then over the 5-year study canids potentially consumed 79 adult and 43 juvenile desert tortoises. Whether this consumption resulted from predation or scavenging is unknown. Esque et al. (2010) suggested that anthropogenic food sources in this area might be enhancing coyote numbers, and thus, predation on desert tortoises. However, further research on predation and other mortality factors is warranted to determine the effects on desert tortoise population trends.

CRediT authorship contribution statement

Erica C. Kelly: Formal analysis, Investigation, Data curation, Writing – original draft. **Brian L. Cypher:** Conceptualization, Methodology, Investigation, Writing – review & editing, Visualization, Supervision, Project administration. **Tory L. Westall:** Investigation, Data curation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank the Endangered Species Recovery Program of California State University, Stanislaus, for providing workspace and the tools necessary to prepare and analyze scats. We would like to specifically thank Alexandria Y. Madrid, Erin N. Tennant, and Christine L. Van Horn Job for their assistance in collecting coyote and desert kit fox scats. We would also like to thank Dr. David J. Germano for determining the ages of desert tortoises from scutes removed from scats. Support for this project was generously provided by the Endangered Species Recovery Program, California State University, Stanislaus, and the U.S. Fish and Wildlife Service.

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