OBSERVER ERROR IN IDENTIFYING SPECIES USING INDIRECT SIGNS: ANALYSIS OF A RIVER OTTER TRACK SURVEY TECHNIQUE

A Thesis

by

JONAH WY EVANS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Wildlife and Fisheries Sciences

OBSERVER ERROR IN IDENTIFYING SPECIES USING INDIRECT SIGNS:

ANALYSIS OF A RIVER OTTER TRACK SURVEY TECHNIQUE

A Thesis

by

JONAH WY EVANS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	Jane M. Packard
Committee Members,	Amanda Stronza
	Billy Higginbotham
Head of Department,	Delbert Gatlin III

May 2006

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Observer Error in Identifying Species Using Indirect Signs:

Analysis of a River Otter Track Survey Technique.

(May 2006)

Jonah Wy Evans, B.A., Prescott College

Chair of Advisory Committee: Dr. Jane M. Packard

Indirect signs of species presence (e.g., tracks, scats, hairs) are frequently used to detect target species in occupancy, presence/absence, and other wildlife studies. Indirect signs are often more efficient than direct observation of elusive animals, making such signs well suited for long-term and broad-scale monitoring programs. However, error associated with misidentification of indirect signs can be high, and should be measured if meaningful inferences about population parameters are to be made. This study addressed the need for systematic approaches to estimate and minimize variation due to observer error in identifying indirect signs. I reanalyzed data from 4 replicates of a presence/absence survey of northern river otters (*Lontra canadensis*) that had been conducted by Texas Parks and Wildlife Department (1996-2003). Sixteen observers had recorded tracks at sample points under bridges (n = 250) distributed throughout 27 counties in the Piney-Woods ecoregion of east Texas. My objectives were to 1) determine if observers were a source of bias in the survey, 2) estimate the proportion of error associated with track identification skill, and 3) evaluate the use of an international certification procedure that measured observer tracking skill. The null hypothesis that observers had no effect on the variation in reported sign was rejected. Indeed, binary logistic regression tests indicated that observers were significantly associated with variation in reported track presence. Observers were not randomly distributed among bridge sites, and therefore were significantly correlated with 4 habitat variables that may have influenced heterogeneity in otter occupancy and probability of detection (watershed, vegetation-type, water-type, bridge-area). On average, experienced observers (n = 7) misidentified 44% of otter tracks, with a range of 0% to 100% correct detection. Also, 13% of the tracks of species determined to be “otter-like” were misidentified as belonging to an otter. During the certification procedure, participants misidentified the tracks of 12 species as otter. Inaccurate identification of indirect signs is a likely source of error in wildlife studies. I recommend that observer skill in identification of indirect signs be measured in order to detect and control for observer bias in wildlife monitoring.

DEDICATION

To my parents and grandparents

For their love and support

And to all those who dedicate their lives to improving

the relationship between people and the earth

ACKNOWLEDGEMENTS

I first would first like to thank the late Dan Boone, whose interest in furbearers led to the creation of the otter monitoring project of The Texas Parks and Wildlife Department. This project simply could not have happened without the enthusiasm and insight of Gary Calkins, the current Texas Parks and Wildlife Department District 6 Leader. His desire to gather meaningful data and improve the otter survey is highly appreciated. All the TPWD staff that participated in the track evaluation workshops deserve recognition for their great attitudes and enthusiasm for learning; they truly made the evaluation a success.

The TPWD Furbearer Program provided financial support for the training and evaluation workshops. Duane Schlitter and John Young were invaluable in arranging the funding for these workshops. John Young, TPWD mammalogist, initially suggested this project and helped us get started. Mark Elbroch shared his knowledge in track and sign identification and humbly evaluated the tracking skills of the TPWD staff. He also offered valuable suggestions for this paper. I also would like to thank Louis Liebenberg for developing the system for evaluating trackers used in this study, and for his vision to create a global wildlife-monitoring network.

Members of my graduate committee offered valuable guidance and suggestions: Billy Higginbotham and Amanda Stronza. Jane Packard put many hours into discussing and revising this thesis; her suggestions greatly improved its quality. I would like to thank my grandparents for their support and guidance during my graduate studies. Finally, Ciel Wharton helped me in countless ways on all stages of this project.

TABLE OF CONTENTS

Page

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The use of indirect signs (i.e., tracks, scat, hair, and other signs) to determine a species presence is widespread in wildlife monitoring (e.g., Conner et al. 1983, Kruuk et al. 1986, Beier and Cunningham 1996, Becker et al. 1998). A few of the innovative ways that these signs are applied include: scent stations (Conner et al. 1983), track plates (Allen et al. 1996, Mahon et al. 1998, Mooney 2002), scat transects (Mason and Macdonald 1987), pellet group counts (Campbell et al. 2004), hair snares (Foran et al. 1997), track surveys (Beier and Cunningham 1996), and animal structure (nest or den) counts (Wilson and Delahay 2001).

While indirect signs are often the most effective and least expensive way to detect elusive animals (Beyer and Cunningham 1996), correct identification can be challenging and requires practice and experience (Halfpenny 1986, Smallwood and Fitzhugh 1989, Stapper 1989, Silveria et al. 2003). Some indirect signs of detection, such as the tracks of certain species, can be highly variable (Appendix A) depending on several factors such as the type of substrate, moisture level, age of the track, and animal behavior (Liebenberg 1990, Smallwood and Fitzhugh 1993, Rezendes 1999, Elbroch 2003). However, in many research projects utilizing indirect methods to determine species presence (e.g., Conner et al. 1983, Shackelford and Whitaker 1997), observer skill is either overlooked or assumed to be high (Wilson and Delahay 2001). This oversight

---

This thesis follows the style of The Journal of Wildlife Management.

may limit the inferences that can be drawn from survey results (Anderson 2001).

Indirect signs have been widely applied as the means of detecting target species in presence/absence surveys (Stanley and Royle 2005, MacKenzie et al. 2006). Recent advances in the analysis of presence/absence data use repeated surveys and rigorous statistical procedures to estimate site occupancy (MacKenzie et al. 2006). However, prior to these approaches, analyses of presence/absence data typically used the percent of sites with the target species reported as an index of relative abundance (e.g., Lode 1993). The underlying assumption was that $C = Np$, where the index (C) was equivalent to the product of the population parameter of interest (N) and the detection probability (p) (Anderson 2001). Without a measure of detection probability (p), it must be assumed that (p) remains constant across observers, habitats, time, and other factors (Anderson 2001). As Anderson (2001) points out, this assumption is likely to be incorrect in most cases. In situations where (p) is <1, non-detection of the target species at a site does not imply true absence (Gu and Swihart 2004, MacKenzie 2005). One solution is to use a measure of the detection probability and calculate an unbiased estimate of the true number of sites occupied (MacKenzie et al. 2002).

Analyses of presence/absence data typically assume that observers never falsely report the target species at a site when absent (MacKenzie et al. 2002). With the use of indirect signs, the chance of an observer falsely reporting the target species may be high (Wilson and Delahay 2001), yet little consideration has been given to controlling and measuring the effects of observer error. In presence/absence surveys, this may result in both "false negatives" (i.e., failure to identify the tracks and signs of the target species correctly) and "false positives" (i.e., misidentifying other tracks and signs as those of the target species). Thus, the probability of correctly reporting the presence of the target species is a function of both the probability of encountering the target species and the probability of correct identification. In this paper, I examine issues related to observer reliability in a study of northern river otters in east Texas.

The standard survey procedures for European river otters (*Lutra lutra*) (Ruiz-Olmo et al. 2001, Bifolchi and Lodé 2005) were evaluated for variation in detection probability by Romanowski et al. (1996) and Ruiz-Olmo et al. (2001). Observers searched for indirect signs (usually scats and tracks) along transects on riverbanks (typically 600 m) from bridge sites and reported the presence/absence of otters at each site. When a single radio-collared otter was present, the probability of sign detection on small and medium-width streams was 71% (Ruiz-Olmo et al. 2001). When 2 or more radio-collared otters were present, the detection probability rose to 97%. Even in disparate areas, in which the variation in the percentage of sites with otters reported varied from 100% to 42%, approximately 96% of otter signs were reported within the first 200 m of the transect (Romanowski et al. 1996). In lowland streams in Poland, about 50% of the otter signs were recorded directly under bridges when otters were present (Romanowski et al. 1996). Detection probability has not been explicitly studied for Northern river otters.

Other presence/absence methods for surveying otters include scent stations and track transect surveys (Robson and Humphrey 1985, Clark et al. 1987). Clark et al. (1987), found the results from scent stations to be correlated with track surveys.

Although both methods were effective in determining changes in otter distribution, the variability of the results precluded their use as indicators of annual fluctuations in population size (Clark et al. 1987). Robson and Humphrey (1985) questioned the value of scent stations for otters, and recommend their use as only a 1-time determination of distribution.

Despite the challenges inherent in river otter surveys, in order for state wildlife agencies to issue federal tags for transport of otter pelts across state boundaries they are required to monitor otter populations and to report the results to the U. S. Fish and Wildlife Service. This is a result of the river otter's listing in Appendix II of the Convention on the International Trade of Endangered Species (CITES) (CITES 2005). This widely distributed species is listed due to its resemblance to threatened and endangered species listed in Appendix I of CITES. In compliance with the CITES treaty, the U.S. Fish and Wildlife Service is required to demonstrate that harvest for export is not detrimental to the species (CITES 1979). State agencies are responsible for providing evidence that otter populations are harvested in a sustainable manner.

Based on museum specimens, the historic range of otters in Texas once included the eastern half of the state as well as parts of the Panhandle (Schmidly 2004). However, their current range is thought to be restricted to the eastern quarter of the state (Schmidly 2004). Otters have also been reported along the Gulf Coast, near Galveston Island (Jackson et al. 1998). Foy (1984) determined otter peak activity in a coastal marsh habitat of southeastern Texas to be in the winter months.

Biologists in District 6 of the Texas Parks and Wildlife Department (TPWD) have conducted track surveys for otters in east Texas since 1977 (Bartnicki and Boone 1989). However, they did not use the standard transect methods for the surveys due to limited resources and lack of access to stream banks, which are primarily located on private property in east Texas. Instead, a survey was developed in which only the area directly under bridges was searched for otter tracks.

TPWD conducted exploratory surveys during the winter months of 1977-1979 (Fig. 1) in different counties each year (Bartnicki and Boone 1989). In 1983, a survey of 426 bridges was conducted in 42 counties, with otter sign reported at only 4 bridges. However, it was concluded that the results were inconclusive and the survey design needed to be refined. The survey was suspended for 12 years while the District Leader collected and evaluated information on otter survey techniques.

A revised survey design was initiated in 1995 and replicated on an annual basis for 3 years (1995-1997). In 1997, TPWD assessed its statewide priorities and the costs of the otter survey and subsequently extended the interval between surveys to every 3 years: 2000, 2003, and 2006. Observers were assigned to survey bridge sites based on convenience of travel, knowledge of the area, and county boundaries. The percent of bridges with otters reported each year (Fig. 2) was used as an index to relative abundance (Young 2003, McGinty and Young 2003). There was a notable decrease in the percent of bridges with reported otters in 1997, possibly due to heavy rainfall and floods reducing detection probability.

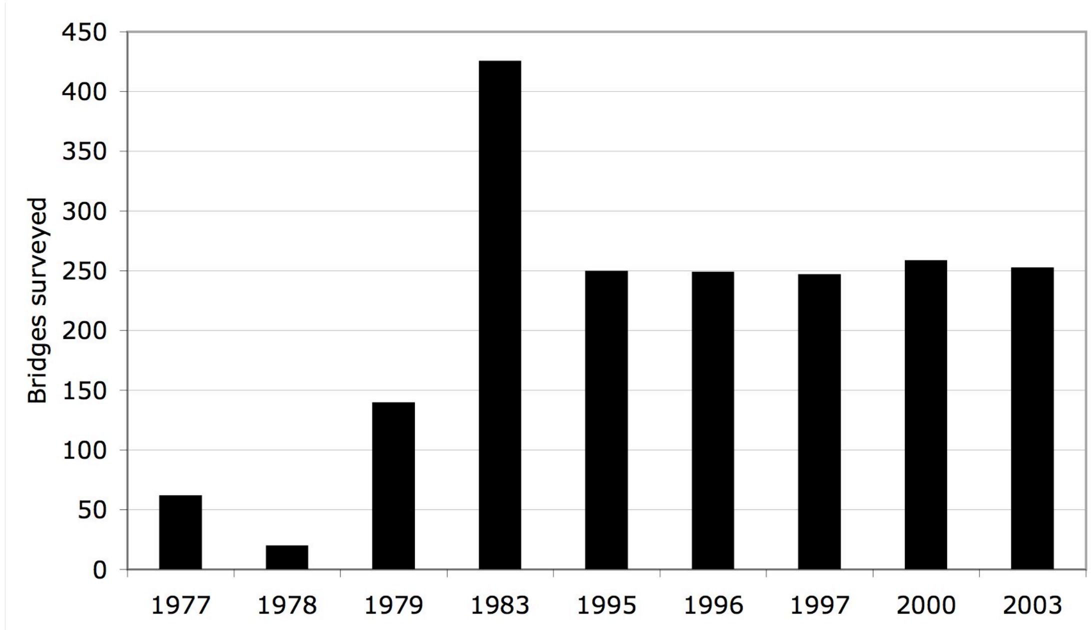


Fig. 1. The number of bridges surveyed each year (1977-2003).

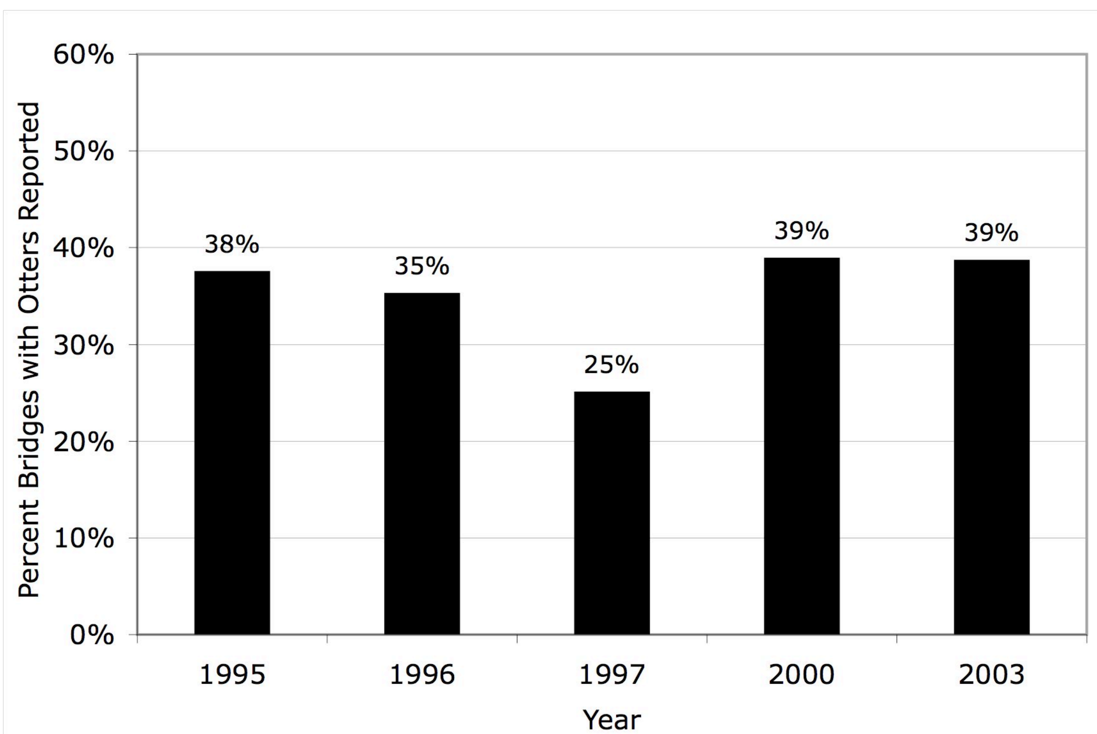


Fig. 2. The percentage of bridge sites with otter tracks reported (1995-2003).

In 2004, The Wildlife Management Institute (WMI) was asked to review the science-based management procedures of TPWD (WMI 2005). The review questioned the statement by TPWD that the Texas river otter population was stable (WMI 2005) for several reasons: (a) without an estimate of detection probability, the percentage of bridges with otter sign could not be calibrated to otter abundance, (b) although observer skill was likely a source of variation, no methods to estimate observer reliability were used, (c) selection criteria for sample locations were not random, and (d) robust statistical analyses were not applied in a manner that allowed for estimates of error. Similar issues are prevalent in other wildlife monitoring activities that are based on convenience sampling (Anderson 2001).

I used 2 approaches to test the assumption that detection probabilities due to observers were homogeneous. The first approach was a statistical analysis of the existing TPWD survey data and the second approach evaluated results from a standardized field evaluation of observers' track identification skills. My null hypothesis was that observers did not affect the variation in reported otters. The objectives of this study were: 1) to determine if observer bias was a potential source of error in the existing data set, 2) to determine the proportion of error associated with false negatives and false positives in otter track identification, and 3) to evaluate the utility of an existing international certification procedure (CyberTracker Conservation 2006) that systematically measures observer tracking skill.

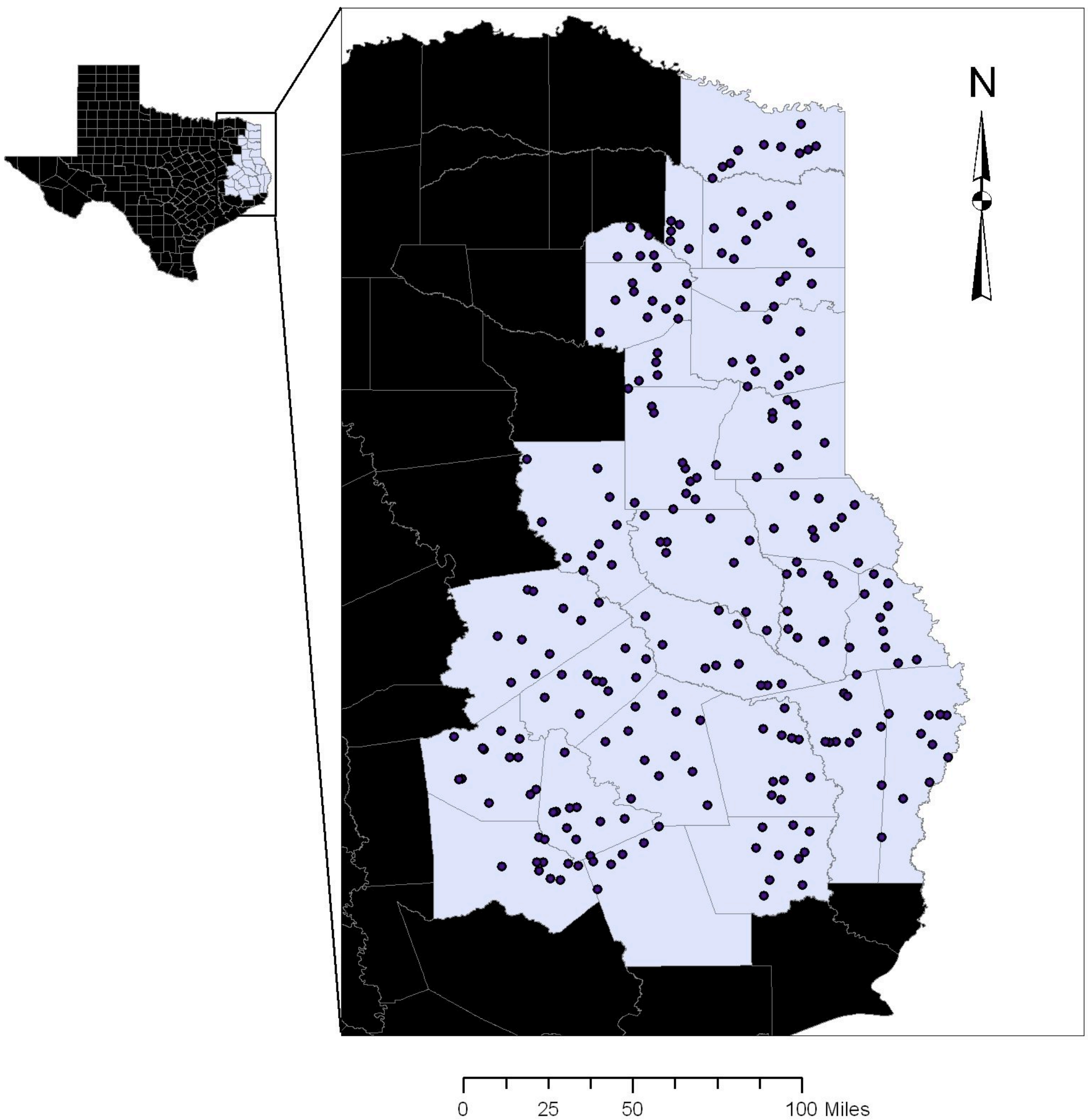


Fig. 3. Locations of bridge sites used for surveying river otters within the study area.

METHODS

TPWD BRIDGE SURVEY

Study Area.—The Piney Woods ecological region of east Texas included 6 major watersheds: the Cypress Creek, Neches River, Sabine River, San Jacinto River, Trinity River, and Sulfur River. The elevation ranged from sea level to over 150 m (492 ft), with the highest elevations occurring in the northwest portion of the study area and the lowest elevations in the south. Major vegetation types were classified as: pine-hardwood; young forest/grassland; post-oak woods, forest and grassland mosaic; willow oak-water oak-blackgum forest; and other vegetation types (McMahan et al. 1984). The substrates consisted mostly of sandy loams and sands in the uplands and sandy loams and clay loams in the bottomlands (Arbingast 1976). There were large tracts of land owned by corporations and the U.S. Forest Service, utilized primarily for timber production and other uses. More than 50% of the region was forested and approximately 18% was used for cropland (National Resource Conservation Service 2006).

Data Collection.—The standardized study design between 1995 and 2003 consisted of searches under bridge sites for otter tracks during the winter peak in otter activity (mid-January to mid-March) (G. Calkins, Texas Parks and Wildlife Department, personal communication). Each year of the study, approximately 250 bridge sites were surveyed once, throughout the 27-county region (Fig. 3). Most counties contained 10 bridge sites. The bridge sites were not randomly selected. Instead, selection was conducted in an ad hoc manner, based on accessibility and suitability of the bridge for reading tracks. If tracking substrate under a bridge became unsuitable (e.g., flooding, scouring, fencing), another bridge was chosen nearby on the same waterway. Because sites were subject to relocation, some sites depicted in Fig. 3 were not consistent for all years.

Due to the high turnover rate of field observers, only 5 of 21 observers conducted the survey in all years (1995- 2003). In a given year, usually 12 observers participated in the survey. Observers were not assigned to bridges at random, rather they were assigned to the counties within their areas of responsibility; usually the same observer surveyed all selected bridges in a given county. The observers worked primarily alone and searched for tracks on all suitable under-bridge substrates that were within the public right-of-way (G. Calkins, Texas Parks and Wildlife Department, personal communication). If a bridge site was disturbed by heavy rainfall or flooding within 1 week of the survey, the search was postponed to a later date. Occurrence of otter scats and other signs were not recorded in these surveys.

At each bridge site, observers recorded the presence of tracks identified as otters and other furbearers, including beaver (*Castor canadensis*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and mink (*Mustela vison*). In addition, site location, date, substrate, and observer identity were recorded. The search duration was as long as necessary for the observer to systematically examine tracks in all suitable areas under the bridge.

In 1996, there was a 1-day training facilitated by the most experienced observers, emphasizing track identification from slides and in the field. Subsequently, when new observers were added they were trained in the field by experienced co-workers (G. Calkins, Texas Parks and Wildlife, personal communication).

Data Analysis.—My analyses focused on the target species, river otter, and the years of standardized data collection (1996, 1997, 2000, 2003). The null hypothesis was that observers had no effect on the variation in reported presence of river otters. The first year of the standardized survey (1995) was primarily reconnaissance and bridge-site selection (G. Calkins, Texas Parks and Wildlife Department, personal communication) and was therefore deemed unsuitable for inclusion in this analysis. The coordinates for most bridge sites were located by written directions and points on county maps and entered into a geographical information system (GIS) using Arc View 9.1 (ESRI Institute, Redlands, California, USA). Incomplete or erroneous directions were a source of missing data in some years.

Otter distributions have been associated with several environmental factors (Macdonald and Mason 1983, Lode 1993). Therefore, I chose 4 spatial factors as potential explanatory variables for the effect of observer on reported river otter presence: watershed, water type, vegetation type, and bridge area (Table 1; Appendix B). The appropriate habitat attributes for each point were joined with the river otter bridge data in the GIS. The substrate data gathered by observers at each bridge site was not included as a factor because of low confidence in the reliability of the data (G. Calkins, Texas Parks and Wildlife, personal communication).

While 16 observers participated in the otter survey from 1996-2003, I analyzed data only for the observers who surveyed more than 25 bridges (n = 13). Because observers were not assigned to bridges at random, I examined correlations between observers and possible confounding habitat variables. For example, if a given observer exclusively surveyed bridges at a particular stream type at which otters were never reported, it would be difficult to infer whether otters were undetected because of (a) bias in detection probability caused by the stream type, (b) bias caused by the observer's inability to identify otter tracks, or (c) actual otter presence/absence in that stream type.

The effect of each variable was evaluated for its predictive value on reported otters in binary logistic regression tests. A variable was considered significant if any of its categories showed significance (alpha<0.05). Correlations between variables were determined through a chi-square test of independence. The relative predictability of each variable was evaluated through comparison of the G^2 likelihood ratios (also known as the change in -2 log likelihood ratio). All statistical tests were conducted with SPSS 11 (SPSS Inc, Chicago, Illinois).

Table 1. Description of variables used in analysis of TPWD otter bridge survey data.

Variable[a]	Importance to reported otter presence	Categories
Observer	Correct identification of otter tracks is critical to all further analyses	13 observers
Watershed	Potential large-scale distribution factor	1. Cypress Creek
		2. Neches River
		3. Sabine River
		4. San Jacinto River
		5. Trinity River
		6. Sulfur River
Water Type	Potential otter habitat selection criteria	1. Intermittent Stream
		2. Stream/water body
		3. Major Stream
Vegetation Type	Potential otter habitat selection criteria	1. Pine Hardwood
		2. Willow Oak-Water oak-Blackgum Forest
		3. Young forest/grassland
		4. Other
Bridge Area	Frequently effects the amount of area under the bridge to search for tracks	1. < 250 m^2
		2. 250-499 m^2
		3. 500-749 m^2
		4. 750-999 m^2
		5. 1000-7000 m^2

[a] The existing GIS layers were acquired from the following sources: *watershed,* Texas Water Development Board (1991); *water type,* Texas Department of Transportation/Texas General Land Office (2000); *vegetation type*, McMahan et al. (1984); and *bridge area,* National Bridge Inventory Database (2004).

EVALUATION OF OBSERVER SKILL

Data Collection.—A standardized evaluation system, developed by Louis Liebenberg (CyberTracker Conservation 2006), was used to measure observer track identification skills at 2 workshops. Wharton (2006) described the training and evaluation procedures at these workshops in detail. Mark Elbroch, a certified senior tracker evaluator in South Africa and North America (CyberTracker Conservation 2006), facilitated the evaluations.

During the workshops, observations by 23 TPWD staff were compared to the observations of the evaluator. Six of the 13 experienced otter observers were unavailable for this evaluation. Five experienced observers joined 15 other TPWD staff and participated in the first 2-day evaluation (Oct. 31-Nov. 1, 2005). In a second evaluation (Jan 23-24, 2006), 2 additional experienced otter observers were tested.

Questions were based on the tracks and signs of a variety of species in diverse substrate types encountered at bridges, wetlands, and upland forest sites in Jasper and Newton County, Texas. Because the questions depended on actual signs encountered in the field, specifics differed between the first workshop (59 questions) and the second workshop (81 questions). The evaluator chose locations where river otter tracks were likely to be found.

The questions were not focused exclusively on otters and similar species. Instead, in accordance with the standard used in South Africa (CyberTracker Conservation 2006), participants were asked to identify indirect signs chosen explicitly to test diversity of natural history knowledge. For example, in addition to otter-sized species, questions included indirect signs of great-blue heron (*Ardea herodias*), marsh rice rat (*Oryzomys palustris*), house cat, crayfish, and even grass blowing in the wind.

The CyberTracker evaluation procedure uses objective criteria to place questions into 3 categories of difficulty: easy, difficult, and very difficult (L. Liebenberg, CyberTracker Conservation, personal communication). Scoring is weighted, with the point values for each question based on the difficulty rating (CyberTracker Conservation 2006). Correctly answering a question rated as easy, difficult, or very difficult is worth 1(+), 2(+), or 3(+) points respectively. Incorrectly answering a question rated as easy, difficult, or very difficult is worth 3(x), 2(x), or 1(x) points respectively. The final score is calculated by dividing the number of correct (+) points by the sum of the correct (+) and the incorrect (x) points and expressed as a percentage (CyberTracker Conservation 2006). Thus, participants with the same numbers of correct and incorrect questions could receive different scores depending on the weights of the questions.

At the end of an evaluation, certificates are awarded for the following scores: level 1 (70-79 points), level 2 (80-89 points), level 3 (90-99 points), and track and sign specialist (100 points). However, for the purposes of this study, only the answers from participants' initial evaluation related to river otter were analyzed.

Data Analysis.—Descriptive statistics were calculated for the answers from all 23 participants to determine which species' tracks were mistakenly identified as river otter tracks at least once. Subsequently, the dataset was partitioned into experienced otter observers (n = 7) who had participated in at least 2 years of the river otter surveys, and other participants (n = 16). For each experienced observer, an index of "false negatives" and "false positives" was calculated. The index of false positives was based on the number of "otter-like" track questions incorrectly called otter. An "otter-like" track was defined as any track made by a species that was misidentified as an otter >1 time during the evaluations of all 23 participants. The index of false negatives was based the number of times a river otter track was misidentified as another species.

RESULTS

TPWD BRIDGE SURVEY

Across observers, the percentage of sites with otters reported varied from 7% to 59%, with a mean of 34% (Fig. 4). Observer was significantly associated with variation in reported otter presence ($G^2 = 118.620$, $P < 0.000$).

The effect of observer on reported otter presence was confounded by the effect of watershed and bridge area. Observer was correlated with watershed ($\chi^2 = 1775.5$, df = 78, $P < 0.000$) and bridge area ($\chi^2 = 269.645$, df = 78, $P < 0.000$), which were significantly associated with reported otters. Observer was also correlated with vegetation type ($\chi^2 = 336.6$, df = 52, $P < 0.000$). The variable that did not show predictive significance on reported otter, water type ($\chi^2 = 240.2$, df = 39, $P < 0.000$), was correlated with observer as well.

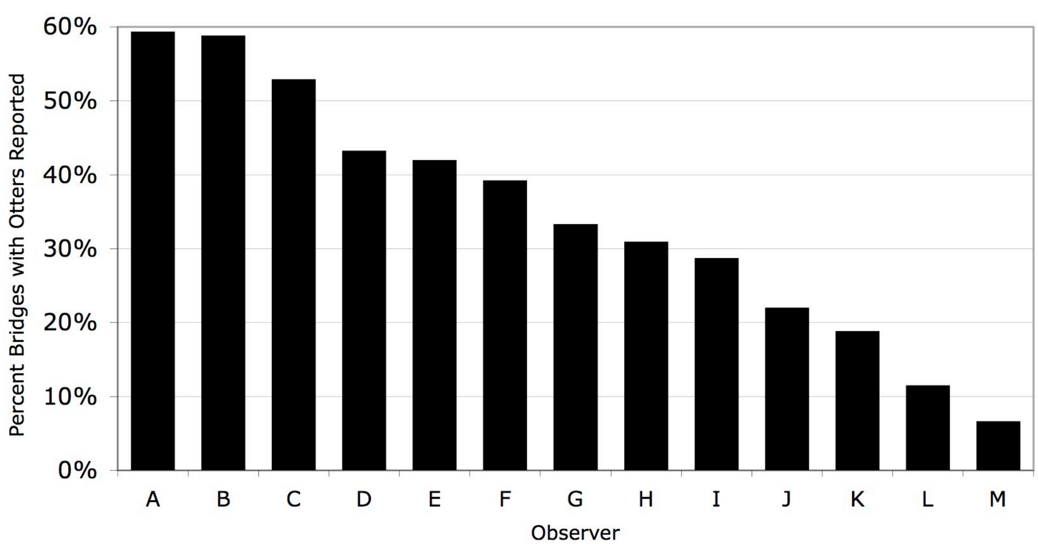


Fig. 4. The percentage of sites with reported otter presence for each observer ($n = 13$).

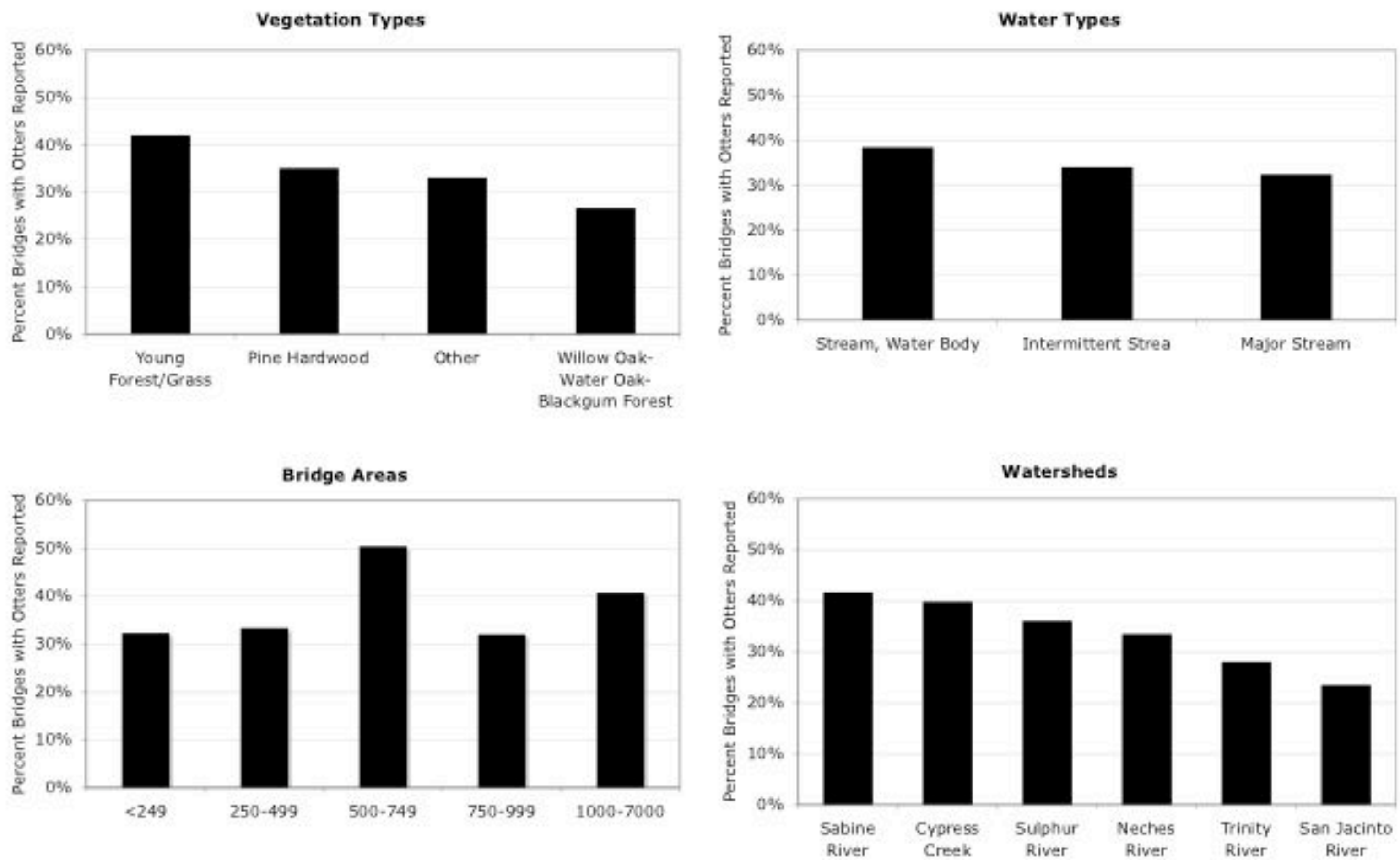


Fig. 5. Percentage of bridge sites with reported otters by each spatial factor.

Two of the 4 spatial variables (Fig. 5), were significantly associated with variation in reported otter presence: watershed (G^2 = 14.524, P = 0.013) and bridge area (G^2 = 24.218, P < 0.000). Although the overall predictive ability of the vegetation type was not significant (G^2 = 5.704, P = 0.127), one category was found to be significantly different than would be expected by chance. Variation in otter presence was not directly associated with water type (G^2 = 2.171, P = 0.338).

OBSERVER TRACK IDENTIFICATION SKILL

Based on the answers of all 23 participants, tracks of 12 species were misidentified as otter (Table 2), 8 of which were called otter more than once and therefore considered "otter-like." The species whose tracks were most frequently confused with otter tracks were swamp rabbit (*Sylvilagus floridanus*), raccoon, and opossum. The tracks of nutria (*Myocastor coypus*), marsh rice rat (*Oryzomys palustris*), turtle sp., and bullfrog (*Rana catesbeiana*) were infrequently confused with otter.

For experienced observers (Table 3), when asked to identify the tracks of an "otter-like" species, the index of false positives ranged from 6% to 19% (mean = 13%, SD = 4.5, n = 7). When asked to identify an otter track, the index of false negatives ranged from 0% to 100% (mean = 44%, SD = 35.7, n = 7).

The scores achieved on the evaluation by the experienced observers were significantly higher than the other participants. Of the 7 experienced observers evaluated, 1 achieved "level 2", 4 achieved "level 1", and 2 did not achieve a level. Of the other 16 participants, 3 achieved "level 1" and 13 did not achieve a level on their first evaluation. The average score for experienced observers (69%) was significantly higher (independent samples *t*-test, t = 2.379, df = 21, *P* = 0.027) than the average score for the other participants (59%).

Table 2. Species misidentified as river otter during the evaluations of track identification skill of 23 TPWD biologists.

Confusing species			Misidentified as "Otter"	
Common name[a]	Track questions	Completed answers[b]	Number	Index of error
Raccoon	14	193	24	12%
Opossum	8	109	11	10%
Dog	7	106	2	2%
House Cat	8	99	2	2%
Bobcat	6	87	3	3%
Armadillo	6	77	2	3%
[Nutria]	5	76	1	1%
Gray Fox	4	62	3	5%
[Rice Rat]	4	55	1	2%
[Turtle]	2	31	1	3%
Swamp Rabbit	1	20	9	45%
[Bullfrog]	1	20	1	5%

[a] Species in brackets were not included in the calculation of the index of false positives (see Table 3). The tracks of species not in brackets were categorized as "otter-like."

[b] Each value represents a count of all questions answered for the tracks of the indicated species, summed over all 23 observers who answered those questions.

Table 3. The percentage of false positives and false negatives calculated from the evaluations of the track identification skill of the 7 experienced TPWD biologists.

	False positives [b]			False negatives [c]		
Observer [a]	"Otter-like" spp. track questions	"Otter-like" spp. called otter	Index of error	Otter track questions	Otter tracks misidentified as other species	Index of error
D	17	1	6%	9	1	11%
B	17	3	18%	9	2	22%
A	16	3	19%	4	0	0%
J	16	2	13%	4	2	50%
I	16	2	13%	4	2	50%
C	16	2	13%	4	3	75%
L	11	1	9%	4	4	100%
Mean			**13%**			**44%**

[a] Observer identification letters are consistent throughout this document in order to enable comparison between tables and figures.
[b] The index of false positives for each observer was calculated as the number of times a species was misidentified as an otter, divided by the number of times asked to identify tracks of an "otter-like" species.
[c] Given that the track was an otter, the index of false negatives was calculated as the number of times an otter track was misidentified, divided by the total otter questions for each observer in the evaluation (4 questions in the first workshop, 9 questions in the second workshop).

DISCUSSION

INTERPRETATION OF RESULTS

Confounded variables were a problem when testing the effect of observer on reported river otters. All 4 habitat variables were correlated with observer. This was not a total surprise, as observers were assigned to bridge sites by county boundaries. Relative to observer, the significant habitat variables (watershed, bridge area, and vegetation type) were weakly associated with reported otter sign as made apparent by their low G^2 likelihood ratios.

Because observers were assigned to bridges by geographical areas, it was not possible to separate the effect of observer error from the habitat variables that also varied across the landscape. One potential solution would be to assign observers to bridge sites at random for future surveys. However, this is inefficient and impractical over large study areas. Another option would be to schedule more than 1 observer to each bridge (or subset of bridges) and estimate the error associated with detection during bridge surveys. Despite the correlations between observers and the other habitat variables, the strong predictive significance of observer is enough to raise concern.

During the evaluations of track identification skill, 13% percent of the tracks of "otter-like" species were identified as otter by the experienced otter observers. This suggests that there was a positive bias in the number of bridges with otters reported, especially since the tracks of these abundant species are frequently encountered under bridges. Therefore, the average proportion of "false positives" reported at a bridge site could be higher than 13% when multiple "otter-like" species are present. Several of the species determined to be "otter-like," such as gray fox and house cat, leave tracks that are considerably different from otters and were rarely mistaken as such. The species most frequently encountered at bridge sites and likely to have been mistaken for otter were the raccoon and opossum.

The experienced observers misidentified 44% of otter tracks. This suggests that there was a negative bias in the number of bridges with otters reported. However, this estimate is based on the relatively small number of otter track questions encountered during the evaluation procedure. The results are enough to conclude that more rigorous training in track identification was needed and would greatly decrease the probability of false positives and false negatives associated with observer skill. This does not mean that the experience and training the otter observers received was ineffective. The average score for otter observers of 69% was significantly higher than the average score for other participants of 59%. The highest score that any participant received when first evaluated was 83% (level 2), followed by 73% (level 1), with an average score of 62% (CyberTracker Conservation 2006).

In South Africa, trackers are generally only hired for research purposes if they achieved a score of 90% (level 3) or higher on the track evaluation (M. Elbroch, CyberTracker Conservation, personal communication). Similarly, Lehner (1996) suggests that inter-observer reliability should be greater than 95% but that >90% may be all that can be expected in field studies.

Although the scores of the TPWD observers signified the need for more rigorous training, rapid improvement is possible. Wharton (2006) demonstrated the utility of this evaluation system as an educational tool and showed significant improvement between the observers from the first evaluation discussed here (mean = 61%), and a second evaluation (mean = 79%) 3-months later. One benefit of evaluation systems over training alone is that the participants become aware of their strengths and weaknesses, enabling fast learning. One noteworthy participant demonstrated the educational utility of this evaluation system, scoring 69% on the first evaluation and 90% on the second evaluation.

This study utilized 2 methods to determine if observer error influenced the TPWD otter survey results: observer based analysis of the survey data and quantitative evaluation of observer skill. Based on the corresponding results of these investigations, temporal changes in the otter population cannot be inferred from these data.

MANAGEMENT IMPLICATIONS

Reliable data on river otters in Texas is needed in order to make informed management decisions based on the actual status of the population. The current high prices of otter pelts may result in an increase in trapping pressure (D. Hamilton, Missouri Department of Conservation, personal communication), signifying the need for better monitoring. However, even if identification of tracks and other signs by observers were increased to 100% accuracy, this would not address all of the issues with this survey. If the issuance of CITES tags by TPWD is to have no detriment to the otter population, several additional issues should be addressed in order to fine tune the bridge survey technique (Appendix C).

Tracks and other indirect signs of species presence are commonly used in wildlife studies; however, correct identification requires training and practice. While identification of river otter tracks can be difficult, they are not a special case. Few species leave tracks so distinctive as to never cause confusion in identification. Moreover, identifying the tracks of a species may vary in difficulty depending on the presence other species in the region with similar tracks. Therefore, issues with observer reliability in the use of indirect signs are likely to be widespread and not limited to just river otter track surveys in Texas.

It is reasonable to assume that studies that fail to account for observer skill may be biased. Reid et al. (1987) developed a method to estimate otter populations using snow tracks, but concurs that misinterpretation of tracks could result in underestimation or overestimation of the population size. However, even though correct identification of tracks and indirect signs is challenging, it can be accomplished with very high accuracy by skilled observers. Stander et al. (1997) found that in a test for accuracy of highly skilled observers on pre-confirmed tracks, 100% of species were identified correctly of 147 questions. Likewise, a study by Zuercher et al. (2003) compared scat identifications by skilled local observers to identification by molecular analysis and found 100% agreement between the 2 methods.

When observer skill is a source of error in a study, the results reflect not only the parameter of interest (occupancy) and the probability of encountering the tracks, but also the varying detection probabilities caused by observer skill. As in any scientific research, the precision and accuracy of the measurement device must be known (or at least constant) in order to make meaningful inferences about the object of interest. However, in most cases observer skill in the identification of indirect signs is either neglected or assumed to be high. In order to collect reliable data, the probability of encountering the signs of the target species when present should be measured (MacKenzie and Royle 2005), as well as observer skill level. Therefore, it is not possible to judge if studies that use indirect signs of species presence are reliable, unless: 1) the signs of the species presence are unmistakable even to a novice observer, or 2) observer skill in identification of these signs is measured and reported. Basing management decisions on the results of any wildlife studies that use tracks or other indirect signs without a measure of observer skill is not recommended.

Many wildlife studies would benefit greatly from adopting standardized methods of evaluating the skill of field biologists and data collectors (Appendix D). Methods like the evaluation of track identification skill could be applied in a wide variety of research both for testing the validity of collected data (as demonstrated here) and for quantitatively evaluating the tracking skill of observers. The levels achieved by participants are publicly available and enable selection of skilled data collectors by project managers. The CyberTracker evaluation has led to the validation of traditional ecological knowledge in South Africa. In the United States, this methodology could prove useful for validating the skills of citizen scientists and data collectors without formal education in wildlife science (Wharton 2006).

Even with the challenges inherent in identifying indirect signs, they are still likely to be the most effective way to study many species. With the latest advances in presence-absence data analysis and occupancy estimation (MacKenzie et al. 2006), the use of indirect signs to detect species presence may become even more widespread. Stanley and Royle (2005) developed an extension of the site-occupancy model specifically enabling indirect signs to be used in determining species abundance and occupancy. However, even the most complex statistical procedures are of little use if the ability of the data collectors to identify the signs is inadequate. Use of standardized evaluations of observer skill, together with occupancy estimation procedures, will enable sound inferences to be made about population parameters with efficiency and confidence.

CONCLUSION

Based on the analyses of the past otter survey data and results from the evaluations of observer track identification skills, it is not possible to infer temporal changes in the otter population from these data.

Correct identification of indirect signs is challenging and it can not be assumed that even experienced field observers are accurate in the identification of these signs. Relying on this assumption could result in considerable bias in survey results and lead to misinformed management decisions. However, the identification of indirect signs by field observers is an important and necessary component to many wildlife studies.

Tools for evaluating field skills resolve this dilemma by providing managers with actual knowledge of observer skill level. Evaluations of field skills may reveal previously overlooked sources of error, enabling appropriate corrective measures to be made.

When considering the issue of observer in indirect sign surveys, managers have several options: 1) adequately train and evaluate current field observers, 2) select pre-evaluated field observers of adequate skill level, or 3) use methods to record tracks (such as track plates, plaster casts, photographs) and verify the species' identities with the aid of an outside (evaluated) track and sign specialist.

LITERATURE CITED

Allen, L., R. M. Engeman, and H. Krupa. 1996. Evaluation of three relative abundance indices for assessing dingo populations. Wildlife Research 23:197–206.

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

Arbingast, S. A. 1976. Atlas of Texas. The University of Texas at Austin Bureau of Business Research. Austin, Texas, USA.

Bartnicki, P. L., and D. B. Boone. 1989. Special report: Status of the river otter (*Lutra lutra*) in Texas. Texas Parks and Wildlife Department, Austin, Texas, USA.

Becker, E. F., M. A. Spindler, and T. O. Osborne. 1998. A population estimator based on network sampling of tracks in the snow. Journal of Wildlife Management 62:968–977.

Beier, P., and S. C. Cunningham. 1996. Power of track surveys to detect changes in cougar populations. Wildlife Society Bulletin 24:540–546.

Bifolchi, A., and T. Lodé. 2005. Efficiency of conservation shortcuts: an investigation with otters as umbrella species. Biological Conservation 126:523–527.

Campbell, D., G. M. Swanson, and J. Sales. 2004. Comparing the precision and cost-effectiveness of faecal pellet group count methods. Journal of Applied Ecology 41:1185–1196.

Clark, J., 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.

Conner, M. C., R. F. Labisky, and D. R. Progulske Jr. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes, and opossums. Wildlife Society Bulletin 11:146–152.

[CITES] Convention on International Trade in Endangered Species of Wild Flora and Fauna. 1979 June 22. CITES home page. <http://www.cites.org/>. Accessed 2006 Feb 23.

[CITES] Convention on International Trade in Endangered Species of Wild Flora and Fauna. 2005 June 23. CITES Appendices I, II, and III. <http://www.cites.org/eng/app/appendices.shtml>. Accessed 2006 Feb 23.

CyberTracker Conservation. 2006. CyberTracker Conservation home page. <http://cybertracker.org/>. Accessed 2006 Feb 26.

Elbroch, M. 2003. Mammal tracks and sign: a guide to North American species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Foran, D. R., S. C. Minta, and K. S. Heinemeyer. 1997. DNA-based analysis of hair to identify species and individuals for population research and monitoring. Wildlife Society Bulletin 25:840–847.

Foy, M. K. 1984. Seasonal movement, home range, and habitat use of river otter in southeastern Texas. M.S. Thesis, Texas A&M University, College Station, Texas, USA.

Gu, W., and R. K. Swihart. 2004. Absent or undetected? Effects of non-detection of species occurrence on wildlife-habitat models. Biological Conservation 116:195–

203.

Halfpenny, J. 1986. A field guide to mammal tracking in North America. Second edition. Johnson Publishing Company, Boulder, Colorado, USA.

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

Jackson, M. A., D. Fertl, and J. F. Bergan. 1998. Recent records of the river otter (*Lutra canadensis*) along Texas Gulf Coast. Texas Journal of Science 50:243–247.

Kruuk, H., J. W. H. Conroy, U. Glimmerveen, and E. J. Ouwerkerk. 1986. The use of spraints to survey populations of otters *Lutra lutra*. Biological Conservation 35:187–194.

Lehner, P. N. 1996. Handbook of ethological methods. Second edition. Cambridge University Press, New York, New York, USA.

Liebenberg, L. 1990. A field guide to the animal tracks of southern Africa. David Phillip Publishers, Claremont, South Africa.

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.

Macdonald, S. M., and C. F. Mason. 1983. Some factors influencing the distribution of otters *(Lutra lutra)*. Mammal Review 13:1–10.

MacKenzie, D. I. 2005. Was it there? Dealing with imperfect detection for species presence/absence data. Australian and New Zealand Journal of Statistics 47:65–74.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42:1105–1114.

MacKenzie, D. I., J. D. Nichols, G. B. Lacheman, 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. 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.

Mahon, P. S., P. B. Banks, and C. R. Dickman. 1998. Population indices for wild carnivores: a critical study in sand-dune habitat, south-western Queensland. Wildlife Research 25:11–22.

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.

McGinty, K. D., and J. Young. 2003. Fur-bearing animal recommendations. Federal Aid in Wildlife Restoration Project W-134-2. Small Game and Furbearer Research and Surveys. Texas Parks and Wildlife Department. Austin, Texas USA.

McMahan, C. A., R. G. Frye, and K. L. Brown. 1984. The vegetation types of Texas - including cropland. Texas Parks and Wildlife Department, Austin, Texas, USA.

Mooney, K. A. 2002. Quantifying avian habitat use in forests using track-plates. Journal of Field Ornithology 73:392–398.

National Bridge Inventory Database. 2004. Compiled from U.S. government sources

(Federal Highway Administration). Albuquerque, New Mexico, USA.

National Resource Conservation Service. 2006. U.S. Department of Agriculture handbook 296: land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. Washington, DC, USA.

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

Rezendes, P. 1999. Tracking and the art of seeing: how to read animal tracks and sign. Harper Collins Publishers, Inc., New York, New York, USA.

Robson, M. S., and S. R. Humphrey. 1985. Inefficacy of scent-stations for monitoring river otter populations. Wildlife Society Bulletin 13:558–561.

Romanowski, J., M. Brzezinski, and J. P. Cygan. 1996. Notes on the technique of the otter field survey. Acta Theriologica 41:199–204.

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

Schmidly, D. J. 2004. The mammals of Texas. Sixth edition. University of Texas Press, Austin, Texas, USA.

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

Smallwood, K.S. and E.L. Fitzhugh. 1989. Differentiating mountain lion and dog tracks. Pages 58–63 *in* R.H. Smith, editor. Proceedings of the Third Mountain

Lion Workshop. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Smallwood, K. S., and E. L. Fitzhugh. 1993. A rigorous technique for identifying individual mountain lions *Felis concolor* by their tracks. Biological Conservation 65:51–59.

SPSS (Statistical Package for the Social Sciences, Inc). 2002. SPSS Base 11.5. SPSS, Inc., Chicago, Illinois, USA.

Stander, P. E., Ghau, and D. Tsisaba. 1997. Tracking and the interpretation of spoor: a scientifically sound method in ecology. Journal of Zoology 242:329–341.

Stanley, T. R., and J. A. Royle. 2005. Estimating site occupancy and abundance using indirect detection indices. Journal of Wildlife Management 69:874–883.

Stapper, R. J. 1989. A comparison of scent-station surveys and track counts for surveying furbearer populations in the Big Thicket National Preserve, Texas. M.S. Thesis, Texas A&M University, College Station, Texas, USA.

Texas Department of Transportation/Texas General Land Office. 2000. Hydrography-detailed. Texas Department of Transportation/Texas General Land Office, Austin, Texas, USA.

Texas Water Development Board. 1991. Major river basins in Texas. Texas Water Development Board, Austin, Texas, USA.

Wharton, C. A. 2006. Are we gathering reliable data? The need for measuring observer skill in wildlife monitoring. M.S. Professional Paper. Texas A&M University, College Station, Texas, USA.

Wildlife Management Institute. 2005. A comprehensive review of science-based methods and processes of the Wildlife and Parks Divisions of the Texas Parks and Wildlife Department. A report to the Executive Director of the Texas Parks and Wildlife Department. Wildlife Management Institute, Washington, DC, USA.

Wilson, G. J., and R. J. Delahay. 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildlife Research 28:151–164.

Young, J. 2003. Performance report, as required by U.S. Fish and Wildlife Service Division of Management Authority: River otter status. Texas Parks and Wildlife Department, Austin, Texas, USA.

Zuercher, G. L., P. S. Gipson, and G. C. Stewart. 2003. Identification of carnivore feces by local peoples and molecular analyses. Wildlife Society Bulletin 31:961–970.

APPENDIX A

PHOTOGRAPHS OF OTTER AND “OTTER-LIKE” TRACKS

OTTER TRACKS

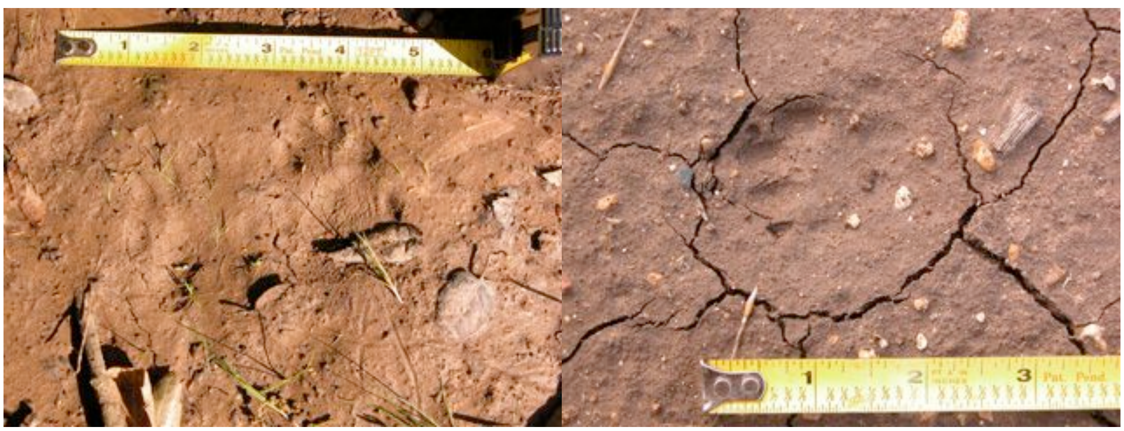
Typical otter lope pattern.

A clear left-front foot (left) and right-hind foot (right).

Obscure otter tracks.

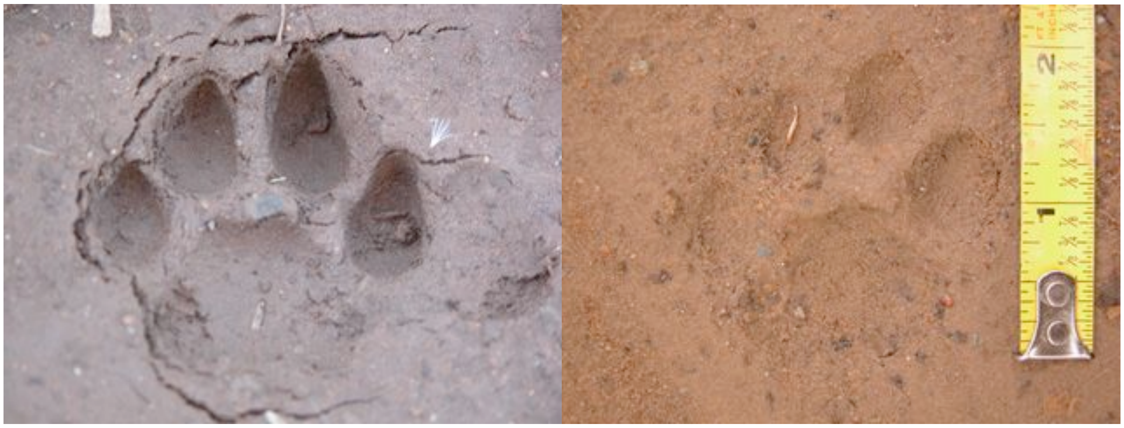
“OTTER-LIKE” SPECIES TRACKS

Clear raccoon tracks.



Obscure raccoon tracks.

Clear opossum tracks (left) and obscure (right).



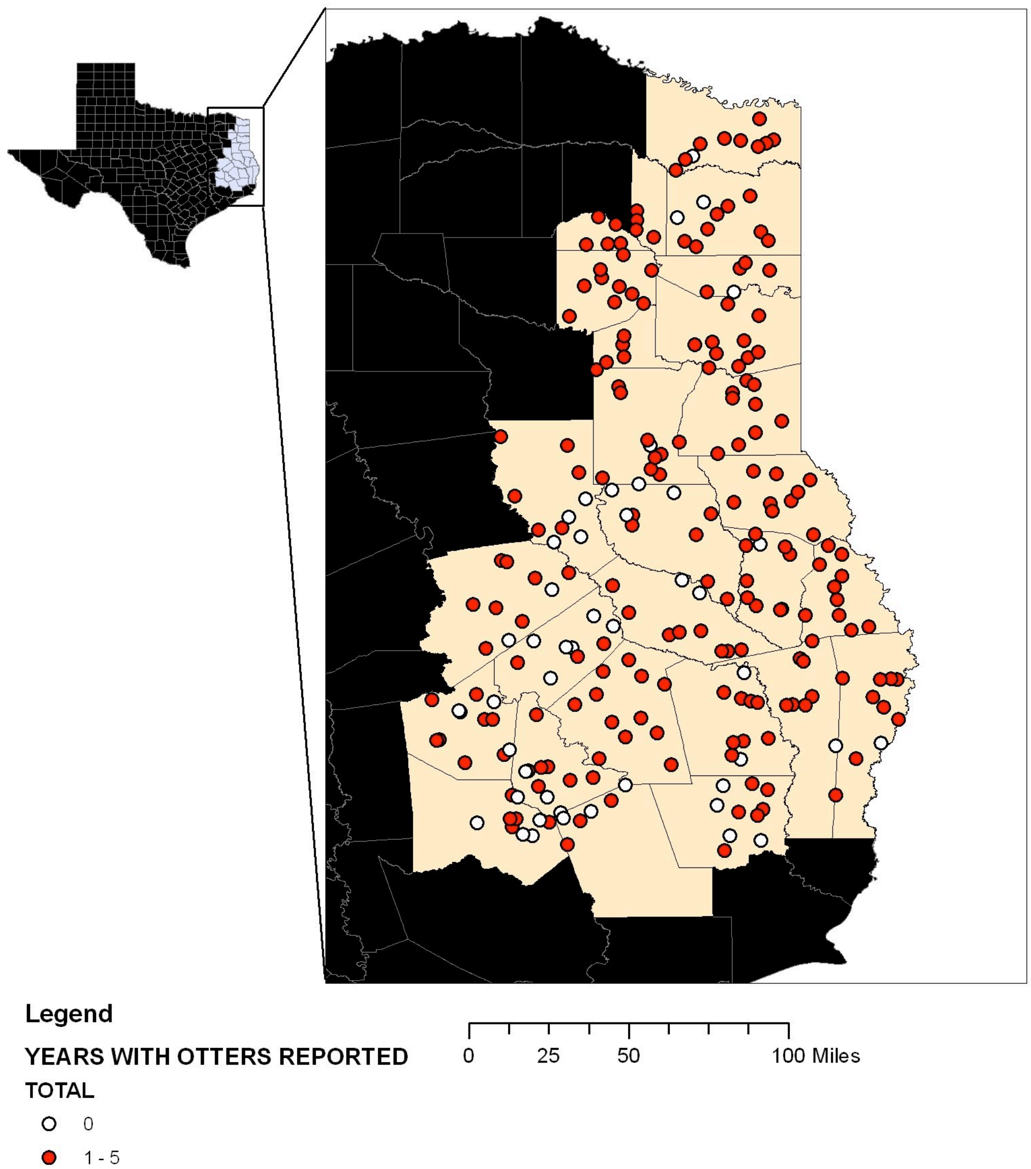
Bobcat tracks.

Nutria tracks, the smaller tracks are the front feet.

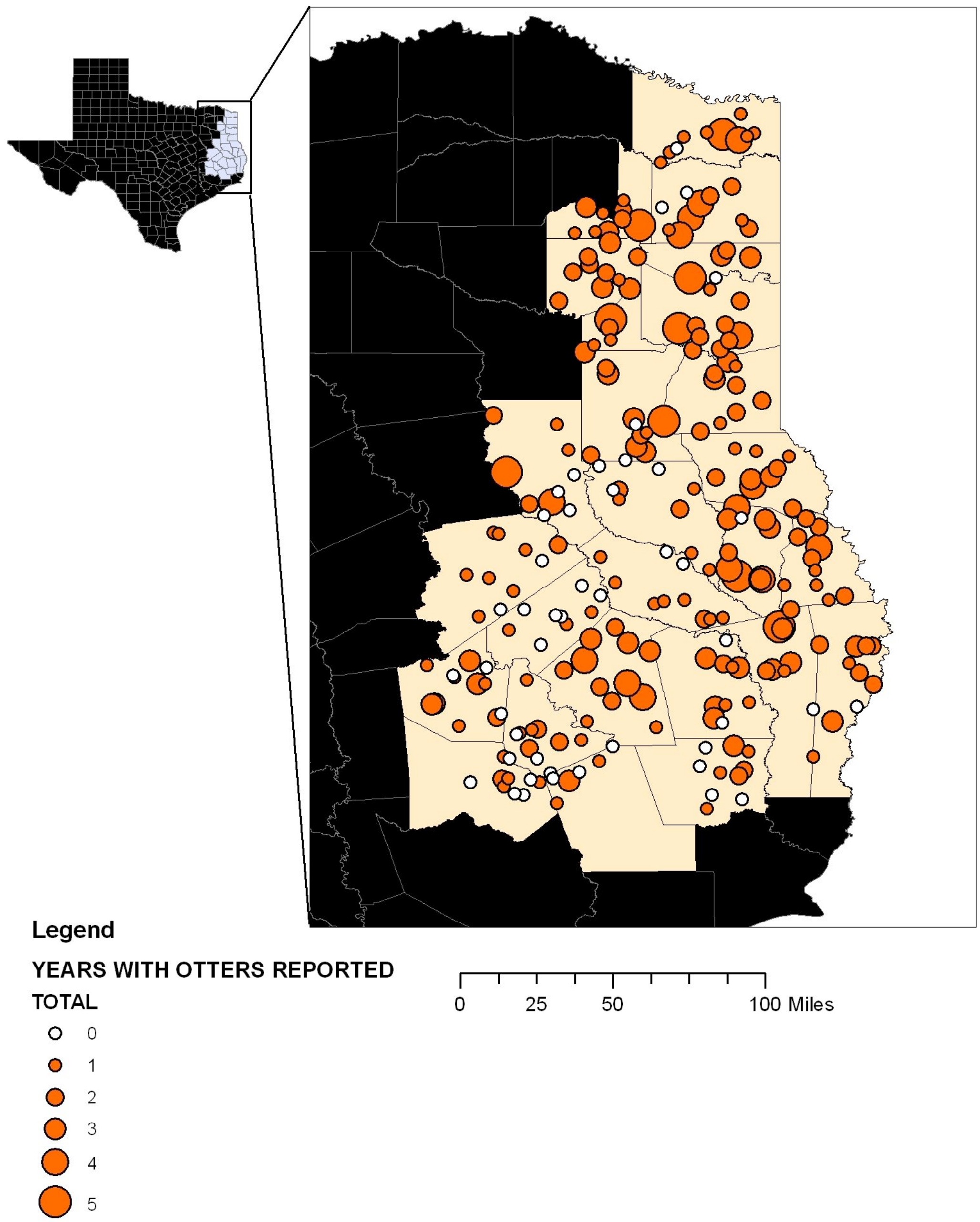
APPENDIX B

ADDITIONAL MAPS

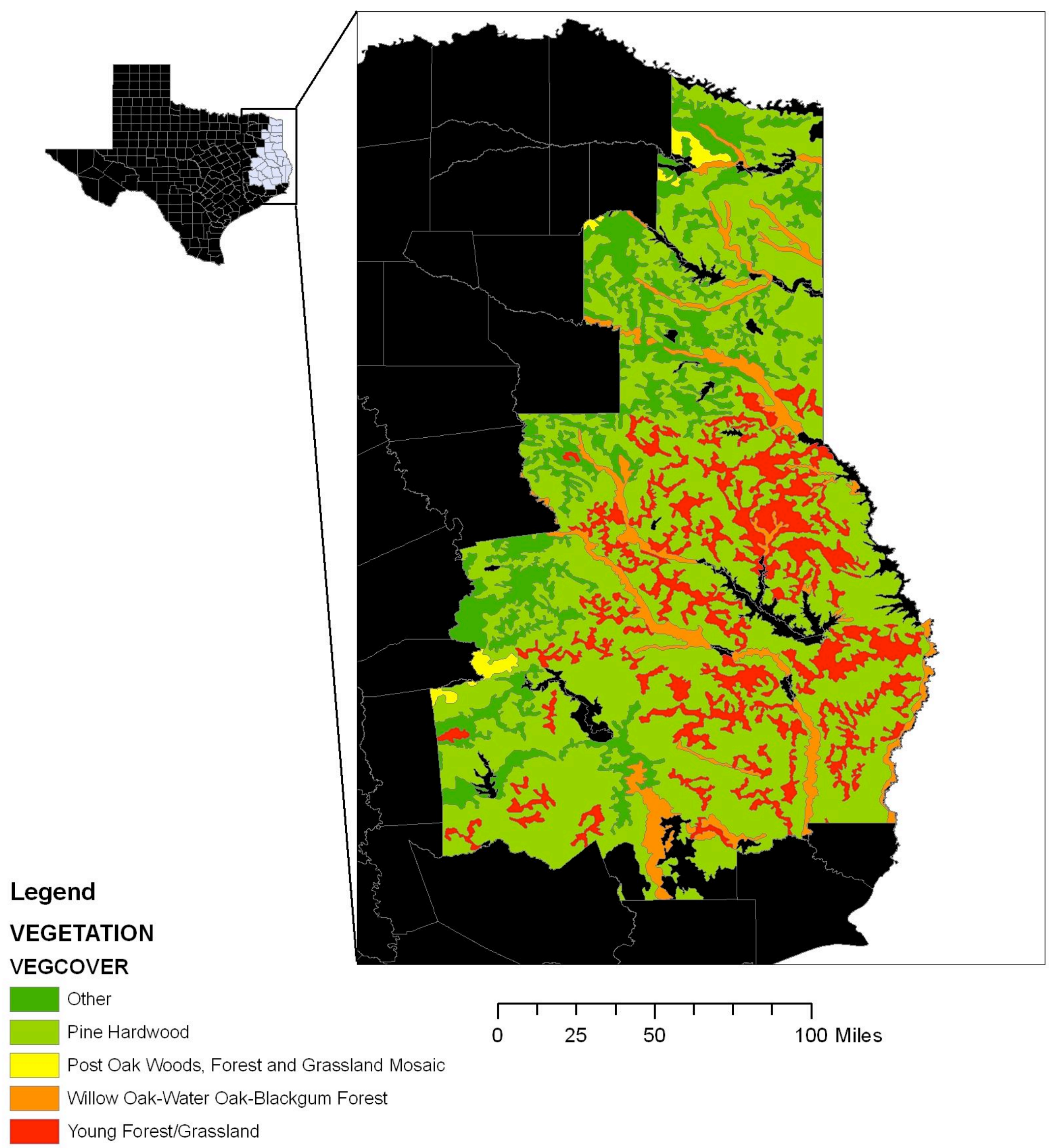
BRIDGES WITH AND WITHOUT REPORTED OTTER PRESENCES FROM 1995-2003



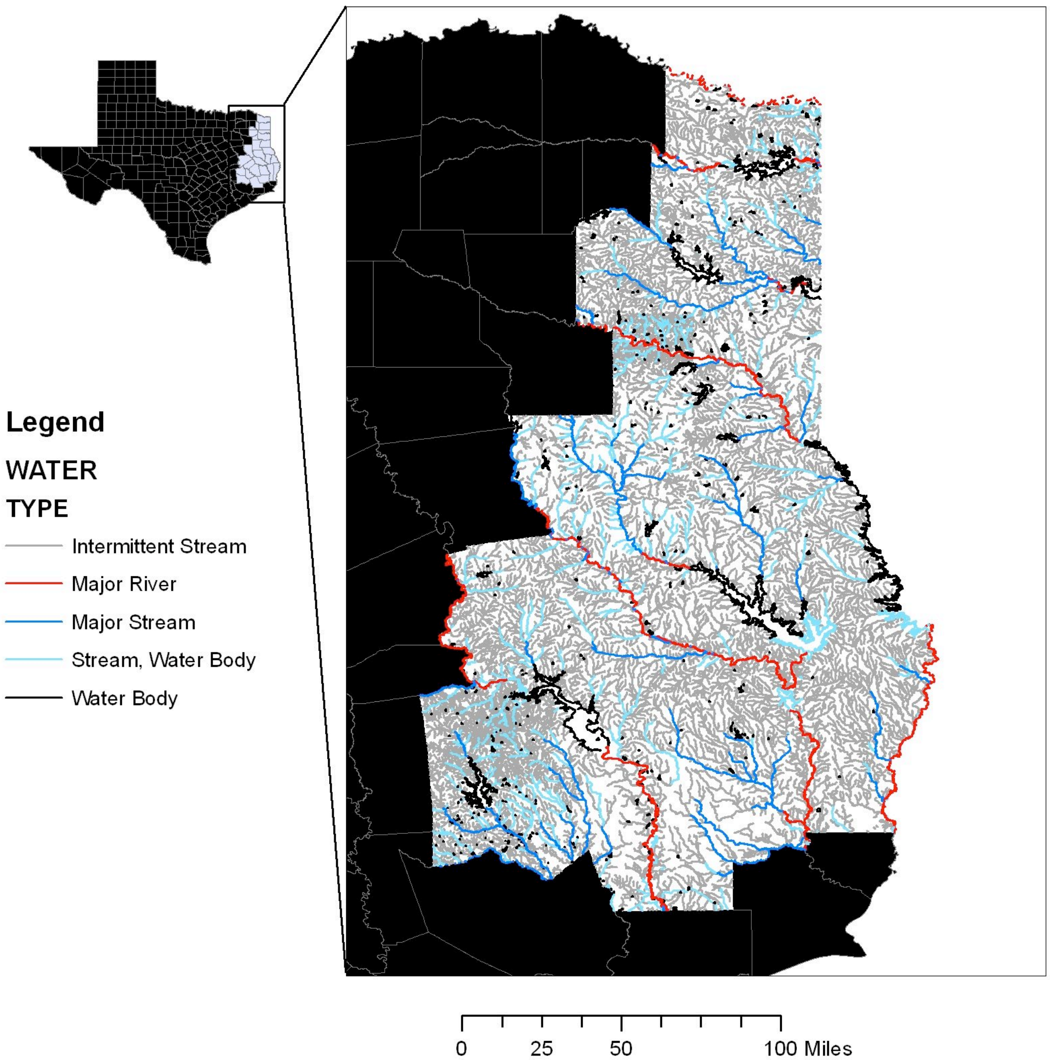
TOTAL REPORTED OTTER PRESENCES FROM 1995-2003



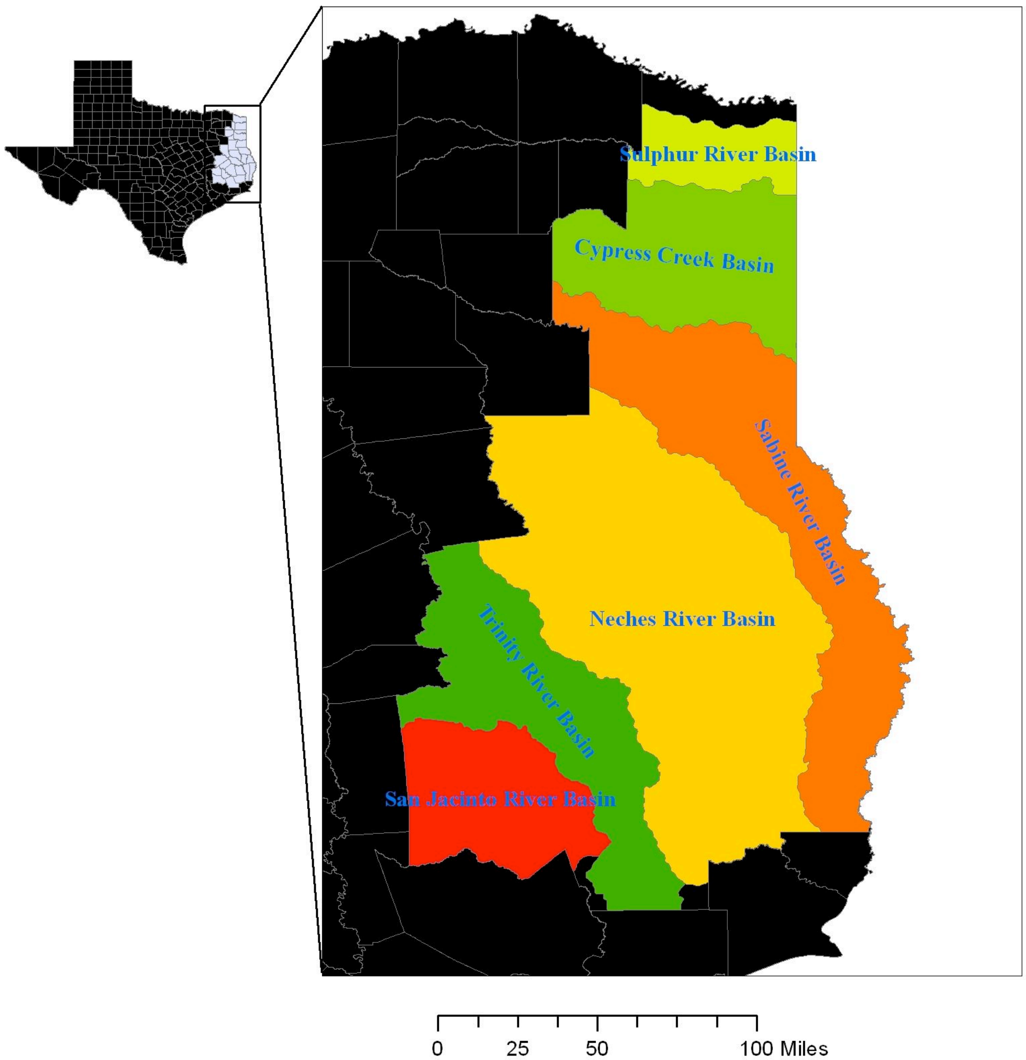
VEGETATION TYPES

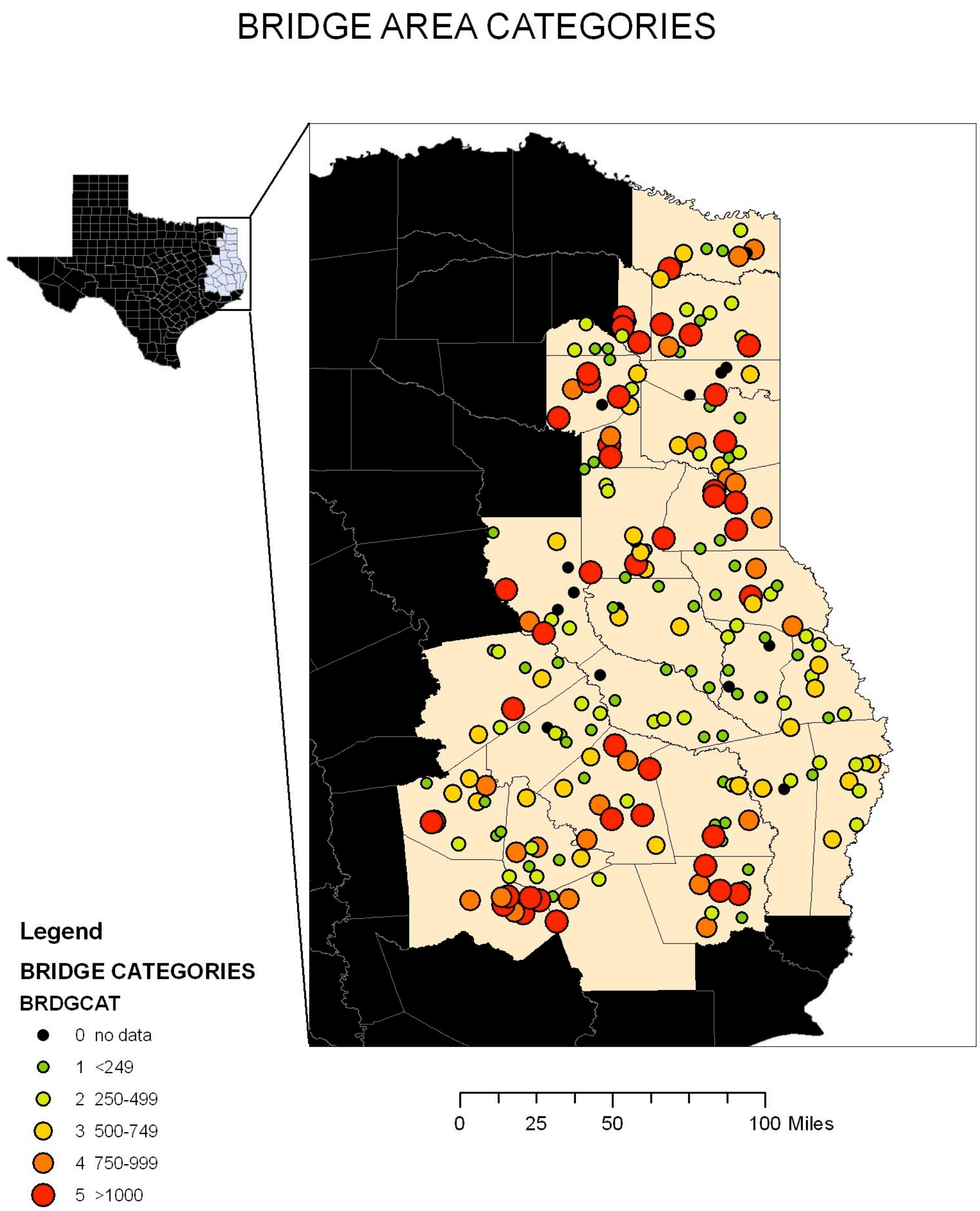


WATER TYPES


Legend
WATER
TYPE
Intermittent Stream
Major River
Major Stream
Stream, Water Body
Water Body
0
25
50
100 Miles

WATERSHEDS


Sulphur River Basin
Cypress Creek Basin
Sabine River Basin
Neches River Basin
Trinity River Basin
San Jacinto River Basin
0
25
50
100 Miles


BRIDGE AREA CATEGORIES
Legend
BRIDGE CATEGORIES
BRDGCAT
0 no data
1 <249
2 250-499
3 500-749
4 750-999
5 >1000
0
25
50
100 Miles

APPENDIX C

RECOMMENDATIONS FOR TPWD BRIDGE SURVEY

This section addresses some of the concerns identified through this thesis with the TPWD bridge survey and offers suggestions for improvement.

Issue I How can observer error in identifying otter tracks be reduced?

1. Train and evaluate the track identification skills of field staff at regular intervals to maintain consistency and improve competency in track identification.
2. When possible, establish a minimum threshold of 90% for acceptable track identification skill by observers. Otherwise, use the highest scoring observers available, as this will improve confidence in the data collected.
3. The development of a photographic library of the tracks of otters and "otter-like" species would serve as a valuable training tool. Also, if an observer is unsure of the identity of a track, the highest certified trackers available could identify photographs.
4. While it is common to randomly assign observers to survey sites, this is impractical when large areas are surveyed. Therefore, it is important to decrease variation between observers through clearly understood sampling protocols.

Issue II How can trends in the otter population be inferred from multiple years of survey data if there is imperfect and variable detection probability?

1. The parameter of interest is the percent of bridge sites occupied, not the percent of sites with otters detected. Therefore, in order to compare the results from different years, the probability of detecting otter tracks at bridge sites should be measured, ideally, each year the survey is conducted.

2. A simple method would be to compare the current bridge survey method with the (more robust) standard survey method of extended searches of approximately 600 meters up and down stream from a random sample of bridge sites. The proportion of times otter tracks were detected at bridge sites when present (determined through the more robust transect method) could then be used as an estimate of detection probability.
5. Performing multiple surveys of bridge sites in a single season, as described by MacKenzie (2006), offers an alternate method of determining detection probability and estimating the percent of sites occupied. The model developed by Stanley and Royle (2005) incorporates the length of the sampling interval into estimates of detection probability, allowing for indirect signs to be used more appropriately. I would recommend an interval of no less than 2 weeks for repeated surveys, as this is the time often required for otters to cover the area within their territories (D. Hamilton, Missouri Department of Conservation, personal communication). Also, if repeated surveys are conducted within 1 season, all otter tracks under each bridge should be erased or otherwise marked as to prevent double counting of the same track.
6. Use of occupancy based study designs and analyses may prove invaluable. Training in these methods is available (e.g., Occupancy Estimation and Modeling workshop, 31 May - 2 June 2006, San Marcos, Texas).

Issue III How can the otter study be redesigned to better answer the management questions?

1. Consider a redesign of the survey based on watershed boundaries rather than county boundaries. Otter populations may be somewhat confined by watershed boundaries and population changes may vary by watershed.
2. Bridge sites should be reselected randomly from a pool of bridges with suitable substrates for reading tracks within each watershed. In order to reduce variation, efforts should be made to select bridges with similar size and substrate characteristics. In addition, bridge sites should be spaced adequately apart in order to ensure 1 otter could not mark >1 bridge sites.
3. The bridge sites are not random points along waterways and may be a source of bias. A study of otters, independent of bridge sites would eliminate this bias. However, it is understood that there are accessibility issues with waterways in east Texas and the bridge survey may be the only feasible option.
4. In order to reduce variation due to stochastic events, the survey should be conducted at more frequent intervals than every 3 years.

Issue IV How should scientifically based management decisions be made from the survey results?

1. Objective criteria should be pre-established for determining whether CITES tags should be issued.
2. Significant decreases in overall otter occupancy estimates for multiple seasons may indicate over-harvesting and should be grounds for management changes.

APPENDIX D

RESOURCES FOR IMPROVING TRACKING SKILLS

TRACK AND SIGN EVALUATIONS

CyberTracker Conservation http://cybertracker.org

Wildlife Tracking in North America http://wildlifetrackers.com

IDENTIFICATION GUIDES FOR NORTH AMERICA

Elbroch, M., and E. Marks. 2001. Bird tracks and sign: a guide to North American species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Elbroch, M. 2003. Mammal tracks and sign: a guide to North American species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Halfpenny, J. 1986. A field guide to mammal tracking in North America. Second edition. Johnson Publishing Company, Boulder, Colorado, USA.

Murie, O. J., and M. Elbroch. 2005. A field guide to animal tracks. Third edition. Houghton Mifflin Company, New York, New York, USA.

Rezendes, P. 1999. Tracking and the art of seeing: how to read animal tracks and sign. HarperCollins Publishers, Inc., New York, New York, USA.

VITA

Jonah Wy Evans
25 Spring Creek Rd.
Boerne, TX, 78006

EDUCATION

Master of Science, Texas A&M University, Department of Wildlife and Fisheries Sciences, College Station, Texas. 2006

Bachelor of Arts, Prescott College, Major in Environmental Studies, Prescott, Arizona. 2002

WORK EXPERIENCE

Research Technician (River Otter), Missouri Dept of Conservation, Houston, Missouri (May 2005-August 2005)

Naturalist, Naturalists at Large, San Francisco Bay Area, California (September 2003-March 2004)

Naturalist, Great Hollow Wilderness School, New Fairfield, Connecticut (June 2003-August 2003)

Research Technician (Golden-cheeked Warbler and Black-capped Vireo), Performance Group Incorporated, San Antonio, Texas (March 2003-June 2003)

Backcountry Trip Leader, Prescott College, Prescott, Arizona (August 2002-September 2002)

Teacher-Naturalist, Great Smoky Mountains Institute at Tremont, Townsend, Tennessee (May 2002-August 2002)

Nature Summer Camp Director, Cibolo Nature Center, Boerne, Texas (June 2001-July 2001)