Journal of Wildlife Management 75(1):144–150; 2011; DOI: 10.1002/jwmg.12

*Research Article*

# Factors Affecting Detectability of River Otters During Sign Surveys

**MACKENZIE R. JEFFRESS,**[1,2] *Kansas Cooperative Fish and Wildlife Research Unit, Division of Biology, Kansas State University, Manhattan, KS 66506, USA*

**CRAIG P. PAUKERT,**[3] *United States Geological Survey, Kansas Cooperative Fish and Wildlife Research Unit, Division of Biology, Kansas State University, Manhattan, KS 66506, USA*

**BRETT K. SANDERCOCK,** *Division of Biology, Kansas State University, Manhattan, KS 66506, USA*

**PHILIP S. GIPSON,** *Department of Natural Resources Management, Texas Tech University, Lubbock, TX 79409, USA*

**ABSTRACT** Sign surveys are commonly used to study and monitor wildlife species but may be flawed when surveys are conducted only once and cover short distances, which can lead to a lack of accountability for false absences. Multiple observers surveyed for river otter (*Lontra canadensis*) scat and tracks along stream and reservoir shorelines at 110 randomly selected sites in eastern Kansas from January to April 2008 and 2009 to determine if detection probability differed among substrates, sign types, observers, survey lengths, and near access points. We estimated detection probabilities ($p$) of river otters using occupancy models in Program PRESENCE. Mean detection probability for a 400-m survey was highest in mud substrates ($p = 0.60$) and lowest in snow ($p = 0.18$) and leaf litter substrates ($p = 0.27$). Scat had a higher detection probability ($p = 0.53$) than tracks ($p = 0.18$), and experienced observers had higher detection probabilities ($p > 0.71$) than novice observers ($p < 0.55$). Detection probabilities increased almost 3-fold as survey length increased from 200 m to 1,000 m, and otter sign was not concentrated near access points. After accounting for imperfect detection, our estimates of otter site occupancy based on a 400-m survey increased >3-fold, providing further evidence of the potential negative bias that can occur in estimates from sign surveys when imperfect detection is not addressed. Our study identifies areas for improvement in sign survey methodologies and results are applicable for sign surveys commonly used for many species across a range of habitats. © 2011 The Wildlife Society.

**KEY WORDS** detection probability, Kansas, *Lontra canadensis*, river otter, scat, sign surveys, tracks.

Sign surveys measure spatial patterns of animals based on detection or non-detection of animal tracks, feces, or other signs of animal presence (Heinemeyer et al. 2008). Given that sign surveys are often inexpensive and easy to implement compared to other methods, sign surveys are a popular, noninvasive method to study animal distributions, habitat selection, behavior, abundance, and diet (Humphrey and Zinn 1982, Medina 1997, Ben-David et al. 1998, Heinemeyer et al. 2008). Sign surveys are particularly common for carnivores and have been used to evaluate North American river otter (*Lontra canadensis*) distribution (Chromanski and Fritzell 1982), habitat preferences (Dubuc et al. 1990, Newman and Griffin 1994), and relative abundance (Reid et al. 1987, Shackelford and Whitaker 1997, Gallagher 1999). River otter sign surveys have typically been limited to short-distance, single-visit presence-absence surveys (Long and Zielinski 2008), which has led to some concern about a lack of accountability for false absences (Ruiz-Olmo et al. 2001, Gallant et al. 2007, Evans et al. 2009, Marcelli and Fusillo 2009). False absence occurs when the species is concluded to be absent from a site when it was actually present but undetected, and these errors can result in biased estimates of occupancy, underestimation of population size, and misrepresentation of habitat preferences (MacKenzie and Nichols 2004, Mazerolle et al. 2005, Pagano and Arnold 2009).

Methods are now available to account for imperfect detection by measuring the detection probability, which is the probability of detecting the species during a given survey. In particular, MacKenzie et al. (2006) provided an explicit hierarchical modeling approach that allows for estimation of the probability of site occupancy by incorporating and estimating the probability of detection. These models also permit for the inclusion of covariates that may influence detectability, such as weather, time of day, and habitat structure. Several factors may affect the detection probability of river otters during sign surveys. For example, tracking books often emphasize the importance of substrate composition in the detection of animal tracks and scat (Murie and Elbroch 2005, Lowery 2006, Young and Morgan 2007). However, studies that use sign surveys often do not account for potential substrate differences in their analysis (Mason and Macdonald 1987, Dubuc et al. 1990, Shackelford and Whitaker 1997). Techniques for river otter sign surveys also vary and may focus on only one sign type (i.e., scat or tracks; Reid et al. 1987, Lodé 1993, Evans et al. 2009). Therefore, detection probability of the sign of interest is important to consider (O'Connell et al. 2006, Nichols et al. 2008). Additionally, wildlife surveys often rely upon trained observers to collect field data, but recent studies have noted differences in observers' ability to detect animals or animal sign (Freilich and LaRue 1998, Evans et al. 2009, Pagano and Arnold 2009).

Received: 17 September 2009; Accepted: 2 June 2010

[1] *E-mail: jeffress@uidaho.edu*

[2] *Present Address: Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844, USA.*

[3] *Present Address: United States Geological Survey, Missouri Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO 65211, USA.*

Because time, personnel, and funding are limited, wildlife surveyors are forced to choose between allocating more effort to search each site and surveying additional sites (MacKenzie et al. 2006). Consequently, understanding how detection probabilities vary by search effort can help determine an optimal sampling design. Otter sign surveys also tend to vary in length, from 200 m to 1,200 m (Clark et al. 1987, Eccles 1989, Shackelford and Whitaker 1997, Roberts et al. 2008), and these variations may affect conclusions of occupancy and distribution. Although Mason and Macdonald (1987) attempted to predict the occurrence of European otter (*Lutra lutra*) sign for up to 1,000 m with results from shorter surveys using logistic regression, no one has shown how detection probability varies with increased distances based on actual survey results. Furthermore, river otter surveys are often conducted near bridges due to their accessibility (Clark et al. 1987, Shackelford and Whitaker 1997, Bischof 2003), but bridges and other anthropogenic structures may influence the animal's marking behavior and its use of the site. River otters may actually prefer to mark near or under bridges, avoid bridges due to disturbance, or use the area as frequently as random stretches of shoreline (Reuther and Roy 2001, Elmeros and Bussenius 2002, Gallant et al. 2008). Therefore, surveys that focus on bridges may or may not affect the probability of detecting sign.

Occupancy modeling techniques incorporate detection probability through multiple visits in time or space to a survey site (MacKenzie et al. 2002). Determining occupancy rates that correct for detection probability and the factors that affect these measurements will improve the assessment of river otter distribution and our understanding of the species' population trends and habitat associations. Additionally, conducting systematic surveys over time is important for species monitoring, management, and conservation and efforts should be made to continually evaluate and improve methodologies (Yoccoz et al. 2001). Our objective was to evaluate factors that affect detection probability of river otters from sign surveys. We focused on 5 factors that have been incompletely addressed in previous studies: substrate, sign type, observer experience, survey length, and access-point bias. We predicted that substrates that tend to camouflage scat and tracks (e.g., leaf litter, grass) would have lower detection probabilities compared to open, muddy areas. We also predicted that the 2 common sign types, scat and tracks, would have different detection probabilities. By comparing detection probabilities of individual observers, we can possibly correct for observer bias. We also sought to evaluate survey lengths and the effect of distance from access points to help identify optimal survey procedures.

## STUDY AREA

We conducted river otter sign surveys across the eastern third of Kansas (about 54,000 $\text{km}^2$), from the Missouri border and west to approximately Manhattan, Kansas (96.6°W), and between the borders with Nebraska and Oklahoma. The study area ranged in elevation from 204 m to 510 m and consisted of 5 Level III ecoregion classifications (Omernik 1987), including the Central Irregular Plains in the east, Flint Hills in the west, and Western Corn Belt Plains in the north. The area was predominately rural ($>95\%$) with 2 city populations $>100,000$ (Kansas City and Topeka; U.S. Census Bureau 2007). Grassland was the dominant land cover (56.3%), followed by cropland (25.4%) and woodland (11.1%). Most sites were hardwood stands and mixed oak (*Quercus* spp.) and had a low percentage of canopy cover given the absence of leaves during the survey season. Ground vegetation was often dead or dormant grasses and forbs, and leaf litter was a dominant cover for sites (68.9%). Rocky banks and maintained grasses were present at some reservoir sites. River otters were classified as a furbearer in Kansas, but given recent reintroduction and recovery efforts in the state, they were not legally harvested at the time of our study.

## METHODS

### Survey Methods and Design

We sampled 14-digit United States Geological Survey (USGS) Hydrological Unit Code (HUC 14) watersheds, which are a subwatershed classification ranging from about 4,000 ha to 16,000 ha (Laitta et al. 2004). We selected watersheds containing $\geq 1$ third order stream or higher or reservoirs with shorelines $\geq 3,600$ m (Dubuc et al. 1990, Kiesow and Dieter 2005, Barrett 2008) as potential survey sites, resulting in 529 watersheds available for sampling. We subsequently excluded first and second order streams from sampling due to their small size and limited potential for river otter use (Prenda et al. 2001, Kiesow and Dieter 2005, Barrett 2008). Sites were the sampling unit for occupancy modeling. Sites were 5 m in width and ranged in size from 1,200 m to 3,600 m, depending on accessibility (Fig. 1). We conducted sign surveys continuously on 1 side of the shoreline either upstream or downstream of the start point, which was determined by landowner permission or a coin toss. Surveys began at bridges, low-water crossings, or locations where water was adjacent to a roadway, such as boat launches (Lodé 1993, Shackelford and Whitaker 1997, Bischof 2003).

We conducted sign surveys between 9 February and 13 April 2008 and 28 January and 8 April 2009. Late winter and early spring are a common survey time because 1) it is the breeding season for river otters and scent marking activity is expected to be at its highest (Gallagher 1999), 2) differentiation of otter and raccoon (*Procyon lotor*) scat is expected to be easier due to differing diets (i.e., otter scat is primarily composed of fish scales, whereas raccoon scat is often seeds and vegetation; Swimley et al. 1998, McElwee 2008), and 3)

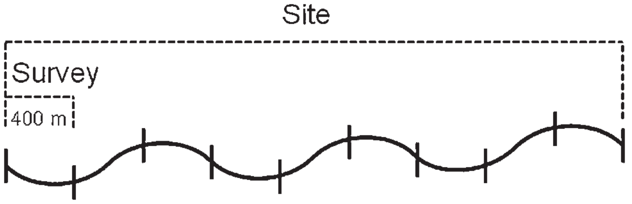

**Figure 1.** A schematic of the sampling protocol we used to determine river otter occupancy at each site in eastern Kansas, USA, 2008–2009. We used each 400-m survey as a spatial replicate to estimate detection probabilities at a site, which consisted of $\leq 9$ replicates (i.e., 3,600 m).

vegetation density is lower than in other months making sign more visible (Swimley et al. 1998, Ostroff 2001). Sites sampled within the same year were $\geq$16 stream km apart, whereas sites in different years were $\geq$8 stream km apart to ensure spatial independence based on average home range sizes and past otter surveys in the Midwest (Shackelford and Whitaker 1997, Barrett 2008). We did not sample sites within 2 days of measureable precipitation (>0.2 cm) to avoid sign degradation (Clark et al. 1987, Shackelford and Whitaker 1997, Barrett 2008).

We trained personnel conducting sign surveys for 1 day in the field in sign identification prior to conducting surveys, and we included only sign that observers recorded as definitive otter sign (rated 75–100% confident), so as to reduce the possibility of false positive detections. Locations of all tracks ($\geq$1 foot track) and scat ($\geq$1 piece of scat) and their descriptions (e.g., type, size) were recorded. Along the survey the observer stopped every 400 m to collect covariate information. Repeat surveys for estimation of detection probability differed for the various analyses and were accomplished either by using spatial replication of survey segments (i.e., 400 m) or independent multiple observers. Dominant substrate type (i.e., vegetation, mud, rock, leaf litter, and snow) was visually estimated for every 400-m survey. Mean search time for sign was 18 min (SD = 6 min) per 400-m survey. A subset of sites ($n = 19$) were surveyed with independent multiple (2–3) observers (4 different observers total) of 2 experience levels, novice (surveyed 7–20 sites over the study period) and experienced (surveyed 49–81 sites), to determine observer effects on detection probability. The 2 experienced observers surveyed all sites for a given year, whereas the 2 novice observers were secondary observers for a subset of sites. All multi-observer surveys were conducted during the same day and observers either walked opposite ends of the survey or were spaced by time and distance to ensure independence.

### Data Analysis

We developed several sets of a priori candidate models based on our experience and the literature to determine the effects of substrate, sign type, observer, survey length, and proximity to access points on river otter sign detection probability ($p$). We then conducted 5 analyses to test our predictions. Because our focus of these analyses was detection probability, we held the probability of occupancy ($\psi$) constant across time and space in all models, and all models included the intercept on both $\psi$ and $p$. Our simplest model represented probability of occupancy and probability of detection as constant across all substrates, observers, survey lengths, and habitat types, notated as $\psi(\cdot)\ p(\cdot)$. We standardized continuous covariates (except for proportions) using a $z$-transformation and treated remaining categorical covariates as dummy variables with values of 0 or 1 (Donovan and Hines 2007). We conducted all analyses using software program PRESENCE (PRESENCE Version 2.3, www.mbr-pwrc.usgs.gov/software.html, accessed 20 Apr 2009). We ranked models using Akaike's Information Criterion corrected for small-sample size ($\mathrm{AIC_c}$; Burnham and Anderson 2002) and used $\mathrm{AIC_c}$ differences ($\Delta\mathrm{AIC_c} = \mathrm{AIC_c} - \text{min. } \mathrm{AIC_c}$) and Akaike weights to evaluate model fit to the data. We considered models with $\Delta\mathrm{AIC_c} \leq 2$ to be competitive models (Burnham and Anderson 2002).

We used a single-season, single-species, custom occupancy model parameterization to estimate the effect of substrate type on detection probability. We used the 3–9 continuous 400-m surveys for our detection replicates. Therefore, a 3,600-m site had 9 detection histories. The 2 models we evaluated were substrate effect on detection probability $\psi(\cdot)\ p(_{\text{substrate}})$ and detection probability held constant $\psi(\cdot)\ p(\cdot)$. We then used a multi-method model to analyze detection probabilities for the 2 sign types (scat and tracks). Therefore, a 3,600-m site had 18 detection histories, with 9400-m surveys for each sign type. Multi-method models allow detection probabilities to vary for different methods (i.e., sign type) and estimate an additional parameter, probability that an individual is available for detection at the site, given it is present ($\theta$; Nichols et al. 2008). The candidate models for this analysis included effects of sign type $\psi(\cdot)\ \theta(\cdot)\ p(_{\text{type}})$ on detection probability and detection probability held constant $\psi(\cdot)\ \theta(\cdot)\ p(\cdot)$. We held $\psi$ and $\theta$ constant for both candidate models. To analyze differences among observers, we used observers as replicates for each 400-m survey. Therefore, a 400-m survey searched by 3 independent observers had 3 detection histories. Our candidate models for this analysis included effects of observer on detection probability $\psi(\cdot)\ p(_{\text{observer}})$ and detection probability held constant $\psi(\cdot)\ p(\cdot)$.

We examined differences in detection probabilities for various survey lengths by running 5 additional analyses based on encounter histories for 200-, 400-, 600-, 800-, and 1,000-m surveys. Given that we surveyed 1,200–3,600 m of continuous shoreline for each site, a 200-m survey length had $\leq$18 detection histories, whereas a 1,000-m survey length had $\leq$2 detection histories. To ensure independent detections we told observers to survey the entire site and therefore they were not aware of the pooling of lengths. We then used the simplest model $\psi(\cdot)\ p(\cdot)$ to estimate the probability of detection for each survey length and compared these rates as survey length increased. Finally, we tested whether sign was concentrated near access points by comparing 2 models: 1) detection probability varying by 400-m survey $\psi(\cdot)\ p(_{\text{survey}})$ and 2) detection probability held constant across all 400-m transects $\psi(\cdot)\ p(\cdot)$.

We made several assumptions for our analysis. First, we assumed that river otter sign was never falsely detected. Second, we assumed that detection histories at each site were independent. Lastly, these single-season occupancy models assume the population is closed (MacKenzie et al. 2002). The closure assumption may not be met with large mammals with variable home ranges, however it can be relaxed if movement in and out of a sample area during the survey season is random (MacKenzie et al. 2004, Longoria and Weckerly 2007).

## RESULTS

We surveyed 110 sites over a 2-year period (46 in 2008, 64 in 2009). We detected otter sign at 35 sites resulting in a naïve

**Table 1.** Model sets and rankings for evaluating covariate effects on detection probability ($p$) based on 400-m river otter sign surveys conducted in eastern Kansas, USA, 2008–2009. We held both probability of occupancy ($\psi$) and probability that individuals are available for detection conditional upon presence ($\theta$) constant across time and space. For each model we present the number of parameters ($K$), deviance, Akaike's Information Criterion corrected for small sample size ($AIC_c$), the difference between the model $AIC_c$ and the best fit model $AIC_c$ ($\Delta AIC_c$), and the Akaike weight of the model ($w_i$). $n$ = number of 400-m surveys we used in the analysis.

| Model | $K$ | $AIC_c$ | $\Delta AIC_c$ | Deviance | $w_i$ |
|---|---|---|---|---|---|
| Substrate ($n = 110$) | | | | | |
| $\psi(\cdot)\ p(_{\text{substrate}})$ | 6 | 513.6 | 0.0 | 500.8 | 0.986 |
| $\psi(\cdot)\ p(\cdot)$ | 2 | 522.1 | 8.5 | 518.0 | 0.014 |
| Sign type ($n = 110$) | | | | | |
| $\psi(\cdot)\ \theta(\cdot)\ p(_{\text{type}})$ | 3 | 694.7 | 0.0 | 688.5 | 1.000 |
| $\psi(\cdot)\ \theta(\cdot)\ p(\cdot)$ | 2 | 735.3 | 40.6 | 731.2 | 0.000 |
| Observer ($n = 165$) | | | | | |
| $\psi(\cdot)\ p(_{\text{observer}})$ | 5 | 249.7 | 0.0 | 239.3 | 0.997 |
| $\psi(\cdot)\ p(\cdot)$ | 2 | 261.4 | 11.7 | 257.3 | 0.003 |
| Access bias ($n = 110$) | | | | | |
| $\psi(\cdot)\ p(\cdot)$ | 2 | 522.1 | 0.0 | 518.0 | 0.984 |
| $\psi(\cdot)\ p(_{\text{survey}})$ | 10 | 530.3 | 8.2 | 508.1 | 0.016 |

estimate of occupancy of 0.318. Based on a model with all parameters held constant, our probability of river otter occupancy was 0.329 (SE 0.046) and our overall probability of detection, using tracks and scat combined for a detection history, was 0.337 (SE 0.029) per 400-m survey.

We used all 110 sites to assess the effects of substrate type on detection probability and the best-fitting model included a substrate effect on the detection probability (Table 1). The mud substrate had the highest detection probability ($p = 0.598$, SE = 0.076) and leaf litter ($p = 0.265$, SE = 0.037) and snow substrates ($p = 0.177$, SE 0.115) had the lowest detection probabilities (Fig. 2). We found no tracks in snow substrates, which was the dominant substrate for only 2.1% of surveys. For the sign type analysis, the best fit model included detection probability varying by sign type (Table 1). Scat had an overall detection probability of 0.533 (SE = 0.063), whereas tracks had only 0.180 (SE = 0.035). Independent multiple ($\geq 2$) observer searches were conducted for 165 400-m surveys. The best fit model for the observer analysis included an observer effect on detection probability (Table 1). The 2 experienced observers had the highest detection probabilities ($p = 0.782$, SE = 0.132 and $p = 0.714$, SE = 0.132). Of the novice observers, one was slightly lower than the experienced observers ($p = 0.545$, SE = 0.101), whereas the other novice observer was lower than the others despite the same amount of training ($p = 0.145$, SE = 0.078).

Detection probability was lowest for the 200-m surveys ($p = 0.227$, SE = 0.018) and highest for the 1,000-m surveys ($p = 0.608$, SE = 0.061; Fig. 3). Detection probability increased nearly linearly as the survey length increased, with an average increase of 0.048 for every additional 100 m. Precision of the detection probability estimates decreased as the survey length increased because longer surveys resulted in fewer survey replicates. Finally, detection probability did not appear to be affected by the proximity to the access point, with the best fit model including both occupancy and detection probability held constant ($\psi(\cdot)\ p(\cdot)$; Table 1).

## DISCUSSION

Our study was the first to report use of spatial replication to assess detection probability for river otter sign surveys, which allowed us to examine multiple factors that may affect detection probability. Our overall detection probability using

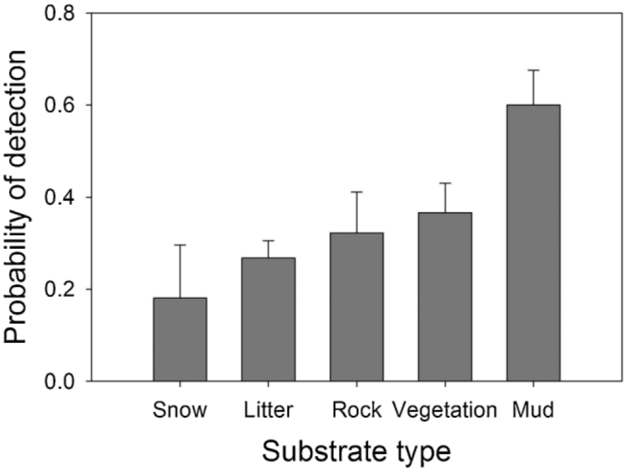

**Figure 2.** Probability of detecting river otter sign (scat and tracks) by substrate type for 400-m surveys conducted in eastern Kansas, USA, 2008–2009. Error bars represent one standard error.

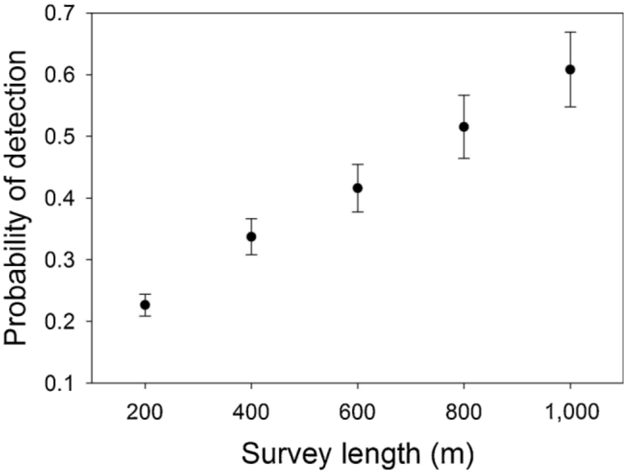

**Figure 3.** Probability of detection for 5 incremental survey lengths estimated from river otter sign surveys conducted in eastern Kansas, USA, 2008–2009. Error bars represent one standard error.

both sign types was 0.337 for a 400-m survey, indicating that we detected the species about one third of the time it was present. If we had only surveyed the first 400-m of each site and thus not accounted for detection probability, 10 sites would have been classified as occupied and we would have estimated occupancy at 0.091. Consequently, accounting for detection probability for a 400-m survey increased the probability of occupancy by 24%. Two primary sources of bias in detection of animals or sign are perception and availability (Alpízar-Jara and Pollock 1996). Perception bias occurs when the observer fails to detect the animal or sign during a survey, whereas availability bias happens when the observer cannot see the object, such as in cases where it is hidden (Alpízar-Jara and Pollock 1996, Anderson 2001, Martin 2007). Our results indicated that perception bias caused by observer differences and availability bias due to substrate type, sign type, and survey length influenced the probability of detecting river otters during sign surveys.

Tracks had an overall detection probability almost 3 times lower than scat, which is cause for concern because track surveys are common for many species. Track surveys in dust and mud have been used for raccoon (Heske et al. 1999), mountain lion (*Puma concolor*; Smallwood and Fitzhugh 1995), and striped skunk (*Mephitis mephitis*; Engeman et al. 2003), and track surveys in the snow are common for northern species like the wolverine (*Gulo gulo*; Ulizio 2005) and Canada lynx (*Lynx canadensis*; McKelvey et al. 2006). Both track surveying methods (snow surveys and dust or mud surveys) have been used in several otter studies (Ruiz-Olmo et al. 2001, Martin 2007, Evans et al. 2009). However, the quality of snow and mud as tracking mediums could be affected by recent weather and many of these substrates are often not consistently available and have limited use for widespread systematic surveys (Heinemeyer et al. 2008). As with tracks, scat had been the focus of several otter surveys (Mason and Macdonald 1987, Swimley et al. 1998, Maxfield et al. 2005) and other species such as American mink (*Mustela vison*; Bonesi and Macdonald 2004), swift fox (*Vulpes velox*; Harrison et al. 2004), and coyotes (*Canis latrans*; Prugh et al. 2005). Given that little extra effort is needed to record multiple sign types, we suggest that future survey efforts focus on both sign types, tracks and scat, to maximize detections and use multi-method occupancy models while accounting for the potential substrate effects on detection probability of sign (O'Connell et al. 2006, Mattfeldt and Grant 2007, Nichols et al. 2008).

Detection probabilities were lower for novice observers than experienced observers, which was contradictory to the results of Freilich and LaRue (1998) who found that variability among observers' ability to find tortoises (*Gopherus agassizii*) and their sign was not related to experience level. However, other studies have concluded that observer experience can affect detection probability (Sauer et al. 1994, Laake et al. 1997, Pagano and Arnold 2009). Therefore, we suggest observers gain field survey experience and that at least a subset of sites be surveyed by multiple observers to correct for observer differences in all surveys.

The single-season occupancy models we used allow for false absences but not false presences (Royle and Link 2006). We trained observers and asked them to use measurements and field guides to confidently identify sign, however there was potential to misidentify otter tracks and scat. False positives could result in concluding the species is present when it is absent, thus biasing estimates of occupancy (Royle and Link 2006, McElwee 2008, Evans et al. 2009). Freilich and LaRue (1998) determined that observers overestimated numbers of tortoise burrows and McElwee (2008) found observers often confused raccoon and river otter scat. We suggest that observers be thoroughly trained and tested on scat and track identification. For example, Evans et al. (2009) used a standardized tracker evaluation program and documented improvement in observer skills after a training course. Genetic testing could be used to verify scat specimens (McElwee 2008), and scat detection dogs have been shown to be effective at locating scat from other carnivore species while ignoring non-target species (Long et al. 2007).

Detection probability increased almost 3-fold as survey length increased from 200 m to 1,000 m. Mason and Macdonald (1987) found that otter sign was encountered within the first 200 m of a survey for most occupied sites (69–79%), but our results showed a detection probability of only 0.23 for the same length. Mason and Macdonald (1987) also determined that extending surveys from 600 m to 1,000 m may increase detection by 6–12%, which was similar to our study where we found detection probability increased from 0.42 to 0.61 with the same changes in survey length. Whereas Gallant et al. (2008) suggested that surveys be conducted over longer distances to increase detection rates, we found that survey lengths of 200–1,000 m had detection probabilities between 0.2 and 0.8, which is reasonable when determining the size of site to survey (MacKenzie et al. 2006). Furthermore, our results support the conclusions of Gallant et al. (2008) that otter activity based on sign was neither higher nor lower near access points than other stretches of shoreline, and sampling at or near bridges did not likely bias survey results.

## MANAGEMENT IMPLICATIONS

Past wildlife sign surveys have often failed to account for imperfect detection of species and refining survey and analysis methods may lead to less biased estimates of occupancy. However, additional factors may have affected river otter sign detection probability, such as waterbody type (Ruiz-Olmo et al. 2001) or population density (Kéry 2002). We encourage continued exploration of factors affecting detectability during sign surveys and suggest future studies conduct longer surveys with spatial or temporal replication, account for differences in substrate types and observers, and record both sign types. Our results could be used to help improve sign survey methodologies and to develop a standardized river otter survey protocol. A standardized protocol would allow for easier comparison of sign survey results and improve understanding of species occupancy rates and habitat associations at larger scales. Our results could also be applied to other areas where otter sign surveys are conducted and to other species commonly sign surveyed. Furthermore, our methods could be expanded to collect information on multiple species to provide more community-level information with minimal additional effort.

## ACKNOWLEDGMENTS

We thank Kansas Department of Wildlife and Parks and the Kansas State University for funding our research. J. Whittier provided technical assistance with analysis using Geographic Information System (GIS). M. Jeffress and K. Blecha were field technicians, and B. Tristch served as an undergraduate researcher. We also appreciate the Kansas landowners that granted us permission to access survey sites. This manuscript benefited from reviews by C. Allen, D. Otis, and T. Rodhouse.

## LITERATURE CITED

Alpízar-Jara, R., and K. H. Pollock. 1996. A combination line transect and capture-recapture sampling model for multiple observers in aerial surveys. Environmental and Ecological Statistics 3:311–327.

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

Barrett, D. 2008. Status and population characteristics of the northern river otter (*Lontra canadensis*) in central and eastern Oklahoma. Thesis, Oklahoma State University, Stillwater, USA.

Ben-David, M., R. T. Bowyer, L. K. Duffy, D. D. Roby, and D. M. Schell. 1998. Social behavior and ecosystem processes: river otter latrines and nutrient dynamics of terrestrial vegetation. Ecology 79:2567–2571.

Bischof, R. 2003. Status of the northern river otter in Nebraska. Prairie Naturalist 35:117–120.

Bonesi, L., and D. W. Macdonald. 2004. Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*). Journal of Zoology 262:65–72.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer Verlag, New York, New York, USA.

Chromanski, J. F., and E. K. Fritzell. 1982. Status of the river otter (*Lutra canadensis*) in Missouri. Transactions of the Missouri Academy of Science 16:43–48.

Clark, J. D., T. Hon, K. D. Ware, and J. H. Jenkins. 1987. Methods for evaluating abundance and distribution of river otters in Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41:358–364.

Donovan, T. M., and J. Hines. 2007. Exercises in occupancy modeling and estimation. <http://www.uvm.edu/envnr/vtcfwru/spreadsheets/occupancy/occupancy.htm>. Accessed 30 Apr 2010.

Dubuc, L. J., W. B. Krohn, and R. B. Owen, Jr. 1990. Predicting occurrence of river otter by habitat on Mount Desert Island, Maine. Journal of Wildlife Management 54:594–599.

Eccles, D. R. 1989. An evaluation of survey techniques for determining relative abundance of river otters and selected other furbearers. Thesis, Emporia State University, Emporia, Kansas, USA.

Elmeros, M., and N. Bussenius. 2002. Influence of selection of bank side on the standard method for otter surveys. International Union for Conservation of Nature Otter Specialist Group Bulletin 19:67–74.

Engeman, R. M., K. L. Christensen, M. J. Pipas, and D. L. Bergman. 2003. Population monitoring in support of rabies vaccination program for skunks in Arizona. Journal of Wildlife Disease 39:746–750.

Evans, J. W., C. A. Evans, J. M. Packard, G. Calkins, and M. Elbroch. 2009. Determining observer reliability in counts of river otter tracks. Journal of Wildlife Management 73:426–432.

Freilich, J. E., and E. L. LaRue, Jr. 1998. Importance of observer experience in finding desert tortoises. Journal of Wildlife Management 62:590–596.

Gallagher, E. 1999. Monitoring trends in reintroduced river otter populations. Thesis, University of Missouri, Columbia, USA.

Gallant, D., L. Vasseur, and C. H. Bérubé. 2007. Unveiling the limitations of scat surveys to monitor social species: a case study on river otters. Journal of Wildlife Management 71:258–265.

Gallant, D., L. Vasseur, and C. H. Bérubé. 2008. Evaluating bridge survey ability to detect river otter *Lontra canadensis* presence: a comparative study. Wildlife Biology 14:61–69.

Harrison, R. L., P. G. S. Clarke, and C. M. Clarke. 2004. Indexing swift fox populations in New Mexico using scats. American Midland Naturalist 151:42–49.

Heinemeyer, K. S., T. J. Ulizio, and R. L. Harrison. 2008. Natural sign: tracks and scat. Pages 45–74 *in* R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey methods for carnivores. Island Press, Washington, D.C., USA.

Heske, E. J., S. K. Robinson, and J. D. Brawn. 1999. Predator activity and predation on songbird nests on forest-field edges in east-central Illinois. Landscape Ecology 14:345–354.

Humphrey, S. R., and T. L. Zinn. 1982. Seasonal habitat use by river otters and Everglades mink in Florida. Journal of Wildlife Management 46:375–381.

Kéry, M. 2002. Inferring the absence of a species—a case study of snakes. Journal of Wildlife Management 66:330–338.

Kiesow, A., and C. D. Dieter. 2005. Availability of suitable habitat for northern river otters in South Dakota. Great Plains Research 15:31–44.

Laake, J. L., J. Calambokidis, S. D. Osmek, and D. J. Rugh. 1997. Probability of detection harbor porpoise from aerial surveys: estimating g(0). Journal of Wildlife Management 61:63–75.

Laitta, M. T., K. J. Legleiter, and K. M. Hanson. 2004. The national watershed boundary dataset. Hydro Line: GIS for Water Resources Summer: 1–7.

Lodé, T. 1993. The decline of otter *Lutra lutra* populations in the region of the Pays De Loire, western France. Biological Conservation 65:9–13.

Long, R. A., and W. J. Zielinski. 2008. Designing effective noninvasive carnivore surveys. Pages 8–44 *in* R. A. Long, P. MacKay, W. J. Zielinski, and J. C. Ray, editors. Noninvasive survey techniques for carnivores. Island Press, Washington, DC, USA.

Long, R. A., T. M. Donovan, P. Mackay, W. J. Zielinski, and J. S. Buzas. 2007. Effectiveness of scat detection dogs for detecting forest carnivores. Journal of Wildlife Management 71:2007–2017.

Longoria, M. P., and F. W. Weckerly. 2007. Estimating detection probabilities from sign of collared peccary. Journal of Wildlife Management 71:652–655.

Lowery, J. C. 2006. The tracker's field guide: a comprehensive handbook for animal tracking in the United States. Globe Pequot, Guilford, Connecticut, USA.

MacKenzie, D. I., and J. D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27:461–467.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

MacKenzie, D. I., J. A. Royle, J. A. Brown, and J. D. Nichols. 2004. Occupancy estimation and modeling for rare and elusive populations. Pages 149–172 *in* W. L. Thompson, editor. Sampling rare or elusive species. Island Press, Washington, DC, USA.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, San Diego, California, USA.

Marcelli, M., and R. Fusillo. 2009. Monitoring peripheral populations of the Eurasian otter (*Lutra lutra*) in southern Italy: new occurrences in the Sila National Park. IUCN Otter Specialist Group Bulletin 26:10–14.

Martin, D. J. 2007. River otters in southeastern Minnesota: activity patterns and an aerial snow-track survey to index populations. Thesis, Minnesota State University, Mankato, USA.

Mason, C. F., and S. M. Macdonald. 1987. The use of spraints for surveying otter (*Lutra lutra*) populations: an evaluation. Biological Conservation 41:167–177.

Mattfeldt, S. D., and E. H. C. Grant. 2007. Are two methods better than one? Area constrained transects and leaf litterbags for sampling stream salamanders. Herpetological Review 38:43–45.

Maxfield, B., T. Bonzo, C. McLaughlin, and K. Bunnell. 2005. Northern river otter management plan. DWR Publication 04–30, Utah Division of Wildlife, Resources, Salt Lake City, USA.

Mazerolle, M. J., A. Desrochers, and L. Rochefort. 2005. Landscape characteristics influence pond occupancy by frogs after accounting for detectability. Ecological Applications 15:824–834.

McElwee, B. 2008. The use of molecular scatology to study river otter (*Lontra canadensis*) genetics. Thesis, Rochester Institute of Technology, Henrietta, New York, USA.

McKelvey, K. S., J. Von Kienast, K. B. Aubry, G. M. Koehler, B. T. Maletzke, J. R. Squires, E. L. Lindquist, S. Loch, and M. K. Schwartz. 2006. DNA analysis of hair and scat collected along snow tracks to document the presence of Canada lynx. Wildlife Society Bulletin 34:451–455.

Medina, G. 1997. A comparison of the diet and distribution of southern river otter (*Lutra provocax*) and mink (*Mustela vison*) in southern Chile. Journal of Zoology 242:291–297.

Murie, O. J., and M. Elbroch. 2005. A field guide to animal tracks. Third edition. Houghton Mifflin, Harcourt, Boston, Massachusetts, USA.

Newman, D. G., and C. R. Griffin. 1994. Wetland use by river otters in Massachusetts. Journal of Wildlife Management 58:18–23.

Nichols, J. D., L. L. Bailey, A. F. O'Connell, Jr., N. W. Talancy, E. H. C. Grant, A. T. Gilbert, E. M. Annand, T. P. Husband, and J. E. Hines. 2008. Multi-scale occupancy estimation and modeling using multiple detection methods. Journal of Applied Ecology 45:1321–1329.

O'Connell, A. F. Jr., N. W. Talancy, L. L. Bailey, J. R. Sauer, R. Cook, and A. T. Gilbert. 2006. Estimating site occupancy and detection probability parameters for meso- and large mammals in a coastal ecosystem. Journal of Wildlife Management 70:1625–1633.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118–125.

Ostroff, A. C. 2001. Distribution and mesohabitat characteristics of river otter in eastern Kansas. Thesis, Emporia State University, Emporia, Kansas, USA.

Pagano, A. M., and T. W. Arnold. 2009. Detection probabilities for ground-based breeding waterfowl surveys. Journal of Wildlife Management 73:392–398.

Prenda, J., P. López-Nieves, and R. Bravo. 2001. Conservation of otter (*Lutra lutra*) in a Mediterranean area: the importance of habitat quality and temporal variation in water availability. Aquatic Conservation: Marine and Freshwater Ecosystems 11:343–355.

Prugh, L. R., C. E. Ritland, S. M. Arthur, and C. J. Krebs. 2005. Monitoring coyote population dynamics by genotyping faeces. Molecular Ecology 14:1585–1596.

Reid, D. G., M. B. Bayer, T. E. Code, and B. McLean. 1987. A possible method for estimating river otter (*Lutra canadensis*) populations using snow tracks. Canadian Field Naturalist 101:576–580.

Reuther, C., and A. Roy. 2001. Some results of the 1991 and 1999 otter (*Lutra lutra*) surveys in the River Ise catchment, Lower-Saxony, Germany. International Union for Conservation of Nature Otter Specialist Group Bulletin 18:28–40.

Roberts, N. M., S. M. Crimmins, D. A. Hamilton, and E. Gallagher. 2008. An evaluation of bridge-sign surveys to monitor river otter (*Lontra canadensis*) populations. American Midland Naturalist 160:358–363.

Royle, J. A., and W. A. Link. 2006. Generalized site occupancy models allowing for false positive and false negative errors. Ecology 77:835–841.

Ruiz-Olmo, J., D. Saavedra, and J. Jiménez. 2001. Testing the surveys and visual and track censuses of Eurasian otters (*Lutra lutra*). Journal of Zoology 253:359–369.

Sauer, J. R., B. G. Peterjohn, and W. A. Link. 1994. Observer differences in the North American Breeding Bird Survey. Auk 111:50–62.

Shackelford, J., and J. Whitaker. 1997. Relative abundance of the northern river otter, *Lutra canadensis*, in three drainage basins of southeastern Oklahoma. Proceedings of the Oklahoma Academy of Science 77:93–98.

Smallwood, K. S., and E. L. Fitzhugh. 1995. A track count for estimating mountain lion *Felis concolor californica* population trend. Biological Conservation 71:251–259.

Swimley, T. J., T. L. Serfass, R. P. Brooks, and W. M. Tzilkowski. 1998. Predicting river otter latrine sites in Pennsylvania. Wildlife Society Bulletin 26:836–845.

Ulizio, T. J. 2005. A noninvasive survey method for detecting wolverine. Thesis, University of Montana, Missoula, USA.

U.S. Census Bureau. 2007. Population estimates. Annual estimates of the population through 2006-07-01. <http://www.census.gov/popest/estimates.html>. Accessed 17 Jul 2009.

Yoccoz, N. G., J. D. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology 16:446–453.

Young, J., and T. Morgan. 2007. Animal tracking basics. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

*Associate Editor: Jeff Bowman.*