EVALUATION OF PREDATOR ATTENDANCE AT PITFALL TRAPS IN TEXAS

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ABSTRACT—Researchers using drift-fence sampling with associated pitfall traps have analyzed a number of problems associated with this technique. One unquantified problem is the effect foraging vertebrate predators might have on animals captured in pitfall traps. We used Deer Cam® cameras and track-monitoring stations to estimate amount and variety of vertebrate predators attending pitfall arrays in Bastrop and Guadalupe counties, Texas. We recorded 316 photographs of 19 species of vertebrates over 327 camera days among 16 drift-fence arrays. During 1,838 trap nights, we documented 679 individual track sets at track-monitoring stations established on 50 individual pitfall traps and 8 control plots. Ten potential vertebrate predators were documented visiting pitfall arrays with the raccoon (*Procyon lotor*) being the most frequently recorded species. Statistical analyses indicate that presence of predators at track-monitoring stations or pitfall traps did not influence detectability or capture success of small vertebrates. However, these results could be confounded by the low effect size and reduced power due to low number of animals captured in pitfall traps during the study. Consistent and frequent visits by predators to pitfall traps indicate that risks exist for confined animals and the potential consequences increase for rare or endangered taxa, which potentially could be exposed to higher levels of predation when confined to pitfall traps.

RESUMEN—Investigadores que usan muestreos de cercas de deriva y trampas de hoyo han analizado algunos problemas con la técnica. Un problema no cuantificado es el efecto que los vertebrados depredadores pueden tener en los animales capturados en las trampas. Utilizamos cámaras Deer Cam® y estaciones de huellas para estimar la cantidad y diversidad de depredadores que visitaron las trampas en los condados de Bastrop y Guadalupe, Texas. Registramos 19 especies de vertebrados en 316 fotografías durante 327 cámara-noches en 16 series de cercas de deriva. Durante 1838 trampa-noches, documentamos 679 juegos de huellas individuales en 50 trampas y en 8 sitios control. Se documentaron 10 depredadores potenciales visitando las trampas, siendo el mapache (*Procyon lotor*) la especie más frecuente. El análisis estadístico indica que la presencia de los depredadores en las trampas o en las estaciones de huellas no afectó significativamente a la detectabilidad o al éxito de captura de pequeños vertebrados. Sin embargo, estos resultados pueden estar sesgados debido al bajo tamaño del efecto y el poder estadístico reducido por la muestra pequeña de animales capturados durante el estudio. La frecuente y consistente visita de depredadores a las trampas de hoyo indica un riesgo potencial para los animales capturados. Las posibles consecuencias son más graves cuando los taxones capturados son raros o están en peligro de extinción, ya que pueden estar expuestos a niveles mayores de depredación durante su confinamiento en las trampas.

Pitfall traps with or without associated terrestrial drift fences remain a commonly applied technique in sampling small terrestrial vertebrates (Shoop, 1965; Stenhouse, 1985; Sutton et al., 1999; Jenkins et al., 2003). Several studies have evaluated their effectiveness and reported problems with the method (Brown, 1997; Crosswhite et al., 1999) including mortality of trapped animals (Yunger et al., 1992; Enge, 2001).

Mortality factors associated with pitfall trapping include desiccation (Jenkins et al., 2003), drowning (Aubry and Stringer, 2000), starvation (Yunger et al., 1992), exposure (Padget-Flohr and Jennings, 2001), and predation among animals within the trap (Dodd and Scott, 1994). However, predation upon animals caught in pitfall traps by foraging vertebrate predators rarely is mentioned. Most direct predation events mentioned in the literature are anecdotal and the majority address predation within pitfall traps by trapped mammals such as shrews (Jenkins et al., 2003) or minor disturbances to

pitfall covers by meso-carnivores such as the raccoon (Sutton et al., 1999). Such studies support the idea that predation of captured animals in pitfall traps is possible (Gibbons and Semlitsch, 1981; Heyer et al., 1994). However, effects of predation by vertebrates on pitfall trapping has not been studied quantitatively.

Objectives of this study were to quantify activities of vertebrate predators along drift-fence arrays, to highlight potential threats to captured animals, and to elucidate potential bias in data collection on vertebrate communities as a result of active predation. Using motion-sensitive cameras and track-monitoring stations we documented the variety and frequency of visitation of potential predators along terrestrial drift fences with pitfall traps used in a study of an ecologically sensitive species, the endangered Houston toad (*Bufo houstonensis*). We anticipated high rates of visitation and potential predation by dexterous mesocarnivores such as raccoons and Virginia opossums (*Didelphis virginiana*), which we hypothesized would pose the greatest threat to captured animals.

MATERIALS AND METHODS—*Study Area*—We conducted our study at two sites in south-central Texas. The first site was the Boy Scouts of America's Griffith League Ranch, a 2,012-ha ranch located in north-central Bastrop County within the Lost Pines Ecological Region of Texas. Plant communities consisted of mixed-conifer hardwoods of loblolly pine (*Pinus taeda*), blackjack oak (*Quercus marilandica*) and post oak (*Quercus stellata*), mature stands of loblolly pines, several open pastures and mixed deciduous hardwoods of oaks (*Quercus*) with an understory of yaupon (*Ilex vomitoria*), American beauty berry (*Callicarpa americana*), and farkleberry (*Vaccinium arboreum*). Soils were 91% sandy loam.

The second site was in northern Guadalupe County, Texas. The 9-ha private property was surrounded on all sides by similar-sized or larger-sized privately owned parcels of land used for hunting and ranching operations. The primary vegetation was characteristic of the ecotone between the blackland prairie and the Texas Hill Country. The majority of the property was open pasture with scattered honey mesquite (*Prosopis glandulosa*). Five permanent ponds were on the property. Vegetation typical of pond edges included large stands of mesquites and black willows (*Salix nigra*). Texas persimmon (*Diospyros texana*), hackberry (*Celtis laevigata*), agarita (*Berberis trifoliolata*), and bumelia (*Bumelia lanuginosa*) grew along a creek drainage crossing the property. Prickly pear (*Opuntia lindheimeri*) and tasajillo (*Opuntia leptocaulis*) also occurred along these riparian corridors. Soils were black clay with stone cobble.

Drift-fence Arrays—We constructed drift-fence arrays using aluminum flashing 18 cm high by 15 m long with 19-L buckets as pitfalls. Flashing was buried 5 cm and pitfall traps were flush with the ground. Both Y-shaped and straight-line drift-fence arrays were used during the study (Bury and Corn, 1987). Y-shaped arrays consisted of three arms of aluminum flashing radiating from a central pitfall trap with each arm terminating in a pitfall trap, resulting in a total of 4 pitfall traps/array. Straight-line drift-fence arrays consisted of a single arm of aluminum flashing with pitfall traps placed at the ends and along the length of the drift-fence barrier. We installed 18 drift-fence arrays, 13 Y-shaped arrays, and 5 straight-line arrays, to monitor the local herpetofauna, including the endangered Houston toad, during a 2-year period beginning in September 2001 on the Griffith League Ranch. Drift-fence arrays were supplemented with standard funnel traps (22.9 by 22.9 by 76.2 cm) placed alongside the drift-fence barrier to capture larger snakes and other animals capable of escaping pitfall traps (Christiansen and Vandewalle, 2000; Ford and Hampton, 2005).

Drift-fence arrays in Guadalupe County consisted of six straight-line arrays with 2 pitfall traps/array and were constructed to test response of predators to novel drift-fence operations and to monitor the herpetofauna and small-mammal communities. We set drift-fence arrays in Guadalupe County in pairs along the outer perimeter of the property boundaries, using pre-existing boundary fencing to minimize material required to exclude livestock from arrays. Each array was 100 m apart and pairs were separated by 300 m. We surrounded each array with welded-wire livestock panels with 15.24 cm squares made from gauge rods 0.635 cm in diameter, which were supported by 1.8 m T-posts. A gate allowed access to arrays. We placed protective fencing 1.2 m from the drift-fence flashing. We cut 45 by 45-cm holes in the livestock paneling to allow predators free movement within the protective fencing, and hence access to pitfalls and drift-fence arrays. Funnel traps (22.9 by 22.9 by 76.2 cm) accompanied each drift-fence array to supplement monitoring efforts of the local vertebrate fauna, and were placed opposite to one another along each stretch of aluminum flashing. We checked traps daily for captured animals.

Camera Stations—We installed Deer Cam® Model DC-100 cameras (DeerCam®, Park Falls, Wisconsin) on 10 of 18 drift-fence arrays across the Griffith League Ranch and a camera on each of the 6 drift-fence arrays in Guadalupe County, for a total of 16 cameras across both sites. We chose drift-fence arrays and pitfall traps to monitor with cameras randomly. Central cameras were placed at pitfall traps in the interior of a drift fence and terminal cameras were placed at pitfall traps at the end of a drift fence. We set cameras to record date and time for each photograph to help distinguish capture of multiple versus repeat visitors. We also adjusted camera settings to high sensitivity to take photographs at 30-s intervals after disruption of the motion sensor. All cameras were operational 24 h/day and checked periodically (about once a week) for proper functioning.

Track-monitoring Stations—Track-monitoring stations consisted of a 2-m diameter circle of cleared earth around the pitfall trap. Each station was systematically raked prior to monitoring to remove any previous

tracks in order to record activity between raking events. Y-shaped arrays had the central and one randomly chosen terminal pitfall trap outfitted with track-monitoring stations. Straight-line drift-fence arrays had track-monitoring stations placed on terminal pitfalls only. To prevent re-growth of vegetation, we dug a 13 cm deep hole 2 m in diameter around the pitfall trap, lined it with artificial pond liner (65 mm EPDM), and filled it with sand. We installed a total of 38 track-monitoring stations across 18 drift-fence arrays on Griffith League Ranch. Additionally, control plots were installed for comparison of rates of visitation between monitoring stations with and without pitfall traps. Five control plots of 2-m circles without a pitfall trap at the center were placed >100 m from the nearest track-monitoring station at an array for a total of 43 track-monitoring stations. We raked each track-monitoring station 4 times/month when pitfall traps were operational (21 October 2003–17 June 2004). After 17 June 2004, all pitfall traps were permanently closed and rakings reduced to twice a month to detect whether predators continued visiting stations after pitfall traps were closed.

We installed 15 track-monitoring stations in Guadalupe County. All six drift-fence arrays at this site were fitted with two track-monitoring stations. Three control plots, ≥50 m from the nearest drift-fence array also were installed. Track-monitoring stations were monitored weekly while pitfall traps were open 23 June–5 October 2004. In October 2004, all pitfall traps were closed for 8-months and not monitored. Beginning 9 May 2005, traps were reopened and raking of track-monitoring stations was initiated to examine how quickly predators began visiting pitfall stations after being closed for an extended period of time. Stations were monitored every day for four, 4-day sampling periods (9–13 May, 8–11 June, 4–7 July 2005) during the second phase of the study.

At both sites, we raked track-monitoring stations to clear any previous tracks and prepare the sand for new tracks. We checked each station the following morning after raking for occurrence, pattern, and kinds of animal tracks present. Tracks were identified to species, when possible. We also recorded presence or absence of animals in pitfall traps. We used track-monitoring stations as an index of predator abundance and to document differences in variety, rate of visitation, and trap affinity of vertebrate predators.

Analyses—We used a variety of statistical analyses. We first calculated a 95% confidence interval of two proportions. The first proportion was number of track-monitoring stations with tracks and captured vertebrates in the pitfalls compared to all track-monitoring stations with tracks. The second proportion was number of vertebrates caught in pitfall traps with track-monitoring stations that did not have tracks versus total number of track-monitoring stations with no tracks. In doing so, these two values could be directly compared to determine whether the proportion of animals caught in pitfall traps was directly affected by presence or absence of predator tracks in track-monitoring stations. Although we did have other active pitfall traps in this study, these were not affixed with track-monitoring stations, and thus excluded from our analyses of visitation by predators. However,

although track-monitoring stations were only monitored on a weekly basis, all pitfall traps were checked daily.

We performed a nominal logistic regression using JMP (version 5.0.1a, SAS, Institute, Inc., Cary, North Carolina). We treated tracks as a categorical variable and presence or absence of animals in pitfall traps as a numerical variable. We only used information obtained when pitfall traps were physically open in our analyses. Finally, we performed a Chi-Square test of independence using the program S-PLUS (version 6.1, Insightful Corporation, Seattle, Washington) to test for an association between rates of visitation and presence or absence of a pitfall trap.

RESULTS—*Griffith League Ranch*—Ten Deer Cam® Model DC-100 cameras were installed on 11 February 2004 and remained operational until 1 September 2004 for a total of 210 camera-days. A total of 455 photographs documented 15 species of animals (Table 1). The most-frequently photographed species was the raccoon (*Procyon lotor*) with 190 photographs (41.8% of photographs). The next-highest categories were researchers (81 photographs; 17.8%) and empty frames (77 photographs; 16.9%). Cameras documented prolonged visitation of specific predators and illustrated activities of predators at pitfall traps. Thirty-two photographs showed predators either physically in pitfall traps or looking into or investigating contents of pitfall traps (Fig. 1). These animals included the raccoon, gray fox (*Urocyon cinereoargenteus*), eastern fox squirrel (*Sciurus niger*), striped skunk (*Mephitis mephitis*), Virginia opossum (*Didelphis virginiana*), bobcat (*Lynx rufus*), and coyote (*Canis latrans*).

Track-monitoring stations were in place and operational 21 October 2003–20 December 2004. During this time, 563 (36.5%) of 1,541 track-station trap-nights had tracks present. This period was split into two phases based on number of raking events per month. During 21 October 2003–17 June 2004, raking occurred 4 times/month. There were 443 (35.8%) of 1,236 track-station trap-nights with tracks present, including 20 instances when >1 animal was recorded at a track-monitoring station. During this period, the most frequent visitor was the raccoon with 292 track recordings, followed by the American crow (*Corvus brachyrhynchos*; *n* = 53) and unknown or unidentifiable tracks (*n* = 31). Other species documented included the gray fox (*n* = 25), unidentified snakes (*n* = 13), Virginia opossum (*n* = 11), unidentified rodents

TABLE 1—Individual vertebrates photographed at pitfall traps on Griffith League Ranch, Bastrop Co., Texas (11 February–1 September 2004) and a ranch in Guadalupe Co., Texas (23 June–5 October 2004). Percentages were calculated using only photographs of animals, excluding blank photographs and photographs of researchers.

| | Study Area | | |
Species	Griffith League Ranch	Guadalupe County Ranch	Totals
Raccoon (*Procyon lotor*)	190 (64.0%)	9 (47.4%)	199 (63.0%)
American crow (*Corvus brachyrhynchos*)	35 (11.8%)	0	35 (11.1%)
Wild turkey (*Meleagris gallopavo*)	14 (4.7%)	0	14 (4.4%)
White-tailed deer (*Odocoileus virginianus*)	14 (4.7%)	0	14 (4.4%)
Gray fox (*Urocyon cinereoargenteus*)	7 (2.4%)	0	7 (2.2%)
Bobcat(*Lynx rufus*)	7 (2.4%)	0	7 (2.2%)
Domestic cat (*Felis catus*)	0	6 (31.6%)	6 (1.9%)
Greater roadrunner (*Geococcyx californianus*)	6 (2.0%)	0	6 (1.9%)
Nine-banded armadillo (*Dasypus novemcinctus*)	5 (1.7%)	0	5 (1.6%)
Coyote(*Canis latrans*)	5 (1.7%)	0	5 (1.6%)
Eastern fox squirrel (*Sciurus niger*)	4 (1.3%)	0	4 (1.3%)
Great-crested flycatcher (*Myiarchus crinitus*)	3 (1.0%)	0	3 (1.0%)
Striped skunk (*Mephitis mephitis*)	2 (0.7%)	1 (5.3%)	3 (1.0%)
Virginia opossum (*Didelphis virginiana*)	2 (0.7%)	0	2 (0.6%)
Three-toed box turtle (*Terrapene carolina*)	2 (0.7%)	0	2 (0.6%)
Coypu (*Myocastor coypus*)	0	1 (5.3%)	1 (0.3%)
Mourning dove (*Zenadia macroura*)	1 (0.3%)	0	1 (0.3%)
Northern mockingbird (*Mimus polyglottos*)	0	1 (5.3%)	1 (0.3%)
Eastern cottontail (*Sylvilagus floridanus*)	0	1 (5.3%)	1 (0.3%)
Totals	297	19	316

($n = 10$), striped skunk ($n = 10$), white-tailed deer (*Odocoileus virginianus*; $n = 6$), unidentified birds ($n = 5$), nine-banded armadillo (*Dasypus novemcinctus*; $n = 2$), and coyote ($n = 1$). During 18 June–20 December 2004, raking occurred 2 times/month and all pitfall traps were closed. Of 305 track-station trap-nights, 120 (39.3%) had tracks present, including six instances where >1 animal was recorded at a track-monitoring station. Again, the most-frequent visitor was the raccoon with 71 recorded visits, followed by unidentifiable tracks ($n = 15$), American crow ($n = 7$), gray fox ($n = 7$), unidentified snakes ($n = 7$), white-tailed deer ($n = 4$), unidentified rodents ($n = 3$), nine-banded armadillo ($n = 3$), bobcat ($n = 3$), Virginia opossum ($n = 2$), coyote ($n = 1$), and striped skunk ($n = 1$).

Six incidences of predation upon toads occurred near pitfall traps. Five involved predation upon Hurter's spadefoot toads (*Scaphiopus hurterii*), which were partially consumed up to the pectoral region. Raccoon tracks occurred simultaneously at all five sites. The sixth incidence was upon a Gulf Coast toad (*Bufo nebulifer*), whose carcass was found alongside a pitfall trap with its hind limbs chewed off. Raccoon tracks also were recorded at this site at that time. This type of predation, in which the rear portion of toads are consumed leaving behind the head and neck, has been documented in both the striped skunk and raccoon (Schaaf and Garton, 1970; Groves, 1980).

Overall capture success at pitfall arrays during 21 October 2003–17 June 2004 was low. Only 113 captures occurred across all arrays and pitfalls with 116 animals in pitfalls and 19 animals in funnel traps. In pitfalls with track-monitoring stations, i.e., pitfall traps monitored for predator activity, only 63 instances occurred where pitfall traps captured animals.

All statistical analyses comparing effects of tracks on presence or absence of animals in pitfall traps showed no significant difference. The 95% confidence interval calculated for proportion of track-station trap-nights with tracks and animals ($n = 24$) to total track-station trap-nights with tracks ($n = 352$) versus proportion of track-station trap-nights with no tracks and animals ($n = 39$) to total track-station trap-nights with no tracks ($n = 650$) contained zero ($-0.024 < P_1 – P_2 < 0.040$). The two proportions,
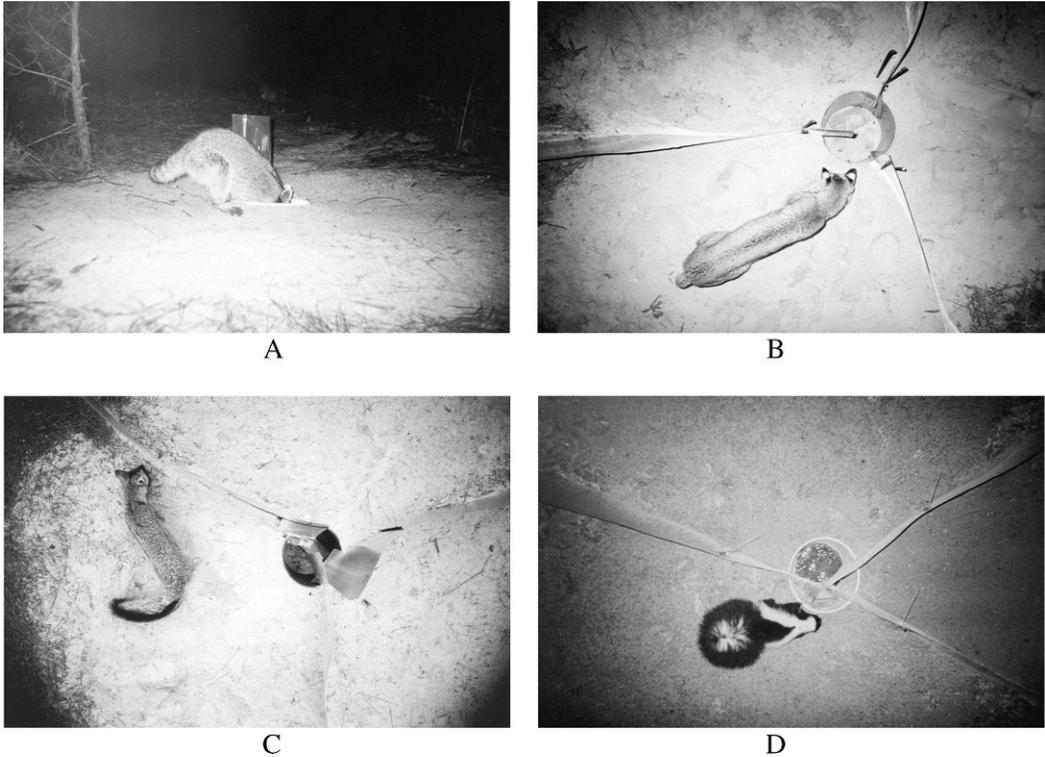
FIG. 1—Predators actively investigating or entering pitfall traps at Griffith League Ranch, Bastrop Co., Texas, 11 February–1 September 2004: A) raccoon, *Procyon lotor*; B) bobcat, *Lynx rufus*; C) gray fox, *Urocyon cinereoargenteus*; and D) striped skunk, *Mephitis mephitis*.

P_1 (track-station trap-nights with tracks and captured animals/total track-station trap-nights with tracks) = 0.068 and P_2 (track-station trap-nights without tracks and captured animals/total track-station trap-nights without tracks) = 0.060, did not differ, indicating that presence of predators at track-monitoring stations or pitfall traps did not influence detectability or capture success of small vertebrates. This result could be confounded by the low-effect size and reduced power due to low number of animals captured in pitfall traps during the study.

A nominal logistic regression also indicated no effect of predators on capture success of pitfall traps (χ^2 = 1.21, P = 0.272, r^2 = 0.001, n = 745, df = 1). These results further support the conclusion that presence of predators at track-monitoring stations did not affect rate of capture by pitfall traps.

During the 2 months in which both the track monitoring stations and control plots were operational on the Griffith League Ranch, no significant differences occurred in visitation rates

at track monitoring stations and control plots (χ^2 = 0.3667, P = 0.5448, n = 252), indicating that patterned foraging was not occurring. The proportion of track monitoring stations with tracks present and a pitfall present (n = 87) to the total number of track station trap nights with a pitfall present (n = 216) was 0.403 compared to the proportion of control plots with tracks present (n = 12) to total control plot trap nights (n = 36) which was 0.333. These two proportions did not differ significantly (95% confidence interval for the difference $-0.097 <$ P_1–$P_2 <$ 0.237), leading us to conclude that during this 2-month period predator visitation to track monitoring stations was not influenced by whether or not the station actually surrounded a pitfall trap or not.

Guadalupe County—Six Deer Cam cameras were installed 23 June 2004 and remained in operation until 5 October 2004 for a total of 117 camera days. During this period, 256 photographs were taken including 199 empty frames. A total of 19 photographs documented six species

of vertebrates, with the other 38 photographs recording researchers (Table 1). The most-frequent predator was the raccoon with nine photographs followed by the domestic cat (*Felis catus*) with six photographs. Five individual domestic cats, identified from their unique pelage patterns, attended track-monitoring stations and their associated pitfall traps. Only one other potential vertebrate predator was documented on film; the striped skunk appeared in one photograph. Other animals documented by the motion-sensitive cameras included the northern mockingbird (*Mimus polyglottos*), eastern cottontail (*Sylvilagus floridanus*), and coypu (*Myocastor coypus*). Each occurred in one photograph. Photographic documentation was low compared to track-monitoring data in Guadalupe County.

Track-monitoring stations were in place and operational 23 June–5 October 2004 and 8 May–7 July 2005. During these periods, 96 (28.8%) of 333 track-station trap-nights had tracks. Tracks occurred in monitoring stations on the first day of operation. A single Virginia opossum was recorded at a track-monitoring station on 23 June 2004. Six sets of tracks were recorded at four stations on the following day with tracks of a passerine bird, raccoon, Virginia opossum, and domestic cat. Individual sets of raccoon tracks were recorded at three stations. Rates of visitation increased in frequency with a peak activity of 24 recordings of tracks in July. There were 16 sets of tracks in August and 18 in September. During 23 June–5 October 2004, the most-frequent visitor was the domestic cat with 22 visits followed by the raccoon with 11 visits. Other visitors documented included unidentified ($n = 10$), striped skunk ($n = 8$), Virginia opossum ($n = 7$), coypu ($n = 2$), nine-banded armadillo ($n = 1$), and an unidentified bird ($n = 1$).

Beginning in September, all pitfall traps and track-monitoring stations were closed for 8-months. After this 8-months, traps were reopened and raking of monitoring stations was reinitiated. After only 2 days of having traps open, raccoon tracks were recorded at three stations on two drift-fence arrays. Animals recorded during this phase of the study included unidentified ($n = 11$), raccoon ($n = 9$), domestic cat ($n = 4$), nine-banded armadillo ($n = 4$), birds ($n = 3$), snakes ($n = 2$), and coypu ($n = 1$).

The proportion ($P_1 = 0.15$) of track-station trap-nights with tracks that caught animals ($n = 10$) to total track-station trap-nights with tracks ($n = 65$) was not different from the proportion ($P_2 = 0.12$) of track-station trap-nights without tracks that caught animals to total track-station trap-nights without tracks ($n = 122$) as indicated by the 95% confidence interval, which contained zero (95% CI: $-0.074 < P_1 - P_2 < 0.136$). This demonstrated that presence of predators in track-monitoring stations did not influence capture success of animals in pitfall traps. No difference was detected for rates of visitation at control plots and track-monitoring stations in Guadalupe County ($\chi^2 = 0.008$, $P = 0.929$, $n = 183$, $df = 1$) illustrating a lack of preferential visitation of predators to track-monitoring stations with pitfall traps. The proportion of track-monitoring stations with tracks present and a pitfall trap present ($n = 53$) to total number of track-monitoring station trap-nights with a pitfall trap present ($n = 150$) was 0.353 compared to the proportion of control plots with tracks present ($n = 12$) to total control-plot trap-nights ($n = 33$), which was 0.364. The 95% confidence interval of these proportions contained zero ($-0.191 < P_1 - P_2 < 0.169$), indicating there was no significant difference between proportions.

DISCUSSION—In this study, we sought to document the variety, frequency of visitation, and possible effects of predators on animals captured in pitfall traps using both direct and indirect indices of activity of predators at arrays. If we assume that visitation by predators is likely to result in consequent predation, then our two assessments produced logically conflicting results. Based on direct monitoring of predator activity at pitfall arrays, predators are frequently present at each pitfall trap, posing a threat to animals confined to pitfall traps. This was clearly seen in data obtained using motion-sensitive cameras, where predators, such as raccoons, were seen entering or investigating pitfall traps on multiple occasions. Amount of visitation by predators indirectly documented at track-monitoring stations also indicated a possible threat to captured animals. Consistent visitation at pitfall traps by predators seems to document a routine potential for fatal interactions between predators and prey confined to pitfall traps. Despite perceived threats, statistical analyses failed to detect a significant correlation between presence of predators and absence of animals in pitfall traps. This discrepancy could be a result of

several factors including low number of captures in pitfall traps, an inability to determine if an animal was captured before or after the predator visited the track-monitoring station, or preferential selection of prey by vertebrate predators. Capture of multiple individuals in a single pitfall trap also confounds the ability to determine if predators removed only a portion of captured animals from traps. Our data indicate that recording rates of visitation by predators using indirect indices may not provide enough power to detect statistically significant differences regarding effects of vertebrate predators on capture success of pitfall traps.

Several facts regarding predation on drift-fence arrays are highlighted by results of this study. Predators quickly began to visit newly established pitfall traps. Trap lines on the Griffith League Ranch had been established 2 years prior to monitoring of predator activity; however, trap lines in Guadalupe County were entirely new. We find it particularly notable that predators initiated investigations of arrays on the first day traps were opened and continued visitations throughout the study.

Of additional interest, was composition of predators visiting trap lines. Diversity of predators recorded by track-monitoring stations and motion-sensitive cameras was high, ranging from species such as the domestic cat and Virginia opossum to the gray fox and bobcat. In all, 10 potential species of predators were recorded attending pitfall traps. Dominance of raccoons at both camera and track-monitoring stations supported our original assumption about which species might pose the greatest threat to captured animals. However, our results implicated a suite of predators originally believed to pose little or no threat including avian predators like the American crow and greater roadrunner (*Geococcyx californianus*) and larger carnivores such as bobcats and coyotes.

Our study provides one of the first quantitative analyses of predator visitation at pitfall traps and documents some of the major species of predators visiting these traps. Wildlife biologists using terrestrial drift-fence sampling with pitfall traps need to recognize and seek to address predation on captured animals. Protective measures using predator-exclusion devices (Mazerolle, 2003; Ferguson and Forstner, 2006) can help reduce mortality by mammalian and avian predators while retaining functional and efficient pitfall traps. While in some situations (e.g., endangered species), precautionary measures are easily justified, the level of visitation by predators documented in our study leads us to recommend predator-exclusion devices as a normal component of drift-fence arrays. Although we did not detect a statistically significant effect on captures, frequency, consistency, and variety of predators visiting pitfall traps could affect both quantitative and qualitative results from surveys using this type of trapping method.

Additional studies on the direct effect of predator activity on data obtained from drift-fence sampling should continue. In particular, a variety of methods should be used to document whether predators significantly influence capture success at pitfall traps. Use of automated video recordings might help provide direct evidence of removal of animals by specific predators; thus, illustrating areas such as preferential removal, consumption, or both of retained animals by certain predators (Thompson et al., 1999).

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