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A COMPARISON OF SIGN SEARCHES, LIVE-TRAPPING, AND CAMERA-TRAPPING FOR DETECTION OF AMERICAN BADGERS (*TAXIDEA TAXUS*) IN THE CHIHUAHUAN DESERT

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Abstract.—In communities where they occur, American badgers (*Taxidea taxus*) play important ecological, economic, and conservation roles. Central to understanding of badger ecology and management are estimates of badger population status. However, few studies have compared methods of detecting badgers for population surveys. I compared searches for burrows and diggings, live-trapping, and the use of automatic cameras at scent lures, bait stations, and anthropogenic permanent and temporary wildlife water sources in the Chihuahuan Desert of southern New Mexico. Searches for confirmed badger burrows and diggings yielded 0.14–0.88 detections per kilometer of transect. Badgers were trapped in 1.6% of trap-weeks. Percentages of camera-weeks in which badgers were detected included 12.8% at scent lures, 5.6% at bait stations, 54.5% at permanent water sources, and 13.3% at temporary water sources.

Resumen.—Los tejones americanos (*Taxidea taxus*) desempeñan funciones ecológicas, económicas y de conservación importantes en las comunidades en donde se encuentran. Las estimaciones del estado de la población de tejones es fundamental para la comprensión de su ecología y su gestión. Sin embargo, pocos estudios han comparado los métodos de detección de tejones en estudios poblacionales. Comparé búsquedas de madrigueras y excavaciones, capturas y el uso de cámaras automáticas con señuelos de olor, trampas con cebo y fuentes permanentes y temporales antropogénicas de agua silvestre en el desierto de Chihuahua, en el sur de Nuevo México. Las búsquedas de madrigueras de tejones confirmadas y las excavaciones arrojaron 0.14–0.88 detecciones/km por transecto. Los tejones fueron atrapados en 1.6% de las trampas semanales. El porcentaje de cámaras semanales que detectaron tejones, incluyen cámaras con señuelos de olor (12.8%), cámaras en trampas con cebo (5.6%), cámaras en fuentes de agua permanentes (54.5 %), y cámaras en fuentes de agua temporales (13.3%).

American badgers (*Taxidea taxus*) are North American endemic mustelids with ecological, economic, and conservation significance. Badgers consume a wide variety of prey, including rodents, amphibians, reptiles, eggs, lagomorphs, and vegetation, and are themselves prey to larger carnivores (Lindzey 2003). Their digging activities can significantly affect soils at the ecosystem level (Eldridge 2004), and older dens provide microhabitat for numerous species including burrowing owls (*Athene cunicularia*), arthropods, reptiles, lagomorphs, skunks, and kit foxes (*Vulpes macrotis*). Badgers produce mounds and deep holes which may result in damage to livestock and farm equipment (Minta and Marsh 1988), although the actual extent of such damage may be greatly overstated (Quinn 2008). Badger fur is commercially valuable (Lariviére 2014), with as many as 35,000 badgers harvested per year during times of peak demand (Obbard et al. 1987, Fox and Papouchis 2004). Badgers are listed as threatened in Mexico (Luiselli Fernández 2002) and endangered in Canada (i.e., 2 subspecies: *Taxidea taxus jacksoni* and *Taxidea taxus jeffersonii;* Committee on the Status of Endangered Wildlife in Canada 2006). Badgers are also designated a Species of Special Concern in California (California Department of Fish and Game 2014). Central to an understanding of badger ecology and management of badger impacts and conservation are estimates of badger population status. There is little knowledge of how to best detect badgers for population surveys. Quinn (2008:159) stated that the "most needed management tools are means of monitoring badger presence and population sizes."

Counting burrows is the method most commonly used to determine badger presence and to generate relative abundance indices (e.g., British Columbia Ministry of Environment 2007, Lay 2008, Quinn 2008). However, no study has explicitly stated the criteria used to distinguish badger burrows or diggings from those of other species. Entrances of badger

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burrows are generally reported to be wider than high (Elbroch 2003). Although this has long been considered a diagnostic feature separating badger burrows from those of other species (Lay 2008), some researchers have reported limited difference in height and width or even overlap in those dimensions (Hetlet 1968, Elbroch 2003). Given potential overlap in width and height dimensions, modification by erosion, confounding effects caused by other species, and overlap in burrow dimensions with sympatric species (Elbroch 2003), studies which use a width-to-height-ratio criterion become questionable. Also, factors unrelated to population size, such as burrowing rates, soil type, movement patterns, and prey species composition, will influence burrow counts, making comparisons between populations difficult. Thus, comparison of burrow searches with other methods that might provide more reliable data are warranted. Previous tests of burrow searches against alternatives are limited and comprise comparisons with methods such as spotlighting, scent stations, sightings, and hunter surveys, which have significant limitations (Hein and Andelt 1995, Warner and Ver Steeg 1995, Quinn 2008). For more-detailed and precise demographic analyses, it may be preferable to generate individual encounter histories through, for example, live-trapping or automatic photography.

Capture–mark–recapture has been used to measure absolute badger abundance and population characteristics (Messick and Hornocker 1981, Goodrich and Buskirk 1998), and capture without recapture has been used to generate a badger relative abundance index (Hein and Andelt 1995). Previous studies have primarily used leg-hold traps. Potential for injury (Andelt et al. 1999) may preclude use of such devices in surveys, especially where the focal species is endangered, threatened, or rare, or where these devices are currently illegal (e.g., California). Injury rates from enclosure traps (box, cage, cubby) are far less than from leg-hold traps (Mowat et al. 1994, Powell and Proulx 2003). Enclosure traps are thought to be unattractive to badgers (Messick 1987), but they have not been used as extensively as leghold traps.

Automatic cameras have not been used previously to study badgers alone, although badgers have been photographed in studies involving other species (Farber 2011, Stratman 2012). Cameras are noninvasive, produce unambiguous and verifiable evidence of multiple species, and may operate for extended periods with little maintenance. If individuals have unique markings, photographs may be used to generate individual encounter histories without capturing and marking animals (Heilbrun et al. 2006, Magoun et al. 2011). Individual badgers may be identified by unique features of their white dorsal head stripes if close-up photographs of their heads can be obtained (Harrison in review). Given that live- and camera-trapping may be used to obtain demographic and other information, it is of interest to test the use of enclosure traps and automatic cameras to detect badgers.

American badgers occur most commonly in grasslands, woodlands, and cold deserts (Lindzey 2003), but they also occur in hot deserts including the Chihuahuan Desert (Long 1972). The only previous study of badgers in a hot desert habitat was a limited description of dens, diet, and morphology by Lopez-Soto (1980). Badgers will visit and drink at anthropogenic water sources (Rosenstock et al. 2004), but the significance of this source of water to badger physiology has not been established. The water needs of badgers have not been studied and no demographic information on badgers in hot deserts is available.

The purpose of this study was to compare searches for burrows and diggings (sign), live-trapping, and the use of cameras as means to detect badgers. I compared sign surveys on walking and vehicle transects, recorded the dimensions of burrows found, and compared the dimensions of burrows with and without evidence of badger activity. I tested live-trapping with the use of enclosure traps exclusively and tested automatic cameras at scent lures, bait, and anthropogenic permanent and temporary water sources. This is the first study to examine detection methods for badgers in a desert habitat.

STUDY AREA

The study was conducted in the Chihuahuan Desert on the 142,000-ha Armendaris Ranch, a private bison (*Bison bison*) and hunting ranch in Sierra and Socorro Counties in south central New Mexico. Habitat within the study area was dominated by black grama grass (*Bouteloua eriopoda*) and shrubs of creosotebush (*Larrea tridentata*), honey mesquite (*Prosopis glandulosa*), longleaf jointfir (*Ephedra trifurca*), sand sagebrush (*Artemisia filifolia*), and little-leaf sumac (*Rhus microphyllum*). Topography was flat or low rolling hills and elevations were 1300–1500 m. Annual precipitation falls mostly in summer and fall and averaged 23.6 cm from 1951 to 2010 and 20.7 cm during fieldwork (see Methods; Western Regional Climate Center 2014). Average monthly minimum and maximum temperatures were 8.0 °C and 23.7 °C, respectively, from 1951 to 2010, and 9.0 °C and 24.2 °C, respectively, during this study. Trapping was not allowed on the Armendaris Ranch other than for research. Permanent water stations and bird feeders for a quail (*Callipepla* spp.) hunting program were located throughout the Armendaris Ranch along roads at intervals of 1–2 km (Rollins et al. 2009). Within the study area (28,000 ha), there were 62 water-feeder sites (1 site per 4.5 km^2) plus 6 additional bird feeders not located adjacent to a water station (hereafter "drinkers"). The average minimum distance between drinkers was 0.81 km (SD 0.34 km). Anthropogenic permanent water stations consisted of 2000-L reservoirs accessed by 150 × 20-cm openings and filled via sheet metal rainfall collectors ($N = 59$) or concrete aprons ($N = 3$). There were no natural water sources within the study area other than ephemeral pools created by precipitation events. Bird feeders consisted of 200-L plastic barrels with small holes near the bottoms from which milo (grain sorghum, *Sorghum bicolor*) was available. In addition to birds, small rodents were attracted to feeders and often burrowed nearby. Bird feeders produced small areas of elevated small rodent prey density (Harrison personal observation) which may have been attractive to badgers (Messick 1987).

METHODS

Fieldwork was conducted from October 2011 to March 2014. I searched for badger burrows and diggings along transects on foot and by vehicle from August to December 2012 in areas known to be inhabited by badgers through sightings and photographs at drinkers. I chose this time period for sign surveys because it is the time of maximum badger abundance following juvenile dispersal (Messick and Hornocker 1981), and thus is the time when badger sign would likely be most abundant. Two types of walking transects were conducted: linear transects through badger habitat and radial pattern transects centered on bird feeders. All sign located within 50 m of transects was recorded. In areas of obscuring vegetation, additional searching off the transect line was conducted. I conducted 20 linear walking transects which averaged 6.23 km in length for a total length of 124.7 km. Linear transects were approximately 1 × 2-km rectangles located adjacent to but not crossing roads. These transects were placed with one 2-km side parallel to and 100 m from a road and the other 2-km side located 1.1 km from the road. I conducted radial pattern transects consisting of eight 100-m transects extending outward from 68 separate feeders for a total of 54.4 km. Twenty-eight transects were conducted by vehicle with no additional observers while I drove at 15 $km \cdot h^{-1}$ for a total of 126.5 km. All roads were dirt and either 1-lane or 2-track. Other traffic was infrequent and consisted only of ranch vehicles. It is unlikely that roads affected badger movements or home-range establishment.

I recorded all holes with openings within the dimensions given by Elbroch (2003). Following Lay (2008), a hole was classified as a "burrow" if it was ≥50 cm deep and classified as "digging" if it was <50 cm deep. In order to increase the likelihood of accurately ascribing sign to badgers, corroborating evidence was collected when detected, including the presence of hair, tracks, or marks diagnostic of badger digging. The British Columbia Ministry of Environment (2007) included parallel claw marks on the sides of dens or diggings as a diagnostic feature of badger activity. Such marks were reported by Lopez-Soto (1980). During this study I observed parallel markings, which were 1 cm apart on the sides of burrows and as much as 10 cm long (Harrison unpublished data). I considered the appearance of such claw marks as evidence of badger activity. In contrast, sign from canids, which are not able to rotate their forelimbs outwardly sufficiently to leave such marks, and from rodents, which typically leave marks at a smaller scale, could be eliminated. In order to examine the usefulness of counts of burrows and diggings corroborated with claw marks, I compared the dimensions of burrows with and without claw marks and analyzed the data with *t* tests. For each sign survey method (i.e., linear transect, radial transect, vehicle transect), I calculated the number of observations of sign found per kilometer as an index of the detection rate of the method. Sign encounter rates were compared between linear transects, radial transects, and vehicle transects, and data were analyzed with a Kruskal–Wallis test.

I attempted to live-trap badgers in enclosure traps from October 2011 to December 2012. I did not use leghold traps in order to minimize injuries. Traps were 39 × 52 × 108-cm and 26 × 31 × 82-cm single-door cage traps (Tomahawk Live Traps, Hazelhurst, WI) and 80-cm-long by 27-cm-diameter tube traps (The Snare Shop, Lidderdale, IA) which were placed adjacent to drinkers and kangaroo rat (*Dipodomys* spp.) burrow mounds. The average spacing between traps was 1.1 km. Given that no previous study has reported the effectiveness of various baits used in enclosure traps, I tested a variety of baits and lures. Baits included sardines, raisins, chicken (cooked and uncooked), eggshells, canned cat food, pork, and dead laboratory rats (Layne Laboratories, Arroyo Grande, CA). Scent lures were used in combination with baits and included Just Mice™, Caven's Gusto™, skunk essence, Fox Hollow Voo-Doo™, Violator 7™, Carman's Canine Call™ (Minnesota Trapline Products, Pennock, MN), fatty acid scent tablets (USDA, Pocatello Supply Depot, Pocatello, ID), Badger Buster™ (Peterson Furs, Ramona, SD), and Big Stinky™ (A.M. Grawe, Wakpeton, ND). No more than one bait type and one lure type were used together. For shade and camouflage I covered traps with fitted vinyl (Tomahawk Live Traps), vegetation, or boards. Badgers are fossorial and thus, in an attempt to encourage badgers to enter traps, I buried a subset of traps within the soil at the site of the trapping location.

Captured badgers were weighed in the trap and sedated with xylazine (3 mg · kg^{-1} body mass) combined with ketamine (10 mg · kg^{-1}) administered intramuscularly with a jab stick. Individuals were examined for injury and gender, measured, and photographed. When fully recovered from sedation, badgers were released at the site of capture. Handling procedures were approved by the University of New Mexico Institutional Animal Care and Use Committee (Protocol 11-100748-MCC) and the New Mexico Department of Game and Fish (Scientific Collecting and Educational Purpose Permit no. 3381). I calculated number of badgers captured per trap-night or trap-week as indices of the detection rate of trapping.

I used automatic infrared-flash digital cameras (Reconyx HC600 or PC900, Holmen, WI) at 4 types of sites: scent lure stations, bait stations, anthropogenic permanent water sources (drinkers), and anthropogenic temporary water stations. For each site type, I recorded dates and times of badger visits. For indices of the detection rate of cameras, I used the number of badgers photographed per camera-week. To minimize potential bias, I did not test scent lure stations, bait stations, and temporary water stations simultaneously, I located stations >300 m from drinkers, and I did not operate cameras at the 2 drinkers closest to stations during station tests.

At scent lure stations I placed lures on the ground under a perforated 250-mL tin can, which I then staked to the ground. Lures included sardine oil (n = 11 stations), 3 fatty acid scent tablets (n = 6 stations), skunk essence oil (n = 18 stations), Just Mice (n = 6 stations), and Badger Buster (n = 10 stations). A single automatic camera was mounted 5 m from the can and 1 m above the ground on a steel fencepost. Cameras remained set at each lure station for 2 weeks from February to May 2012. Scent lure stations were located midway between drinkers. Badgers remained active in the study area throughout the year (Harrison in press) and thus lures may be tested at any time of year.

Bait stations consisting of 2 cans of commercial cat food, 1 chicken leg, and 1 pork spare rib in a chicken wire basket (Farber 2011) were suspended 1 m above the ground on a steel fencepost during November–December 2013 and February–March 2014. I chose this time period for bait station tests because winter and spring are the times of least prey abundance. Also, during warmer months meat bait becomes putrid and then dried within a few days, reducing its attraction. I covered each basket on 2 sides with boards to reduce drying by wind, sunlight, and low humidity and mounted one camera on the opposite side of the post from the basket. The field of view of all bait-station cameras was directly downward. Bait stations were placed against shrubs so that badgers could not approach from the blind side of the camera. I rubbed the pork rib against the base of the post and allowed liquids

TABLE 1. Average dimensions (cm) of potential badger burrows observed during walking and vehicle surveys in the Chihuahuan Desert of southern New Mexico, August–December 2012. Dimensions with and without claw marks were compared with t tests.

	Burrows with claw marks			Burrows without claw marks			
	Mean	Range	n	Mean	Range	n	P
Width	20.5	17–23	11	22.3	17–32	31	>0.500
Height	19.5	15–31	11	17.3	12–32	30	>0.500
Width − Height	1.0	−9 to 5	11	5.0	−2 to 13	29	>0.500
Mound length	83.5	43–112	11	92.4	42–122	25	>0.500

from the cat food to drip near the base of the post to attract badgers directly beneath the cameras in order to obtain a close-up photograph of dorsal head stripes. Each station was operated for one week. Bait stations were located midway between drinkers at the same locations as scent lure stations but not operated during the same time period as the scent lure stations.

Cameras were placed at drinkers from May 2012 to March 2014. Each camera was maintained weekly, which included changing memory cards and batteries as necessary. Because few desert areas have as high a density of drinkers as was present within the Armendaris Ranch, I briefly tested the use of cameras at temporary water stations May–June 2013. I chose this time period to test temporary water stations because it is a time of year in the study area when precipitation is low and temperatures are high. Each temporary water station consisted of a 6.6-L automobile oil drain pan filled with water and placed in a 30-cm-deep hole which was then covered with boards and soil. The entrance was monitored by a single camera on a steel post. A scent lure (Canine Call or 2 fatty acid scent tablets) was placed next to each pan. Scent lures served as long-distance lures, and the presence of water served as an attractant to encourage badgers to come to a specific location where their head stripes could be photographed at close range. Because scent lures and water were present simultaneously, it was not possible to separate which substance actually attracted badgers to the stations.

RESULTS

I found potential sign (burrows or diggings) of badger presence at an average of 1.70 signs · km^{-1} (95% CI 0.75–2.66) on 20 walking linear transects, including an average of 0.60 signs · km^{-1} (95% CI 0.10–1.10) with claw marks. At bird feeders, potential badger sign was observed at an average of 7.24 signs · km^{-1} (95% CI 4.33–10.15) on 68 walking radial transects, including an average of 0.88 signs · km^{-1} (95% CI 0.44–1.32) with claw marks. During surveys by vehicle, I found an average of 1.03 potential badger signs per kilometer (95% CI 0.29–1.77) on 28 transects, including an average of 0.14 signs · km^{-1} (95% CI 0.04–0.24) with claw marks. Considering both sign with and without claw marks, there were significant differences between the sign encounter rates of the 3 methods (H_c = 22.068, v = 2, P < 0.001). Based upon confidence intervals, more sign was found at bird feeders than on linear or vehicle transects. Considering sign with claw marks only, there were no significant differences between the sign encounter rates of the 3 methods (H_c = 4.736, v = 2, P = 0.095). I found no badger hair or tracks at burrows or diggings.

Average dimensions of potential badger burrows with and without claw marks were not significantly different (Table 1). Among 11 burrows with claw marks, the heights of 2 burrows were less than their widths and one burrow had equal height and width.

I captured 2 badgers in 861 trap-nights (0.0023 captures per trap-night or 0.016 captures per trap-week), including 700 trap-nights using 26 × 31 × 82-cm traps, 35 trap-nights using 39 × 52 × 108-cm traps, 126 trap-nights using tube traps, 761 trap-nights at drinkers, 100 trap-nights at kangaroo rat burrow mounds, 114 trap-nights using 26 × 31 × 82-cm traps buried at drinkers, and 68 trap-nights using tube traps buried at drinkers. One badger was captured in a 26 × 31 × 82-cm single-door cage trap baited with a dead laboratory rat and no scent lure. The other badger was captured in a buried tube trap baited with a pork rib, a chicken drumstick, 2 cans of canned cat food, and no scent lure. Both badgers were captured at drinkers. Sample size of trapped badgers was insufficient for statistical comparisons of trap, bait, or lure types.

Badgers visited scent lure camera stations during 12.8% of a total of 102 camera-weeks. They approached sufficiently close to lures for a close-up photograph of their dorsal head stripes during 3.9% of camera-weeks. The percentages of visits to specific lures were fatty acid scent tablets 37%, Badger Buster 27%, Just Mice 18%, skunk essence 18%, and sardine oil 0%. Sample size of badger visits (n = 13) was too small for statistical analysis of lures.

Badgers visited bait stations during 5.6% of a total of 144 camera-weeks. All cameras at bait stations were pointing directly downward; thus all observed visits by badgers yielded close-up photographs suitable for identification of individual badgers. Badgers visited drinkers with cameras during 54.5% of 1293 camera-weeks, including 2227 separate visits. The average number of visits per camera-week was 1.87 (95% CI 1.58–2.16, range 0–17) from May 2012 to March 2014. The cumulative number of drinkers where badgers had been photographed reached a plateau at 86% of the final value after 9–10 camera-nights and surpassed 95% of the final value at 18 camera-nights. Excluding those drinkers where badgers were never photographed, at least one badger was photographed during 22.0% of camera-nights or on average every 4.5 nights at each site. Photographs useful for individual identification were obtained during 62.2% of visits to drinkers.

I operated temporary water stations for 30 camera-weeks. Badgers were detected on 4 occasions (13.3% of camera-weeks), including 3 occasions that provided photographs suitable for individual identification (10% of camera-weeks).

DISCUSSION

Searches for badger sign by walking or vehicle surveys in the Chihuahuan Desert produced on average 0.14–0.88 confirmed signs per kilometer and 1.03–7.24 combined confirmed and unconfirmed signs per kilometer, including both burrows and diggings. Lay (2008) and Quinn (2008) reported 3.8 and 5.9 (unconfirmed) badger burrows per kilometer, respectively, in coastal central California. Considering both confirmed and unconfirmed sign, detection rates were higher at bird feeders than on linear or vehicle transects. The fact that more badger sign was found near bird feeders than on linear or vehicle transects agrees with the general assumption that more badger sign is likely to be found where prey densities are higher. However, 91% of bird feeders were located adjacent to drinkers. Thus it was not possible to determine if badgers were attracted to those sites by water or prey or both. It is likely that a portion of unconfirmed sign was actually due to badgers, but it was not possible to determine that percentage. It follows that badger activity is likely underestimated by including only sign with claw marks, but overestimated by including sign with and without claw marks.

As anticipated, the width-to-height ratios of burrow openings were not useful for assignment of species. The dimensions of burrows with claw marks broadly overlapped those without claw marks, and some burrows with claw marks had smaller widths than heights. The mean difference between height and width of burrows with claw marks was only 1.0 cm, indicating that erosion or activity by other species could easily confound species assignment for burrows originally dug by badgers. Trapping with enclosure traps produced 0.016 detections per trap-week. This is the only published study that used enclosure traps with badgers. The use of enclosure traps instead of leghold traps does not appear to be overly limiting to capture of badgers, as Hein and Andelt (1995) also reported a low capture rate of 0.032 per trap-week using leghold traps in eastern Colorado grassland, an area which would be expected to have higher badger density than would the Chihuahuan Desert. This study and Hein and Andelt (1995) are the only published studies which attempted to capture badgers without prior knowledge of the locations of badgers. Most other studies set leghold traps or snares at the entrances of occupied dens and, in doing so, experienced higher trapping success. For example, Todd (1980) reported a capture rate of 0.725 badgers per trap-week in Idaho.

Badger detections per camera-week at scent lure stations (0.128), bait stations (0.056), and temporary water stations (0.133) were comparable to each other and to previous studies: Stratman (2012), while surveying swift foxes

(*Vulpes velox*) with cameras at scent lures in eastern Colorado grassland, reported 0.115 badger detections per camera-week. In a camera survey of mesocarnivores at bait stations, Farber (2011) reported 0.023 badger detections per camera-week in coniferous forest in northern California. Hein and Andelt (1995) and Quinn (2008) reported 0.003 and 0.049 badger detections per scent station-week, respectively. Of the survey methods tested, cameras at drinkers recorded the highest number of weekly visits. The percentage of drinkers where badgers were photographed surpassed 95% at 18 camera-nights, indicating that an observation period of 3 weeks at each drinker may be sufficient for detection of badgers.

Comparison between detection rates of searches for sign, live-trapping, and camera-trapping may be made on the basis of observed detection rates combined with reasonable assumptions of survey effort. Assuming a walking speed of 3 km · h^{-1}, a driving speed of 15 km · h^{-1}, searching for sign for 8 h per day, 30 live-traps, 30 camera-traps, 7 d of effort per week, and considering confirmed sign only, then over a one-week period badgers would be detected on average as follows: walking transects 100.8 detections, transects at bird feeders 147.8 detections, driving transects 117.6 detections, live-trapping 0.48 detections, cameras at lures 3.8 detections, cameras at bait 1.7 detections, cameras at temporary water sources 4.0 detections, and cameras at drinkers 16.4 detections. By this measure, the detection rates of sign searches, live-trapping, and camera-trapping were clearly separated. Given the assumptions above, searches for sign will produce the highest number of detections per week and live-trapping will produce the lowest. It should be noted that I assumed daily effort for sign searches and live-trapping, but camera-traps require only one visit per week.

Tests of the various detection methods in this study were not conducted simultaneously, confounding the effects of method, season, and year. Also, the duration of the study extended beyond population closure. However, the purpose of this study was to provide baseline detection rates of 3 broad categories of methods to detect badgers (searches for sign, live-trapping, and camera-trapping) as a basic guide for future research or surveys in desert habitats. Thus, some tests were conducted only during optimum times of year in order to reveal their maximum potential. It would not be logical, for example, to compare tests of bait and temporary water stations simultaneously during summer, when natural bait is most available and anthropogenic bait spoils rapidly but water needs are greatest. My results clearly separated the detection rates of the 3 broad categories of methods as applied in a desert habitat. Which category of method is ultimately chosen for a given project will depend not only upon detection rate but also upon logistics, finances, concern for the welfare of animals, and project goals.

Results of this study are applicable to other desert areas, but detection rates may be different for populations with different densities or in different habitats. The unusually high density of drinkers and bird feeders in the study area may have affected badger density. However, badgers visited drinkers less than twice per week and drank during only 58% of visits (Harrison in press). Rodent prey density was enhanced at feeders, but the spatial extent of this effect was very small (Harrison personal observation). Thus I expect any increase of badger density due to drinkers and feeders to be small. Furthermore, an increase of badger density would not affect the relative order of detection rates of the 3 main categories of survey methods tested here. Sign searches will be relatively less efficient where vegetation is denser and burrows and diggings are obscured, such as in sagebrush steppes, mid- and tall-grass prairies, and agricultural areas. However, sign searches may be relatively more efficient in areas where soil disturbed by badgers contrasts with snow or grass such as in short-grass prairies. The relative efficiencies of live-trapping and the use of automatic cameras at scent lures and bait stations are not likely to be affected by habitat. Anthropogenic water sources can offer little attraction to badgers in nondesert habitats.

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