03/10/14

Swift fox survey assessment and estimation of detection probability

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Abstract

Conservation or recovery plans for species of concern can be enhanced with information about the range of species within a region of interest. However, the presence of species can be missed because of imperfect detection of individuals. Elusive carnivores such as swift fox (*Vulpes velox*) and coyote (*Canis latrans*) present further complications, as they are difficult to observe by definition. We evaluated the effectiveness of two alternative survey methods for elusive carnivores: track plots and camera traps (motion-activated cameras). We deployed 10 cameras in western Nebraska during the fall of 2011 and spring of 2012 and used occupancy modeling to estimate detection probabilities for swift foxes and coyotes. Our findings suggest that camera traps should be considered as a valid option for monitoring programs. Camera traps resulted in higher visitation rates and lower mean time until first detection than track plots. Camera traps detected more species than track plots. We suggest that camera traps used to determine presence or absence of swift fox and coyote should be deployed for at least 5 days over a mackerel lure to reduce the probability of non-detection to < 30%. Non-visual monitoring can be critical for management of elusive carnivores, and new technologies can enhance monitoring programs.

Key words: Camera traps, detection probability, track plots, occupancy.

Our capability to detect changes in population status and trends depends on our ability to detect changes in range expansion and, thus, occupancy of sites within a region. However, because we cannot census entire populations, managers rely on sampling methods that may have errors (e.g., species missed at a given site) to develop management strategies. Reliable population assessments are particularly challenging for rare and elusive species, often of conservation concern, because even intensive sampling efforts may yield low detection probabilities (Thompson 2004, Sollmann et al. 2013). Assessing the efficacy of different survey techniques allows researches and managers to draw upon specific advantages and disadvantages of each approach and identify mechanisms to improve them.

Throughout the past half-century, biologists have studied mammalian populations using track plots, which typically consist of placing a scented attractant or bait within an area of soft sand, sifted dirt, track plate, or other media to capture the tracks of the animal that afterwards can be identified and recorded (Gese 2004*b*). Cameras traps (remotely-triggered cameras) now afford biologists a new way to study populations. Cameras offer the potential to conduct a survey with more limited person-hours in the field, but the strategy requires high initial costs of equipment. In addition, the efficacy of camera traps versus track plots to detect wildlife is under debate. We compared detectability and time to first detection (TFD) using track plots and camera traps of two canid species, one common and one rare: coyote (*Canis latrans*) and swift fox (*Vulpes velox*), respectively. Additionally, we estimated the probability of detection of each species depending upon the method used.

Swift fox are the smallest and most elusive fox found in the prairies and pastures of the North American Great Plains (Allardyce and Sovada 2003). Because they spend most of their day in underground dens, they are difficult to see, and therefore little is known about where they occur in portions of their estimated distribution range. Swift fox is listed as a sensitive species[1] by the U.S. Department of Agriculture (USDA) and the U.S. Forest Service (USFS), and in Nebraska it has been a state endangered species since 1972 (Andelt 1995).

STUDY AREA

We conduced our survey in Sioux County, Nebraska, on The Nature Conservancy's Cherry Ranch conservation unit (29 km^2), in a prairie inhabited by both swift fox and coyotes (James Luchsinger, personal communication). Cherry Ranch has predominantly shortgrass and mixed-grass prairies, with scattered areas of sandhills prairie. Dominant plant species in the area are blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), and western wheatgrass (*Pascopyrum* sp.). The topography of the area is nearly flat with moderate hills. Soils are silt loams to fine sands. Land use is primarily rangeland; the closest agricultural field is more than 2 kilometers from the study area. The climate is semi-arid with average annual precipitation ranging from 14 to 17 inches (Chapman et al.

[1] "The USFS defines a sensitive species as that whose population viability is identified as a concern or predicted downward trends in abundance and/or habitat capability that would reduce its distribution" (Stephens and Anderson 2005).

2001). The annual average temperature ranges from 1^{o} C to 17^{o} C (Average minimum temperature is in January, -11.2^{o} C, and the average maximum temperature in July, 32.1^{o} C).

MATERIAL AND METHODS

To compare the efficacy of track plots and camera traps to detect swift fox and coyotes, we placed 10 evenly dispersed camera traps along a 16 km transect, each one facing a baited track plot. The track plot consisted of a circular ≈0.7 m area cleared of vegetation and covered with a mixture of fine sand and vegetable oil. We baited the stations with canned jack mackerel in oil for 3 consecutive nights and then continued to monitor them for 14 days. The track plots were checked each morning; all tracks were identified and recorded. We installed the camera traps (Bushnell Trophy Cam 119466C, HCO Scoutguard SG560, Moultrier M80 GameSpy Digital, DLC Covert) 2m from the center of the track plots and set them to take 3 photographs 10 seconds apart every time motion was detected.

We considered each station (paired track plot and camera trap) as a sample unit, hereafter referred to as sites. Sites were surveyed for 14 days in two different seasons: fall (November 2011) and spring (March 2012). We recorded presence/absence data for swift fox and coyotes at each site as detection histories (i.e., vectors of 1's and 0's, where "1" represents that at least one individual was detected and a "0" the failure to detect any individual during the survey at that site). We paired cameras and track stations in our study design (1) because we had a limited area to sample and (2) to remove potential problems of inference associated with sampling two sets of sites with two survey techniques. We ensured independence of the two data sets, as the people checking the track plots were blind to the camera images. Similarly, the people reviewing the camera images did not have access to the results of the track plot surveys.

We considered each site to be independent from others during the season as we placed cameras randomly with regard to the animal distributions. We assumed that sites were "closed" to changes in occupancy by the species during the season; in other words, the occupancy state of a site could change between seasons, but not within seasons MacKenzie et al. 2002).

Biologists often assess presence/absence data without the use of occupancy models. Thurs, we compared the efficacy of track plots versus camera traps using more traditional statistics of visitation rates (an index of the number of visits/number of station-nights) and the time to first detection (calculated as the number of days required for each method to detect the species in the station; Foresman and Pearson 1998). We used occupancy models (R Package Unmarked, R version 0.9-5) to estimate occupancy and the probability of detection (i.e., probability that a species is detected given that it is present in the site, Gompper et al. 2006) for each species during both seasons for each of the two collection methods by fitting single-season single-species occupancy models (MacKenzie et al. 2002). We assumed that there were no "false positive" observations and that the detection of an individual at one station was independent of detection at any other station. (MacKenzie et al. 2002).

Based on the estimates of detection probability (*p*) obtained for both surveys (November 2011 and March 2012), we estimated the time in number of days required to reduce the probability of non-detection (ϕ) for the target species using each survey method (i.e., track plots or trail cameras). Accordingly, the formula for estimating the non-detection probability during a period of time can be expressed as $\phi = (1\text{-}p)^K$; where ϕ was the probability of not detecting a species at least once during K days, and p was the probability of detection during a single day (MacKenzie et al. 2002).

RESULTS

In the first survey (14–29 November 2011), we obtained 18 positive records (all species included) with the track plots and 38 with the camera traps. We could not discern whether tracks or pictures occurred from unique individuals. In the second survey (11–25 March 2012), 43 and 77 positive records were observed from track plots and camera traps, respectively (Table 1). During the fall survey, the raw visitation rate for all species was 0.13 records/station-nights for track plots and 0.27 records/station-nights for camera traps. In the spring survey, the visitation rate for all species was 0.31 records/station-nights for track plots and 0.55 records/station-nights for camera traps. Occupancy for swift fox and coyotes was 0.50 (SE = 0.16) and 0.72 (SE = 0.15) respectively in fall and 0.62 (SE = 0.16) and 0.56 (SE = 0.18) in spring.

The meantime to first detection in the fall for swift fox was 5 (SD = 1.73) days for track plots and 4.8 (SD = 1.64); for coyotes it was 10 (SD = 2.52) days for track plots and 8.14 (SD = 2.54) days for camera traps. In the spring, the mean time to first detection for swift fox was 4.75 (SD = 3.86) days for track plots and 6 (SD = 3.58) for camera traps; and for coyotes it was 9 (SD = 5.66) days for track plots and 7 (SD = 4.06) days for camera traps.

The highest daily probability of detection was obtained during fall surveys using camera traps for both swift fox (p = 0.21) and coyote (p = 0.15; Table 2). However, for both species, the difference in the estimated detection probabilities between the two methods was not statistically significant at 5% within either season (Figure 1).

Non-detection probability (i.e., the probability of missing the target species) declined with increased time of survey (number of days). One additional day of surveying using the camera trap method to detect swift fox decreased the non-detection probability ≈ 33%; using track plots the non-detection probability decreased ≈ 22–25 %. For coyotes, one additional day of surveying using camera traps decreased the non-detection probability ≈ 25–33 %; using track plots it decreased 15−28% .

In general, camera traps required fewer days per survey than track plots (Figure 2) to reduce the probability of missing the target species to target levels of 10-30%. The non-detection probability (ϕ) of swift fox declined more quickly than for coyote as the number of survey days increased. At 10 days, ϕ = 0.1−0.25 for swift fox and ϕ = 0.2−0.35 for coyote.

DISCUSSION

Our data were ambiguous as to the superiority of camera traps to track plots. Certainly, our results suggest that camera traps were at least as effective as track plots. And, there is evidence that camera traps have higher visitation rates than track stations. Time to first detection of coyotes was lower when using camera traps, as well. Our results weakly suggest that camera traps can reduce the length of time needed to monitor for species' presence. The small number of sample sites (10) in our study most likely contributed to uncertainty in these comparisons. If person-time is limited and money is available to purchase cameras, we show that camera traps may be a solution for monitoring.

Similar to other canid species, swift fox and coyote presented low detection rates (Table 2). The results showed that swift fox and coyotes are sympatric species in the study area and that both can be recorded using track plots and camera traps. Coyote had a lower probability of detection than swift fox, regardless of the survey method. Coyotes may be avoiding the stations due to scent deposited by humans during the establishment of the survey stations affecting detection probability. Coyotes have larger home ranges (home range sizes of adult male coyotes average 24.85 km^2, and adult females average 14.67 km^2; Bekoff and Gese 2003) than swift foxes (home range size of adult foxes averages 15.9 km^2; Sovada et al. 2003), which may have also lowered the detection probability in the study site

The effect of season in the estimated detection probability for swift fox is not surprising. Previous studies have documented that the highest detection probabilities occur during the fall, September through March (Sargeant et al 2004, Finley et al 2005). Similarly, Olson et al. (2003) reported that the estimated detection probability of adult swift foxes using track plates in early summer (June−July) was of 0.67 per week (95% CI = 0.30−0.93) compared to 0.88 (95% CI = 0.47−1.0) during the fall (August−September). Swift fox detection is higher in the fall than in the spring because during the fall juvenile foxes disperse and occupy new territories (Olson et al. 2003) increasing the likelihood they will come in contact with survey stations. In the spring, swift fox detection probability is expected to be lower because during the breeding season resident adults spend more time in their dens and have limited movement beyond the immediate denning area (Finley et al. 2005, Martin et al. 2007).

The length of each of our surveys was 14 days and by the end of each survey period the probability of non-detection of swift fox and coyote was reduced to < 20%. Based on the estimated detection probability during the fall, camera traps must be used for at least 5 days to increase the period-length probability of detection at a sample site to 70%; 7 days are required to increase the period-length probability of detection to 80%, and at least 10 days are required to achieve a period-detection level of 90%. To increase the probability of detecting coyotes during a survey period to 70%, 8 days would be necessary (10 days for > 80% and >14 days for > 90%). Previous to our assessment, biologists at Nebraska Game and Parks Commission had conducted 3-day monitoring with track plots, and our analysis suggests that design had the a probability of missing the species at a given sample site of >0.6.

Even though sampling for a longer time period may increase detection rates, our results suggest that the choice of survey method can also be a consideration. The initial equipment cost to conduct a survey using camera-traps could be more expensive than a survey using track plots; however, considering the total person-hour expenses, camera traps may ultimately be more cost effective. Indeed, person-hours had been the limiting factor that led Nebraska Game and Parks Commission biologists to use 3-day surveys in the past. The use of track plots requires additional periodic monitoring and rebaiting during the survey period after the establishment of the stations. Although camera traps may be a more attractive method, they present a few technical issues. Improper programming and high sensitivity can fill the card memories quickly and deplete battery life. We believe these problems can be resolved by adjusting the programming to select specific periods of the day with higher chances to record the target species and by reducing sensitivity of the sensor (Knox and Grenier 2011). This would reduce the risk of recording non-target species or other objects passing by the cameras. Proper camera setup, placement, and orientation may also alleviate some of the technical issues.

CONCLUSIONS AND MANAGEMENT APPLICATIONS

Almost all the estimators used to study animal populations are based on count statistics, which include the number of animals counted in a survey (Williams et al. 2001). These counts represent only a fraction of the real number of animals in the area, due to imperfect detectability. Detectability is a significant source of variation and uncertainty in count data because the probability of encountering an animal is usually < 1.0 (MacKenzie et al. 2005, Reppucci et al. 2011). Therefore, it is necessary to incorporate detection probability in order to obtain unbiased estimates of relative abundance, density, and other linked quantities for the population that is being studied (Williams et al. 2001, MacKenzie et al. 2005). Detection probability also is used in occupancy analysis (i.e., the probability that a randomly selected sampling unit in an area is occupied by the species; MacKenzie et al. 2006) and can be used to measure sampling efficacy (Royle and Dorazio 2008).

Because detection probability is an essential estimate needed to formulate robust inferences about occupancy, relative abundance, and other dynamics of rare and common species, this study estimated the probability of detecting swift fox and coyote with track plots and camera traps transects. In the past, the Nebraska Game and Parks Commission (NGPC) has conducted swift fox surveys with little success. They reported between 1−7 swift fox signs from 2001−2010 with survey efforts from 81−431 station/nights (Swift Fox Conservation Team Reports 2001−2010). Hence, it was necessary to collect data on swift fox populations to be able to perform some analysis that help researchers and managers tailor their survey designs.

Our findings suggest that camera-based methods tend to perform better than track plots in the detection of swift fox and coyote. Using camera traps, at least 5 days are required to increase the probability of detection to 70%, 7 days to increase the probability of detection to 80% and at least 10 days to increase it to 90%. Therefore, for future studies we recommend the use of motion-activated camera traps with an array of 10−20 cameras per transect during at least 5 days, using an attractant. As previous studies have suggested (Kamler et al. 2004, Finley et al. 2005), if the purpose of the surveys is focused on the detection of swift foxes present in the area, we recommend surveying during late fall (September−December). However, if the survey intends to estimate adult abundance we recommend surveying in late spring. The visitation rates in the fall may not reflect the distribution and abundance of adult swift fox during the breeding season (spring), because many juveniles detected during fall dispersal may not survive to breed (Sargeant et al. 2003).

Camera traps are a reliable survey method to monitor swift fox and coyotes. Camera traps can be easily deployed by one person and require less time and effort, reducing the long-term survey expenses. In addition, more stations could be run during longer time periods and would facilitate the identification of the species. Camera traps can also function in rain or other unfavorable weather conditions (e.g., subzero temperatures) where track plots cannot.

In conclusion, camera traps provide relative higher rates of detection compared to track plots for a rare (swift fox) and a common (coyote) species. The state agency can also reduce personnel costs related to the surveys with camera methods. Modern digital cameras can be left for extended periods of time, which reduces the probability of not detecting the species. We suggest that NGPC strongly consider the use of remote triggered cameras as detection devices for swift fox surveys in the future.

ACKNOWLEDGEMENTS

We would like to thank the U.S. Department of State, Fulbright Fellowship, and the School of Natural Resources of the University of Nebraska-Lincoln for providing the financial support; to the Nebraska Game and Parks Commission and the Department of Applied Sciences of the Chadron State College for the support and for providing the equipment for this research; and to The Nature Conservancy for the logistical and organizational support. We thank D. Tyre, and P. Freeman for giving us their advices and reviews of this manuscript. Finally, we also express our gratitude to the students of the Department of Applied Sciences of Chadron State College, to S. Thaler and M. I. Posada for their help in the fieldwork, which was an essential key for the success of this work.

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TABLES

Table 1. Summary of the target and non-target species recorded during two surveys (14−29 Nov 2011 and 11−25 Mar 2012) in Sioux County, Nebraska

	Number of records per survey method[a]	
	Track plot	Camera trap
Survey 1	**18**	**38**
Swift fox	10	15
Coyote	8	15
Non-target species[b]	0	8
Survey 2	**43**	**77**
Swift fox	8	12
Coyote	4	8
Non-target species[b]	31	57

[a] These records may not represent different individuals

[b] Non-target species included badgers (*Taxidea taxus*), striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), domestic cats (*Felis catus*), pronghorn (*Antilocapra Americana*), jackrabbit (*Lepus* sp.), small mammals, and birds.

Table 2. Estimates of detection probability (p) and standard error (SE) for swift fox and coyote during two surveys (14−29 Nov 2011 and 11−25 Mar 2012) in Sioux County, Nebraska

	Track plot				**Camera trap**			
			95% CI				95% CI	
Season	p	SE	Lower	Upper	p	SE	Lower	Upper
Fall 2011								
Swift fox	0.142	0.042	0.078	0.245	0.213	0.049	0.132	0.325
Coyote	0.079	0.027	0.039	0.152	0.148	0.037	0.089	0.236
Spring 2012								
Swift fox	0.092	0.032	0.046	0.176	0.138	0.038	0.078	0.232
Coyote	0.051	0.026	0.018	0.135	0.102	0.038	0.048	0.205

Table 3. Model selection results from fitting the occupancy estimation model of MacKenzie et al. (2002). Akaike's Information Criterion (AIC), increase over the lowest AIC (dAIC), and the Akaike's model weight (AIC*w*) for models used to examine survey method and month of the survey that influence the variation in detection of swift fox and coyote during two surveys (14−29 Nov 2011 and 11−25 Mar 2012) in Sioux County, Nebraska.

Model[a]	AIC	dAIC	AIC*w*	*k*
Swift fox				
Fall 2011				
$p\Psi$	149.20	0	0.6	2
p (survey method) Ψ	149.98	0.78	0.4	3
Spring 2012				
$p\Psi$	139.74	0	0.63	2
p(survey method) Ψ	140.83	1.09	0.37	3
Coyote				
Fall 2011				
p (survey method) Ψ	157.07	0	0.55	3
$p\Psi$	157.51	0.44	0.45	2
Spring 2012				
$p\Psi$	98.79	0	0.57	2
p (survey method) Ψ	99.32	0.53	0.43	3

[a] Variable definitions are p = probability of detecting 1 or more individuals during 1 night survey, Ψ = probability of that the site was occupied, survey method = track-station vs. camera-trap, month = month the survey took place.

FIGURES

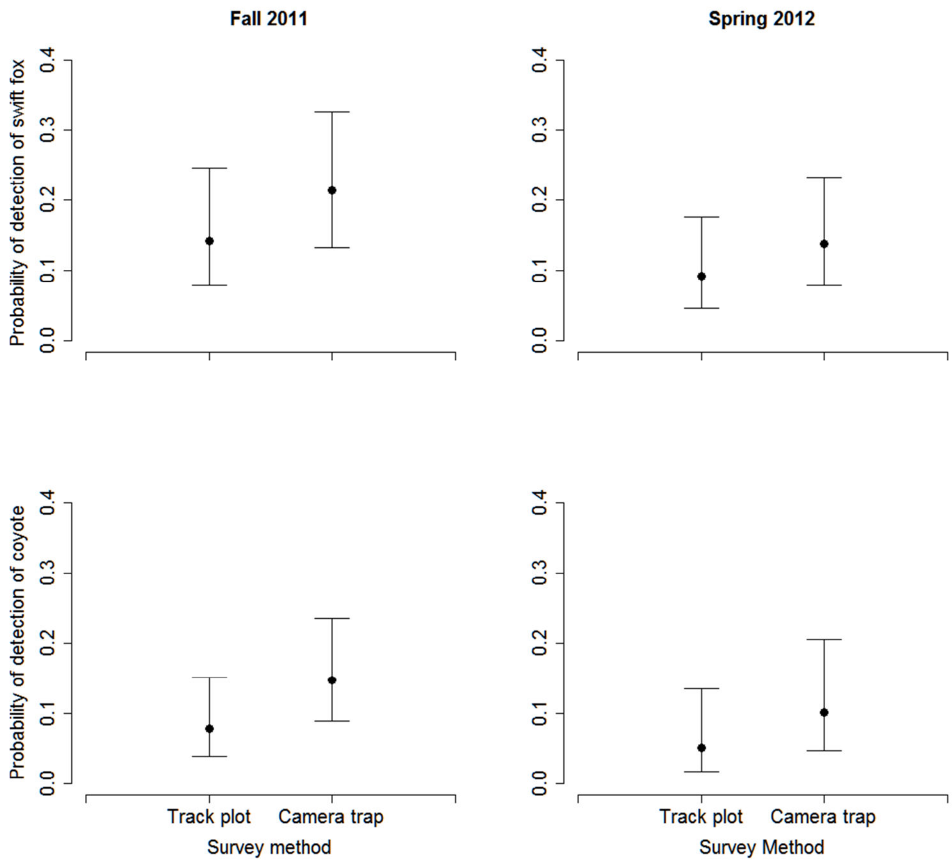

Figure 1. Estimated detection probability of swift fox and coyote over two different seasons (fall and spring) in Sioux County, Nebraska, using track plots and camera traps as survey methods.

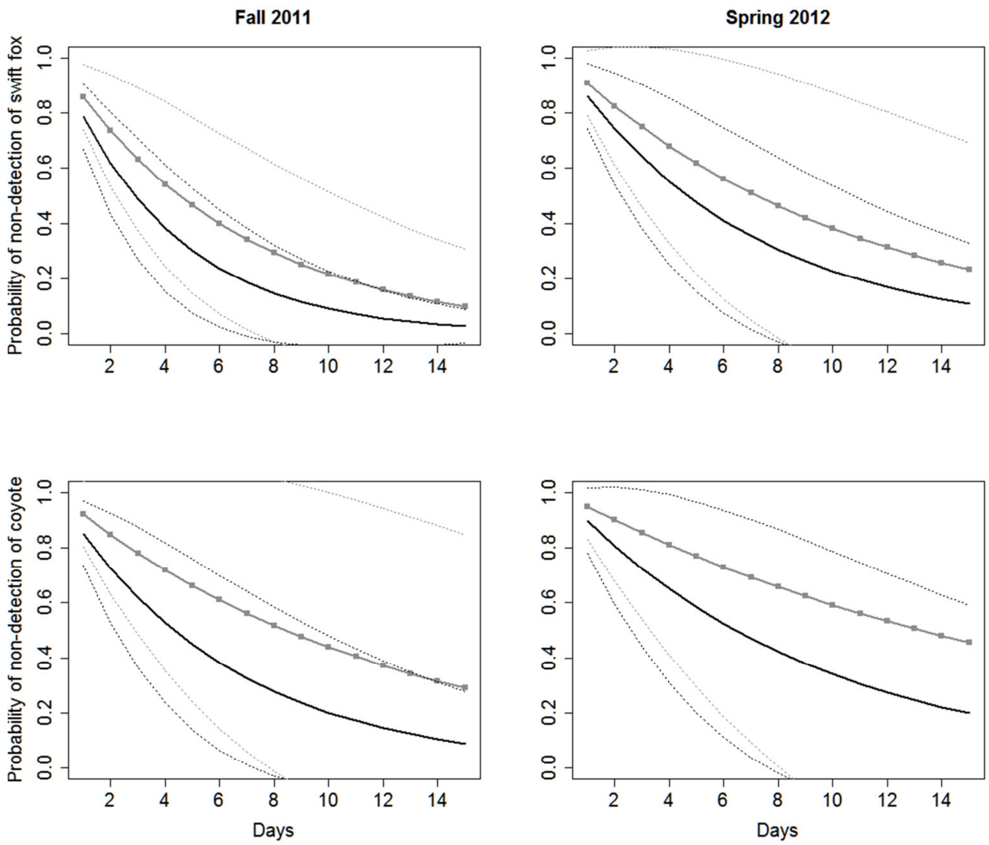

Figure 2. Estimated probability of non-detection of the target species in the fall and spring,as a function of number of days of the survey, in Sioux County, Nebraska. The dotted gray line represent the probability using track plots and the solid black line the probability using camera traps as survey method. The dashed lines are the 95% confidence intervals for estimated probabilities.