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Tools and Technology

A Comparison of Methods for Monitoring Kit Foxes at Den Sites

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ABSTRACT Monitoring mammalian carnivores at den sites with human observers to document behavior, fecundity, litter size, and natal survival is commonplace when compared with monitoring den sites with cameras. However, no published studies exist comparing the effectiveness of human observers versus cameras in a quantitative manner. Obtaining complete and reliable counts of adult and pup kit foxes (*Vulpes macrotis*) can be crucial for estimating population parameters and life-history traits. In the summers of 2010 and 2011, we made weekly counts of adult and pup kit foxes at active den sites using 2 methods: 1) an observer equipped with spotting scope and/or binoculars and 2) a remote infrared motion-sensitive camera. We accumulated 71 and 29 counts at active den sites, respectively. The median number of adults observed at den sites with a camera and observer differed and were 2 adults versus 1 adult, respectively. Similarly, the median number of pups observed at den sites with a remote camera versus an observer differed and was 2 pups versus 1 pup, respectively. We observed these differences despite the similar effort required to manage cameras and conduct observations. We recommend future surveys aimed at ascertaining more reliable counts of kit foxes and similar species at den sites use a survey methodology employing remote cameras or video over a multi-day period.

KEY WORDS camera, observers, survey methods, Utah, *Vulpes macrotis*.

The ability to reliably count or estimate animal numbers via censusing or sampling is a central theme in wildlife conservation and management. Certainly, much methodological, theoretical, and quantitative advancement has been put forth in recent years (Seber 2002, Williams et al. 2002, Mills 2006, Morrison et al. 2008), vastly improving our understanding of sampling techniques. Nevertheless, ascertaining reliable animal counts via censusing or sampling remains a pivotal crux in any sampling design. The challenge of determining reliable counts of animal numbers has been addressed for entire populations and sub-populations (Manzo et al. 2012, Rondon et al. 2012, Sugimoto et al. 2012), but research on the effectiveness of reliably counting family groups or individuals within a particular age class of a family group (i.e., ad versus juv) has received little attention. Counting animals from a relatively small and clustered number of individuals usually leads researchers to employ a method relying on the assumption that all individuals are accounted for (i.e., a census) rather than an estimate based on sampling, thus assuming complete detection (Morrison et al. 2008). However, challenges with such counts can arise when complete detection is not achieved due to behavioral or physiological traits of study animals (MacKenzie et al. 2005). For example, mammalian species living a semi-fossorial lifestyle, such as kit foxes (*Vulpes macrotis*) and similar fossorial and nocturnal species, provide unique challenges because the spatio-temporal window during which reliable above-ground counts can be made (i.e., all individuals of a particular age class must be above ground and within proximity to one-another at the same time) can be restrictive (McGee et al. 2005).

Historically, kit foxes were the most abundant mammalian carnivore throughout the U.S. Army Dugway Proving Ground, Utah, USA, and other areas of the Great Basin (Egoscue 1975). This small canid is currently listed as a Utah State Sensitive Species, listed as endangered in Oregon, USA, and the San Joaquin kit fox (*V. m. mutica*) is a federally endangered sub-species. Given the need for management decisions and conservation plans for kit foxes and similar species, it is important that researchers and managers utilize the most effective den-site monitoring technique to acquire reliable information on recruitment, survivorship, and subsequent population trajectories.

The practice of using observers at fox den sites to count pups and adults, measure fecundity, monitor behavior, and document natal survival appears to be the standard methodology in many wildlife studies (Cypher et al. 2000, Koopman et al. 2000, Moehrenschlager and Macdonald

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2003, Wright 2006, Ausband and Foresman 2007). Advantages of human observers may include low costs (e.g., no equipment purchasing) and a wide field of view; whereas, disadvantages could include observer fatigue and an inability to count or monitor under nocturnal conditions. Infrared (i.e., non-flash) motion cameras and video monitoring systems also have been utilized, but to a lesser extent (McGee et al. 2005, Clifford et al. 2007). Potential advantages of these remote monitoring systems include consistent performance (e.g., no observer fatigue) over time and the ability to perform under nocturnal conditions. Disadvantages of cameras include potential equipment failure, a limited field of view, and increased equipment costs.

Studies employing a combination of these methods often do not compare methodologies (Clifford et al. 2007), or compare them in a non-quantitative manner (McGee et al. 2005). Obtaining complete and reliable counts or estimates of adult and pup kit foxes can be crucial for accurately measuring population parameters and life-history traits that influence measures of fecundity, density, recruitment, survival, and population models (e.g., population viability analysis). Hence, utilizing methods that produce unreliable counts or estimates of litters and adults has the potential to negatively influence management actions, conservation decisions, and a general understanding of a species' population dynamics. Given the aforementioned, and the scarcity of knowledge regarding the effectiveness of monitoring techniques at kit fox den sites, comparisons of methods are needed. Our objectives were to 1) document and compare counts of kit fox pups and adults between human observers and remote infrared motion cameras at active den sites; 2) describe factors that may influence the disparity in our findings; and 3) make recommendations on how to best monitor kit foxes and similar fossorial and nocturnal species at den sites.

STUDY AREA

Our study area was located in the eastern portion of the U.S. Army Dugway Proving Ground, Utah, and adjacent lands managed by the Bureau of Land Management (Fig. 1) and covered 202 km^2 of Great Basin Desert habitat. Elevation ranged from 1,288 m to 1,640 m. Due to its mid-latitude location, this arid region is often characterized as cold desert; winters are usually cold, and summers are hot and dry, with the majority of the precipitation falling in spring (Arjo et al. 2007). The majority of our study area and the locations of den sites consisted of 3 vegetation communities: 1) chenopod areas consisting of low shrubby shadscale (*Atriplex confertifolia*), gray molly (*Kochia americana*), and greasewood (*Sarcobatus vermiculatus*); 2) grasslands consisting of areas primarily dominated by exotic cheat grass (*Bromus tectorum*), Russian thistle (*Salsola kali*), and various species of exotic mustards (*Sysimbrium* sp.); and 3) vegetated sand dunes containing fourwing saltbush (*Atriplex canescens*), viscid rabbitbrush (*Chrysothamnus viscidiflorus*), hopsage (*Grayia spinosa*), dune rabbitbrush (*C. nauseosus* var. *turbinatus*), and horsebrush (*Tetradymia glabrata*), as well as several native perennials and grasses.

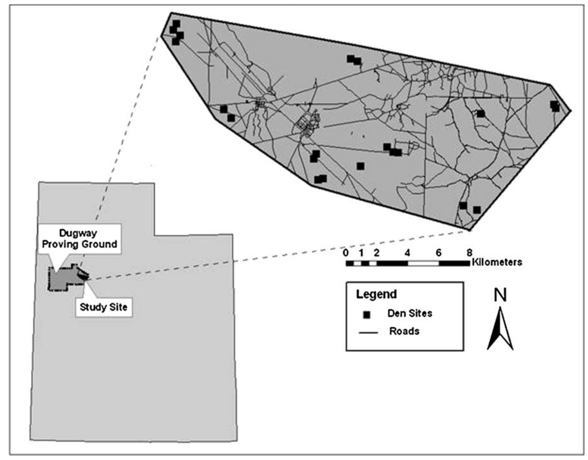

Figure 1. Map of Utah (USA) showing location of study site and monitored kit fox den sites within and adjacent to the U.S. Army Dugway Proving Ground, 2010–2011.

METHODS

Data Collection

During the summers (period of 1 May to 15 Jul) of 2010 and 2011 we monitored adult and pup kit foxes at their den sites. Active den sites were located on a weekly basis by employing homing techniques (Morrison et al. 2008) on adult kit foxes that had been previously captured with box-traps (Kozlowski et al. 2008) in autumn, winter, or spring, and fitted with radiocollars (model M1930; Advanced Telemetry Systems, Isanti, MN). When an active den site was located, we placed an infrared motion camera (model NF4300; Cuddeback Digital, De Pere, WI) 2 m from the most utilized den entrance (Egoscue 1956). Cameras were programmed to take a motion-triggered picture, but were restricted to 3-minute intervals between photos. After 6 days, we recovered camera images and redeployed cameras; we kept cameras at the same den sites unless radiocollared foxes moved to a new den site (Fig. 2).

Between 1 and 6 days following the deployment of a camera, we monitored active den sites and tabulated the number of adults and pups with the use of 10×42 binoculars (model Monarch 10×42; Nikon Inc., Melville, NY) and $60\times$ spotting scopes (model Fieldscope II; Nikon Inc.). We monitored the den site for a 1.5-hour interval encompassing an hour before and 30 minutes after dusk. We selected a 1.5-hour observation period because this approximated the amount of time needed to deploy, retrieve, and review camera images for each den site. We restricted observation points by remaining >100 m from den sites. We monitored den sites from a vehicle whenever possible. If den sites were >300 m from established roads, we monitored them by walking no nearer than 100 m from the den site and hiding behind brushy vegetation; a distance >300 m restricted our ability to monitor den sites from roads due to a decrease in performance of optics with increasing distance from den sites. All observers were trained by lead personnel (B. M. Kluever and S. J. Dempsey); field technicians conducted ≥ 1 den-site observation under the

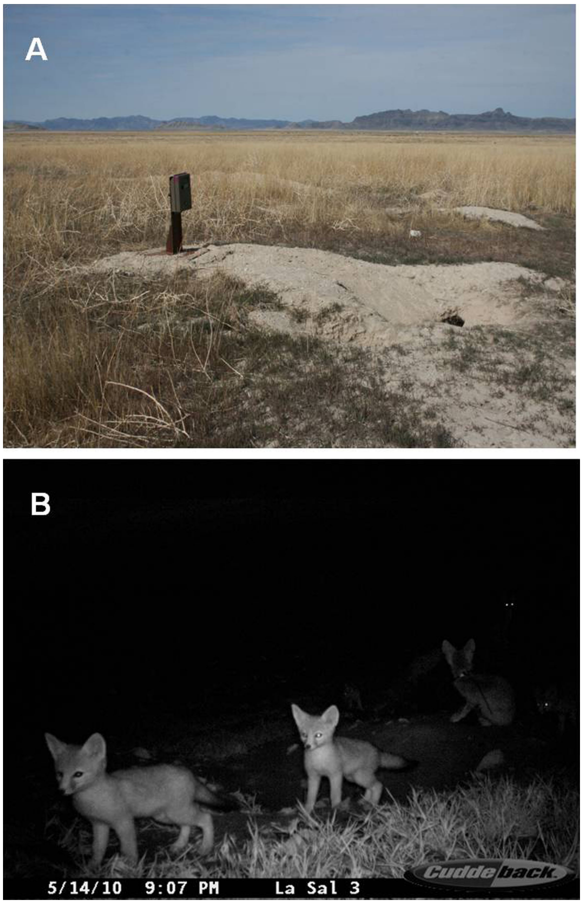

Figure 2. Example of utilizing a remote camera at kit fox den sites during 2010–2011with (A) location of camera in relation to an active kit fox den site within the study area at the U.S. Army Dugway Proving Ground, Utah, USA, and (B) image of kit fox pups and adult photographed with a remote camera.

supervision of lead personnel before conducting solo observations.

Data Analyses

We made "camera counts" for adult and pup kit foxes by tabulating the maximum number of adults or pups captured in a single picture event per den site per week. Similarly, "counts from observers" were achieved by counting the number of adults and pups at each active den site during each week. Count data were not normally distributed; therefore, we tested for differences in weekly maximum count between cameras and observers using a Wilcoxon signed-rank test (Zar 2009) at a significance level of $P < 0.10$. All statistical analyses were conducted in JMP 9.0 (SAS Institute, Cary, NC).

RESULTS

For adult and pup kit foxes, we accumulated 71 and 29 counts of adults and pups at 22 den sites, respectively. For adults and pups, 41% (29 of 71) and 66% (19 of 29) of den-site count comparisons differed between human observers and remote cameras, respectively. The average distance from observers to active den sites was 223.9 m (SD = 89.2). The average number of images containing foxes for each weekly camera sampling per den-site period was 88.4 (SD = 104.6), and ranged from 1 to 451 images. The median number of adults observed at den sites with a camera and observer differed (Wilcoxon test, $z = -1.86$, df = 1, $P = 0.062$) and were 2 adults versus 1 adult, respectively. Similarly, the median number of pups observed at den sites with a remote camera versus an observer differed (Wilcoxon test, $z = -3.13$, df = 1, $P = 0.002$) and was 2 pups versus 1 pup, respectively. Thus, we found evidence that remote cameras placed at den sites for a 6-day period produced different adult and pup counts than did a weekly 1.5-hour period of human observation initiated near dusk.

DISCUSSION

The temporal disparity of data recording between the methodologies likely attributed to the observed difference in pup counts. Cameras allowed for constant surveillance of den sites (usually up to 6 days), while observers were limited to a single 1.5-hour survey window per week. It is plausible that an increase in both the duration and frequency of observations would produce a more reliable count, but we selected and maintained a 1.5-hour survey window because this duration was roughly equivalent to the time needed to deploy cameras and parse camera data. Researchers have reported a similar duration and timing for observing kit foxes to our study (Cypher et al. 2000), while others did not report the length or frequency of observation periods (Olson and Lindzey 2002, Moehrenschlager and Macdonald 2003, Arjo et al. 2007, Ausband and Foresman 2007).

The ability to survey den sites during nocturnal hours, something that is not afforded with an observer using traditional optics, was advantageous; nearly 30% of pup images were recorded between the hours of 2200 and 0500 hours. In addition, the distance between observers and den sites could have hampered our ability to make reliable counts. We felt it necessary to observe den sites at a distance (average distance from den site was 224 m) that kit foxes were not sensitive to (>150 m; Kozlowski et al. 2008). By doing so, visually obstructing vegetation and variations in topography may have decreased observers' effectiveness to make reliable counts. The need to observe kit foxes and similar species at a distance that does not alter their behavior is another potential weakness of counting foxes using an observer.

By using methodologies that have the potential to produce unreliable counts of pups, researchers run the risk of underestimating litter size and overall fecundity, which could, in turn, lead to inaccurate estimates of survival, recruitment, and population growth. Litter sizes ascertained from observers at den sites have been incorporated into population models for several species of foxes (White and Garrott 1999, Kohmann et al. 2005, Ausband and Foresman 2007); but given our findings, it seems plausible that future research endeavors run the risk of underestimating litter sizes when only using human observers.

Our findings for adult counts for observers versus remote cameras mirrored that of pups, and we again suspect the observed difference is due to the longer temporal window for cameras to collect images, regardless of available visible light. We suspect that underestimating the number of adults utilizing den sites does not have the same significance as underestimating litter size. For example, estimates of adult survival for kit foxes and similar species are usually ascertained by radiotelemetry with subsequent carcass recovery (Moehrenschlager and Macdonald 2003, Arjo et al. 2007, Ausband and Foresman 2007). However, the use of observers rather than cameras does engender a risk of underestimating the number of adults utilizing den sites, which could lead to reduced estimates of population parameters and estimates of the proportion of adult paired foxes persisting on a given landscape. We found no evidence that cameras facilitated den abandonment, because camera placement and retrieval only occurred during afternoon hours when foxes are rarely above ground.

Camera-traps have limitations for estimating population parameters, especially if individuals cannot be identified (Larrucea et al. 2007*a*, *b*; Negroes et al. 2010; Jordan et al. 2011). The purpose of our study, however, was to ascertain maximum counts at den sites, not to estimate abundance or occupancy, or to census kit foxes on the landscape. We do not feel that the use of observers or cameras in our study could have resulted in individual kit fox adults or pups being counted multiple times during observation bouts. This is due to the fact that, for each sampling period, we counted the maximum number of individuals observed by a human at the same time or the maximum number of pups or adults captured in a single photograph. We do not claim that complete detection of all kit fox adults or pups utilizing den sites was achieved with cameras. Rather, we conclude that cameras provide more reliable counts at den sites when compared with observers when equal effort (i.e., 1.5 hr of human effort) is applied.

Other natural-history traits and aspects of behavioral ecology may be overlooked or underestimated when using observers rather than cameras at fox den sites. Instances of cooperative parenting, polygamy, and extra-pair copulations are rarely recorded for kit foxes and similar species (Roemer et al. 2001), but instances of these behaviors have been observed at our study site with remote cameras (B. M. Kluever, unpublished data) and through the use of genetic sampling on swift foxes (Kitchen et al. 2006). In addition, our understanding of other traits, including social organization (Strand et al. 2000, Kitchen et al. 2005) and paternal den attendance (Wright 2006, E. Gese, National Wildlife Research Center, unpublished data) for swift or kit foxes (as well as similar fossorial and nocturnal species) may be buttressed by utilizing remote cameras at den sites.

Cameras did add an increased up-front cost to den-site monitoring. In order to monitor multiple den sites per week, an equal number of cameras to den sites were needed; whereas, a single observer could monitor multiple den sites per week with a single set of optics (e.g., binoculars and spotting scope). However, in general, the maximum number of dens that could be monitored by an observer is less than that of cameras. For example, in 2012 we adopted the method of using only cameras to monitor active den sites, and have monitored up to 10 den sites/week with a single field technician required to set up, monitor, and service the cameras. Monitoring an equal number of den sites per week with a single field technician serving as observer would not be possible. Given the aforementioned, and our study findings, we feel that the additional upfront cost associated with monitoring den sites with remote cameras is warranted.

MANAGEMENT IMPLICATIONS

Our results suggest wildlife managers and researchers using observers at fox den sites should be wary of the effectiveness of this method. This method could be improved if the duration and frequency of observation bouts is increased to several nights per week rather than only once per week. Monitoring den sites at and near dawn in addition to dusk, or monitoring den sites during nocturnal hours with high-resolution night-vision equipment, may also improve the utility of observers. We encourage researchers and managers to specifically report frequency and timing of observation periods when using human observers. If multiple methods are utilized to monitor fox den sites, a comparison of techniques would be useful. Finally, we recommend that remote cameras be used to monitor fox den sites because it produced a more complete and reliable count of adults and pups at the den site.

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