

EFFECTS OF FREE-ROAMING DOGS ON DESERT TORTOISE POPULATIONS IN SAGUARO NATIONAL PARK

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Abstract

Free-roaming dogs (*Canis familiaris*) have been observed with increasing frequency in Saguaro National Park (SNP) and their potential impact on wildlife populations, particularly on the desert tortoise (*Gopherus agassizii*), is largely unknown. Distinguishing between tortoise injuries caused by dogs and injuries caused by native mammalian predators, particularly coyotes, can be difficult. Based on confirmed dog attacks on captive tortoises, incidental observations of predation on wild tortoises, and expert opinion, dog-caused injuries are typified by damage to the gular horn and marginal scutes, particularly above the head and limbs. Severe injuries are often accompanied by numerous chew or scratch marks. Injury assessments were completed for tortoises captured in SNP between 2005 and 2007, and tortoises were classified as having injuries likely caused by dogs, having injuries possibly or likely caused by dogs, or having no such injuries. A higher proportion of observed tortoises were classified in the first two categories in the Tucson Mountain District (TMD; 15.0% likely, 19.5% possibly or likely) compared to the Rincon Mountain District (RMD; 0.8% likely, 3.3% possibly or likely). When tortoises observed before 2006 were included in the analyses, we found that the proportion of tortoises in the TMD with injuries possibly caused by dogs increased from 9.4% to 19.5% between 1997 and 2006. Additionally, of 32 tortoises recaptured between 1999 and 2006, 8 tortoises (25.0%) had likely been attacked by dogs since original capture. Two distinct areas of the TMD had elevated proportions of animals with injuries possibly caused by dogs. Probabilities of a tortoise having injuries likely caused by dogs increased as distance to human development decreased, and adult male tortoises were more likely to have these injuries than females. Given the developing body of evidence suggesting that free-roaming dogs are negatively impacting tortoises in SNP, management actions should be taken to control dog populations in the park.

Introduction

Dogs, whether domestic or feral, are believed to be a significant threat to wildlife in protected areas (Lenth et al., 2006; Sime, 1999). The potential impacts of free-roaming dogs are varied, ranging from harassment to direct mortality of wildlife species. However, little of this information has been published in peer-reviewed literature. Early studies focused on the effects of dogs on game species, such as deer (Corbett et al., 1971; Gentry, 1983; Sweeney et al., 1971). Many of these studies cited evidence that hunting or free-roaming dogs may induce stress in deer during prolonged chases. Later studies suggested that dogs may in fact be preying on ungulate species (Fuller, 1990; Gavin et al., 1984; Nelson and Woolf, 1987). Dogs may also affect wildlife populations through disease transmission. In a review of dog and wildlife interactions in the Rocky Mountain region, Sime (1999) stated that dogs may serve as vectors for canine distemper, rabies, parvovirus, or plague.

In addition to the studies evaluating the effect of dogs on ungulate populations, there have been a few studies that have investigated their effects on other wildlife species. Among these, Kruuk and Snell (1981) demonstrated that feral dogs in the Galapagos Islands preferentially preyed on large, male marine iguanas, altering population structure and dynamics. Free-roaming dogs are also known to prey on Australian wombats and wallabies (Tiggs et al., 1984), wild turkeys (Miller and Leopold, 1992), and small mammals (Scott and Causey, 1973).

To date, there has only been one peer-reviewed paper that has documented the predation of terrestrial tortoises by free-roaming or feral dogs. Causey and Cude (1978) captured and radio-collared feral dogs on a military reservation in Alabama to investigate potential effects of these dogs on wildlife populations. They observed one incident in which a pack of six feral dogs were attacking an adult gopher tortoise (*Gopherus polyphemus*) that had been removed from a shallow burrow nearby. Despite the fact that the attack was interrupted by the researchers, the tortoise sustained fatal injuries.

Several other incidental observations of dog predation on adult terrestrial tortoises have been reported. Barnett and Rudd (1983) mentioned that feral dogs in the Galapagos Islands prey on terrestrial tortoises; however, no details were provided, and predation events may have been limited to consumption of eggs from exhumed nests. More detailed observations of dog attacks were provided in an unpublished report on the effects of domestic dogs on wildlife in Israel (Brickner, 2002). In this report, the author recounted occasions on which she observed domestic dogs “harassing and injuring” tortoises. The Desert Tortoise Recovery Plan (USFWS, 1994) cited domestic and feral predators as a significant and increasing threat to tortoise populations in the Mojave Desert. Circumstantial evidence and a few direct observations were used to substantiate the claim that free-roaming or feral dogs were negatively impacting desert tortoise populations. Finally, an ongoing study in the Mojave Desert is using information collected from several thousand tortoise observations in an attempt to quantify the long-term effects of free-roaming dogs on Mojave desert tortoises in eastern California (Berry et al., 2007).

Saguaro National Park (SNP) is home to the Sonoran desert tortoise, a species of special concern in Arizona (AGFD, 1996). Because dog sightings in SNP are not uncommon, particularly in the Tucson Mountain District (TMD), park staff and researchers are concerned about the potential impacts of dogs on tortoise populations in the park. Sightings of unleashed dogs seem to be increasing as of late, and remote wildlife cameras in the park have recently captured multiple images of unleashed dogs (D. Swann, *pers. comm.*). While it’s unclear whether these are domestic dogs allowed to run free or feral dogs, it is apparent that unleashed dogs are making their way into areas of the park where sensitive wildlife, like desert tortoises, may be at risk.

Characterizing tortoise injuries possibly or likely caused by dogs

Adult desert tortoises have few native predators. While most evidence corroborates that mountain lions (*Felis concolor*) are the primary predator of adult desert tortoises, a number of other potential predators

have been suggested (Averill-Murray et al., 2002b). These include coyotes (*Canis latrans*), bobcats (*Felis rufus*), kit foxes (*Vulpes macrotis*), gray foxes (*Urocyon cinereoargenteus*), badgers (*Taxidea taxus*), and feral dogs, although many of these species likely prey on hatchling or juvenile desert tortoises. Determining the specific causes of injuries or mortality in wild tortoises is inherently problematic. Injuries are often found long after they were incurred, and predatory attacks are rarely witnessed.

Mountain lions are known to attack adult tortoises, particularly in the Sonoran Desert region (Averill-Murray et al., 2002b). Mountain lions are large animals, capable of crushing or piercing the shell of a tortoise, and as a result most attacks are usually fatal (Adams et al., 2006). After a typical mountain lion attack, the only remains found are shells that have been completely broken open with little to no flesh remaining (Riedle et al., 2007; *pers. obs.*; Fig. 1).

Interestingly, rodents may cause severe trauma to desert tortoises, particularly hatchlings and juveniles. During tortoise winter hibernation, rodents have been known to gnaw on the limbs or other soft tissue, often stripping the flesh from the bone, and resulting in partial or complete limb loss (McArthur et al., 2004; J. Jarchow, *pers. comm.*). Several tortoises found in 2005 and 2006 in SNP exhibited injuries that Dr. James Jarchow, reptile veterinarian for the Arizona-Sonora Desert Museum, believed were likely caused by rodents when the tortoise was a juvenile (Fig. 2).

Finally, the coyote has also been implicated in desert tortoise predation events, but it is believed that they primarily prey upon hatchlings or juveniles because they are typically unable to break through the carapace of an adult tortoise (Averill-Murray et al., 2002b). However, coyotes and other small potential mammalian predators may injure or kill an adult tortoise by chewing on exposed limbs (K. Berry, *pers. comm.*). The extent to which coyotes attack tortoises in the Sonoran Desert is largely unknown.

Because coyotes and dogs are closely related, it is most difficult to distinguish the cause of trauma between these two potential predators. Although no definitive answers are available, experts in the field believe that coyotes will attack exposed limbs or soft tissue, and because they cannot puncture an adult carapace, they will abandon predatory pursuits if soft tissue cannot be easily accessed (J. Jarchow and K. Berry, *pers. comms.*). When free-roaming domestic dogs attack an adult tortoise, there are often chew marks at multiple locations on the marginal scutes, indicative of a relentless and persistent attack or possibly “vicious play” with potential prey (Green and Gipson, 1994).

Perhaps the best way to determine whether dogs are responsible for trauma to a wild tortoise is to compare the observed injuries with documented dog-caused trauma to captive tortoises. Finding documentation of injuries caused by domestic dogs to captive tortoises is not difficult. Veterinary textbooks directly address the prevalence of the problem, discuss treatment necessary for tortoise injuries due to dogs, and provide photos of typical injuries (Mader, 1996; McArthur et al., 2004). Reptile veterinary specialists in the Sonoran Desert have dealt with many such injuries to captive desert tortoises. Dr. Jarchow has treated a number of desert tortoises with severe injuries known to be caused by domestic dogs in his private practice, particularly in the last several years (J. Jarchow, *pers. comm.*).

In these injury cases, Dr. Jarchow has described the damage as concentrated on the marginal scutes (particularly near the head and limbs) and gular horn. The damage is often severe, with partial loss of scute and bone material and potential exposure of visceral tissue (Fig. 3). Other veterinarians in the Sonoran Desert region have corroborated these observations (J. Johnson and T. Driggers, *pers. comms.*). Severe damage is often accompanied by numerous scratch or chew marks, predominantly on the marginal scutes. Many tortoises with these types of injuries have been observed in SNP, the majority of them in the TMD (Fig. 4).

Ongoing studies investigating the effect of free-roaming or feral dogs on Mojave desert tortoise populations seem to support these generalizations regarding the characteristics of dog-induced injuries (K. Berry, *pers. comm.*). In areas of the Mojave Desert, incidental observations of free-roaming dogs (often in packs) have increased over the last several years (C. Everly, *pers. comm.*), along with observations of adult tortoises with severe injuries to the gular and marginals. Dr. Kristin Berry has found correlations between rates of severe gular and marginal injuries in wild tortoises and proximity to human development, further strengthening the assertion that the injuries were caused by free-roaming domestic dogs (Berry et al., 2007).

Numerous desert tortoise research projects have been completed in SNP during the last twenty years, and as part of these projects, hundreds of tortoises have been captured and individually marked. To investigate the effects of free-roaming dogs on tortoise populations in SNP, I compiled information from many of these tortoise observations to assess whether dogs were injuring tortoises, and whether attacks may be increasing in frequency over time. I cautiously differentiated between injuries caused by dogs and injuries caused by other potential predators using information provided by experts, and by making comparisons between observed injuries and documented dog-caused injuries to captive tortoises.

Methods

Data Sources

Tortoises captured between 2005 and 2007

More than 230 tortoises were captured and handled in SNP between 2005 and 2007 as part of a research project evaluating potential monitoring strategies for the species and as part of a wildlife education project. Most tortoise observations in the Rincon Mountain District (RMD) occurred in 2005 ($n = 118$), with a few incidental observations in 2006 ($n = 5$). Most tortoise observations in the TMD occurred in 2006 ($n = 101$), with a few incidental observations in 2007 ($n = 12$). Detailed health and injury assessments and photographs were available for all of these tortoise observations.

Tortoises captured before 2005

More than 150 tortoises were captured and handled in the TMD between 1989 and 2004 during a variety of desert tortoise research projects. Although neither detailed health and injury assessments nor photographs were available for these observations, archived data sheets with general remarks on habitat, health, shell condition, and behavior were provided by the park.

Classification of tortoise injuries

Tortoises captured between 2005 and 2007

Because the cause of injuries to wild tortoises can rarely be confirmed, it was necessary to create an index, representing the probability that an observed injury was caused by free-roaming domestic or feral dogs. Dr. Kristin Berry and colleagues at the U.S. Geological Survey have been working on a similar project in the Mojave Desert for a number of years, assessing the effect of dogs on tortoise populations using data collected from over 6000 tortoise observations. As part of this study, Dr. Berry created a series of classification variables rating the location, extent, and probable source of tortoise injuries (K. Berry, *pers. comm.*) Using the work done by Dr. Berry as a template, I created four classification variables that categorized the extent of trauma to the shell and limbs, the location of severe or moderate damage, the likely source of trauma, and the probable type of mammalian predator, if trauma was due to predation (Table 1). All tortoises were rated for each of the four classification variables. Tortoises were then separated into three groups: tortoises with injuries likely caused by dogs (Variable TRAUMA ≥ 4 , Variable LOC ≥ 2 , Variable SOURCE = 4, Variable MAMMAL = 4), tortoises with injuries possibly or likely caused by dogs (Variable TRAUMA ≥ 4 , Variable LOC ≥ 2 , Variable SOURCE = 4, Variable MAMMAL ≥ 3), and tortoises without dog-related injuries.

Tortoises captured before 2005

Because less detailed information was available for these tortoises, it was not possible to rate them using the classification variables created for tortoises captured between 2005 and 2007. Instead, I used the

general remarks on the tortoise processing data sheets to sort the animals into two groups. Tortoises with moderate to severe trauma to the gular or marginals were categorized as having injuries possibly caused by dogs. The second group included all tortoises without these injuries.

Proportion of tortoises with injuries

The proportion of observed tortoises with trauma likely caused by dogs was calculated for all tortoises captured in the RMD and all tortoises captured in the TMD between 2005 and 2007. Similar calculations were completed for tortoises with trauma possibly or likely caused by dogs. Proportions of tortoises in each category were compared between the two districts using Fisher's exact test.

For tortoises captured in the TMD between 1989 and 2004, the proportion of tortoises with injuries possibly caused by dogs was calculated for each year. The proportions were compared between years with a minimum of 10 tortoise observations, and years with a minimum of 50 tortoise observations using Chi-squared tests. Additionally, tortoise observations were combined for 1996 and 1997 (two years of a desert tortoise research project estimating density at a long-term study plot; Wirt and Robichaux, 2001) and the collective proportion of tortoises with injuries was compared to the proportion with injuries possibly caused by dogs in 2006 and 2007 with Fisher's exact test.

Finally, for those tortoises captured in more than one year between 1989 and 2007, long-term health and injury assessments could be made. Approximate dates of predator attacks were estimated for those tortoises that did not have injuries when first captured, but presented evidence of moderate or severe trauma due to mammalian predators during subsequent captures. The proportion of total recaptures with injuries observed subsequent to first capture and possibly caused by dogs was calculated.

The effect of sex, size, and location on injury rates

In order to determine whether sex, size, or location of a tortoise affected the probability of injury, logistic regression analyses were completed for injuries likely caused by dogs and injuries possibly or likely caused by dogs. Tortoises used in the analyses included all those captured in the TMD in 2006 and 2007. Tortoise sex, midline carapace length (MCL), and location (UTMs) were recorded in the field. Later, all locations were plotted in ArcView 3.3, and the following measurements were estimated to the nearest meter using aerial photographs provided by the park: minimum distance to a residential or commercial building, minimum distance to a paved road, and minimum distance to an unpaved road. For those measurements that could not be made using the park-provided aerial photographs (because the nearest structure fell outside of the photograph boundary), measurements were estimated using Google Earth.

Regression analyses were not completed for tortoise observations in the RMD because the rate of injuries likely caused by dogs was much lower than that in the TMD and these low sample sizes prevented such analyses. Additionally, analyses were not completed for observations before 2006 because many of the locations provided were imprecise. For many locations previous to 2006, datums were not provided (unknown or unrecorded) or the associated error was substantial, preventing accurate measurements to the nearest building or road.

Results

Proportion of tortoises with injuries

A total of 123 tortoises were captured and processed in the RMD in 2005 and 2006. Of these captures, 4 tortoises had injuries that were at least possibly caused by dogs and 1 of the 4 tortoises had injuries that were likely caused by dogs. A total of 113 tortoises were captured and processed in the TMD in 2006 and 2007. Of these captures, 22 tortoises had injuries that were at least possibly caused by dogs and 17 of the 22 tortoises had injuries that were likely caused by dogs. These observations strongly suggest that the

proportions of tortoises with injuries possibly caused by dogs (Fisher's exact test, 2-tailed $p < 0.0001$) and likely caused by dogs ($p < 0.0001$) differed between the two districts.

The proportion of captured tortoises in the TMD with injuries possibly caused by dogs varied over the years, ranging from 0 – 58.3% (Fig. 5). Substantial evidence suggests that the proportion of tortoises with injuries differed among years with a minimum of 10 tortoise captures ($X^2 = 23.68$, $df = 6$, $p = 0.0006$) and among years with a minimum of 50 tortoise captures ($X^2 = 6.65$, $df = 2$, $p = 0.04$). The proportion of tortoises with injuries seemed to be increasing over the years studied (Fig. 5), however, small sample sizes in several of these years prevented a more thorough analysis. A direct comparison between the combined captures in 1996 and 1997 and captures in 2006 and 2007 suggests that the proportion of tortoises with injuries was greater during the latter time period (Fisher's exact test, 1-tailed $p = 0.01$), with 9.4% of tortoises with injuries in 1996 and 1997 and 19.5% with injuries in 2006 and 2007.

Fourteen tortoises captured in 2006 were originally captured between 1989 and 2004. Of these 14 recaptures, 5 tortoises (35.7%) had likely been attacked by dogs since original capture (Table 2). Additionally, 18 tortoises captured between 1999 and 2004 were originally captured between 1989 and 1997. Of these recaptures, 3 tortoises (16.7%) had likely been attacked by dogs since original capture.

The effect of sex, size, and location on injury rates

Two areas of the TMD had elevated proportions of tortoises with injuries possibly or likely caused by dogs (Fig. 6). The first is the area just south of Panther Peak, closely associated with Panther Peak wash. The second area is south of the visitor center, between Kinney and Mile Wide Roads. Although these areas have been the focus of many desert tortoise research projects, it is unlikely that the high number of tortoises observed with injuries was solely due to a high number of tortoise observations. Within the Panther Peak area, 44.4% of tortoises had injuries possibly or likely caused by dogs ($n = 18$), and within the area south of the visitor center, 37.5% of tortoises had such injuries ($n = 16$). Outside of these two

areas, only 10.1% of tortoises had injuries consistent with dog attacks ($n = 79$), and for all areas combined 19.5% of tortoises had injuries consistent with dog attacks ($n = 113$).

There was convincing evidence that the probability of having injuries caused by dogs increased as distances from residential or commercial buildings decreased in both analyses (Table 3). Evidence also suggested that adult male tortoises were more likely to have injuries associated with dogs than adult female tortoises (Fig. 7). Male tortoises were 3.85 times more likely to have injuries likely caused by dogs (95% CI: 0.91 – 26.75) and 3.73 times more likely to have injuries possibly or likely caused by dogs (95% CI: 1.05 – 17.87), with all other variables held constant. Finally, there was no evidence to suggest that the probability of injuries associated with dogs differed for tortoises in different size classes.

Unexpectedly, the probability of having injuries likely caused by dogs increased as distances to roads increased. However, this relationship was not strongly supported for injuries possibly or likely caused by dogs (Table 3). The two variables measuring distances from paved and unpaved roads were combined into a new variable, minimum distance to any road, for the regression analyses. The variables were merged because, unlike models with the original two variables, models including the new variable explained significantly more variation than models that excluded all road variables (drop-in-deviance test for injuries likely caused by dog, $X^2 = 4.47$, $df = 1$, $p = 0.03$).

Discussion

Although determining the source of trauma for individual desert tortoises is often difficult, many independent lines of evidence suggest that free-roaming dogs are negatively impacting tortoise populations in SNP. Recently observed tortoise injuries are consistent with those seen in captive tortoise populations where injuries have been confirmed to be dog-related. These injuries are characterized by severe trauma to the gular and marginal areas, as well as occasional damage to the plastron or limbs. According to leading experts, these injuries are unlikely to be caused by other mammalian predators, such

as mountain lions, coyotes, or rodents (J. Jarchow, *pers. comm.*). Rodents may cause severe damage to the limbs and soft tissue of young tortoises during winter hibernation. Mountain lions are the only predators capable of crushing an adult tortoise shell and typically result in the death of the tortoise. Although coyotes are not capable of breaking through an adult tortoise shell, they may severely or fatally injure an adult tortoise by chewing on exposed soft tissue. Unlike feral dogs, coyotes are not known to “play” with potential prey and excessively chew the gular and marginal scutes.

Another line of evidence stems from the fact that more injuries were observed in the TMD, where extensive human development and roads surround the park. A number of desert tortoise research projects in SNP have been carried out since 1989 and an increasing number of injuries possibly caused by dogs have been observed. Unfortunately, photographs of tortoises captured in SNP before 2005 were not readily available, so injury assessments for this report had to be solely based on data sheet remarks. Most data sheets included thorough observations related to health, habitat, and behavior, and for this reason, it is unlikely that notes related to severe trauma were omitted. However, if omissions had occurred, injury rates for years prior to 2005 would have been underestimated.

The highest density of tortoises with dog-related injuries in 2006 and 2007 was in the area south of Panther Peak. Because most homes and developments near Panther Peak have been established for more than 10 years, it is likely that tortoise injury rates in this area have been elevated for much of the past decade. All of the tortoises captured in 1996 and 1997 resided in the Panther Peak area, where tortoise injury rates were probably higher than in the rest of the TMD. Consequently, it is likely that injury rates reported here for 1996 and 1997 overestimate overall tortoise injury rates in the TMD during this time period. If this is the case, the increase in tortoise injury rates from 1996 and 1997 to 2006 and 2007, when tortoises were sampled throughout the TMD, is even greater than that reported here.

If the observations of severe trauma to tortoises in SNP are caused by dogs, as I believe them to be, then I would expect the probability of injury to increase with proximity to human development. This relationship between injuries and distances to residential or commercial buildings was supported in these analyses, as well as preliminary results produced in the Mojave Desert study (Berry et al., 2007). It appears that after accounting for the distance to the nearest building, little variation in the probability of injury is explained by the minimum distance to roads. This unexpected result may be caused by the pervasiveness of roads in and around the TMD, so that in effect, no tortoises are far from paved or unpaved roads. Finally, male tortoises were more likely to have dog-related injuries than female tortoises. This is not surprising given that males often have larger home ranges than females (Averill-Murray et al., 2002a), and use of larger areas may increase the likelihood of encountering free-roaming dogs.

If tortoise injuries from free-roaming dogs are common in protected areas like SNP, and possibly increasing in frequency, there is certainly reason for concern. As development and urbanization continue to encircle protected areas, it becomes increasingly important to understand how an increase in domestic dog populations may affect the health of our native ecosystems. Yet, scientific studies investigating the effects of free-roaming or feral dogs on wildlife populations are conspicuously absent in the peer-reviewed literature. Research is needed to identify how control measures may be implemented to minimize negative impacts.

It is unknown whether free-roaming or feral dogs are responsible for adult tortoise mortality in SNP. With limited incidental observations, it is impossible to indisputably prove dogs are responsible for tortoise injuries. Demonstrating that dogs are responsible for adult tortoise mortality, when the evidence (carcasses) may be unavailable or difficult to find, is even less likely. Whether dogs are responsible for adult tortoise mortality or merely severe trauma, it is imperative that SNP incorporate control measures for free-roaming dogs into management plans. Obviously, adult mortality would negatively impact desert

tortoise populations, as they are a long-lived species (Doak et al., 1994). However, severe injuries may also impact population dynamics. Female tortoises may sustain injuries that limit or prevent reproduction. Male tortoises engage in brutal combat that often determines which males are able to mate with available females (Niblick et al., 1994; Ruby and Niblick, 1994). Those males that sustain severe gular injuries due to dog attacks, are less able to fight these battles, and consequently may have reduced mating opportunities.

Of immediate concern in SNP are those areas where the highest proportions of tortoise injuries were observed: the area south of Panther Peak and the area south of the visitor center in the TMD. Additional patrols by park staff or volunteers may be necessary to document the presence of domestic dogs and take appropriate control measures. Additionally, it is likely that most dogs found roaming the park are pets that have been allowed to escape from yards or homes. Increasing awareness of the negative impacts that released pets may have on native wildlife populations, especially among homeowners bordering the park in these areas, may be beneficial. All evidence points to an increase in these dog-related problems as human populations around the park continue to expand. It appears necessary for SNP to both incorporate some type of control measures into management plans and increase awareness of these dog-related issues in park staff, volunteer, researcher, visitor, and neighbor populations.

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Table 1. Classification variables rating the location, extent, and probable source of tortoise injuries. The template for these variables was provided by Dr. Kristin Berry at the U.S. Geological Survey.

Variable TRAUMA: Trauma to Shell and Limbs	
1	No evidence of trauma
2	Evidence of trauma low. Trauma confined to chips on marginal/carapacial scutes (one marginal scute may have <10% damage).
3	Evidence of trauma minor. Up to 5 scutes, each with less than 10% damage; one scute may have less than 40% damage.
4	Evidence of trauma moderate. Up to 11 scutes with less than 40% damage; 6 or more scutes with 10% damage.
5	Evidence of trauma severe. At least 11 scutes with less than 40% damage, or at least one scute with more than 40% damage; loss of part or all of limb.
Variable LOC: Location of Moderate or Severe Damage to Gular and Marginals	
1	No moderate or severe damage to gular or marginals
2	Reduction in size of anterior or posterior marginals resulting in additional exposure of limb or soft body parts (at least 40% loss of material on an individual scute)
3	Gular severely damaged (at least 40%), or gular lost
4	2 & 3 above
Variable SOURCE: Source of Trauma	
1	No trauma
2	Chips likely from wear or rocky terrain
3	Crushing injury, or injuries from a likely fall
4	Indications of mammalian predation (chew marks, missing limbs or part of shell, bites, punctures)
5	Other or unknown
Variable MAMMAL: Mammalian Source of Trauma	
1	No evidence of trauma caused by a mammal
2	Trauma likely caused by wild mammalian predator (rodent, coyote, or mountain lion)
3	Trauma possibly caused by dogs (observational notes indicate injuries likely caused by dogs, but few or no conclusive photographs; injuries to tortoise look like they resulted from a persistent mammalian predator with lots of chew or scratch marks, but injuries not concentrated on gular or marginal scutes near the limbs and head; some damage to gular, but not severe enough or lacking distinctive chew marks to conclusively determine that dogs caused the injuries)
4	Trauma likely caused by dogs (moderate to severe injuries concentrated on gular or marginal scutes near the limbs and head)

Table 2. Tortoises captured in the TMD on more than one occasion between 1996 and 2006, incurring dog-related injuries after first capture.

Tortoise ID	Location	Sex	Last Capture Before Injuries	First Recapture With Injuries
22	Panther Peak	M	1997	2006
29	Panther Peak	M	1997	2002
91	Panther Peak	M	1996	2004
194	Panther Peak	F	2003	2004
213	Panther Peak	M	1997	2006
712	Panther Peak	F	2000	2002
802	Panther Peak	M	2003	2006
830	Panther Peak	M	1997	2006

Table 3. Parameter estimates for logistic regression analyses based on “Injuries Likely Caused by Dogs” and “Injuries Possibly or Likely Caused by Dogs”. P-values provided are from likelihood ratio tests. MCL = Midline Carapace Length.

Injuries Likely Caused by Dogs				Injuries Possibly or Likely Caused by Dogs			
Parameter	Estimate	SE	<i>p</i>	Parameter	Estimate	SE	<i>p</i>
Males Relative to Females	1.348	0.823	0.069	Males Relative to Females	1.317	0.702	0.041
Juveniles Relative to Females	0.470	1.436	0.744	Juveniles Relative to Females	1.663	1.316	0.206
MCL (mm)	-0.004	0.012	0.776	MCL (mm)	0.016	0.012	0.161
Dist. To Building (km)	-2.592	1.214	0.001	Dist. To Building (km)	-1.726	0.788	0.003
Dist. To Road (km)	2.218	1.223	0.035	Dist. To Road (km)	1.183	0.881	0.147

Figure 1. Photographs of tortoises likely killed by mountain lions. A) Photograph taken on 29 July 2007 by B. Weise near Rocking K Ranch in the RMD. B) Photograph taken on 12 January 2006 by E. Zylstra in the Mother's Day Burn area in the RMD.



Figure 2. Photographs of trauma likely caused by rodents. A) Photograph taken on 30 July 2005 by E. Zylstra near the Cactus Forest Trail in the RMD. B) Photograph taken on 18 September 2005 by E. Zylstra near Wildhorse Canyon in the RMD.



Figure 3. Photographs of tortoises brought to James Jarchow, DVM, with injuries confirmed to be caused by dogs. A) Photograph taken 14 April 2006 by J. Jarchow of tortoise with gular chewed off by dogs. B) Photograph taken 10 November 2006 by J. Jarchow of tortoise with severe damage to rear marginals. C) Photograph taken 22 August 2006 by J. Jarchow of tortoise with severe damage to anterior marginals.

A)



B)



C)



Figure 4. Photographs of wild tortoises with injuries likely caused by dogs. A) Photograph taken on 15 September 2007 by E. Zylstra near the TMD visitor center of tortoise with severe trauma to the gular. B) Photograph taken on 14 October 2006 by E. Zylstra in the Panther Peak area of tortoise with chew damage to anterior marginals. C) Photograph taken on 15 September 2007 by E. Zylstra near the TMD visitor center of tortoise with severe trauma to anterior marginals.

A)



B)



C)



Figure 5. Proportion of captured tortoises with possible dog-related injuries in years with a minimum of 10 tortoise captures.

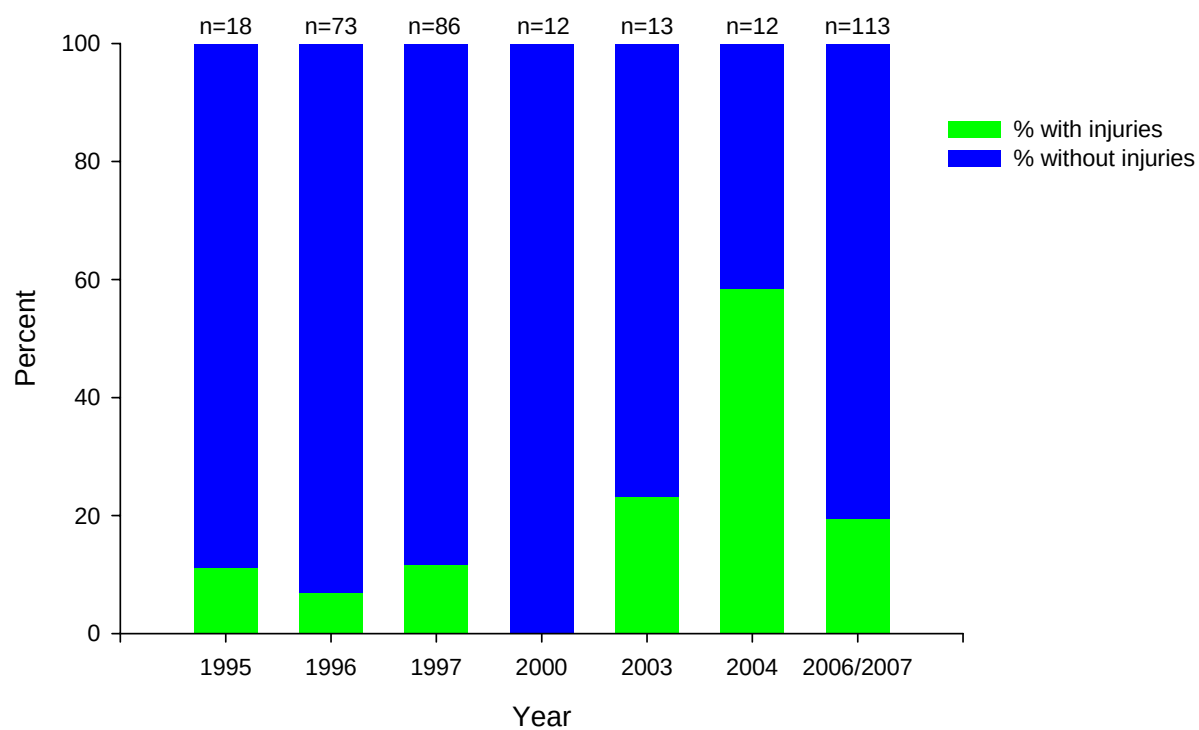


Figure 6. Map of all tortoise locations in the Tucson Mountain District in 2006 and 2007. Locations of tortoises with possible or likely dog-related injuries are in green. Locations of tortoises without dog-related injuries are in blue. The two areas with the highest proportion of dog-related injuries are circled in red.

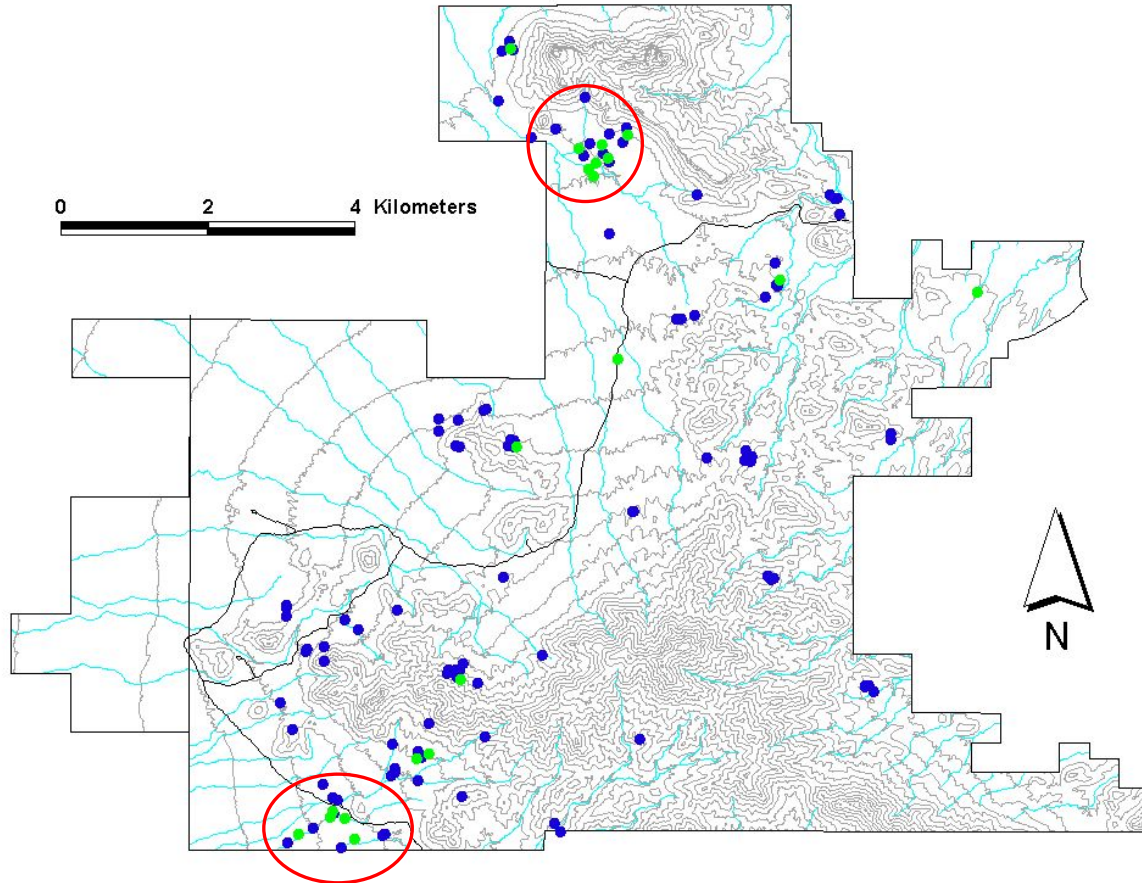


Figure 7. Predicted probability of injuries likely caused by dogs as a function of the distance to the nearest residential or commercial building.

