STATUS AND POPULATION CHARACTERISTICS OF THE NORTHERN RIVER OTTER (*LONTRA CANADENSIS*) IN CENTRAL AND EASTERN OKLAHOMA

By

DOMINIC ALAN BARRETT

Bachelor of Science

Southeastern Oklahoma State University

Durant, Oklahoma

2004

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2008

STATUS AND POPULATION CHARACTERISTICS
OF THE NORTHERN RIVER OTTER (*LONTRA CANADENSIS*) IN CENTRAL AND
EASTERN OKLAHOMA

Thesis Approved:

David M. Leslie, Jr.
Thesis Advisor

Craig A. Davis

William L. Fisher

A. Gordon Emslie
Dean of the Graduate College

ACKNOWLEDGMENTS

Funding for this research was provided by the Federal Aid, Pittman-Robertson Wildlife Restoration Act under Project W-158-R of the Oklahoma Department of Wildlife Conservation and Oklahoma State University. The project was administered through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, United States Geological Survey, Oklahoma State University, Wildlife Management Institute, and United States Fish and Wildlife Service cooperating). This research was partially supported by the National Science Foundation Louis Stokes Alliance for Minority Participation Bridge to Doctorate Program under grant number HRD-0444082.

In addition to financial contributors, I would like to thank my family and friends for always supporting me. Without them, I am not sure I would have continued my path and conquered the obstacles placed before me. I thank my Dad for introducing me to the outdoors and showing me a great appreciation for everything natural. I thank my Mom for her friendship and willingness to listen no matter what the circumstance.

Thank you to Stacey K. Davis and Ashley A. Foster for their assistance in the field and many hours of humorous conversation. I thank Dave Hamilton from the Missouri Department of Conservation and Mike Fischer from the Arkansas Trappers Association, for introducing me to the "fine art" of tracking and trapping river otters. I also thank numerous private land owners across eastern Oklahoma for allowing me access. I especially thank Mildred (Mig) Hamilton and Roger Canada for their hospitality and generosity. I thank several employees from the Oklahoma Department of Wildlife Conservation and United States Fish and Wildlife Service for their aid in pursuing such an intimidating task. I want to thank Sheryl Lyon, Joyce Hufford, and Judy Gray for their assistance. Last but not least, I would like to thank my committee members, Craig A. Davis and William L. Fisher, for their support and guidance. In particular, I appreciate my advisor, David (Chip) M. Leslie, Jr., for providing me this opportunity, constant encouragement, inspiration, and an open door. I thank you all for your time and efforts.

TABLE OF CONTENTS

Chapter Page

1. CURRENT DISTRIBUTION OF AN EXPANDING RIVER OTTER (*LONTRA CANADENSIS*) POPULATION

2. SPATIOTEMPORAL AGE STRUCTURES AND POPULATION CHARACTERISTICS OF A PARTIALLY REESTABLISHED RIVER OTTER (*LONTRA CANADENSIS*) POPULATION

LIST OF TABLES

Table Page

Chapter I

Chapter II

LIST OF FIGURES

Figure Page

Chapter I

Chapter II

APPENDICES

CHAPTER I

DISTRIBUTION OF AN EXPANDING RIVER OTTER (*LONTRA CANADENSIS*) POPULATION

ABSTRACT

In 1984 and 1985, the Oklahoma Department of Wildlife Conservation reintroduced northern river otters (*Lontra canadensis*) in eastern Oklahoma. As a result of reintroduction efforts and immigration from Arkansas, river otters have become reestablished throughout eastern Oklahoma. In the past, distributional data have been limited to incidental harvest by state and federal trappers and roadkills collected opportunistically. Our goal was to determine the precise distribution of river otters in Oklahoma via sign surveys and mail surveys. During winter and spring of 2006 and 2007, we visited 340 bridge sites within 28 different watersheds and identified river otter signs in 11 counties where river otters were not previously documented. Approximately 300 (27%) mail surveys were returned by state and federal natural resource employees, private organizations, and professional and recreational trappers. Mail surveys revealed the possibility of river otters occurring in 8 additional counties where they were not documented previously by published literature, USDA Animal and Plant Health Inspection Service records, or by sign survey efforts.

Key words: distribution, *Lontra canadensis*, mail survey, northern river otter, sign survey, sightings, track survey

INTRODUCTION

Prior to European settlement and westward expansion, northern river otters (*Lontra canadensis*; hereafter “river otter”) inhabited much of the U.S. and were found in all major rivers of North America (Anderson 1977; Hall 1981). River otters were documented throughout Oklahoma except in the Panhandle (Duck and Fletcher 1944). However, because of habitat destruction, human settlement, unregulated harvest, and water pollution, river otter populations became severely depleted or extirpated in much of their historic range by the early 1900s (Toweil and Tabor 1982; Jenkins 1983; Lariviere and Walton 1998). River otters were extirpated in 7 states and severely depleted in 9 other states including Oklahoma (Raesly 2001; Melquist et al. 2003). As a result, river otters have been protected by Oklahoma state law since 1917. Between 1917 and 1971, there were only 4 documented accounts of river otters in Oklahoma (Hatcher 1984).

Due to habitat improvement, construction of reservoirs, wetland restoration, recent reintroduction efforts, and management, river otters have returned to 90% of their historical range in the U.S. (Melquist et al. 2003). Moreover, increases in populations of beaver (*Castor canadensis*) and associated creation of wetland habitats across the U.S. provide river otters additional habitat in areas with limited resources (Jenkins 1983; Swimley et al. 1999). Habitat use by river otters is partially contingent upon shelter availability (Reid et al. 1994); river otters do not excavate their own dens (Melquist et al. 2003) and often occupy beaver lodges and bank dens (Melquist and Hornocker 1983).

Within Oklahoma, about 250,000 ponds and 145 major reservoirs have been constructed since the 1930s (Schackelford and Whitaker 1997). In addition, >130 wetlands in Oklahoma have been restored by the Wetland Reserve Program of the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service and in cooperation with other agencies (S. Tully, pers. comm. 2005). Ponds (Reid et al. 1988), reservoirs (Sheldon and Toll 1964), and restored wetlands (Polechla 1987; Newman and Griffin 1994) provide additional habitat for river otters.

In 1984 and 1985, the Oklahoma Department of Wildlife Conservation (ODWC) released 10 river otters at Wister Wildlife Management Area (WMA) in Leflore County and 7 river otters at McGee Creek WMA in Atoka County (Base 1986); all translocated river otters were purchased in coastal Louisiana (Bayou Otter Farm, Theriot, Louisiana, USA). During a 2-year period throughout the mid-to-late 1990s, 22 river otters were released at the Wichita Mountains Wildlife Refuge (WMWR) in Comanche County. Six river otters reintroduced to WMNWR were obtained from Louisiana (Bayou Otter Farm); the remaining 16 were captured by USDA Animal and Plant Health Inspection Service (APHIS) employees near Tahlequah, Oklahoma (R. Smith, ODWC, pers. comm. 2005). Since the mid-1970s, river otter numbers in Oklahoma have increased probably due to immigration from increasing populations in Arkansas (Hatcher 1984) and relocation efforts within Oklahoma. Dispersing river otters can move up to 42 km in 1 day (Melquist and Hornocker 1983). Base (1986) reported that accidental trappings and observations of river otters commonly occurred along the Fouche Maline, lower Arkansas River tributaries, Mountain Fork, Poteau River, and Sans Bois Creek in southeastern Oklahoma. In general, the annual number of river otters accidentally captured in Oklahoma by APHIS employees pursuing beavers (*Castor canadensis*) has increased (J. Steuber, pers. comm. 2005).

Oklahoma has 126,459 km of streams and rivers, 18,686 km of shoreline, and 290,078 ha of surface water (http://www.owrb.ok..gov/util/waterfact.php, accessed 5 January 2008). Because river otters are capable of occupying many different aquatic environments (Mech 2002; Melquist et al. 2003), it is likely that many of Oklahoma's water bodies are suitable otter habitat and capable of sustaining river otter populations (Caire et al. 1989). However, no formal study has been conducted to assess contemporary distribution of river otters in Oklahoma. Shackelford and Whitaker (1997) examined habitat and relative abundance of river otters in the Little River, Poteau River, and Sans Bois Creek drainages in southeastern Oklahoma. Determining distribution is a fundamental part of conservation planning, and Macdonald (1990) noted that field surveys are an essential tool in designing conservation programs for otters.

We used mail surveys and sign surveys to examine river otter distribution in Oklahoma. During winter and spring 2006 and 2007, we conducted river otter sign surveys throughout 28 watersheds in eastern and central Oklahoma. Mail surveys were sent to state and federal natural resource employees, private organizations, and private and professional trappers in 2006.

MATERIALS AND METHODS

River otters are difficult to observe because they are generally nocturnal (Melquist and Hornocker 1983) and occur at low densities (Melquist and Hornocker 1983; Foy 1984; Shirley et al. 1988). Most researchers recommend using >1 method to monitor river otters (Melquist and Dronkert 1987; Chilelli et al. 1998; Gallagher 1999). Methods used by researchers to examine otter (Lutrinae) distribution and other parameters (e.g., density) have included carcass collection (Polechla 1987; Gallagher 1999), fecal DNA analysis (Dallas et al. 2003; Hansen 2004; Hung et al. 2004), infrared technology (Garcia de Leaniz et al. 2006), population models (Hamilton 1998; Gallagher 1999; Woolf and Nielson 2001), radiotelemetry studies (Reid et al. 1994; Sjoasen 1997; Durbin 1998; Perrin and Carranza 2000), and radiotracer implants (Shirley et al. 1988; Testa et al. 1994).

Indirect methods used to examine river otters include sign surveys (Robson 1982; Zackheim 1982; Foy 1984; Karnes and Tumlison 1984; Clark et al. 1987; Eccles 1989; Mack et al. 1994; Shackelford and Whitaker 1997; Gallagher 1999; Bischof 2003; Bluett et al. 2004), aerial snow-track surveys (Reid et al. 1987; St-Georges 1995), scent-station indices (Humphrey and Zinn 1982; Robson and Humphrey 1985; Clark et al. 1987), latrine-site surveys (Karnes and Tumlison 1984; Newman and Griffin 1994), otter harvest surveys (Chilelli et al. 1996; Gallagher 1999; Scognamillo 2005), and mail surveys inquiring about distributional and status information (Zackheim 1982; Blumberg 1993; Kiesow 2003). Sign surveys are more cost-effective and likely to detect otter presence than scent-station surveys (Robson and Humphrey 1985; Clark et al. 1987; Eccles 1989).

North American river otters have been described as an "ecological equivalent" to Eurasian otters (*Lutra lutra*; Chanin 1985), and researchers outside of North America and Europe have used sign surveys to examine other species of otter (Lutrinae; Chehebar 1985; Lee 1996). Studies involving documentation of otter signs (e.g., scat, tracks, latrines) are commonly used on other continents including Africa (Macdonald and Mason 1983a, 1984; Rowe-Rowe 1992; Carugati and Perrin 2006), Asia (Lee 1996; Anoop and Hussain 2004; Shenoy et al. 2006), Europe (Romanowski 2006; MacDonald et al. 2007; Prigioni et al. 2007; Sulkava and Luikko 2007), and South America (Chehebar 1985; Medina-Vogel et al. 2003). Within North America, documentation of river otter sign has been used to determine distribution (Chromanski and Fritzell 1982), habitat preferences (Dubuc et al. 1990; Newman and Griffin 1994), population size (Reid et al. 1987), and relative abundance (Shackelford and Whitaker 1997; Gallagher 1999).

Sign surveys.—Sign surveys were conducted in the vicinity of bridges (Shackelford and Whitaker 1997), low-water crossings, and locations where flowing water was adjacent to roadways or access points (Lodé 1993; Romanowski et al. 1996). Examining bridges does not affect chances of detecting river otter presence (Gallant 2007). Sign surveys were conducted in 28 watersheds in eastern and central Oklahoma on private, state, and federal lands. Riparian vegetation varied from native grasses along prairie streams to oak (*Quercus*)-hickory (*Carya*) dominated forest further east. Stream substrates ranged from clay to bedrock with more rocky substrates occurring in eastern areas.

Using ArcMap 9.1 (Environmental Systems Research Institute, Inc., Redlands, California, USA), we selected sites along $\geq 3^{rd}$ order streams (Swimley et al. 1999;

Kiesow and Dieter 2005); sites were ≥ 8–16 km stream km apart (Shackelford and Whitaker 1997). Originally, sign surveys were conducted at ≥ 8 km intervals; however, to conserve time and increase efficiency, survey distance was increased to ≥ 16 km. Larger streams (i.e., streams with greater length and higher order) were given priority over smaller streams (Dubuc et al. 1990). Extremely large rivers (e.g., ≥ 8th order) that were canalized and lacked suitable latrine sites were not sampled (Romanowski et al. 1996). Bridge sites with steep banks >45° (Gallagher 1999) and ≤ 16 stream km were not sampled (Shackelford and Whitaker 1997). Mean linear home ranges of reintroduced river otters in southeastern Oklahoma were >16 km (Base 1986). Therefore, it is likely that a home range would overlap with 1–2 sample points (Chanin 2003). Sites within residential areas were not sampled. No sites were sampled within 3 days of measurable precipitation (> 0.2 cm) or a high water event (Clark et al. 1987; Shackelford and Whitaker 1997), and each site was visited once. Because of time constraints and limited manpower, we were not able to visit sample sites twice.

Sign surveys were conducted from January to May 2006 and January to June 2007 (Shirley et al. 1988; Gallagher 1999; Shackelford 1994) because river otter activity levels (corresponding with mating season) are greatest during winter (Foy 1984) and spring (Melquist and Hornocker 1983). Sign surveys were continued until June 2007 because record high precipitation and unusually high water levels prevented field work after that. Using USGS Real-Time Water Data (http://waterdata.usgs.gov/ok/nwis/rt), efforts were made to sample streams and rivers when discharge was between 25th and 75th percentile of that sampling date. We did not search sites where nonhydrophytic vegetation within or near the streambed was inundated or where no water was present.

We intensively searched both sides of streams for otter sign throughout 4 belt transects (Elmeros and Bussenius 2002) of 200 × 5 m upstream and downstream of each bridge, low-water crossing, or access point (Mason and Macdonald 1987; Shackelford 1994; Romanowski et al. 1996). Sites containing beaver bank dens and lodges (Swimley et al. 1999; Karnes and Tumlison 1984), beaver scent mounds (Karnes and Tumlison 1984), points of land (Dubuc et al. 1990; Newman and Griffin 1994; Swimley et al. 1998), isthmuses, mouths of perennial streams (Newman and Griffin 1994), logjams (Melquist and Hornocker 1983), elevated debris-covered banks (Karnes and Tumlison 1984), and islands (Mowbray et al. 1976; Swimley 1996) were examined closely because river otters prefer such areas for latrines. River otters deposit feces, anal sac secretions, and urine on latrine sites (Swimley 1996). Personnel conducting sign surveys were trained by experienced employees from the Missouri Department of Wildlife Conservation (Evans 2006).

Presence or absence of river otters and first type of sign observed were recorded. Positive sites were identified as those where river otters were observed and/or sign was identified. Positive sites confirmed the presence of river otters in the searched area. We used Pearson's Chi-square analysis to examine differences in proportion of positive sites among watersheds (Fusillo et al. 2007). Analysis included completed watersheds and those that contained > 5 examined sites (*n* = 21). Latrines were defined by the presence of $\geq$ 1 scat. Regression analyses were used to evaluate the relationship between years since initial capture and the proportion of positive sites from each county. Channel habitat variables were recorded at each identified latrine site. Sample sites were given a detectability rating based on the proportion of trackable substrate, such as exposed banks and sandbars, and searchability (Gallagher 1999). Trackability was determined by visual estimation of the percentage of trackable substrate and was compared between negative and positive sites using a 2-tailed *t*-test ($n = 294$). Number of suitable latrine sites at each sample location were recorded and compared between negative and positive sites using a 2-tailed *t*-test ($n = 126$). Search efforts at each sample site ended if river otters were observed or sign was detected; no efforts were made to quantify river otter sign because previous research did not find a correlation between numbers of scats and river otters (Jenkins and Burrows 1980; Kruuk et al. 1986). Investigating and quantifying only scat can be problematic (Gallant et al. 2007), but regions with mild climates and limited snow fall do not permit use of other methods (e.g., snow track surveys). All statistical tests were conducted using SYSTAT 10 for Windows (SPSS Inc., Chicago, Illinois) and were considered significant at $P < 0.05$.

Mail surveys.—Although collection localities of museum specimens can be used to determine distribution, such methods can be inaccurate. For example, some species are underrepresented and are collected rarely (Hazard 1982; Blumberg 1993). Sighting information also can be used to provide further information. Human-based surveys seeking information on distribution and status of a species are often used and provide useful information when managing species at large spatial scales (Hubbard and Serfass 2004; Lindsey et al. 2004; Stubblefield and Shrestha 2007). Researchers have used mail surveys and questionnaires to examine distribution of river otters (Chromanski and Fritzell 1982; Zackheim 1982; Blumberg 1993; Mack et al. 1994; Kiesow 2003, Bluett et al. 2004) and other carnivores (Quinn 1995; Clark et al. 2002). Mail surveys are inexpensive and efficient when obtaining distributional data throughout a large area (Sommer and Sommer 1991).

We developed a mail survey questionnaire (Appendix A) to obtain information on distribution of river otters in Oklahoma (Oklahoma State University Institutional Review Board Application No. AS061; Appendix B). Some questions were modified from Pike's (1997) survey on mountain lions (*Puma concolor*— Pike et al. 1999). Survey recipients were asked to report river otter sightings and river otter sign that they observed during the last 5 years (2001–2005). Recipients also were asked to identify locations of sightings by placing a symbol on an enclosed map.

Mail surveys (*n* = 1,153) were sent to state and federal biologists and technicians (ODWC, US Fish and Wildlife Service, USDA Forest Service), ODWC game wardens, USDA APHIS employees, US Army Corps of Engineers lake managers and park rangers, Nature Conservancy land stewards, and professional and recreational trappers. Mail surveys were also sent to professional and recreational trappers who purchased a trapping license in 2004–2005 and lived east of Interstate 35. Survey groups were selected based on knowledge and interest in the subject. To increase participation, survey participants remained anonymous and were not asked to identify themselves. Pre-paid postage and pre-addressed return envelopes also were included with the survey (Blumberg 1993). Returned surveys were organized by employer or affiliation (Pike et al. 1999). Because we could not identify nonrespondants, a follow-up reminder was sent to all survey recipients approximately 2 months after initial mailing (Filion 1978).

River otter "death reports" were mailed to ODWC regional biologists and game wardens that opportunistically collected carcasses. Death reports were designed to acquire additional data on river otter distribution and facilitate specimen collection. Recipients were asked to report location (water body, town, county) and general habitat charactersistcs. APHIS employees conducting damage control associated with beaver activity also received “death reports.” River otters are often harvested incidentally by trappers pursuing beavers (Gallagher 1999; Bischof 2003) using non-selective Conibear 330 traps (Hill 1976).

RESULTS

Sign surveys.—We visited 340 riparian reaches throughout eastern and central Oklahoma (Appendix C, D), but 43 sites were not examined because water was not present. We observed river otters or identified river otter sign at 159 of 297 (53.5%) of all examined sites. Of 159 positive sites, we observed river otters at 2 sites, identified tracks at 20 sites, and latrines at 137 sites. Proportion of positive sites within each watershed was 0–100% (Fig. 1). There was a significant difference ($\chi^2 = 123.81$; df = 20; $P < 0.001$) in proportion of positive sites among completed watersheds. During the sign surveys, we identified river otter sign in 11 counties (Carter, Cleveland, Kay, Lincoln, Okfuskee, Osage, Ottawa, Pontotoc, Pottawatomie, Rogers, Tulsa; Fig. 2) where river otters have not been documented in published literature (Caire et al. 1989) or by APHIS records. Sign surveys documented river otter sign in all counties where they were captured by APHIS. Proportion of positive sites within each county were correlated positively ($r^2 = 0.57$; $P < 0.05$) with number of years of since initial capture.

River otter sign was located along the Little River in Pottawatomie County off of US Route 177. Because the latrine occurred beyond the standard 200 m, the sample site was considered negative. One latrine was identified opportunistically along the Arkansas River below Kaw Lake on the border between Kay and Osage counties. River otter signs also were identified opportunistically along the North Canadian River in McIntosh and Okfuskee counties near Indian Nation Turnpike bridge. Two sites were searched opportunistically within the Lower Cimarron Watershed, but no river otter sign was documented. Middle Washita River and Muddy Boggy Creek watersheds were not completed because time constraints and high water levels. River otter sign was documented on Caddo Creek within the Middle Washita River Watershed (Carter County). River otter sign also was documented at 3 examined sites in the Muddy Boggy Creek Watershed.

Elk River and Bois D'arc Creek–Island Bayou watersheds were not sampled. Because the majority of the Elk River Watershed occurs in western Arkansas, only one sample site was selected along the Elk River in Delaware County, Oklahoma, but it was not examined because water was not present. Bois D'arc Creek and Island Bayou Watershed, primarily in Bryan County, was not sampled because no suitable sample sites were located near bridges or access points. All streams within that watershed were small (i.e., < 1 m) or highly entrenched (i.e., >45° banks). Because streams and rivers tended to be more entrenched further west, we located fewer suitable sample sites and, therefore, examined fewer sites in western watersheds. Over 150 sites were removed from the sample because steep banks dominated the shoreline.

Trackability of negative sites ($\bar{x}$ = 4.10) and positive sites ($\bar{x}$ = 3.23) differed (t = 3.81; $P < 0.001$). There was no difference (t = 1.79; $P > 0.05$) between number of suitable latrine sites located at negative and positive sites. Within positive sites, 56.5% of river otter sign occurred within the first 100 m ($\bar{x}$ = 93.3 m). Less than 21% of latrines occurred after 150 m. Most latrines (59.2%) were located within 50 m of a transition between channel habitat variables. Of latrines occurring within 50 m of a stream habitat transition, approximately 75.6% occurred at a transition between pools (main channel, corner, lateral scour, and confluence) and other stream habitat types. Most commonly (74.6%), the transition occurred between pool and riffle (low and high gradient) habitats. Most latrines were located at the bankfull step (64.3%; Rosgen 1996) along straight shorelines (53.9%) with vertical (53.8%) or sloped (31.9%) banks. Latrines commonly occurred near slack water where detritus accumulated within the streambed (33.3%), areas inhabited by beavers (76.9%), and within 50 m of tributaries (21.2%). The mean stream width adjacent to latrines was 22.8 m.

Mail surveys.—Twenty-seven percent of 1,153 mail surveys were returned. Return rates among surveyed groups were 0–46% (Table 1). Thirty-nine percent of all returned surveys reported observing river otters within the last 5 years (2001–2005). Twenty-eight percent of all returned surveys reported observing river otter sign within the last 5 years. Overall, the number of reported river otter sightings and observations of sign among all groups increased from 22 to 89 and 11 to 62, respectively, during the past 5 years. Survey participants reported river otters in 19 new counties (Fig. 2). State and federal wildlife employees reported river otters in 6 new counties (Cotton, Marshall, Okfuskee, Pontotoc, Pottawatomie, and Tulsa). River otter death reports documented otters in 2 new counties (Okfuskee and Tulsa). Mail survey participants identified all counties where river otters were captured by APHIS employees except Creek and Seminole counties. Six new counties were reported by > 1 survey group (Carter, Marshall, Okfuskee, Pontotoc, Pottawatomie, and Tulsa). Locations of river otter sightings or observance of sign was similar among survey groups. Most sightings and/or signs occurred in localized areas (e.g., reservoirs) with high accessibility. Mail survey participants reported river otters throughout all counties identified by sign survey efforts. Combined, sign surveys and mail survey participants found river otters in 19 new individual counties (Fig. 2; Caire et al. 1989), and eight of those counties were not identified by sign surveys.

DISCUSSION

Mason and Macdonald (1987) noted a positive correlation ($r^2 = 0.84$; $P < 0.01$) between the mean number of scats and the proportion of positive sites from each study area. Unlike others (Jenkins and Borrows 1980; Kruuk et al. 1986), Mason and Macdonald (1987) noted that scats can be used to make a broad comparison among populations. Nevertheless, the validity of using scats to determine otter (*Lontra* spp, *Lutra* spp.) occurrence is still debated (Gallant et al. 2007), but researchers throughout Europe continue to examine scats and proportions of positive sites to compare otter densities (Fusillo et al. 2007; MacDonald et al. 2007).

Indirect signs are often effective tools to study wildlife species (Plumptre 2000; Sadlier et al. 2004; Stephens et al. 2006). However, caution should be used when interpreting river otter sign data (Rostain 2000; Gallagher 1999) because several factors can affect detection (Evans 2006, Fusillo et al. 2007); for instance, occupants could be outside of the sampled area but within its home range. Presence can often be determined, but absence can be impossible to determine (MacKenzie 2005). Others have reported that there is not always a relationship between number of scats and number of river otters (Jenkins and Burrows 1980; Melquist and Hornocker 1983; Kruuk and Conroy 1987; Gallagher 1999; Gallant et al. 2007). Furthermore, sites with less scat could be an indication of fewer suitable latrine habitats (Romanowski et al. 1996). In contrast, we determined that no difference occurred between the number of suitable latrine sites at positive and negative sites.

Because of time constraints and high water levels, we did not sample Lower Canadian River and Walnut Creek and Lower North Canadian River watersheds. However, mail surveys, “death reports,” and APHIS records documented river otters within both of these drainages. Sign surveys were conducted within the Little River Watershed, a tributary to the Canadian River in central Oklahoma. River otter sign was documented along the Little River in Pottawatomie County and below Lake Thunderbird in Cleveland County. To reach these locations, river otters must have used the Canadian River above Eufaula Lake. Within the Lower North Canadian River Watershed, we collected 1 river otter carcass and identified river otter signs above Eufaula Lake along the North Canadian River in McIntosh and Okfuskee counties.

We examined 3 sites within the Muddy Boggy Creek Watershed that contained river otter sign. Most likely river otters have become well established throughout this watershed because reintroduction efforts (McGee Creek WMA), suitable habitats, and neighboring watersheds (Clear Boggy Creek Watershed, Kiamichi River Watershed) contained relatively high proportions of positive sites (Fig. 1).

Mail surveys allowed us to obtain specific locations of river otters throughout Oklahoma and were relatively inexpensive and required less time and effort than sign surveys; however, data should be interpreted cautiously. Previous researchers surveyed only natural resource employees because responses from outdoorsman were considered unreliable (Van Dyke and Brocke 1987; McBride et al. 1993; Pike et al. 1999). However, even natural resource professionals can be inaccurate when identifying animal sign unless properly trained (Evans 2006). Within our study, Chi-square analysis revealed that positive responses among surveyed groups (trappers, ODWC, federal employees) did not differ ($\chi^2 = 1.17$; df = 2; $P > 0.10$). Regardless of who is surveyed, researchers must account for issues regarding access; locations commonly visited by outdoorsman and areas not accessible could influence distributional data (Stubblefield and Shrestha 2007). Van Dyke and Brocke (1987) noted that human-based surveys should not be used alone to describe distribution of mountain lions; instead, such surveys should be used with other methods to determine spatial distribution. Mail survey information should only be used as estimates of mammal distribution (Blumberg 1993).

Since the 1970s, river otters have become more prevalent throughout eastern Oklahoma and continued to spread westward, recolonizing parts of their historic range (Hatcher 1984; Base 1986). By 1992, APHIS employees reported catching river otters in 6 counties (Atoka, Haskell, Latimer, Leflore, McCurtain, Pushmataha) in southeastern Oklahoma. Illustrating westward movement, river otters were unintentionally captured in > 1 new county, on average, each year from 1991 to 2007 (Fig. 3), but the majority of annual incidental captures by APHIS employees came from southeastern Oklahoma. Currently, river otters have become well established and commonly occur throughout most of eastern Oklahoma. Although we documented river otters in central Oklahoma, it is unlikely that they occur at high densities throughout watersheds west of Blue River, Clear Boggy Creek, and Lower Washita River watersheds and east of WMNWR. Mail surveys and APHIS harvest records showed few accounts of river otters in central Oklahoma. Furthermore, sign surveys within Little River Watershed (central Oklahoma) showed relatively low proportions of sites containing river otter sign (29%). Similarly, 29% of examined sites along upper portions of the Deep Fork Watershed were positive.

We suggest that no more than broad comparisons among large watersheds should be made from the proportion of positive sites within a watershed (Macdonald 1987) and management decisions should not be based solely on sign indices (Gallagher 1999). Most importantly, sign surveys should be used to monitor sample sites throughout time to document range expansion and/or reduction (Swimley and Hardisky 2000). Large reductions in population size may be more evident when baseline data have been recorded previously. Changes in scat frequency may be detectable only when otter populations have been impacted greatly (Jenkins and Burrows 1980; Mason and Macdonald 1987); for example, Lode (1993) used sign-surveys to document otter decline in France. Sign surveys were used to document range expansion and recolonization in Poland (Romanowski 2006). Other state wildlife agencies already use sign surveys to monitor river otter distributions (Boyd 2006, Evans 2006).

Conducting systematic surveys is essential to species management and conservation throughout time (Elmeros and Bussenius 2002; Gallant 2007) and should be continued in Oklahoma. Within Oklahoma, relatively large watersheds such as Arkansas River, Canadian River, Red River, Cimarron River, and Washita River, follow a west-to-east pattern and facilitate westward dispersal and expansion of river otters. Studies using indirect sign to examine river otter populations should consider detectability and repeated visits to determine river otter presence or absence (Royle and Nichols 2003; MacKenzie 2005). Observer skill should also be evaluated using standardized methods (Evans 2006). To achieve greater statistical power, the number of sites throughout each watershed should be increased. In locations where suitable latrine sites do not exist, European researchers have created artificial latrine sites to increase effectiveness of monitoring efforts (Chanin 2003). Chanin (2003) recommended that sign surveys should be conducted annually for 10 years, and then sampling should occur at intervals of 2–3 years. Because sign surveys cannot detect annual fluctuations in river otter populations (Clark et al. 1987; Gallagher 1999), we recommend visiting sites biennially until variations (e.g., increase, decrease) cease. As baseline data and populations become established, sampling intervals can be repeated less frequently.

ACKNOWLEDGMENTS

Funding for this research was provided by the Federal Aid, Pittman-Robertson Wildlife Restoration Act under Project W-158-R of the Oklahoma Department of Wildlife Conservation and Oklahoma State University. The project was administered through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, United States Geological Survey, Oklahoma State University, Wildlife Management Institute, and United States Fish and Wildlife Service cooperating). This publication was partially supported by the National Science Foundation Louis Stokes Alliance for Minority Participation Bridge to Doctorate Program under grant number HRD-0444082. We would like to thank S. K. Davis and A. A. Foster for their assistance in the field. A special thanks to D. Hamilton from the

Missouri Department of Wildlife Conservation and M. Fischer from the Arkansas Trappers Association for their guidance and training. We also thank R. Thornburg and S. Sheffert of the Oklahoma Fur Bearers Alliance for their insight and assistance. Numerous employees of the ODWC provided much needed assistance; we especially thank A. Crews for helping develop the river otter survey. We thank hundreds of state and federal employees and private and professional trappers who participated in the mail survey. We thank hundreds of landowners across eastern Oklahoma who allowed temporary access to their property. This project was completed as partial fulfillment for the requirements of the degree of Master of Science.

LITERATURE CITED

Anderson, S. 1977. Geographic ranges of North American terrestrial mammals. American Museum Novitates 2629:1–15.

Anoop, K. R., and S. A. Hussain. 2004. Factors affecting habitat selection by smooth-coated otters (*Lutra perspicillata*) in Kerala, India. Journal of Zoology 263:417–423.

Base, D. L. 1986. Evaluation of experimental reintroduction of river otters in Oklahoma. Unpublished report. Oklahoma Department of Wildlife Conservation Nongame Wildlife Program, Oklahoma City, Oklahoma.

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

Bluett, R. D., C. K. Nielson, R. W. Gottfried, C. A. Miller, and A. Woolf. 2004. Status of the river otter (*Lontra canadensis*) in Illinois, 1998–2004. Transactions of the Illinois State Academy of Science 97:209–217.

Blumberg, C. A. 1993. Use of a mail survey to determine present mammal distributions by county in South Dakota. M.S. Thesis, South Dakota State University, Brookings.

Boyd, S. 2006. North American river otter (*Lontra canadensis*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/northamericanriverotter.pdf [28 September 2007]

Caire, W., J. D. Tyler, B. P. Glass, and M. A. Mares. 1989. Mammals of Oklahoma. University of Oklahoma Press, Norman, Oklahoma.

Chanin, P. 1985. The natural history of otters. Facts on File Publications, New York.

Chanin, P. 2003. Monitoring the Otter *Lutra lutra*. Conserving Natura 2000 Rivers Monitoring Series No. 10, English Nature, Peterborough, United Kingdom.

Chehebar, C. E. 1985. A survey of the southern river otter *Lutra provocax* Thomas in Nahuel Huapi National Park, Argentina. Biological Conservation 32:299–307.

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 Southeastern Association of Fish and Wildlife Agencies 41:358–364.

Clark, D. W., S. C. White, A. K. Bowers, L. D. Lucio, and G. A. Heidt. 2002. A survey of recent accounts of the mountain lion (*Puma concolor*) in Arkansas. Southeastern Naturalist 1:269–278.

Dallas, J. F., K. E. Coxon, T. Sykes, P. R. F. Chanin, F. Marshall, D. N. Carss, P. J. Bacon, S. B. Piertney, and P. A. Racey. 2003. Similar estimates of population genetic composition and sex raio derived from carcasses and faeces of Eurasion otter *Lutra lutra*. Molecular Ecology 12:275–282.

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

Duck, L. G., and J. B. Fletcher. 1944. A survey of the game and furbearing animals of Oklahoma. Bulletin 3. Oklahoma Game and Fish Commission, Oklahoma City, Oklahoma.

Durbin, L. S. 1998. Habitat selection by five otters *Lutra lutra* in rivers of northern Scotland. Journal of Zoology 245:85–92.

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

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

Evans, J. W. 2006. Observer error in identifying species using indirect signs: anlysis of a river otter track survey technique. M.S. Thesis, Texas A&M University, College Station.

Filion, F. L. 1978. Increasing the effectiveness of mail surveys. Wildlife Society Bulletin 6:135–141.

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.

Fusillo, R., M. Marcelli, and L. Boitani. 2007. Survey of an otter *Lutra lutra* population in Southern Italy: site occupancy and influence of sampling season on species detection. Acta Theriologica 52:251–260.

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

Gallant, D. 2007. Species-wise disparity in scientific knowledge about otters: an obstacle to optimal management and conservation actions? IUCN Otter Specialist Group Bulletin 24:5–13.

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

Garcia de Leaniz, C., D. W. Forman, S. Davies, and A. Thomson. 2006. Non-intrusive monitoring of otters (*Lutra lutra*) using infrared technology. Journal of Zoology 270:577–584.

Hall, E. R. 1981. The mammals of North America. Second ed. John Wiley & Sons, New York.

Hamilton, D. A. 1998. Missouri's river otter population model: operation and use. Missouri Department of Conservation, Columbia, Missouri.

Hatcher, R. T. 1984. River otters in Oklahoma. Proceedings of the Oklahoma Academy of Science 64:17–19.

Hazard, E. B. 1982. The mammals of Minnesota. University of Minnesota Press, Minneapolis, Minnesota.

Helon, D. A. 2006. Summer home range, habitat use, movements, and activity patterns of river otters (*Lontra canadensis*) in the Killbuck Watershed, northeastern Ohio. M.S. Thesis, West Virginia University, Morgantown.

Hill, E. P. 1976. Control methods for nuisance beaver in the southeastern United States. Vertebrate Pest Conference Proceedings 44:85–98.

Hubbard, B., and T. Serfass. 2004. Assessing the distribution of reintroduced populations of river otters in Pennsylvania (USA) development of a landscape-level approach. IUCN Otter Specialist Group Bulletin 21:60–65.

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.

Hung, C. M., S. H. Li, and L. L. Lee. 2004. Faecal DNA typing to determine the abundance and spatial organization of otters (*Lutra lutra*) along two stream systems in Kinmen. Animal Conservation 7:301–311.

Jenkins, J. H. 1983. The status and management of the river otter (*Lutra canadensis*) in North America. Acta Zoologica Fennica 174:233–235.

Jenkins, D., and G. O. Burrows. 1980. Ecology of otters in northern Scottland. III. The use of faeces as indicators of otter (*Lutra lutra*) density and distribution. Journal of Animal Ecology 49:755–774.

Johnson, S. A., and K. A. Berkley. 1999. Restoring river otters in Indiana. Wildlife Society Bulletin 27:419–427.

Karnes, M. R., and R. Tumlison. 1984. The river otter in Arkansas. III. Characteristics of otter latrines and their distribution along beaver-inhabited watercourses in southwest Arkansas. Proceedings of the Arkansas Academy of Science 38:56–59.

Kiesow, A. M. 2003. Feasibility of reintroducing the river otter (*Lontra canadensis*) in South Dakota. M.S. Thesis, South Dakota State University, Brookings.

Kiesow; A. M., and C. D. Dieter. 2005. Availability of suitable habitat for northern river otters in South Dakota. Great Plains Research 15:31–43.

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.

Kruuk, H., and J. W. H. Conroy. 1987. Surveying otter *Lutra lutra* populations: a discussion of problem with spraints. Biological Conservation 41: 179–183.

Lariviere, S., and L. R. Walton. 1998. *Lontra canadensis*. Mammalian Species 587:1–8.

Lee, L. L. 1996. Status and distribution of river otters in Kinmen, Taiwan. Oryx 30:202–206.

Lindsey, P., J. T. du Toit, and M. G. L. Mills. 2004. The distribution and population status of African wild dogs (*Lycaon pictus*) outside protected areas in South Africa. South African Journal of Wildlife Research 34:143–151.

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

MacDonald, R. A., K. O'Hara, and D. Morrish. 2007. Decline of invasive alien mink (*Mustela vison*) is concurrent with recovery of native otters (*Lutra lutra*). Diversity and Distributions 13:92–98.

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

Macdonald, S. M., and C. F. Mason. 1983b. The otter (*Lutra lutra*) in Tunisia. Mammal Review 13:35–37.

Macdonald, S. M., and C. F. Mason. 1984. Otters in Morocco. Oryx 18:157–159.

Macdonald, S. M., and C. F. Mason. 1985. Otters, their habitat and conservation in northeast Greece. Biological Conservation 31:191–210.

Macdonald, S. M., and C. F. Mason. 1987. Seasonal marking in an otter population. Acta Theologica 32:449–462.

Macdonald, S. 1990. Surveys. Pages 8–10 *in* P. Foster-Turley, S. Macdonald, and C. Mason, eds. Otters: An action plan for their conservation. Kelvyn Press, Broadview, Illinois.

Mack, C., L. Kronemann, and C. Eneas. 1994. Lower Clearwater Aquatic Mammal Survey. Final Report. Nez Perce Tribe. Project Number 90-5 1.

MacKenzie, D. I. 2005. What are the issues with presence-absence data for wildlife managers? Journal of Wildlife Management 69:849–860.

Mason, C. F., and S. M. MacDonald. 1986. Otters: ecology and conservation. Cambridge University Press, Cambridge, England.

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.

Mason, C. F., and S. M. Macdonald. 2004. Growth in otter (*Lutra lutra*) populations in the UK as shown by long-term monitoring. Ambio 33:148–152.

McBride, R. T., R. M. McBride, J. L. Cashman, and D. S. Maehr. 1993. Do mountain lions exist in Arkansas? Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:394–402.

McDonald, K. P. 1989. Survival, home range, movements, habitat use, and feeding habits of reintroduced river otters in Ohio. M.S. Thesis, Ohio State University, Columbus.

Mech, L. D. 2002. Incidence of mink, Mustela vison, and river otter, Lutra canadensis, in a highly urbanized area. Canadian Field-Naturalist 117:115–116.

Medina-Vogel, G., V. S. Kaufman, R. Monsalve, and V. Gomez. 2003. The influence of riparian vegetation, woody debris, stream morphology and human activity on the use of rivers by southern river otters in *Lontra provocax* in Chile. Oryx 37:422–430.

Melquist, W. E., and M. G. Hornocker. 1983. Ecology of river otters in west central Idaho. Wildlife Monographs 83:1–60.

Melquist, W. E., and A. E. Dronkert. 1987. River otter. Pages 625–641 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario, Canada.

Melquist, W. E., P. J. Polechla, Jr., and D. Toweill. 2003. River otter, *Lontra canandensis*. Pages 708–734 *in* The wild mammals of North America: biology, management, and conservation (G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, eds.). John Hopkins University Press, Baltimore, Maryland.

Mowbray, E. E., J. A. Chapman, and J. R. Goldsberry. 1976. Preliminary observations on otter distribution and habitat preferences in Maryland with descriptions of otter field sign. Transactions of the Northeast Section of the Wildlife Society 33:125–131.

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

Perrin, M. R., and I. D. Carranza. 2000. Habitat use by spotted-necked otters in KwaZulu-Natal Drakensberg, South Africa. South African Journal of Wildlife Research 30:8–14.

Perrin, M. R., and C. Carugati. 2006. Abundance estimates of the Cape clawless otter *Aonyx capensis* (Schinz 1821) and the spotted-necked otter *Lutra maculicollis* (Lichtenstein 1835) in the KwaZulu-Natal Drakensberg, South Africa. Tropical Zoology 19:9–19.

Pike, J. R. 1997. A geographic analysis of the status of mountain lions in Oklahoma. M.S. Thesis, Oklahoma State University, Stillwater.

Pike, J. R., J. H. Shaw, D. M. Leslie, Jr., and M. G. Shaw. 1999. A geographic analysis of the status of mountain lions in Oklahoma. Wildlife Society Bulletin 27:4–11.

Plumptre, A. J. 2000. Monitoring mammal populations with line transect techniques in African forests. Journal of Applied Ecology 37:356–368.

Polechla, P. J. 1987. Status of the river otter (*Lutra canadensis*) population in Arkansas with special reference to reproductive biology. Ph.D. Dissertation, University of Arkansas, Fayetteville.

Prigioni, C., A. Balestrieri, and L. Remonti. 2007. Decline and recovery in otter *Lutra lutra* populations in Italy. Mammal Review 37:71–79.

Quinn, T. 1995. Using public sighting information to investigate coyote use of urban habitat. Journal of Wildlife Management 59:238–245.

Raesly, E. J. 2001. Progress and status of river otter reintroduction projects in the United States. Wildlife Society Bulletin 29:856–862.

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.

Reid, D. G., S. M. Herrero, and T. E. Code. 1988. River otters as agents of water loss from beaver ponds. Journal of Mammalogy 69:100–107.

Reid, D. G., T. E. Code, A. C. H. Reid, S. M. Herrero. 1994. Spacing, movements, and habitat selection of the river otter in boreal Alberta. Canadian Journal of Zoology 72:1314–1324.

Robson, M. S. 1982. Monitoring river otter populations: scent stations vs. sign indices. M.S. Thesis, University of Florida, Gainesville.

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.

Romanowski, J. 2006. Monitoring of the otter recolonisation of Poland. Hystrix Italian Journal of Mammalogy 17:37–46.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rostain, R. R. 2000. Social behavior and olfactory communication in the North American river otter, *Lontra canadensis*. M.S. Thesis, San Francisco State University, California.

Rowe-Rowe, D. T. 1992. Survey of South African otters in a fresh-water habitat, using sign. South African Journal of Wildlife Research 22:49–55.

Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777–790.

Sadlier, L. M., C. C. Webbon, P. J. Baker, and S. Harris. Methods of monitoring red foxes *Vulpes vulpes* and badgers *Meles meles*: are field signs the answer? Mammal Review 34:75–98.

Scognamillo, D. G. 2005. Temporal and spatial harvest patterns of river otter in Louisiana and its potential use as a bioindicator species of water quality. Ph.D. Dissertation, Louisiana State University, Baton Rouge.

Shackelford, J. T. 1994. Habitat and relative abundance of river otter, *Lutra canadensis*, in three drainage basins of southeastern Oklahoma. M.S. Thesis, University of Central Oklahoma, Edmond.

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.

Sheldon, W. G., and W. G. Toll. 1964. Feeding habits of the river otter in a reservoir in central Massachusetts. Journal of Mammalogy 45:449–455.

Shenoy, K., S. Varma, and K. V. D. Prasad. 2006. Factors determining habitat choice of the smooth-coated otter, *Lutra perspicillata* in a South Indian river system. Current Science 91:637–643.

Shirley, M. G., R. G. Linscombe, N. W. Kinler, R. M. Knaus, and V. L. Wright. 1988. Population estimates of river otters in a Louisiana coastal marshland. Journal of Wildlife Management 52: 512–515.

Sjoasen, T. 1997. Movements and establishment of reintroduced European otters Lutra lutra. Journal of Applied Ecology 34:1070–1080.

Sommer, B., and R. Sommer. 1991. A practical guide to behavioral research. 3rd edition. Oxford University Press, New York.

St-Georges, M., S. Nadeau, D. Lambert, and R. Decarie. 1995. Winter habitat use by ptarmigan, snowshoe hares, red foxes, and river otters in boreal forest: tundra transition zones of western Quebec. Canadian Journal of Zoology 73:755–764.

Stephens, P. A., O. Yu. Zaumyslova, D. G. Miquelle, A. I. Myslenkov, and G. D. Hayward. 2004. Estimating population density from indirect sign: track counts and the Formozov-Malyshev-Pereleshin formula. Animal Conservation 9:339–348.

Stubblefield, C. H., and M. Shrestha. 2007. Status of Asiatic black bears in protected areas of Nepal and the effects of political turmoil. Ursus 18:101–108.

Sulkava, R. T., and U.-M. Liukko. 2007. Use of snow-tracking methods to estimate the abundance of otter (*Lutra lutra*) in Finland with evaluation of one-visit census for monitoring purposes. Annales Zoologici Fennici 44:179–188.

Swimley, T. J. 1996. Predicting river otter marking sites in Pennsylvania. M.S. Thesis, Pennsylvania State University, University Park.

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.

Swimley, T. J., R. P. Brooks, and T. L. Serfass. 1999. Otter and beaver interactions in the Delaware Water Gap National Recreation Area. Journal of the Pennsylvania Academy of Science 72:97–101.

Swimley, T. J., and T. S. Hardisky. 2000. Otter population trend survey. Final report, Project No. 06670, Job N. 67002. Available online at: http://www.pgc.state.pa.us/pgc/lib/pgc/reports/2000_wildlife/67002-99.pdf [Accessed 3 May 2007]

Testa, J. W., D. F. Holleman, R. T. Bowyer, and J. B. Faro. 1994. Estimating populations of marine river otters in Prince William Sound, Alaska, using radiotracer implants. Journal of Mammalogy 75:1021–1032.

Tumlison, R., and M. Karnes. 1987. Seasonal changes in food habits of river otters in southwestern Arkansas beaver swamps. Mammalia 51:225–231.

Van Dyke, F. G., and R. H. Brocke. 1987. Sighting and track reports as indices of mountain lion presence. Wildlife Society Bulletin 15:251–256.

Woolf, A., and C. K. Nielson. 2001. Predicting growth of the reintroduced otter population in Illinois. Cooperative Wildlife Research Laboratory at Southern Illinois University, Carbondale.

Zackheim, H. S. 1982. Ecology and population status of the river otter in southwestern Montana. M.S. Thesis, University of Montana, Missoula.

Table 1. River otter mail survey statistics based upon return rates of individual groups of survey participants (2006).

Affiliation/Agency	Number of surveys	Number returned	Proportion returned
Professional trappers	54	25	46.3
APHIS Wildlife Services	50	19	38.0
OK Department of Wildlife Conservation	206	76	36.9
Nature Conservancy	7	2	28.6
US Fish and Wildlife Service	39	10	25.6
Recreational trappers	776	176	22.7
US Army Corps of Engineers	20	4	20.0
USDA Forest Service	1	0	0.0

FIGURES

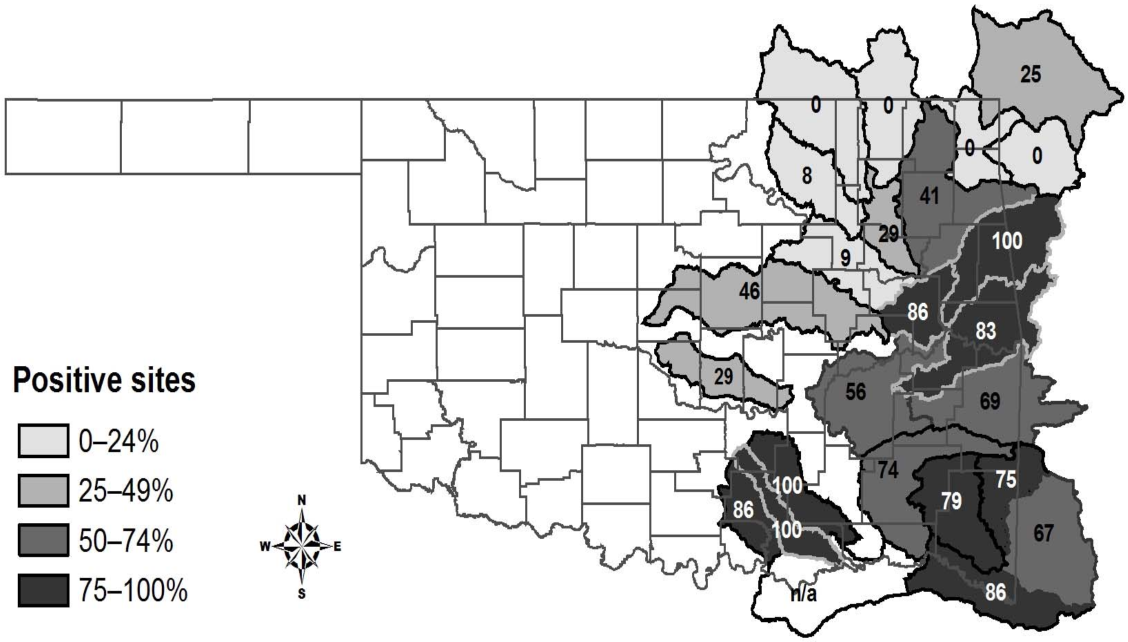


Fig. 1. Watersheds and their percentages of positive sites for river otters during sign surveys, winter and spring, 2006–2007.

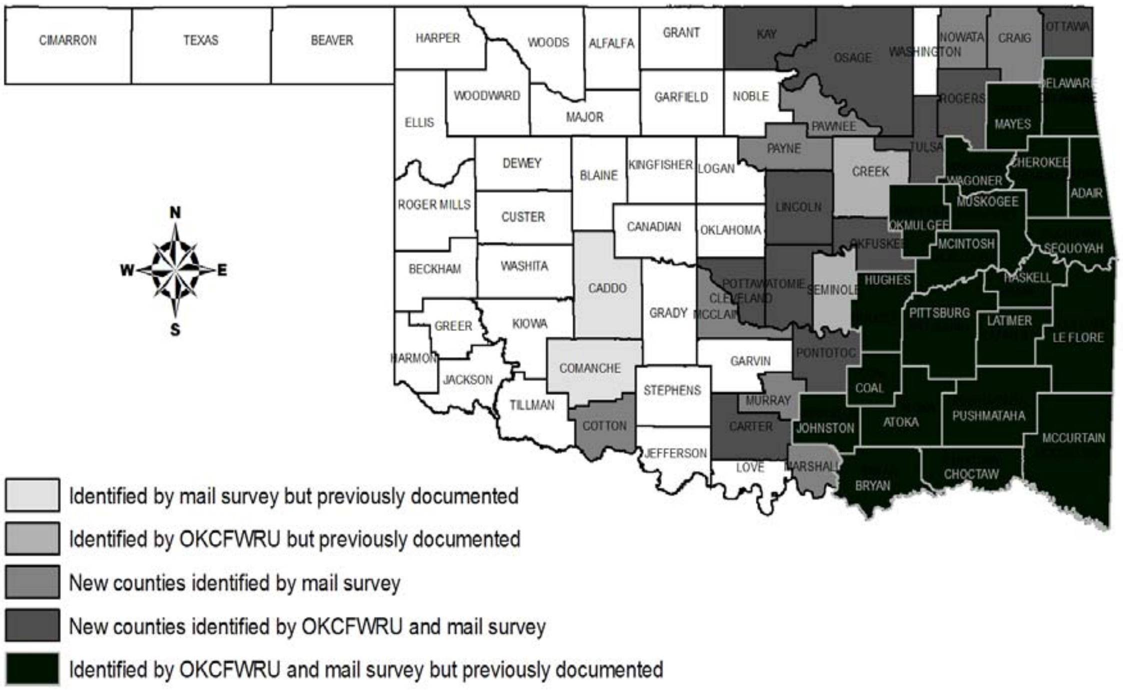


Fig. 2. Changing occurrence of river otters in Oklahoma counties, through 2007.

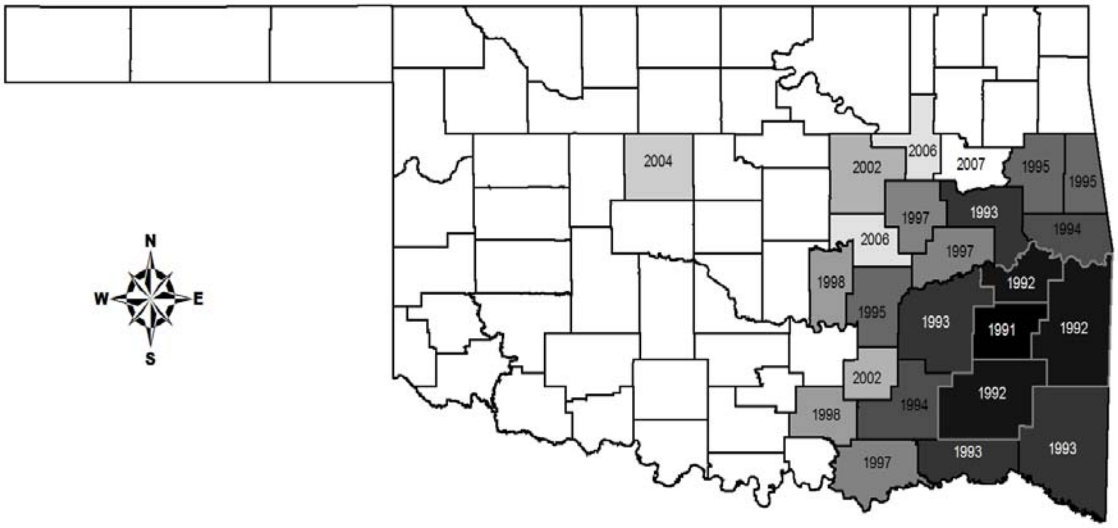


Fig. 3. Oklahoma counties where river otters have been captured by USDA Animal and Plant Health Inspection Service employees; year within each county (1991–2007) represents first year of capture.

CHAPTER II

SPATIOTEMPORAL AGE STRUCTURES AND POPULATION CHARACTERISTICS OF A PARTIALLY REESTABLISHED RIVER OTTER (*LONTRA CANADENSIS*) POPULATION

ABSTRACT

Recolonization of mammalian carnivores has been well documented, and changes in demographics between expanding and established populations have been observed. In the mid-1980s, the Oklahoma Department of Wildlife Conservation (ODWC) reintroduced 17 northern river otters (*Lontra canadensis*) in southeastern Oklahoma from coastal Louisiana. As a result of reintroduction efforts and immigration from Arkansas, river otters have become partially reestablished throughout eastern Oklahoma. Our objective was to examine age structures of river otters in Oklahoma and identify trends that relate to space (watersheds, county), time (USDA Animal and Plant Health Inspection Service [APHIS] county trapping records), and isotopic ($\delta^{13}C$, $\delta^{15}N$) signatures. We hypothesized that river otters in western areas were younger than river otters occurring further east and nutrition ($\delta^{15}N$) would be enhanced in peripheral populations because of low population densities. From 2005–2007, we salvaged river otter carcasses from APHIS and ODWC employees and live-captured river otters using leg hold traps. Seventy-two river otters were sampled. Sex ratios were skewed toward females (1F:0.8M), but sex ratios did not differ among counties or watersheds. Teeth were removed from salvaged and live-captured river otters ($n = 63$) for aging. One-year-old river otters represented the largest age class (30.2%). Proportion of juveniles within Oklahoma (19.0%) was less than other states and differed among watersheds and counties. Mean age of river otters decreased from east-to-west in the Arkansas River and its tributaries. Mean age of river otters differed between Canadian River Watershed (0.8 years) and Arkansas River Watershed (2.9 years) and Canadian River Watershed and Red River Watershed (2.4 years). Populations in extreme eastern Oklahoma had an older age structure than colonizing populations further west. Tissue δ^{13}C values were less in western areas, which probably resulted from allochthonous inputs of C_3 and C_4 plants and stream velocity discrepancies. Tissue δ^{15}N values decreased in western areas and probably resulted from less suitable habitat.

Key words: age structure, carbon isotopes, demography, *Lontra canadensis*, nitrogen isotopes, northern river otter, population characteristics, spatiotemporal trends

INTRODUCTION

Prior to westward expansion and settlement of the United States, northern river otters (*Lontra canadensis*; hereafter “river otter”) inhabited much of North America. They were found in all major rivers of North America (Anderson 1977; Hall 1981) and had one of the largest distributions of North American mammals (Melquist et al. 2003).

By the 1940s, river otters had been documented throughout Oklahoma except in the Panhandle (Duck and Fletcher 1944; Base 1986). Because of habitat destruction, human settlement, unregulated harvest, and water pollution, river otter populations were reduced or extirpated in much of their historic range by the early 1900s (Toweil and Tabor 1982; Jenkins 1983; Lariviere and Walton 1998). River otters were extirpated in 7 states and severely depleted in 9 other states including Oklahoma (Raesly 2001; Melquist et al. 2003). In 1917, river otters became protected by Oklahoma state law. Between 1917 and 1971, there were only 4 documented accounts of river otters in Oklahoma (Hatcher 1984).

Since the mid-1970s, 21 states reintroduced > 4,000 river otters (Raesly 2001). The Oklahoma Department of Wildlife Conservation (ODWC) reintroduced 17 river otters in southeastern Oklahoma in the late 1990s, purchased from a commercial river otter farm in coastal Louisiana (Bayou Otter Farm, Theriot, Louisiana, USA). Due to reintroduction efforts, habitat improvements, construction of reservoirs, and wetland restoration, river otters have returned to 90% of their historical range in the continental U.S. (Melquist et al. 2003).

Accidental trapping and observations of river otters became common in lower Arkansas River tributaries and watersheds in southeastern Oklahoma by the 1980s (Hatcher 1984; Base 1986). Illustrating westward expansion and recolonization, river otters were unintentionally captured in > 1 new county, on average, from 1991 to 2007 by USDA Animal Plant Health Inspection Service (APHIS) employees. The total number of river otters accidentally captured in Oklahoma by APHIS employees pursuing beavers (*Castor canadensis*) also has increased since 1992 (J. Steuber, pers. comm. 2005).

Recolonization of mammalian carnivores has been well documented (Payne 1977; Moore and Millar 1984; Lubina and Levin 1988; Pletscher et al. 1997; Swenson et al. 1998; Bales et al. 2005) and has become more common as a result of reintroduction and management efforts. Rates of recolonization and expansion depend on rates of dispersal, population growth, and spatiotemporal environmental discrepancies. Local variation of dispersal may be attributed to increased human interaction (Cheesman et al. 1988; Lubina and Levin 1988), food availability (Greenwood and Swingland 1983), habitat connectivity (Pyare et al. 2004), differences in mortality, and environmental conditions (Lubina and Levin 1988). Other factors, such as interference competition (Berger and Gese 2007), inbreeding avoidance (Waser 1985; Perrin and Mazalov 2000), mate access (Greenwood 1980), density (Cheeseman et al. 1988), breeding systems, and carrying capacity (Greenwood 1980; Sinclair 1992), influence dispersal and, in turn, affect recolonization and expansion. Demographics of source populations can influence dispersal rates of each gender (Aars and Ims 2000). In some carnivores (e.g., brown bear, *Ursus arctos*), presaturation dispersal can influence range expansion (Swenson et al. 1998). Successful dispersers benefit from reduced intraspecific competition (e.g., mates, food, habitat), favorable habitat conditions, increased reproductive successs, and outbreeding enhancement (Shields 1987; Wolff 1993).

Changes in demographics between expanding and established populations have been observed in black bears (*Ursus americanus*; Bales et al. 2005), brown bear (Swenson et al. 1998), coyotes (*Canis latrans*; Moore and Millar 1984), Antarctic fur seals (*Arctocephalus gazelle*; Payne 1977), gray wolves (*Canis lupus*; Mech 1975; Pletscher et al. 1997), and other mammals (Kozakiewicz and Jurasinska 1989; Apeldoorn et al. 1992). In mammalian carnivores, recolonizing or expanding populations commonly exhibit different demographics (e.g., age structures) than more established populations (Payne 1977; Pletscher et al. 1997; Swenson et al. 1998; Bales et al. 2005). For example, mean age of recolonizing black bears in Oklahoma was less than other populations (Bales et al. 2005). In Sweden, harvested brown bears from an expanding population were predominately subadult males in peripheral areas; conversely, core areas contained mostly females and adult males. Densities of brown bears in core areas were greater than densities in peripheral areas (Swenson et al 1998). Sex ratios in recolonizing gray wolves favored females (Pletscher et al. 1997). However, colonizing coyote populations in New Brunswick, Nova Scotia, and New Hampshire were skewed toward adults and males (Moore and Millar 1984). Wolf pups in well established areas from Minnesota were predominately males, and wolf pups on the "frontier" of wolf range were mostly females (Mech 1975). Mean ages of female breeding Antarctic fur seals were relatively low compared with a stable population of northern fur seals (*Callorhinus ursinus*). When a population becomes established and dense, decreased food availability can cause reduced pregnancy, low growth rates, and poor survival (Payne 1977).

Examination of age structures is useful in understanding species biology and demography and for developing management applications (Novak 1977; Polechla 1987). Before our research was initiated, the age structure of river otters in Oklahoma was unknown. Therefore, our objective was to examine age structures of river otters in Oklahoma and identify trends that relate to space (watersheds, county) and time (APHIS county trapping records). Specifically, we compared age structures and sex ratios of river otters among longer established, core populations, and colonizing peripheral populations.

We hypothesized that river otters in western areas were younger than river otters occurring further east. Similarly, we predicted that mean age of river otters in longer established areas were greater than river otters occurring in areas more recently established. We also explored isotopic signatures to evaluate possible nutritional differences among areas and populations.

MATERIALS AND METHODS

Examination of river otter carcasses provides precise information on age structures and other parameters (Polechla 1987). We obtained teeth from river otter carcasses and live-captured individuals. River otter carcasses were salvaged from APHIS and ODWC employees from 2005 to 2007. River otters were often captured incidentally (Gallagher 1999; Bischof 2003) by APHIS trappers using non-selective Conibear 330 traps while pursuing nuisance beaver (Hill 1976). Road-killed river otters were collected opportunistically by ODWC employees. To facilitate specimen collection, river otter "death reports" were mailed to APHIS employees and ODWC regional biologists and game wardens (Appendix E). Recipients were asked to report captures and kill locations (water body, closest town, county) and submit river otter carcasses to the Oklahoma Cooperative Fish and Wildlife Research Unit.

River otters also were live-captured using double-jaw leg-hold traps (Sleepy Creek® #11; Blundell et al. 1999; Gorman 2004; Helon 2006) from May to October in 2005–2006. Traps were set in shallow water at the base of trails leading to latrines (Mowbray et al. 1979; Serfass et al. 1996), within latrine sites, or on crossover trails leading to adjacent waterbodies (Shirley et al. 1983). Traps located within latrines were baited with fresh scat (Macdonald et al. 1998) or placed randomly throughout the latrine (i.e., blind sets). Anchor chains were about 25 cm and contained 1 shock spring (Gorman 2004) and 2 swivels to reduce injury (Shirley et al. 1983). Traps were anchored using Berkshire® disposable stakes. Prior to use, traps were boiled in logwood trap dye and black trap wax (Adirondack Outdoor Company, Elizabethtown, New York, USA; Blundell et al. 1999) to prevent corrosion and lubricate moving parts. Traps were boiled at least twice per season. To prevent possible entanglement or injury, all vegetation, branches, and debris were removed in a 0.5-m radius of the stake (Serfass et al. 1996). To limit human scent at trap sites, hip boots and rubber gloves were used while setting traps (Blundell et al. 1999).

Trap sites were selected depending on river otter abundance, amount of river otter sign, trapability (e.g., substrate), access, water availability, and relative location to adjacent trap sites (i.e., efforts were made to evenly distribute trap sites). To retain consistency (Gallagher 1999), each site was trapped for approximately 12 days, and we established 8–10 sets (consisting of 2–4 traps/set) per night to achieve 100 trap nights at each trap site per trapping session. However, number of traps per set varied depending on size and shape of the latrine (Blundell et al. 1999). After a river otter was captured, it was restrained by using a chain-link (hold-down) device (Serfass et al. 1993) and immobilized. River otters were hand-injected intramuscularly with Telazol® (8 mg/kg of body weight) and restrained under the hold-down device until immobilized (Serfass et al. 1993). River otters were ear-tagged (size 1, style 1005; Eveland 1978) and web-tagged (size 3, style 1005; National Band and Tag Company, Newport, Kentucky, USA). Animal care and experimental procedures were approved by Oklahoma State University

Institutional Animal Care and Use Committee and followed guidelines of the American Society of Mammalogists (Gannon et al. 2007).

We trapped river otters along the Baron Fork and its tributaries, Sequoyah National Wildlife Refuge (SNWR), and Red Slough Wildlife Management Area (RSWMA) in eastern Oklahoma. The Baron Fork Watershed is relatively small (795 km^2; Garbrecht et al. 2004) and its stream travels approximately 75 km before entering the Illinois River southeast of Tahlequah, Oklahoma. The Baron Fork Watershed is described as Ozark Highlands and contains oak (*Quercus* spp.)-hickory (*Carya* spp.) and oak-pine (*Pinus* spp.) forest types (Tyrl et al. 2002).

The SNWR is located at the confluence of the Arkansas and Canadian rivers at the upper end of Robert S. Kerr Reservoir. The Refuge is approximately 84 km^2 and includes bottomland (Duck and Fletcher 1943) and post oak (*Q. stellata*)-blackjack oak (*Q. marilandica*) forest types (Tyrl et al. 2002); almost one-half of SNWR is periodically inundated (http://www.fws.gov/southwest/refuges/ oklahoma/sequoyah/index.html, accessed 12 August 2007). Aquatic habitats include open-water, riverine, oxbow lakes, wooded sloughs, and ephemeral wetlands. SNWR consists primarily of agriculture and bottomland hardwoods (Eddleman et al. 1985).

The RSWMA is located along Push Creek in the Pecan Creek and Waterhole Creek Watershed in southeastern Oklahoma. RSWMA is a 2,158-ha restored bottomland hardwood and wetland area (Hoagland and Johnson 2004). RSWMA contains approximately 160 ha of reservoir and 1,000 ha of moist soil units. Aquatic habitats consists of deep-water reservoirs, emergent marshes, mudflats, shallow-water impoundments, and periodically inundated prairies. Terrestrial habitats include bottomland hardwood forests, riparian areas, and shrub (http://www.fs.fed.us/r8/ouachita/natural-resources/redslough/info.shtml, accessed 15 September 2007).

Age structures.—Lower canines and/or first lower premolars were removed from river otter carcasses. In 2 instances, a molar was used for aging because premolars were absent or canines were broken. The first premolar from 1 side of the lower mandible was removed from live-captured river otters. Canines and premolars were aged by counts of cementum annuli; an age estimate and range were given for each tooth (Matson's Laboratory, Milltown, Montana). We considered juveniles $\leq$ 1 year old and adults > 1 year old. Examination of the number of cementum annuli is the most accurate technique for aging river otters (Toweill and Tabor 1982; Melquist et al. 2003). Canines typically are used for aging river otters (Fortin et al. 2001; Bowyer et al. 2003; Pitt et al. 2003) and are most reliable when assessing river otter age (Stephenson 1977). However, removal of a canine from live-captured river otters is harmful and not practical. To examine the accuracy of first lower premolars, we aged lower canines and first lower premolars from a sample of 29 river otter carcasses. We used simple linear regression to determine if a relationship existed ($P < 0.05$) between lower canines and first lower premolars.

Hatcher (1984) suggested that river otter numbers in Oklahoma have increased probably due to immigration from increasing populations in Arkansas. To elucidate effects of recolonization on age of river otters, we examined age structures of river otters in eastern Oklahoma in 4 ways, 1) comparison of age structures of pre- and post-1996 counties, 2) regression analyses of mean age and years since initial capture by county (i.e., first recorded capture), 3) age examination from east-to-west at different spatial scales, and 4) comparison of age structures of 4 watersheds. APHIS records documenting first year of capture by county were used to provide evidence of range expansion and to determine when river otters first became established in a county (Fig. 1). We hypothesized that river otters from western counties had a lower mean age than river otters from eastern counties. To examine differences among counties containing river otters, we divided counties into 2 groups relative to initial occurrence, pre-1996 and post-1996. The year 1996 equally divided the counties relative to temporal westward expansion (Fig. 2). We used a 1-tailed *t*-test to compare mean age between pre-1996 (*n* = 44) and post-1996 (*n* = 19) counties. Proportion of juveniles to adults and sex ratios were compared between pre-1996 and post-1996 counties using Chi-square analysis with Yate's correction for continuity. Regression analyses were used to evaluate the relationship between years since initial capture and mean age of river otters from each county. Latimer and Wagoner counties were not included in analyses because sample sizes < 3.

Age structures also were examined at 3 70-km (*n* = 11, 20, 7) and 2 100-km (*n* = 30, 10) intervals from east-to-west in Oklahoma. Because of Hatcher's (1984) speculation, we considered intersections of the Arkansas River and Red River with the Arkansas state line as points of spread. However, trap sites from the Red River were excluded from analyses because sample sizes (e.g., *n* = 3) were low in the 3 different intervals. We used a single factor ANOVA to examine age structures of river otters at 70-km intervals and a 1-tailed *t*-test to examine age structures of river otters at 100-km intervals (Fig. 3).

To further examine age structures of expanding river otters, we used a single factor ANOVA to determine differences among age structures from 4 watersheds

(Arkansas River Watershed [ARRW], n = 20 river otters; Canadian River Watershed [CRW], n = 10; Illinois River Watershed [ILRW], n = 8; Red River Watershed [RRW], n = 20) in eastern Oklahoma (Fig. 4). A Fisher's least significant difference (LSD) test was used to identify pairwise differences among age structures from those areas. Five river otters were removed from this analyses because kill locations were not accurately documented and watershed origination could not be determined. Proportion of juveniles to adults and sex ratios were compared among watersheds using Chi-square analysis. Proportions of males to females between juvenile and adult age classes also were compared (Moore and Millar 1987). All statistical tests were conducted using SYSTAT 10 for Windows (SPSS Inc., Chicago, Illinois) and were considered significant at $P < 0.10$.

Stable isotopes.—Liver, muscle, toenails, and teeth were collected from river otter carcasses that were collected opportunistically by APHIS and ODWC employees. Toenails and teeth were collected from live-captured river otters. All samples were rinsed and cleaned with distilled water, dried to a constant weight at 60°C, and ground to a fine powder using a mortar and pestle. Most samples were frozen until preparation, but some samples of liver and muscle were treated for genetic analyses by storing them in lysis buffer and some teeth were treated with alcohol, formalin, hydrochloric acid, and toluene for aging. To assess differential treatment of samples, we submitted, for example, 2 untreated samples of liver from 1 individual river otter and 2 samples of liver from another individual, 1 treated and 1 untreated. The variation was less in the latter suggesting minimal effect of chemical treatments on isotopic signatures. Ground samples were loaded into 4 x 6-mm tin capsules and analyzed for carbon and nitrogen isotope content using a continuous flow isotope ratio mass spectrometer (Stable Isotopes Facility, University of California, Davis, California, USA; Stable Isotope Facility, Boston University, Boston, Massachusetts, USA) and expressed in per mil notation (‰). Standards for $\delta^{13}C$ were the Peedee Belemnite marine fossil limestone or Solenhofen Limestone, spectrographic graphite, and hydrocarbon oil. Standard for $\delta^{15}N$ was atmospheric nitrogen. We hypothesized that $\delta^{13}C$ of river otters from eastern areas were less than river otters from western areas because of contributing allochthonous sources of ^{13}C. Because of lower population densities and greater food availability, we hypothesized that river otters in western areas would contain higher $\delta^{15}N$ values than eastern areas. Isotopic signatures ($\delta\ ^{13}C$, $\delta^{15}N$) were compared spatially by using a single factor ANOVA and a 1-tailed *t*-test. As with age information, we examined isotope composition of river otters in pre- and post-1996 counties, at intervals of 70-km and 100-km from the intersection of the Arkansas River and the Arkansas state line, and in 4 watersheds (ARRW, CRW, ILRW, RRW) in eastern Oklahoma. Because of small sample sizes at smaller scales (e.g., watersheds), liver and muscle tissues were examined only in pre- and post-1996 counties.

RESULTS

Age structures.—Between carcass collection and trapping efforts, 72 river otters (35F:28M; 9 unknowns) were available for analyses, but only 63 individuals (33F:24M; 7 unknowns) could be aged. One male was captured twice. Nine carcasses were not sexed because of condition or dismemberment. Another 9 river otters (4 males, 3 females, 2 unknowns) were not aged because of problems with tooth collection or preparation. Most river otters (79.2%) were captured by APHIS employees or collected by ODWC employees in 2005–2007. The 95% confidence intervals of the slope of the relationship between ages from canines and premolars ($r^2 = 0.81$; $P < 0.001$) included 1.0 (0.71–1.05), demonstrating that the 2 types of teeth provided comparable age estimates.

Across our entire sample ($n = 63$), juveniles (19.0%) and yearlings (30.2%) were the largest age classes (Fig. 5). River otter ages were < 1 to 10 years old. Mean age of river otters occupying post-1996 counties ($\bar{X} = 1.8$ yrs ± 0.41 *SE*) did not differ from mean age of river otters occupying pre-1996 counties ($\bar{X} = 2.4 \pm 0.34$ yrs; $t = 1.07$; df = 61; $P = 0.14$). Approximately 32% of river otters occupying post-1996 counties were juveniles, but only 13.6% of river otters occupying pre-1996 counties were juveniles (Fig. 6). Proportions of juveniles did not differ between pre- and post-1996 counties ($\chi^2 = 1.73$; df = 1; $P > 0.10$). Proportions of yearlings from pre- and post-1996 counties were 31.8%, and 26.3%, respectively, but did not differ ($\chi^2 = 0.019$; df = 1; $P > 0.10$). Sex ratios also did not differ between pre- and post-1996 counties ($\chi^2 = 0.00$; df = 1; $P > 0.10$). Years since initial capture was correlated with mean age of river otters from each county-year ($r^2 = 0.41$; $P < 0.10$; Fig. 7).

Mean age of river otters in 0–70-km ($\bar{X} = 3.0 \pm 0.88$ yrs), 70–140-km ($\bar{X} = 2.1 \pm 0.37$ yrs), and 140–210-km ($\bar{X} = 0.9 \pm 0.40$ yrs) intervals did not differ ($F = 2.41$; df = 2, 35; $P > 0.10$; Fig. 3a), but mean age of river otters in 100-km intervals differed ($P < 0.01$; Fig. 3b). Mean age of river otters in 0–100-km interval was 2.4 years ± 0.41 (yrs), and mean age of river otters in 100–200-km interval was 1.0 years ± 0.30 (yrs). Mean age differed by watershed ($F = 2.39$; df = 3, 54; $P < 0.10$; Fig. 4). River otters from ARRW ($\bar{X} = 2.9 \pm 0.53$ yrs) and RRW ($\bar{X} = 2.4 \pm 0.48$ yrs) were older than those from CRW ($\bar{X}$

= 0.8 ± 0.20 yrs). Mean age of river otters from ILRW was 1.9 years ± 0.64 (yrs). Proportion of juveniles ($\chi^2 = 2.53$; df = 3; $P > 0.10$) and sexes ($\chi^2 = 3.63$; df = 3; $P > 0.10$) did not differ among watersheds. ARRW, ILRW, RRW, and CRW had 10.0%, 12.5%, 25.0%, and 30.0% juveniles, respectively. ILRW, ARRW, CRW, and RRW had approximately 31%, 60%, 60%, and 61% females, respectively.

Because sample size was small ($n = 5$) in lower reaches of the RRW (McCurtain County), we did not separate lower and upper reaches of RRW. Mean age of lower reaches of RRW was 3.0 years (range: 0–8 years old). Only 1 pup was captured from the lower end of the RRW; in contrast, 4 pups were captured from the upper end of the RRW. ANOVA and Fisher's LSD were rerun without the 5 individuals from McCurtain County, and no new differences were determined. However, mean age of river otters occupying RRW decreased to 2.2 years. River otter age in the RRW probably was affected by reintroduction efforts during the mid 1980s (Base 1986). River otters were first captured in lower end of the RRW during the early 1990s (1992, 1993), and it was at least 5 years later (1997, 1998) when river otters were first captured throughout upper portions of RRW (Fig. 1).

Stable isotopes.—Mean δ^{13}C differed ($P < 0.05$) between pre- and post-1996 counties for liver, muscle, and toenails, but mean δ^{13}C of teeth did not differ ($t = 0.71$; df = 50; $P = 0.24$). Mean δ^{13}C of post-1996 counties and tissues were less enriched than mean δ^{13}C of pre-1996 counties (Table 2). Mean δ^{15}N of all tissues from pre- and post-1996 counties did not differ ($P > 0.10$), but mean δ^{15}N of liver, muscle, and toenail consistently decreased from pre- to post-1996 counties.

Mean $\delta^{15}N$ of teeth differed ($F = 2.70$; df = 2, 27; $P < 0.10$) in 70-km intervals, but $\delta^{13}C$ of toenails and teeth and $\delta^{15}N$ of toenails did not differ ($P > 0.10$). Mean $\delta^{15}N$ of teeth from 70–140-km ($\bar{x} = 14.4$) was less than the mean $\delta^{15}N$ of teeth from 140–210-km ($\bar{x} = 16.0$). Mean $\delta^{15}N$ of teeth from 0–70-km was 15.8. Mean $\delta^{13}C$ increased from east to west in 70-km intervals. Mean $\delta^{13}C$ and $\delta^{15}N$ of toenails and teeth did not differ ($P > 0.10$) in 100-km intervals. Among watersheds, mean $\delta^{15}N$ of toenails differed ($F = 6.69$; df = 3, 45; $P < 0.01$), but mean $\delta^{13}C$ did not differ ($F = 1.90$; df = 3, 45; $P > 0.10$). Mean isotope values of teeth differed among watersheds for $\delta^{13}C$ ($F = 13.31$; df = 3, 44; $P < 0.001$) and $\delta^{15}N$ ($F = 6.90$; df = 3, 44; $P < 0.01$; Table 3).

DISCUSSION

Population parameters, including age structures, of recently recolonized river otter populations have been examined (Testa et al. 1994; Blundell et al. 2002; Bowyer et al. 2003). Researchers (Blundell et al. 1999; Blundell et al. 2002; Bowyer et al. 2003; Testa et al. 2003) thoroughly examined a recently reestablished population of river otters occupying a marine-terrestrial interface in Prince William Sound (PWS), Alaska, USA; parts of PWS were affected by the Exxon Valdez oil spill in 1989. Proportion of males to females in eastern Oklahoma (1F:0.8M) differed from the sex ratio of river otters captured in PWS from 1989 to 1998 (1F:1.64M; Bowyer et al. 2003), but sex ratios varied annually in oiled and unoiled areas. In contrast, the sex ratio of river otters in eastern Oklahoma was similar to a reintroduced river otter population in Iowa (1F:0.88M; Pitt et al. 2003). Gorman (2004) suggested that sex ratios skewed toward females could be caused by smaller home ranges of females and more time spent in restricted areas especially during spring (Melquist and Hornocker 1983), causing females to be in contact with traps more often than males. During parturition and natal care, female river otters probably remain close to dens and venture out for only short periods. Because river otters occasionally use beaver dens for natal rearing (Gorman et al. 2006), female river otters could increase chances of encountering traps that were set for beavers by APHIS employees. Gorman (2004) also noted that female river otters are more susceptible to incidental harvest than males. In addition to incidental captures in Oklahoma (0.88M:1F), we captured 5 males and 8 females (1F:0.63M) during our trapping efforts where river otters were targeted. An APHIS employee also captured 2 males and 2 females while targeting nuisance river otters in southern Oklahoma in 2007.

Most often, sex ratios of river otters are skewed toward males (McDaniel 1963; Melquist and Hornocker 1983; Polechla 1987; Route 1988) but vary widely among years and annually (0.64M:1F to 3.31M:1F; Chilelli et al. 1996). Some researchers have suggested that female river otters are less susceptible to trapping because they are solitary or form family groups with young (Melquist et al. 2003) and occupy exclusive home ranges (Foy 1984; Woolington 1984; Griess 1987; Rock et al. 1994). In contrast, males have larger home ranges (Melquist and Dronkert 1987; Reid et al. 1994; Gorman et al. 2006) and occur in bachelor groups (McDonald 1989; Blundell et al. 2002). Melquist and Hornocker (1983) and Erickson and McCullough (1987) noted overlapping home ranges between both sexes. Others have found that male home-range size is not greater than female home-range size (Johnson and Berkley 1999; Spinola 2003) until breeding season (Spinola 2003). Occasionally, female home ranges are larger than male home ranges (Griess 1987). Gorman (2004) concluded that larger male home ranges resulted in fewer males being trapped because less time was spent near traps. Conversely, Lauhachinda (1978) argued that larger male home ranges increase the chance of a male river otters being trapped.

Sex-biased dispersal probably influenced the preponderance of females in Oklahoma. Female river otter dispersal distances were greater than male dispersal distances in New York (Spinola 2003) but similar in Oklahoma (Base 1986) and less than males during breeding season in Alaska (Blundell et al. 2002). Blundell et al. (2002) investigated dispersal properties of river otter in PWS and concluded that natal dispersal remained low for both sexes, but some male river otters exhibited breeding dispersal. Similar to the present study, a preponderance of females has been documented in other recolonizing mammalian carnivores such as black bears (Onorato 2003; Bales et al. 2005) and gray wolves (Mech 1975; Pletscher et al. 1997). Animals disperse because of competition avoidance (food and mating), habitat availability, social reasons, and environmental disruptions (Greenwood 1980, Pyke 1983, Waser 1985). Females gain future reproductive success in expanding populations if they are not limited by space (Swenson et al. 1998; Bales et al. 2005); furthermore, females do not compete for reproductive rights and are more likely to successfully produce offspring in an expanding population (Clutton-Brock 1988; Bales et al. 2005) where intraspecific competition is usually less intense (Hrdy and Williams 1983). Recolonization is affected by the ability to find mates at low densities (Hurford et al. 2006) and can be further complicated by disparate sex ratios.

Sex ratios of pre- and post-1996 counties were skewed toward females (1F:0.83M, 1F:0.73M, respectively) but did not differ statistically. Similarly, sex ratios from examined watersheds, except ILRW, also were skewed toward females but did not differ statistically. Female preponderance in western areas (i.e., counties, watersheds) could be an artifact of density (Mech 1975) rather than population age, timing of settlement, or capture bias. Similar to some ungulates (Mysterud et al. 2000), Mech (1975) theorized that disproportionate sex ratios in gray wolves were an outcome of density and nutritient availability. Within high density areas, sex ratios of pups were skewed toward males; conversely, equal sex ratios or preponderance of females occurred in areas with lower densities (Mech 1975). Densities of river otters from oiled and unoiled areas in PWS did not differ statistically (Testa et al. 1994; Bowyer et al. 2003), and sex ratios from 1989 to 1998 were similar between areas (1F:1.82M, 1F:1.44M, respectively; Bowyer et al. 2003).

Differences among age structures of river otters from newly recolonized areas have not been documented until the present study. In established populations, age structures of river otters did not differ statistically between oiled and unoiled areas in PWS (Bowyer et al. 2003; Testa et al. 2003), but pre-spill river otter ages were not available for these areas before 1989. In our study, 19.0% of river otters were juveniles and 30.2% were yearlings (Fig. 4). Proportion of juveniles in Oklahoma was less than in neighboring states of Arkansas and Missouri (Table 1). However, the Oklahoma population contained a higher proportion of juveniles than Illinois where river otters have been established more recently (Bluett et al. 2004) and other states where river otters have been established longer (Alabama, Georgia; Lauhachinda, 1978). In Iowa, 41% of river otter carcasses collected from a recently reintroduced population were juveniles (≤ 1 year old; Pitt et al. 2003), but proportion of juveniles did not differ from previous studies

(Docktor et al. 1987; Polechla 1987; Gallagher 1999) and were similar to surrounding states. Pitt et al. (2003) did not differentiate or examine differences of ages from longer established areas (northeastern and eastern Iowa along the Mississippi River); instead, population characteristics were calculated for all of Iowa.

Proportion of juveniles in our sample could be under-represented because of yearling behavior (Foy 1984) and season of capture. Yearling river otters have smaller activity centers and home ranges than adults (Foy 1984) and thus may be less likely to encounter traps. Most carcasses (79.5%) were obtained from APHIS employees conducting beaver nuisance control or ODWC employees; beaver control efforts were focused primarily during late winter and early spring. Approximately 45% of river otters trapped by APHIS employees were captured in February and March (2005–2007); 81.6% were captured from January to April when river otters pups are relatively inactive. Parturition occurs between January (McDaniel 1963) and May (Woolington 1984; Noll 1988) and is probably influenced by latitude (Polechla 1987). In Arkansas and Missouri, estimated parturition dates range from late January to late March (Polechla 1987; Gallagher 1999) with most births (55%) occurring in February (Polechla 1987). In Minnesota, mean initiation date of denning was 31 March (Gorman et al. 2006). Altricial pups remain in natal dens for 7–8 weeks after parturition (Noll 1988; Gorman et al. 2006), therefore, reducing chances of encountering traps set for beavers.

Some county trapping records (i.e., APHIS records) in eastern and southeastern Oklahoma did not parallel published literature that documented river otter captures in the early 1980s (Hatcher 1984). Some river otter captures by APHIS employees probably occurred before accurate documentation began. In 1981–1982, Hatcher (1984) reported 4 captures and numerous sightings from southeastern Oklahoma. Base (1986) also reported that accidental trappings and observations of river otters commonly occurred along the Fouche Maline, Lower Arkansas River tributaries, Mountain Fork, Poteau River, and Sans Bois Creek in southeastern Oklahoma. Although discrepancies among years occurred, natural recolonization of river otters is probably a slow process (Blundell et al. 2002) and discrepancies had little effect on our study.

In Oklahoma, relatively large watersheds such as ARRW, CRW, RRW, Cimarron River Watershed, and Washita River Watershed, are oriented west-to-east and facilitate westward dispersal by river otters. Because of reintroduction efforts, habitat improvements, construction of reservoirs, and wetland restoration (Melquist et al. 2003), river otters will continue to expand their distribution in Oklahoma and eventually reoccupy historic distributions in western Oklahoma.

Our analyses and evaluation of historical records indicated that core populations of river otters occurred along lower portions of the Arkansas River in eastern Oklahoma and the Red River in southeastern Oklahoma. By examining pre- and post-1996 county occurrences, 70-km and 100-km intervals, and 4 watersheds, we determined that river otters in western populations (CRW) contained younger individuals than eastern populations (ARRW), suggesting expanding populations in the former. Reinforcing the conclusion that mean age was lower in western areas, a correlation between mean age and years since initial capture from each county year was established.

Stable isotopes.—Within aquatic systems, δ^{13}C and δ^{15}N values are influenced by autochthonous and allochthonous energy sources (Finlay 2001; Hein et al. 2003). In addition to energy sources, variations in watershed size (Finlay 2001), stream velocity

(France and Cattaneo 1998; Finlay et al. 1999) also influences isotopic signatures. In larger watersheds (> 10 km^2), $\delta^{13}C$ values of consumers show greater similarities with algal $\delta^{13}C$ than terrestrial $\delta^{13}C$ (Finlay 2001). Because river otters consume wide varieties of prey (e.g., amphibians, birds, fish, insects, mammals; Toweill and Tabor 1982) and have extensive movements (Melquist et al. 2003), isotopic signatures of river otters (Blundell et al. 2002a) and prey vary widely (Whitledge and Rabeni 1997). For instance, crayfish (Suborder Pleocyemata) are readily consumed by river otters (Sheldon and Toll 1964; Toweill 1974) and approximately two thirds of crayfish (*Orconectes* spp.) production originates from allochthonous inputs and another 30–50% originates from animal matter (Whitledge and Rabeni 1997).

River otters occupy low and high order streams (Melquist et al. 2003) and move seasonally (Blundell et al. 2002b) and disperse over large areas (Blundell et al. 2002b). In Oklahoma counties, $\delta^{13}C$ values of river otter tissues increase from east to west (pre- and post-1996 counties) and probably resulted from allochthonous sources of particulate organic matter and transitions from C_3 plants (e.g., trees) to C_4 plants (e.g., prairie grasses) further west (Bruner 1931; Kelly 2000). In addition to contributions by C_3 and C_4 plants, variations in slope from east to west probably contributed to differences in $\delta^{13}C$. Stream velocity increases with slope and increased water velocity causes $\delta^{13}C$ to be more negative than areas with less velocity (e.g., western Oklahoma; France and Cattaneo 1998; Finlay et al. 1999). Although probable causes are presented, differences among $\delta^{13}C$ values were minimal (but significant) in our study and less than those reported by previous researchers (Kelly 2000).

In the past, inferences have been made regarding nutrition and δ^{15}N (Hobson et al. 1993; Sponheimer et al. 2003; Walter 2006). Population density directly affects forage availability (Walter 2006), and nutritional stress causes an increase in δ^{15}N values of tissues (Hobson and Clark 1992; Hobson et al. 1993; Kelly 2000). However, fecal δ^{15}N values have been correlated to %N ($r^2 = 0.25$; $P < 0.05$; Codron and Brink 2007); therefore, elevated δ^{15}N values suggest enhanced nutrition. Within our study, δ^{15}N of teeth at 70-km intervals differed statistically but did not suggest decreased nutritional stress further west. Instead, increasing δ^{15}N values suggested enhanced nutrition in peripheral populations further west. Changes in nutritional stress and enhanced nutrition were also suggested by statistical differences among watershed δ^{15}N values. However, in contrast, lower δ^{15}N of toenails and teeth in RRW imply decreased nutritional stress further west and/or more suitable conditions occurring further east. CRW δ^{15}N values of toenails and teeth were also less but not significantly different than eastern watersheds (ARRW, ILRW). It is unlikely that river otters in eastern Oklahoma occur at densities where nutritional stress has become a prevailing factor. Decreased nutritional stress probably had no affect on δ^{15}N values. Instead, we suggest that lower δ^{15}N values are artifacts of less suitable habitat. For instance, prairie streams (further west) are often ephemeral (Dodds et al. 2004) and less permanent than streams in eastern Oklahoma.

In addition to nutrition, age probably influenced δ^{15}N values. Within other taxa (Gu et al. 1996; Overman and Parrish 2001) and other mammals (Niño-Torres et al. 2006; Tucker et al. 2007), researchers have documented a positive correlation between age and δ^{15}N. In longbeaked common dolphins (*Delphinus capensis*), Niño-Torres et al. (2001) determined significant differences in δ^{15}N occurred among age groups. Within our study, age accounted for approximately 26% of the variation in all δ^{15}N values and approximately 37% of the variation in mean δ^{15}N values by age. In fish (Gu et al. 1996; Overman and Parrish 2001) and some marine mammals (Niño-Torres et al. 2006), researchers concluded that the correlation between age and δ^{15}N values was a result of older individuals occupying higher trophic levels or better quality habitats. As piscivores age and grow, their diets usually shift and larger fish are consumed (Overman and Parrish 2001). Similarly, the diet of Eurasian otter (*Lutra lutra*) cubs and sub-adults consisted mostly of crustaceans; conversely, adults were more likely to prey upon fish that were more profitable energetically (Watt 1993; Carss 1995). Perhaps, river otters became more efficient at capturing larger prey as age increased; the consumption of larger fish probably includes more piscivorous fish (e.g., black basses [*Micropterus* spp.]) and subsequent trophic levels that increase δ^{15}N. Because river otters exhibit sexual dimorphism (Melquist et al. 2003), δ^{15}N of toenails of males and females also were compared to further examine the relationship between size (similar to age) and δ^{15}N by using a 1-tailed *t*-test. We determined that male δ^{15}N and female δ^{15}N differed ($P < 0.10$) and male δ^{15}N were higher than female δ^{15}N; therefore, male river otters consume prey with higher δ^{15}N values and occupy a higher trophic level than female river otters.

Management implications.—River otter management is challenging, and a single method for evaluating river otter status does not exist (Toweill and Tabor 1982; Melquist et al. 2003). Harvest data should be examined cautiously because pelt prices, economics, and weather conditions can influence trapping effort and the number of individuals harvested (Melquist et al. 2003). Harvest surveys alone are not applicable in areas where otters are protected (Swimley et al. 1998). Instead of examining only one parameter such as harvest, managers should use a combination of indices to assess river otter populations (Polechla 1987; Chilelli et al. 1996; Gallagher 1999; Melquist et al. 2003). In addition to other techniques, such as sign surveys or catch per unit effort (Gallagher 1999), managers should examine age structures from core and peripheral areas. Swenson et al. (1998) recommended that sex and age data of brown bears harvested from expanding populations be used to identify core and peripheral areas. Similar to brown bears (Swenson et al. 1998), river otters were younger in peripheral areas than core areas, based on some of our analyses. Monitoring catch per unit effort data (Chilelli et al. 1996) and proportion of juveniles provides insight on population trends and is indicative of annual recruitment and population stability. Age data can be used to compare populations, manage proactively throughout time (Polechla 1987), and provide better insight on the status and characteristics of the population (Bowyer et al. 2003).

ACKNOWLEDGMENTS

Funding for this research was provided by the Federal Aid, Pittman-Robertson Wildlife Restoration Act under Project W-158-R of the Oklahoma Department of Wildlife Conservation and Oklahoma State University. The project was administered through the Oklahoma Cooperative Fish and Wildlife Research Unit (Oklahoma Department of Wildlife Conservation, United States Geological Survey, Oklahoma State University, Wildlife Management Institute, and United States Fish and Wildlife Service cooperating). This publication was partially supported by the National Science Foundation Louis Stokes Alliance for Minority Participation Bridge to Doctorate Program under grant number HRD-0444082. We would like to thank S. K. Davis and A.

A. Foster for their assistance in the field. We also thank J. Sanchez and other U.S. Fish and Wildlife Service employees from SNWR for their aid in capturing river otters. A special thanks to D. Hamilton from the Missouri Department of Wildlife Conservation and M. Fischer from the Arkansas Trappers Association for their guidance and training. We thank R. Thornburg and S. Sheffert of the Oklahoma Fur Bearers Alliance and numerous employees of the ODWC for their insight and assistance. We thank hundreds of state and federal employees and private and professional trappers who participated in the mail survey. This project was completed as partial fulfillment for the requirements of the degree of Master of Science.

LITERATIVE CITED

Aars, J., and R. A. Ims. 2000. Population dynamic and genetic consequences of spatial density-dependent dispersal in patchy populations. American Naturalist 155:252–265.

Anderson, S. 1977. Geographic ranges of North American terrestrial mammals. American Museum Novitates 2629:1–15.

Bales, S. L., E. C. Hellgren, D. M. Leslie, Jr., and J. Hemphill, Jr. 2005. Dynamics of a recolonizing population of black bears in the Ouachita Mountains of Oklahoma. Wildlife Society Bulletin 33:1342–1351.

Base, D. L. 1986. Evaluation of experimental reintroduction of river otters in Oklahoma. Unpublished report, Oklahoma Department of Wildlife Conservation, Nongame Wildlife Program, Oklahoma City, Oklahoma.

Ben-David, M. 2002. Can river otters naturally recolonize the Grand Canyon? River Otter Journal 11:4–5.

Berger, K. M., and E. M. Gese. 2007. Does interference competition with wolves limit the distribution and abundance of coyotes? Journal of Animal Ecology 76:1075–1085.

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

Bluett, R. D., C. K. Nielson, R. W. Gottfried, C. A. Miller, and A. Woolf. 2004. Status of the river otter (*Lontra canadensis*) in Illinois, 1998–2004. Transactions of the Illinois State Academy of Science 97:209–217.

Blundell, G. M. 2001. Social organization and spatial relationships in coastal river otters: assessing form and function of social groups, sex based dispersal, and gene flow. Ph.D. Dissertation, University of Alaska, Fairbanks.

Blundell, G. M., M. Ben-David, and R. T. Bowyer. 2002a. Sociality in river otters: cooperative foraging or reproductive strategies. Behavioral Ecology 13:134–141.

Blundell, G. M., M. Ben-David, P. Groves, R. T. Bowyer, and E. Geffen. 2002b. Characteristics of sex-biased dispersal and gene flow in coastal river otters: implications for natural recolonization of extirpated populations. Molecular Ecology 11:289–303.

Blundell, G. M., J. W. Kern, R. T. Bowyer, and L. K. Duffy. 1999. Capturing river otters: a comparison of Hancock and leg-hold traps. Wildlife Society Bulletin 27:184–192.

Bowyer, R. T., G. M. Blundell, M. Ben-David, S. C. Jewett, T. A. Dean, and L. K. Duffy. 2003. Effects of the Exxon Valdez oil spill on river otters: injury and recovery of a sentinel species. Wildlife Monographs 153:1–53.

Boyd, D. K., and D. H. Pletscher. 1999. Characteristics of dispersal in a colonizing wolf population in the central Rocky Mountains. Journal of Wildlife Management 63:1094–1108.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecological Monographs 1:99–188.

Carss, D. N. 1995. Foraging behaviour and feeding ecology of the otter *Lutra lutra*: a selective review. Hystrix 7:179–194.

Cheeseman, C. L., W. J. Cresswell, S. Harris, and P. J. Mallinson. 1988. Comparison of dispersal and other movements in two badger (*Meles meles*) populations. Mammal Review 18:51–59.

Chilelli, M., B. Griffith, and D. J. Harrison. 1996. Interstate comparisons of river otter harvest data. Wildlife Society Bulletin 24:238–246.

Clutton-Brock, T. H. 1988. Reproductive success. Pages 472–485 in Reproductive success (T. H. Clutton-Brock, ed.). University of Chicago Press, Chicago, Illinois.

Codron, D., and J. S. Brink. 2007. Trophic ecology of two savanna grazers, blue wildebeest *Connochaetes taurinus* and black wildebeest *Connochaetes gnou*. European Journal of Wildlife Research 53:90–99.

Docktor, C. M., R. T. Bowyer, and A. G. Clark. 1987. Number of corpora lutea as related to age and distribution of river otters in Maine. Journal of Mammalogy 68:182–185.

Dodds, W. K., K. B. Gido, M. R. Whiles, K. M. Fritz, and W. J. Matthews. 2004. Life on the edge: the ecology of Great Plains prairie streams. Bioscience 54:205–216.

Duck, L. G., and J. B. Fletcher. 1943. A game type map of Oklahoma. Oklahoma Game and Fish Department, Oklahoma City, Oklahoma.

Duck, L. G., and J. B. Fletcher. 1944. A survey of the game and furbearing animals of Oklahoma. Bulletin 3. Oklahoma Game and Fish Commission, Oklahoma City, Oklahoma.

Eddleman, W. R., C. T. Patterson, and F. L. Knopf. 1985. Interspecific relationsips between American coots and waterfowl during fall migration. Wilson Bulletin 97:463–472.

Erickson, D. W., and C. R. McCullough. 1987. Fates of translocated river otters in Missouri. Wildlife Society Bulletin 15:511–517.

Eveland, T. 1978. The status, distribution, and identification of suitable habitat of river otters in Pennsylvania. M.S. Thesis, East Stroudsburg University, East Stroudsburg.

Finlay, J. C. 2001. Stable-carbon-istotope ratios of river biota: implications for energy flow in lotic food webs. Ecology 82:1052–1064.

Finlay, J. C., M. E. Power, and G. Cabana. 1999. Effects of water velocity on algal carbon isotope ratios: implications for river food web studies. Limnology and Oceanography 44:1198–1203.

Fortin, C., G. Beauchamp, M. Dansereau, N. Lariviere, and D. Belanger. 2001. Spatial variation in mercury concentrations in wild mink and river otter carcasses from the James Bay Territory, Quebec, Canada. Archives of Environmental Contamination and Toxicology 40:121–127.

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.

France, R., and A. Cattaneo. 1998. δ^{13}C variability of benthic algae: effects of water colour via modulation by stream current. Freshwater Biology 39:617–622.

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

Gannon, W. L., R. S. Sikes, and The Animal Care and Use Committee of the American Society of Mammalogists. 2007. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 88:809–823

Garbrecht, J., M. Van Liew, and G. O. Brown. 2004. Trends in precipitation, streamflow, and evapotranspiration in the Great Plains of the United States. Journal of Hydrologic Engineering 9:360–367.

Gorman, T. A. 2004. Survival, spatial characteristics, and natal den use of river otters (*Lontra canadensis*) in southeastern Minnesota. M.S. Thesis, Minnesota State University, Mankato.

Gorman, T. A., J. D. Erb, B. R. McMillan, and D. J. Martin. 2006. Space use and sociality of river otters (*Lontra canadensis*) in Minnesota. Journal of Mammalogy 87:740–747.

Gorman, T. A., J. D. Erb, B. R. McMillan, D. J. Martin, and J. A. Homyack. 2006. Site characteristics of river otter (Lontra canadensis) natal dens in Minnesota. American Midland Naturalist 156:109–117.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behavior 28:1140–1162.

Greenwood, P. J., and I. R. Swingland. 1983. Animal movement: approaches, adaptations, and constraints. Pages 1–6 in The ecology of animal movement (I. R. Swingland and P. J. Greenwood, eds.). Clarendon Press, Oxford, England.

Griess, J. M. 1987. River otter reintroduction in Great Smokey Mountains National Park. M.S. Thesis, University of Tennessee, Knoxville.

Gu, B., C. L. Schelske, and M. V. Hoyer. 1996. Stable isotopes of carbon and nitrogen as indicators of diet and trophic structure of the fish community in a shallow hypereutrophic lake. Journal of Fisheries Biology 49:1233–1243.

Hall, E. R. 1981. The mammals of North America. Second ed. John Wiley & Sons, New York.

Hatcher, R. T. 1984. River otters in Oklahoma. Proceedings of the Oklahoma Academy of Science 64:17–19.

Hein, T., C. Baranyi, G. J. Herndl, W. Wanek, and F. Schiemer. 2003. Allochthonous and autochthonous particulate organic matter in floodplains of the River Danube: the importance of hydrological connectivity. Freshwater Biology 48:220–232.

Helon, D. A. 2006. Summer home range, habitat use, movements, and activity patters of river otters (*Lontra canadensis*) in the Killbuck Watershed, northeastern Ohio. M.S. Thesis, West Virginia University, Morgantown.

Hill, E. P. 1976. Control methods for nuisance beaver in the southeastern United States. Vertebrate Pest Conference Proceedings 44:85–98.

Hoagland, B. W., and F. Johnson. 2004. The vascular flora of Red Slough and Grassy Slough Wildlife Management Areas, Gulf Coastal Plain, McCurtain County, Oklahoma. Castanea 69:284–296.

Hobson, K. A., and R. G. Clark. 1992. Assessing avian diets using stable isotopes II: factors influencing diet-tissue fractionation. Condor 94:189–197.

Hobson, K. A., R. T. Alisauskas, R. G. Clark. 1993. Stable nitrogen isotope enrichment in avian tissue due to fasting and nutritional stress: implication for isotopic analyses of diet. Condor 95:388–394.

Hooker, S. K., S. J. Iverson, P. Ostrom, and S. C. Smith. 2001. Diet of northern bottlenose whales inferred from fatty-acid and stable-isotope analyses of biopsy samples. Canadian Journal of Zoology 79:1442–1454.

Hrdy, S. B., and Williams, G. C. 1983. Behavioral biology and the double standard. Pages 3–17 *in* Social behavior of female vertebrates (S. K. Wasser ed.). Academic Press, New York.

Hurford, A., M. Hebblewhite, and M. A. Lewis. 2006. A spatially explicit model for an Allee effect: why wolves recolonize so slowly in Greater Yellowstone. Theoretical Population Biology 70:244–254.

Jenkins, J. H. 1983. The status and management of the river otter (*Lutra canadensis*) in North America. Acta Zoologica Fennica 174:233–235.

Johnson, S. A., and K. A. Berkley. 1999. Restoring river otters in Indiana. Wildlife Society Bulletin 27:419–427.

Kelly, J. F. 2000. Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. Canadian Journal of Zoology 78:1–27.

Kozakiewicz, M., and E. Jurasinska. 1989. The role of habitat barriers in woodlot recolonization by small mammals. Holarctic Ecology 12:106–111.

Kuehn, D. W., and W. E. Berg. 1983. Use of radiographs to age river otters. Wildlife Society Bulletin 11:68–70.

Lariviere, S., and L. R. Walton. 1998. *Lontra canadensis*. Mammalian Species 587:1–8.

Lauhachinda, V. 1978. Life history of the river otter in Alabama with emphasis on food habits. Ph.D. Dissertation, Auburn University, Auburn, Alabama.

Liers, E. E. 1951. Notes on the river otter (*Lutra canadensis*). Journal of Mammalogy 32:1–9.

Lubina, J. A., and S. A. Levin. 1988. The spread of a reinvading species: range expansion in the California sea otter. American Naturalist 131:526–543.

Macdonald, D. W., G. Mace, and S. Rushton. 1998. Proposals for future monitoring of British mammals. Department of the Environment, Transport and the Regions, London, United Kingdom.

McDaniel, J. C. 1963. Otter population study. Proceedings of the Southeastern Association of Game and Fish Commissioners 17:163–168.

Mech, L. D. 1975. Disproportionate sex ratios of wolf pups. Journal of Wildlife Management 39:737–740.

Melquist, W. E., and A. E. Dronkert. 1987. River otter. Pages 625–641 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario, Canada.

Melquist, W. E., and M. G. Hornocker. 1983. Ecology of river otters in west central Idaho. Wildlife Monographs 83:1–60.

Melquist, W. E., P. J. Polechla, Jr., and D. Toweill. 2003. River otter, *Lontra canandensis*. Pages 708–734 *in* The wild mammals of North America: biology, management, and conservation (G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, eds.). John Hopkins University Press, Baltimore, Maryland.

Moore, G. C., and J. S. Millar. 1984. A comparative study of colonizing and longer established eastern coyote populations. Journal of Wildlife Management 48:691–699.

Mowbray, E. E., D. Pursley, and J. A. Chapman. 1979. The status, population characteristics and harvest of the river otter in Maryland. Publications in Wildlife Ecology. No. 2. Maryland Wildlife Administration, Anapolis, Maryland.

Mysterud, A., N. G. Yoccoz, N. CHR. Stenseth, and R. Langvatn. 2000. Relationships between sex ratio, climate and density in red deer: the importance of spatial scale. Journal of Animal Ecology 69:959–974.

Niño-Torres, C. A., J. P. Gallo-Reynoso, F. Galván Magaña, E. Escobar-Briones, and S. A. Macko. 2006. Isotopic analysis of $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ “a feeding tale” in teeth of the longbeaked common dolphin, *Delphinus capensis*. Marine Mammal Science 22:831–846.

Noll, J. M. 1988. Home range, movement, and natal denning of river otters (*Lutra canadensis*) at Kelp Bay, Baranof Island, Alaska. M.S. Thesis, University of Alaska, Fairbanks.

Novak, M. 1977. Determining the average size and composition of beaver families. Journal of Wildlife Management 41:751–754.

Onorato, D. P. 2003. Conservation ecology of an isolated population of black bears in the Big Bend ecosystem. Ph.D. Dissertation, Oklahoma State University, Stillwater.

Overman, N. C., and D. L. Parrish. 2001. Stable isotope composition of walleye: ^{15}N accumulation with age and area-specific differences in $\delta^{13}C$. Canadian Journal of Fisheries and Aquatic Sciences 58:1253–1260.

Payne, M. R. 1977. Growth of a fur seal population. Philosophical Transactions of the Royal Society of London 279:67–79.

Penak, B., and T. Code. 1987. The river otter live capture program in Ontario, Canada. IUCN Otter Specialist Group Bulletin 2:12–20.

Perrin, N., and V. Mazalov. 2000. Local competition, inbreeding, and the evolution of sex-biased dispersal. American Naturalist 155:116–127.

Pitt, J. A., W. R. Clark, R. D. Andrews, K. P. Schlarbaum, D. D. Hoffman, and S. W. Pitt. 2003. Restoration and monitoring of the river population in Iowa. Journal of the Iowa Academy of Science 110:7–12.

Pletscher, D. H., R. R. Ream, D. K. Boyd, M. W. Fairchild, and K. E. Kunkel. 1997. Population dynamics of a recolonizing wolf population. Journal of Wildlife Management 61:459–465.

Polechla, P. J. 1987. Status of the river otter (*Lutra canadensis*) population in Arkansas with special reference to reproductive biology. Ph.D. Dissertation, University of Arkansas, Fayetteville.

Pyare, S., S. Cain, D. Moody, C. Schwartz, and J. Berger. 2004. Carnivore re-colonisation: reality, possibility and a non-equilibrium century for grizzly bears in the Southern Yellowstone Ecosystem. Animal Conservation 7:1–7.

Pyke, G. H. 1983. Animal movements: an optimal foraging approach. Pages 7–31 in The ecology of animal movement (I. R. Swingland and P. J. Greenwood, eds.). Clarendon Press, Oxford, England.

Raesly, E. J. 2001. Progress and status of river otter reintroduction projects in the United States. Wildlife Society Bulletin 29:856–862.

Reid, D. G., T. E. Code, A. C. H. Reid, S. M. Herrero. 1994. Spacing, movements, and habitat selection of the river otter in boreal Alberta. Canadian Journal of Zoology 72:1314–1324.

Rock, K. R., E. S. Rock, R. T. Bowyer, and J. B. Faro. 1994. Degree of association and use of a helper by coastal river otters, *Lutra canadensis*, in Prince William Sound, Alaska. Canadian Field-Naturalist 108:367–369.

Route, W. T. 1988. Distribution and abundance of river otter in Voyageurs National Park, Minnesota. M.S. Thesis, Michigan Technological University, Houghton.

Serfass, T. L., R. L. Peper, M. T. Whary, and R. P. Brooks. 1993. River otter (*Lutra canadensis*) reintroduction in Pennsylvania: prerelease care and clinical evaluation. Journal of Zoo and Wildlife Medicine 24:28–40.

Serfass, T. L., R. P. Brooks, T. J. Swimley, L. M. Rymon, and A. H. Hayden. 1996. Considerations for capturing, handling, and translocating river otters. Wildlife Society Bulletin 24:25–31.

Sheldon, W. G., and W. G. Toll. 1964. Feeding habits of the river otter in a reservoir in central Massachusetts. Journal of Mammalogy 45:449–455.

Shirley, M. G., R. G. Linscombe, and L. R. Sevin. 1983. A live trapping and handling technique for river otter. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 37:182–189.

Skellam, J. G. 1951. Random dispersal in thereotical populations. Biometrika 38:196–218.

Spinola, R. M. 2003. Spatio-temporal ecology of river otters translocated to western New York. Ph.D. Dissertation, Pennsylvania State University, University Park.

Sponheimer, M., T. Robinson, L. Ayliffe, B. Roeder, J. Hammer, B. Passey, A. West, T. Cerline, D. Dearing, and J. Ehleringer. 2003. Nitrogen isotopes in mammalian herbivores: hair δ^{15}N values from a controlled feeding study. International Journal of Osteoarchaeology 13:80–97.

Stephenson, A. B. 1977. Age determination and morphological variation of Ontario otters. Canadian Journal of Zoology 5:1577–1583.

Swenson, J. E., F. Sandegren, and A. Soderberg. 1998. Geographic expansion of an increasing brown bear population: evidence for presaturation dispersal. Journal of Animal Ecology 67:819–826.

Testa, J. W., D. F. Holleman, R. T. Bowyer, and J. B. Faro. 1994. Estimating populations of marine river otters in Prince William Sound, Alaska, using radiotracer implants. Journal of Mammalogy 75:1021–1032.

Toweill, D. E. 1974. Winter food habits of river otters in western Oregon. Journal of Wildlife Management 38:107–111.

Toweill, D. E., and J. E. Tabor. 1982. River otter, *Lutra canadensis*. Pages 688–703 *in* The wild mammals of North America (J. A. Chapman and G. A. Feldhamer, eds.). Johns Hopkins University Press, Baltimore, Maryland.

Tucker, S., W. D. Bowen, and S. J. Iverson. 2007. Dimensions of diet segregation in grey seals *Halichoerus grypus* revealed through stable isotopes of carbon ($\delta^{13}C$) nitrogen ($\delta^{15}N$). Marine Ecology Progress Series 339:271–282.

Tyrl, R. J., T. G. Bidwell, and R. E. Masters. 2002. Field guide to Oklahoma plants. Oklahoma State University, Stillwater, Oklahoma.

van Apeldoorn, R. C., W. T. Oostenbrink, A. van Winden, and F. F. van der Zee. 1992. Effects of habitat fragmentation on the bank vole, *Clethrionomys glareolus*, in an agricultural landscape. Oikos 65:265–274.

Walter, W. D. 2006. Ecology of a colonizing population of Rocky Mountain Elk (*Cervus elaphus*). Ph.D. Dissertation, Oklahoma State University, Stillwater.

Waser, P. M. 1985. Does competition drive dispersal? Ecology 66:1170–1175.

Watt, J. 1993. Ontogeny of hunting behaviour of otters (*Lutra lutra* L.) in a marine environment. Symposium of the Zoological Society of London 65:87–104.

Whitledge, G. W., and C. F. Rabeni. 1997. Energy sources and ecological role of crayfishes in an Ozark stream: insights from stable isotopes and gut analysis. Canadian Journal of Fisheries Aquatic Sciences 54:2555–2563.

Wolff, J. O. 1993. What is the role of adults in mammalian juvenile dispersal? Oikos 68:173–176.

Woolington, J. D. 1984. Habitat use and movements of river otters at Kelp Bay, Baranof Island, Alaska. M.S. Thesis, University of Alaska, Fairbanks.

Table 1. Comparison of the percentage of juveniles and adults in river otter populations by state or province (adapted from Gallagher 1999 and Polechla 1987).

Authors	State or Province	Sex	% Juveniles	% Adults
Present study	Oklahoma	Both	19.5	80.5
Bluett et al. (2004)	Illinois	Both	16.8	83.2
Gorman (2004)	Minnesota	Both	46.2*	53.8
Pitt et al. (2003)	Iowa	Both	41.1	58.9
Blundell et al. (1999)	Alaska	Both	2.6	97.4
Gallagher (1999)	Missouri	Both	44.0	56.0
Docktor et al. (1987)	Maine	F	44.7	55.3
Polechla (1987)	Arkansas	Both	44.3	55.7
Kuehn and Berg (1983)	Minnesota	Both	53.9	46.1
Anderson (1981)	Virginia	Both	26.0	74.0
Lauhachinda (1978)	Georgia and Alabama	Both	8.2	91.8
Tabor (1974)	Oregon	F	36.3	63.7
Stephenson (1974)	Ontario	Both	43.5	56.5

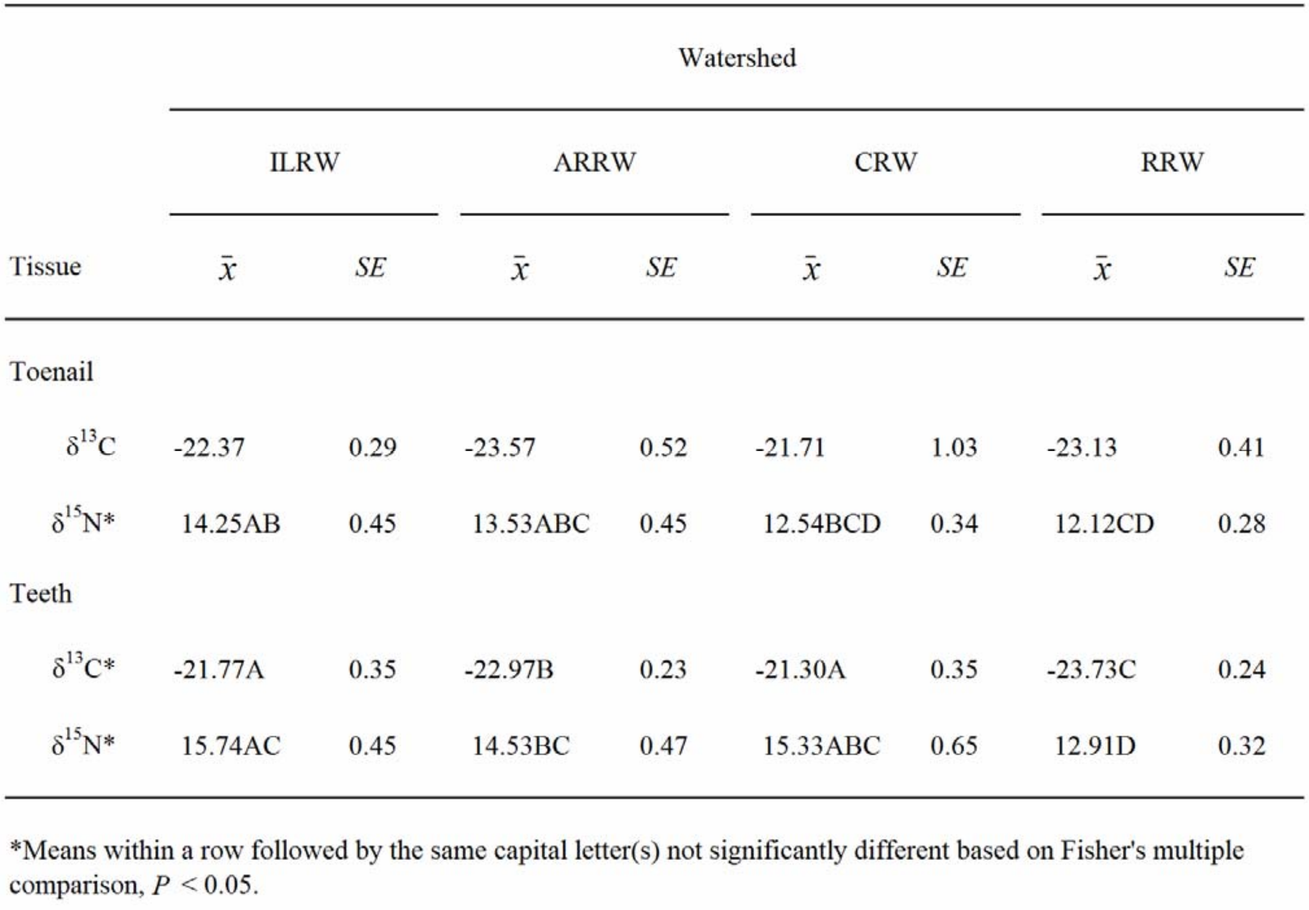
*Juveniles include individuals < 2 years old.

Table 2. Isotopic signatures of river otter liver (n = 24), muscle (n = 25), toenail (n = 49), and teeth (n = 52; 2005–2007); samples categorized by trap site (pre- and post-1996 counties).

	Pre-1996		Post-1996	
Tissue	$\bar{x}$	*SE*	$\bar{x}$	*SE*
Liver				
$\delta^{13}C$*	-26.00	0.64	-24.04	0.63
$\delta^{15}N$	13.49	0.39	12.68	0.53
Muscle				
$\delta^{13}C$*	-26.22	0.31	-25.23	0.40
$\delta^{15}N$	11.97	0.36	11.63	0.52
Toenail				
$\delta^{13}C$*	-23.33	0.32	-22.27	0.34
$\delta^{15}N$	13.20	0.34	12.86	0.29
Teeth				
$\delta^{13}C$	-22.91	0.21	-22.64	0.31
$\delta^{15}N$	14.28	0.31	14.51	0.50

*$P < 0.05$

Table 3. Isotopic signatures of river otter toenail (*n* = 49) and teeth (*n* = 48; 2005–2007); samples categorized by watershed (Illinois River Watershed [ILRW], *n* = 13, 8; Arkansas River Watershed [ARRW], *n* = 12, 18; Canadian River Watershed [CRW], *n* = 4, 6; and Red River Watershed [RRW], *n* = 20, 16).



	Watershed							
	ILRW		ARRW		CRW		RRW	
Tissue	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
Toenail								
$\delta^{13}C$	-22.37	0.29	-23.57	0.52	-21.71	1.03	-23.13	0.41
$\delta^{15}N$*	14.25AB	0.45	13.53ABC	0.45	12.54BCD	0.34	12.12CD	0.28
Teeth								
$\delta^{13}C$*	-21.77A	0.35	-22.97B	0.23	-21.30A	0.35	-23.73C	0.24
$\delta^{15}N$*	15.74AC	0.45	14.53BC	0.47	15.33ABC	0.65	12.91D	0.32

*Means within a row followed by the same capital letter(s) not significantly different based on Fisher's multiple comparison, $P < 0.05$.

FIGURES

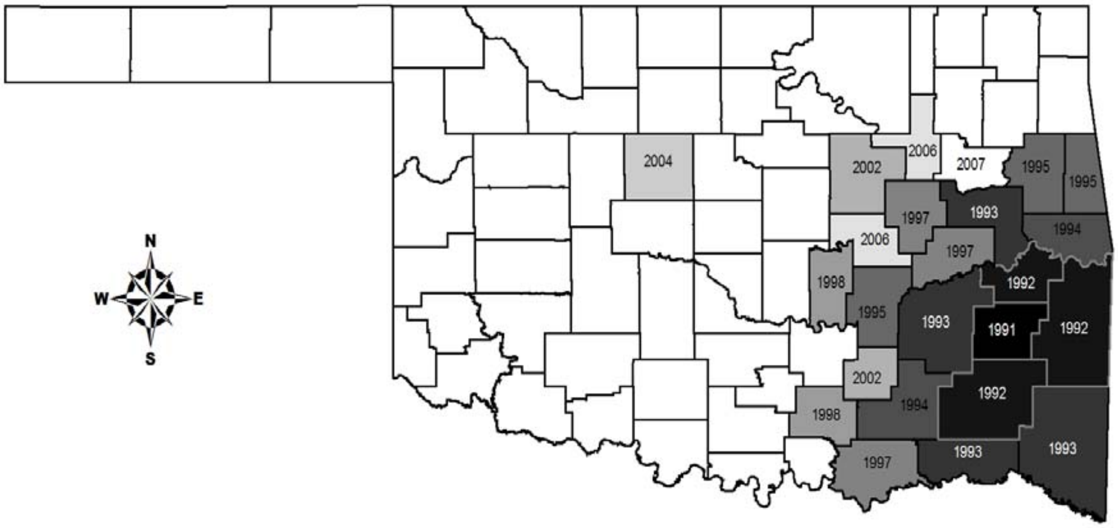


Fig. 1. Oklahoma counties where river otters have been captured by USDA Animal and Plant Health Inspection Service employees; year within each county (1991–2007) represents first year of capture.

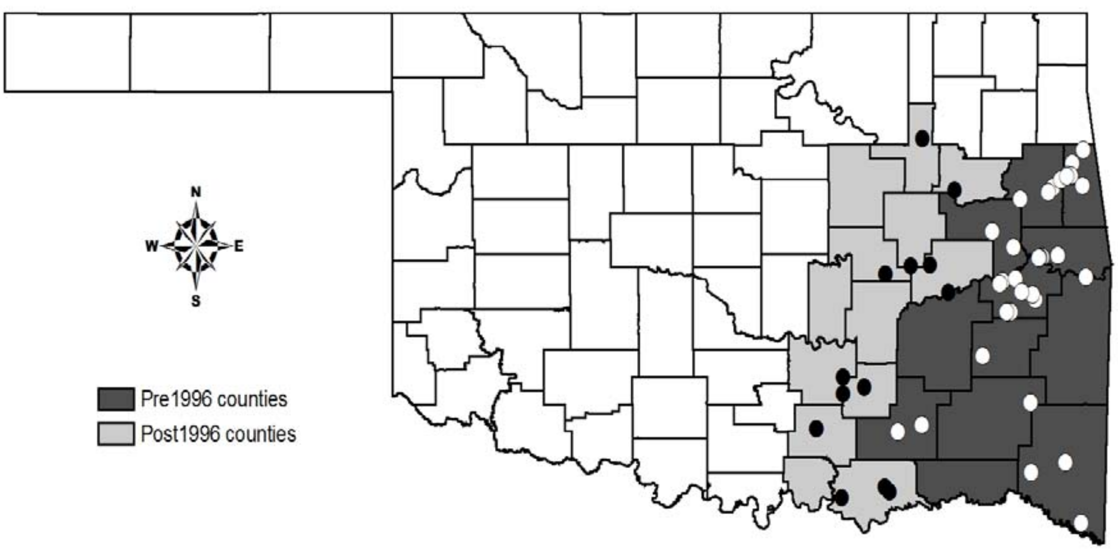


Fig. 2. River otter capture sites ($n = 58$) within pre- (empty circles) and post-1996 (shaded circles) counties (2005–2007).

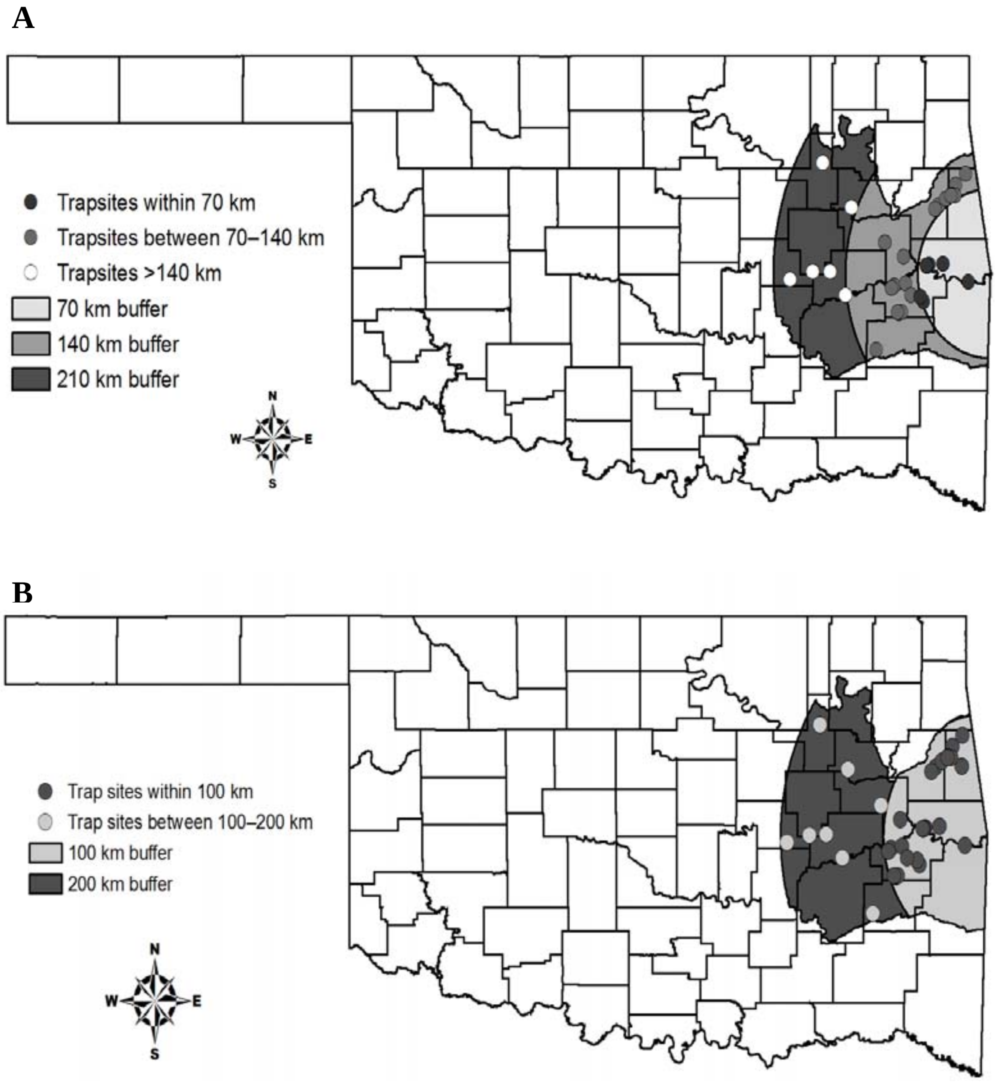


Fig. 3. River otter capture sites from the Arkansas River and its tributaries and within, A) 70, 140, and 210 km, and B) 100 and 200 km of Arkansas state border (2005–2007).

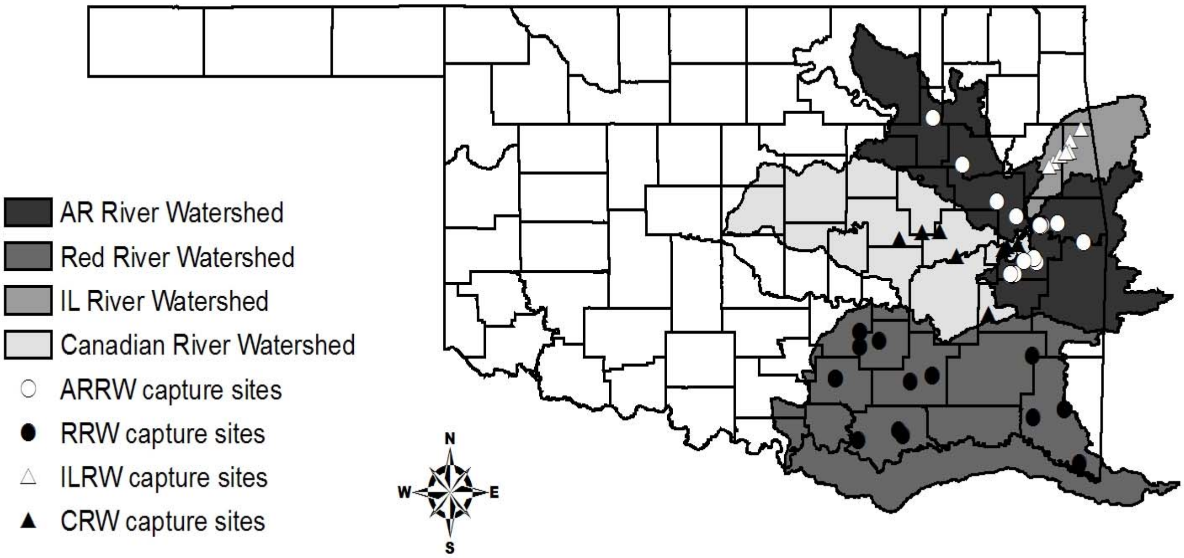


Fig. 4. River otter capture sites within 4 watersheds in eastern Oklahoma (2005–2007).

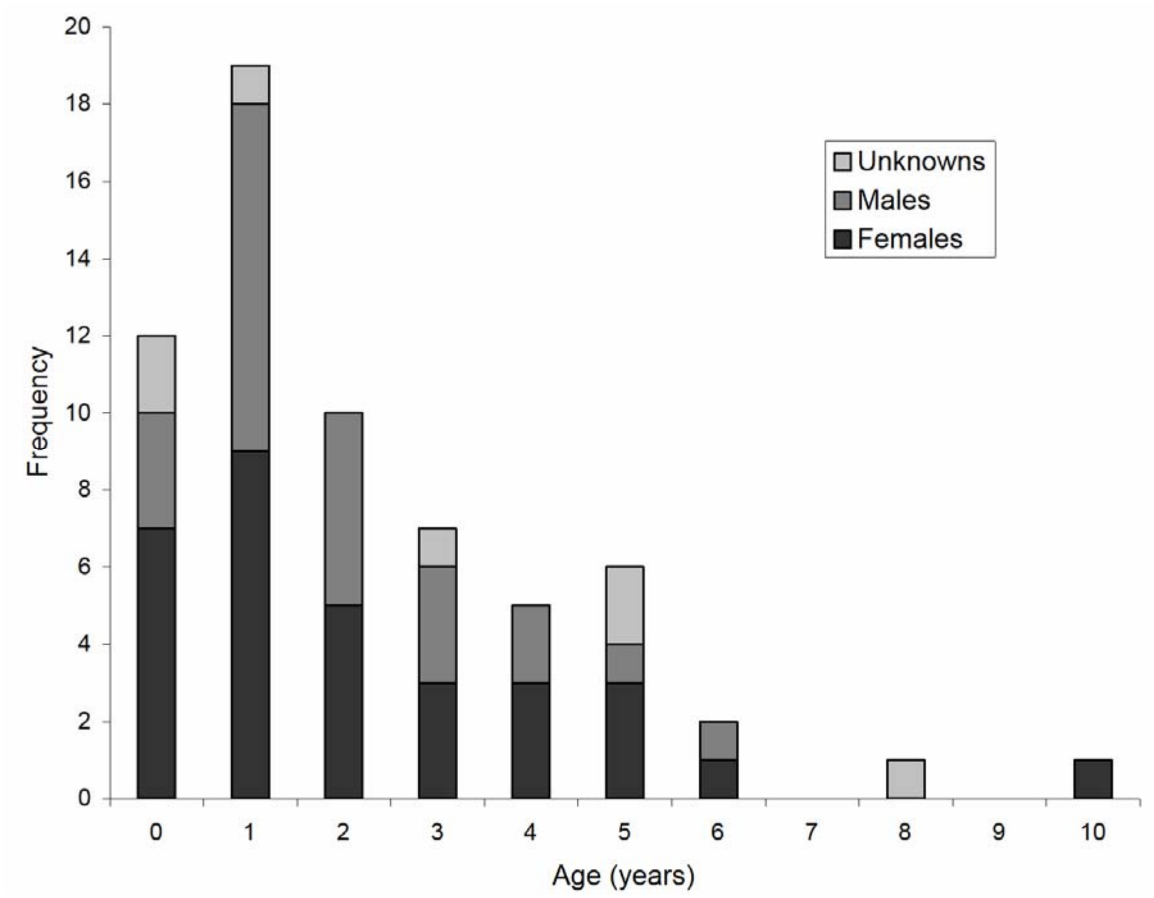


Fig. 5. Age distribution of river otters captured by USDA APHIS and OKCFWRU in Oklahoma and collected by ODWC employees (2005–2007).

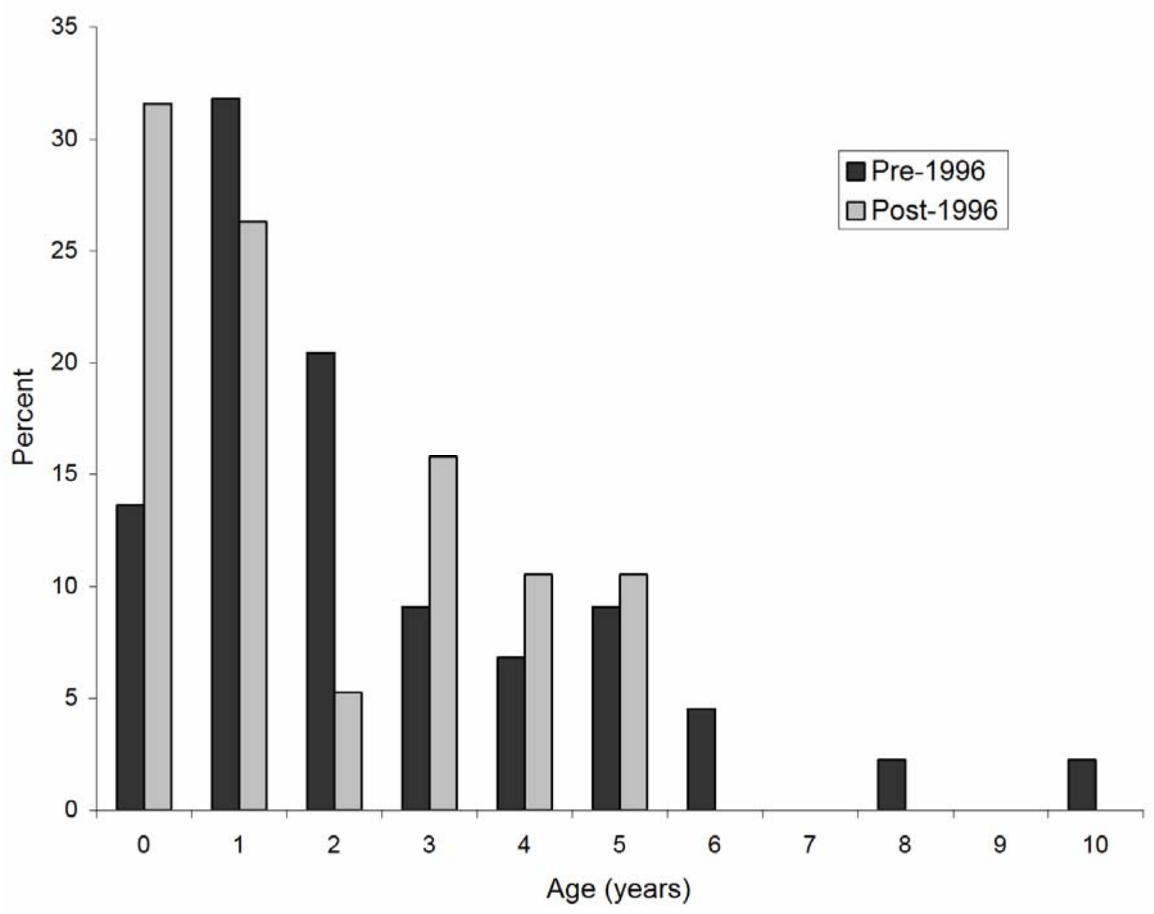


Figure 6. Age distribution of river otters captured in pre- and post-1996 counties in eastern Oklahoma (2005–2007).

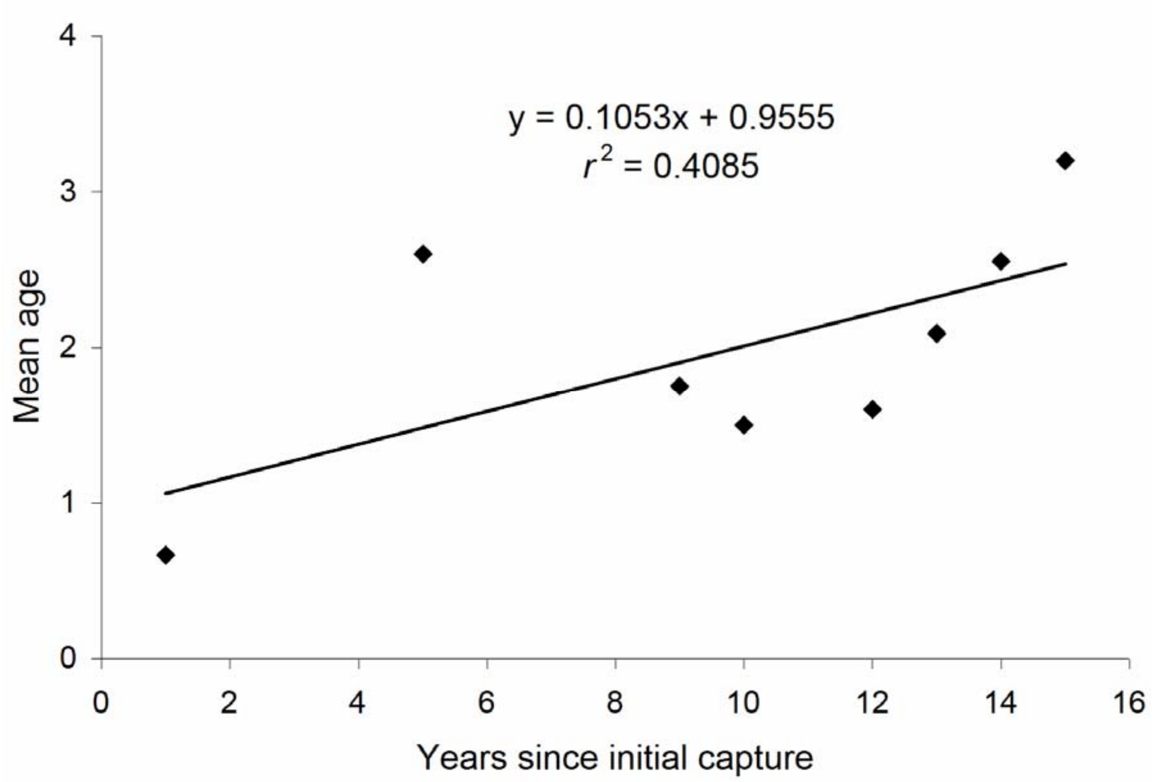


Fig. 7. Relationship between mean age and years since initial capture of river otters in Oklahoma, 1991–2007.

APPENDICES

Appendix A. Mail survey and distributional questionnaire (2005).

1. Have you trapped in Oklahoma during the last five years (2001–2005)?

☐ No → Please continue with question 3.

☐ Yes → Which year(s)? Check all that apply.

☐ 2005
☐ 2004
☐ 2003
☐ 2002
☐ 2001

2. In the last five years (2001–2005), have you accidentally caught river otters while trapping in Oklahoma? *(Reminder: Your answers to this survey are confidential.)*

☐ No → Please continue with question 3.
☐ Yes → Approximately how many and which county(s)?

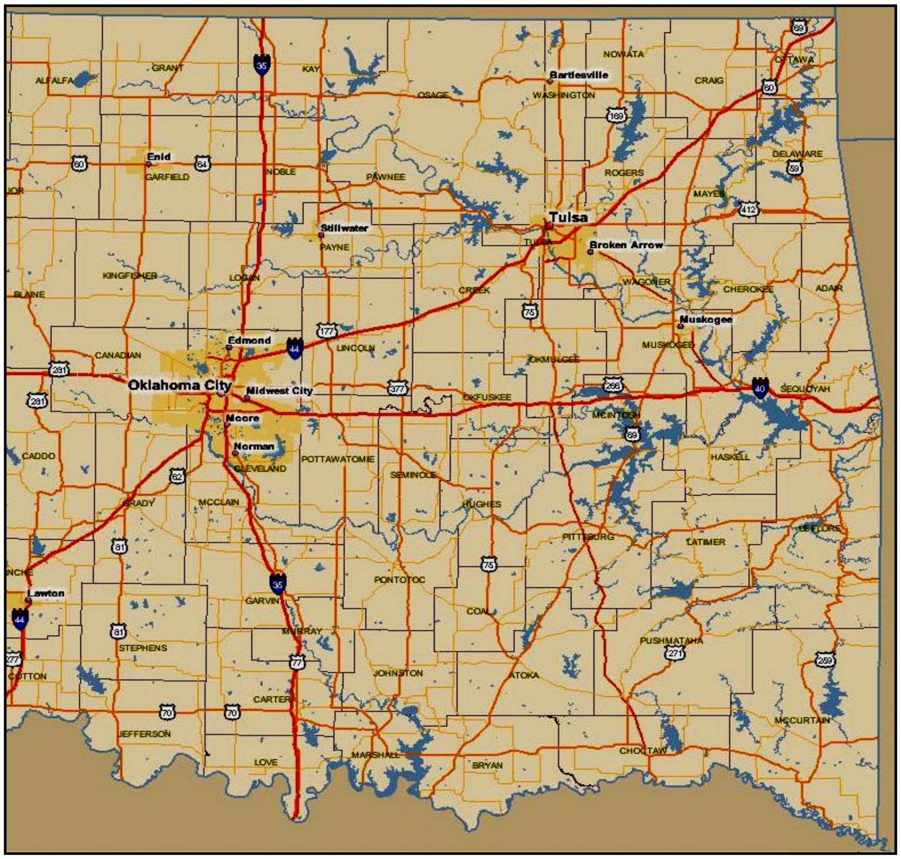
Year	Number captured	County(s)
2005		
2004		
2003		
2002		
2001		

3. Have you seen a river otter(s) in Oklahoma during the last five years (2001–2005)?

☐ No → Please continue with question 5.
☐ Yes

4. For each river otter sighting in Oklahoma during the last five years, please identify each location on the map with a dot and label each dot with a corresponding number.

Sighting Number on Map	Location *Name of water body, distance from local town (miles)*	Approximate Date *Month/year or season/year*	Description *Description of the otter(s), and circumstances of each sighting, activity (feeding, playing) , habitat, etc.*
1			
2			
3			
4			
5			

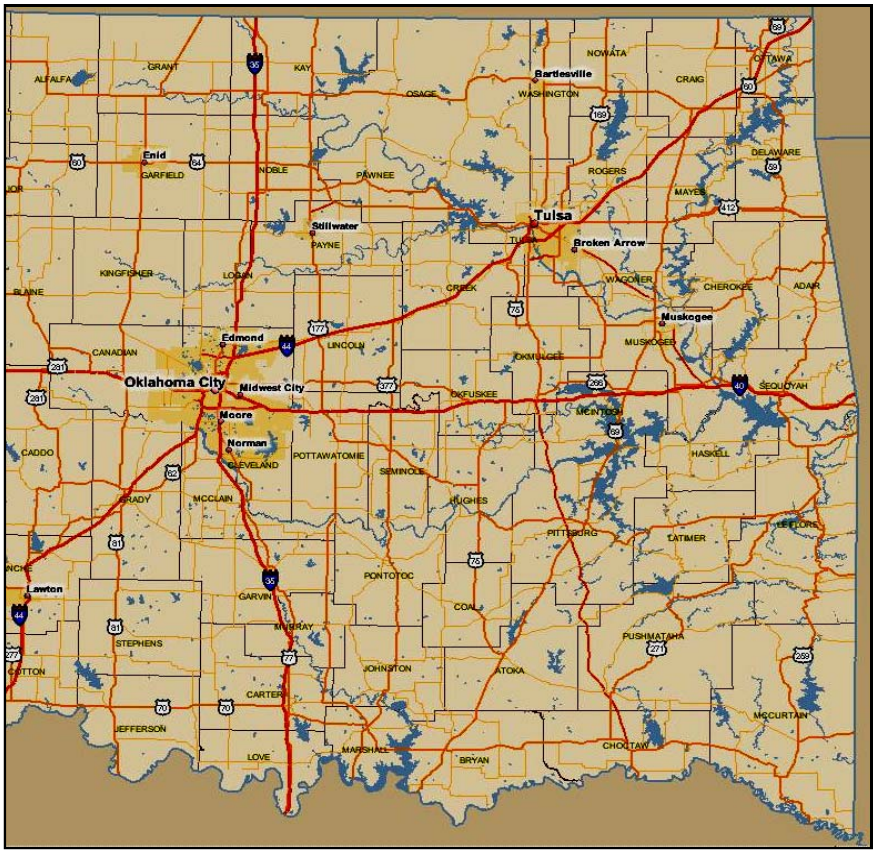


5. Have you found river otter sign in Oklahoma during the last five years (2001–2005)?

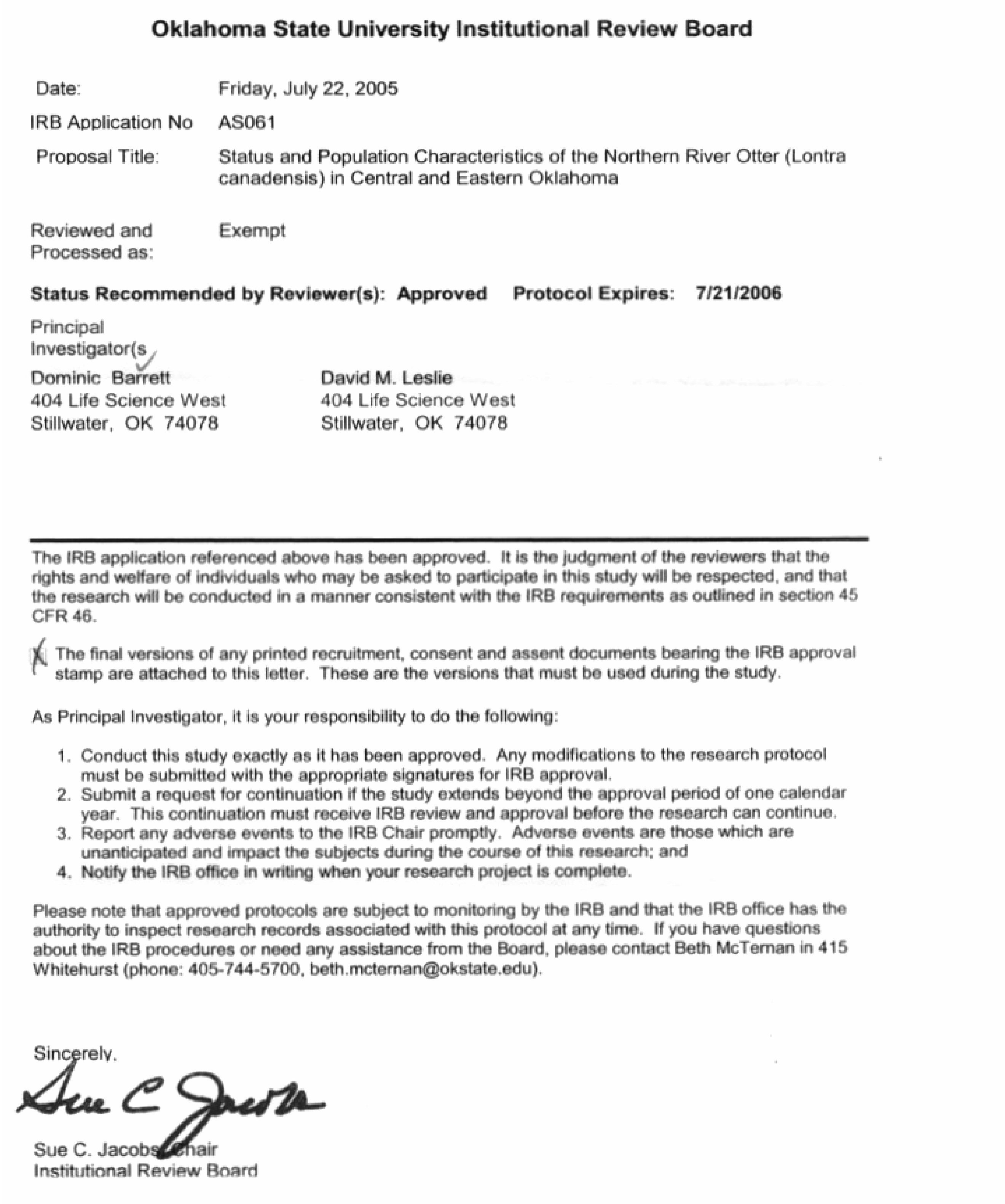
   ☐ No → You have completed the survey. Do not continue.
   ☐ Yes

6. For each river otter sign you have seen in Oklahoma during the last five years, please identify the location on the map with a dot and label each dot with a corresponding number.

Sighting Number on Map	Location *Name of water body, distance from local town (miles)*	Approximate Date *Month/year or season/year*	Description of sign *Scat, tracks, latrine, crossover, den, etc.*
1			
2			
3			
4			
5			



Appendix B. Institutional Review Board letter and approval form.



Oklahoma State University Institutional Review Board

Date:	Friday, July 22, 2005
IRB Application No	AS061
Proposal Title:	Status and Population Characteristics of the Northern River Otter (Lontra canadensis) in Central and Eastern Oklahoma
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 7/21/2006

Principal Investigator(s

Dominic Barrett 404 Life Science West Stillwater, OK 74078	David M. Leslie 404 Life Science West Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 415 Whitehurst (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Sue C Jacobs

Sue C. Jacobs, Chair
Institutional Review Board

Appendix C. Locations of sign survey sites visited in winter and spring 2006 and 2007; river otters and/or sign was recorded as present (P) or absent (A) and sites that did not contain water were not searched (NW).

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Illinois River (2006)	Flint Creek	1/16/2006	P	Latrine	36.21880836	-94.63852577
	Flint Creek	1/16/2006	P	Latrine	36.19398694	-94.70743666
	Illinois River	1/17/2006	P	Latrine	36.10431458	-94.78290849
	Illinois River	1/17/2006	P	Latrine	36.03181455	-94.91103292
	Ballard Creek	1/17/2006	P	Latrine	36.09142707	-94.58899417
	Ballard Creek	1/17/2006	P	Latrine	36.0314108	-94.56747481
	Baron Fork	1/17/2006	P	Latrine	35.94791832	-94.68877553
	Baron Fork	1/17/2006	P	Latrine	35.91927292	-94.61935803
	Baron Fork	1/17/2006	P	Latrine	35.9088672	-94.56204677
	Illinois River	1/18/2006	P	Latrine	35.92618212	-94.92384215
	Caney Creek	1/18/2006	P	Latrine	35.78497974	-94.85590146
	Unknown Creek #2	1/19/2006	P	Latrine	35.89052701	-94.94944434
	Unknown Creek #3	1/19/2006	P	Latrine	35.84464121	-94.93195323
	Illinois River	1/19/2006	P	Latrine	35.58849905	-95.06197491
	Caney Creek	1/19/2006	P	Latrine	35.84516457	-94.79118604
	Baron Fork	1/19/2006	P	Latrine	35.92157702	-94.83733177
	Tyner Creek	1/20/2006	P	Latrine	35.96602868	-94.76975385
	Tyner Creek	1/20/2006	P	Latrine	36.01090774	-94.73632171
	Evansville Creek	1/20/2006	P	Latrine	35.8312719	-94.57611605
	Unknown Creek #1	1/17/2006	NW	n/a	35.96566734	-94.867643

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Illinois River (2006)	Peacheater Creek	1/17/2006	NW	n/a	36.00229559	-94.63496991
	Elk Creek	1/19/2006	NW	n/a	35.729527	-94.90408818
	Unknown Stream D	1/19/2006	NW	n/a	35.74049547	-94.84650375
Elk River	Unknown Stream A	1/23/2006	NW	n/a	36.61222342	-94.65683328
Lake O' the Cherokees	Sycamore Creek	1/23/2006	A	No sign	36.76848762	-94.69254839
		1/24/2006	A	No sign	36.80785272	-94.64485637
	Lost Creek	1/24/2006	A	No sign	36.83482334	-94.62545461
	Neosho River	1/24/2006	A	No sign	36.79868267	-94.8193598
	Coal Creek	1/24/2006	A	No sign	36.85904268	-94.92129221
	Neosho River	1/24/2006	A	No sign	36.92901732	-94.95704664
	Tar Creek	1/24/2006	A	No sign	36.92911992	-94.85882532
	Honey Creek	1/23/2006	A	No sign	36.54189033	-94.70247005
	Tar Creek	1/24/2006	A	No sign	36.98735981	-94.84620485
	Russel Creek	1/25/2006	A	No sign	36.98772929	-95.06494571
	Fourmile Creek	1/24/2006	A	No sign	36.98680468	-94.93287692
	Unknown Stream A	1/23/2006	NW	n/a	36.4747631	-94.86722466
	Horse Creek	1/24/2006	NW	n/a	36.69762533	-94.90929108
	Cow Creek	1/24/2006	NW	n/a	36.89332835	-94.9814073
	Elm Creek	1/24/2006	NW	n/a	36.92161275	-94.91798739
	Mud Creek	1/25/2006	NW	n/a	36.94314678	-95.043971
	Russel Creek	1/25/2006	NW	n/a	36.9862943	-95.13733207
Spring River	Fivemile Creek	1/25/2006	A	No sign	36.98346902	-94.69176519
	Spring River	1/25/2006	A	No sign	36.87129878	-94.76555242

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Spring River	Spring River	1/25/2006	A	No sign	36.92592507	-94.74111632
	Warren Brook	1/25/2006	P	Latrine	36.90195476	-94.70717842
Lower Neosho River	Little Cabin Creek	1/25/2006	A	No sign	36.79400356	-95.05334943
	Little Cabin Creek	1/25/2006	A	No sign	36.67044089	-95.08394974
	Big Cabin Creek	1/26/2006	A	No sign	36.85912482	-95.16102947
	Middle Fork Big Cabin	1/26/2006	A	No sign	36.82980727	-95.24115016
	West Fork Big Cabin Creek	1/26/2006	A	No sign	36.72830997	-95.21811686
	Pryor Creek	1/26/2006	A	No sign	36.61223176	-95.37858018
		1/26/2006	A	No sign	36.55370302	-95.41716987
	Big Cabin Creek	1/27/2006	A	No sign	36.61410143	-95.16126643
	Locust Creek	1/27/2006	A	No sign	36.60576001	-95.06090647
	Big Cabin Creek	1/27/2006	A	No sign	36.51693237	-95.14001453
	Pryor Creek	1/31/2006	A	No sign	36.37991692	-95.302287
		1/31/2006	A	No sign	36.43776194	-95.34616459
		1/31/2006	A	No sign	36.48489062	-95.3997568
		2/1/2006	A	No sign	36.2928178	-95.34199996
		2/1/2006	A	No sign	36.24935076	-95.26035435
	Chouteau Creek	2/1/2006	A	No sign	36.17462408	-95.31070646
		2/1/2006	A	No sign	36.20313286	-95.35078394
	Ranger Creek	2/2/2006	A	No sign	35.88427571	-95.19998143
	Double Spring Creek	2/2/2006	A	No sign	35.95983379	-95.07621048
	Snake Creek	2/7/2006	A	No sign	36.20614875	-95.06508426
	Beaty Creek	2/9/2006	A	No sign	36.41178089	-94.61186478
	Big Cabin Creek	1/26/2006	A	No sign	36.65595143	-95.19341798

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Lower Neosho River	Bull Creek	1/26/2006	A	No sign	36.67047425	-95.12048612
	Wolf Creek	1/25/2006	NW	n/a	36.78597436	-94.99954582
	Big Cabin Creek	1/26/2006	NW	n/a	36.90496738	-95.19760097
	White Creek	1/26/2006	NW	n/a	36.67911918	-95.26958995
	White Oak Creek	1/27/2006	NW	n/a	36.5833219	-95.20250271
	Rock Creek	1/31/2006	NW	n/a	36.52437902	-95.34964241
	Chouteau Creek	2/2/2006	NW	n/a	36.26381004	-95.44583514
	Brushy Creek	2/2/2006	NW	n/a	36.15015118	-95.34177641
	Flat Rock Creek	2/2/2006	NW	n/a	36.04265059	-95.38651826
	Clear Creek	2/2/2006	NW	n/a	36.00788824	-95.20978893
	Unknown Stream A	2/9/2006	NW	n/a	36.3166587	-94.94930235
	Brush Creek	2/9/2006	NW	n/a	36.40537301	-94.79545126
	Pecan Creek	2/2/2006	NW	n/a	35.90518177	-95.08289186
	Little Cabin Creek	1/25/2006	NW	n/a	36.72883694	-95.05421008
	Big Cabin Creek	1/26/2006	NW	n/a	36.78625993	-95.18486333
	Rock Creek	1/27/2006	P	Latrine	36.45383801	-95.22023857
	Crutchfield Brook	2/1/2006	P	Latrine	36.19957206	-95.20809637
	Fourteenmile Creek	2/2/2006	P	Latrine	36.00137475	-95.06863894
		2/2/2006	P	Latrine	35.97727636	-95.15466518
	Clear Creek	2/2/2006	P	Latrine	36.02793893	-95.17207548
	Spring Creek	2/3/2006	P	Latrine	36.11831018	-95.2242198
		2/3/2006	P	Latrine	36.14826861	-95.15827434
		2/3/2006	P	Latrine	36.10414082	-95.09558785
		2/3/2006	P	Latrine	36.09054806	-95.01483525

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Lower Neosho River	Spring Creek	2/3/2006	P	Latrine	36.13984262	-94.91548003
	Saline Creek	2/8/2006	P	Latrine	36.28203557	-95.09302852
		2/9/2006	P	Latrine	36.30860335	-95.02442918
		2/9/2006	P	Latrine	36.30389147	-94.87857099
	Spavinaw Creek	2/9/2006	P	Latrine	36.4022785	-94.96344706
	Beaty Creek	2/10/2006	P	Latrine	36.35548853	-94.77617414
	Spavinaw Creek	2/10/2006	P	Latrine	36.32319164	-94.68503812
Robert S. Kerr Reservoir	Little Sallisaw Creek	2/14/2006	A	No sign	35.44929709	-94.75630769
	Camp Creek	2/13/2006	NW	n/a	35.74122855	-94.71883203
	Big Skin Bayou	2/14/2006	NW	n/a	35.51887142	-94.65484785
	Little Sans Bois	2/13/2006	P	Latrine	35.33790353	-95.00877413
	Big Skin Bayou	2/13/2006	P	Latrine	35.3729714	-94.63796309
		2/14/2006	P	Latrine	35.43443229	-94.67256141
	Sallisaw Creek	2/14/2006	P	Latrine	35.4554417	-94.85805863
		2/14/2006	P	Latrine	35.50694707	-94.83290093
		2/14/2006	P	Latrine	35.57661627	-94.83043212
		2/14/2006	P	Latrine	35.74122855	-94.71883203
		2/14/2006	P	Latrine	35.6414565	-94.77337332
	Big Lee Creek	2/15/2006	P	Observation	35.52035895	-94.46774038
	Little Lee Creek	2/15/2006	P	Latrine	35.60866876	-94.56570044
		2/15/2006	P	Latrine	35.65206438	-94.62184721
	Vian Creek	2/15/2006	P	Latrine	35.48931506	-94.9832944
	Sans Bois Creek	2/16/2006	NW	n/a	35.10026006	-95.24393924
	Unknown Stream A	2/16/2006	A	No sign	35.2507459	-94.92053255

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Robert S. Kerr Reservoir	Mountain Fork	2/16/2006	A	No sign	35.0761356	-95.13865616
	Cache Creek	2/15/2006	A	No sign	35.28265673	-94.73346532
		2/15/2006	P	Latrine	35.27784711	-94.79647326
	Sans Bois Creek	2/16/2006	P	Latrine	35.16394182	-95.10369089
		2/16/2006	P	Latrine	35.11485698	-95.17373099
	Fish Creek	2/16/2006	P	Latrine	35.15332807	-95.15605909
	Sans Bois Creek	2/16/2006	P	Latrine	35.10476525	-95.36699412
		2/16/2006	P	Latrine	35.09779905	-95.43636686
	Beaver Creek	2/16/2006	P	Latrine	35.17427025	-95.28286521
Dirty-Greenleaf Creek	Spaniard Creek	2/28/2006	NW	n/a	35.60314575	-95.34039575
	Dirty Creek	2/28/2006	A	No sign	35.51188988	-95.23848019
	Butler Creek	2/28/2006	NW	n/a	35.58091485	-95.41867895
	Shady Grove Creek	2/28/2006	NW	n/a	35.47381785	-95.4867369
	Georges Fork	2/28/2006	NW	n/a	35.43514031	-95.32599748
	Manard Bayou	2/27/2006	P	Latrine	35.79424761	-95.16271918
	Greanleaf Creek	2/27/2006	P	Latrine	35.76899151	-95.02708666
		2/27/2006	P	Latrine	35.67318678	-95.12798633
	Dirty Creek	2/27/2006	P	Latrine	35.4709478	-95.15011867
	Coody Creek	2/28/2006	P	Tracks	35.70683911	-95.34028192
	South Fork	2/28/2006	P	Tracks	35.40603717	-95.22085908
Polecat-Snake Creek	Cane Creek	2/28/2006	A	No sign	35.67979465	-95.81971169
	Cloud Creek	2/28/2006	A	No sign	35.75448789	-95.61096995
	Unknown Stream A	3/1/2006	A	No sign	35.78409294	-95.44960457
	Duck Creek	3/1/2006	A	No sign	35.8858215	-95.87263838

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Polecat-Snake Creek	Snake Creek	3/1/2006	A	No sign	35.76928605	-95.89235757
	Duck Creek	3/1/2006	A	No sign	35.87024541	-96.01577422
	Polecat Creek	3/1/2006	A	No sign	35.94552261	-96.29531262
		3/1/2006	A	No sign	36.00119563	-96.45859905
	Rock Creek	3/2/2006	A	No sign	36.0756644	-96.22602177
	Shell Creek	3/6/2006	A	No sign	36.15324545	-96.17045889
	Unknown Stream B	2/28/2006	NW	n/a	35.69669986	-95.52293424
	Cloud Creek	2/28/2006	NW	n/a	35.62429807	-95.65964685
	Cane Creek	2/28/2006	NW	n/a	35.68962176	-95.69514186
	Unknown Stream C	2/28/2006	NW	n/a	35.76611082	-95.71325214
	Concharty Creek	3/1/2006	NW	n/a	35.87766783	-95.66194081
	Polecat Creek	3/2/2006	P	Latrine	36.02472883	-96.06986641
Lower Verdigris River	Verdigris River	3/6/2006	A	No sign	36.38694531	-95.67695833
	Dog Creek	3/6/2006	A	No sign	36.39428585	-95.52378709
	Bull Creek	3/8/2006	A	No sign	36.02895766	-95.49367871
	Coal Creek	3/8/2006	A	No sign	36.04308385	-95.58321144
	Salt Creek	3/8/2006	A	No sign	36.15138223	-95.6726994
	Dog Creek	3/8/2006	P	Latrine	36.2945469	-95.60149371
	Verdigris River	3/8/2006	P	Latrine	35.88548245	-95.4247943
Middle Verdigris River	California Creek	3/12/2006	A	No sign	36.78612214	-95.67348361
		3/12/2006	A	No sign	36.89874751	-95.73790566
	Cedar Creek	3/12/2006	A	No sign	36.85153744	-95.55196429
	Madden Creek	3/27/2006	A	No sign	36.65172603	-95.46755559
	Opossum Creek	3/12/2006	A	No sign	36.96916756	-95.73255717

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Middle Verdigris River	Salt Creek	3/27/2006	A	No sign	36.68009676	-95.48576728
	Snow Creek	3/12/2006	A	No sign	36.96076144	-95.55218372
	Talala Creek	3/12/2006	A	No sign	36.55826831	-95.66876879
	Unknown Stream A	3/27/2006	A	No sign	36.66367435	-95.62955892
	Big Creek	3/12/2006	NW	n/a	36.7797487	-95.46803906
		3/12/2006	NW	n/a	36.90501214	-95.39561279
	Panther Creek	3/27/2006	NW	n/a	36.62057402	-95.46749666
	Unknown Stream B	3/27/2006	NW	n/a	36.52480013	-95.51816468
Lower Canadian River	Unknown Stream A	3/25/2006	A	No sign	34.98605755	-95.56912355
	Longtown Creek	3/25/2006	A	No sign	35.17499596	-95.45131205
	Chum Creek	4/4/2006	A	No sign	34.75302371	-95.86120069
	Elm Creek	4/5/2006	A	No sign	34.71154595	-95.66235948
	Brushy Creek	4/5/2006	A	No sign	34.87123914	-95.5871081
	Gaines Creek	4/5/2006	A	No sign	34.90193493	-95.49037381
	Buffalo Creek	4/5/2006	A	No sign	34.79617132	-95.48317376
	Canadian River	3/25/2006	A	No sign	35.26530099	-95.23830685
	Mill Creek	3/24/2006	P	Tracks	35.23115111	-95.83998299
	Rock Creek	3/24/2006	P	Latrine	35.12536109	-95.77187559
	Taloka Creek	3/25/2006	P	Latrine	35.2959941	-95.13258121
	Coal Creek	4/4/2006	P	Tracks	34.98264964	-95.82390214
		4/4/2006	P	Latrine	34.86942287	-96.00961913
	Big Wildhoarse Creek	4/4/2006	P	Latrine	34.95749722	-95.9655574
	Peaceable Creek	4/5/2006	P	Latrine	34.8373154	-95.74185798
	Brushy Creek	4/5/2006	P	Latrine	34.65314881	-95.79451913

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Lower Canadian River	Gaines Creek	4/5/2006	P	Latrine	34.81040312	-95.34862108
	Unknown Stream B	4/4/2006	P	Latrine	34.97069361	-96.14824357
Bird Creek	Bird Creek	3/29/2006	A	No sign	36.20296111	-95.75854325
	Delaware Creek	3/29/2006	A	No sign	36.27214191	-96.03164602
	Quapaw Creek	3/29/2006	A	No sign	36.36136525	-96.06883351
	Bird Creek	3/30/2006	A	No sign	36.39523929	-95.99136796
		3/30/2006	A	No sign	36.53739545	-96.15568385
	Candy Creek	3/30/2006	A	No sign	36.5268252	-96.04923268
	Birch Creek	3/30/2006	A	No sign	36.5743557	-96.31138265
	Hominy Creek	3/31/2006	A	No sign	36.423118	-96.33871076
		3/31/2006	A	No sign	36.50997162	-96.44789779
	Little Hominy Creek	3/31/2006	A	No sign	36.57532297	-96.44531063
	Bird Creek	3/31/2006	A	No sign	36.6314844	-96.24190204
	Clear Creek	4/6/2006	A	No sign	36.63364442	-96.42090973
	Middle Bird Creek	4/6/2006	A	No sign	36.73718247	-96.46672153
	Bird Creek	3/29/2006	P	Latrine	36.24796095	-95.86788551
Caney River	Cotton Creek	3/13/2006	A	No sign	36.93795822	-95.84607404
	Mission Creek	3/13/2006	A	No sign	36.89337588	-96.07368596
	Caney River	3/13/2006	A	No sign	36.98989693	-96.29261926
	Buck Creek	3/13/2006	A	No sign	36.94048729	-96.4268769
	Sand Creek	3/14/2006	A	No sign	36.75894415	-96.31436669
	Pond Creek	3/14/2006	A	No sign	36.93076244	-96.27821781
	Sand Creek	3/14/2006	A	No sign	36.7369	-96.20795189
	Caney River	3/28/2006	A	No sign	36.6701347	-95.97906416

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Caney River	Sand Creek	3/28/2006	A	No sign	36.73240093	-96.08030104
	Caney River	3/28/2006	A	No sign	36.82962899	-95.95975729
	Coon Creek	3/28/2006	A	No sign	36.81496485	-95.87139065
	Hogshooter Creek	3/28/2006	A	No sign	36.69890299	-95.84595543
	Curl Creek	3/28/2006	A	No sign	36.65560006	-95.80024062
	Caney River	3/28/2006	A	No sign	36.50891156	-95.84266118
	Horsepen Creek	3/28/2006	A	No sign	36.38990924	-95.84818158
Lower Little River (Southeastern OK)	Rock Creek	4/12/2006	A	No sign	34.16201103	-94.56685354
		4/12/2006	P	Latrine	34.06511966	-94.4752877
	Robinson Creek	4/12/2006	P	Latrine	34.26954556	-94.48621385
	Buck Creek	4/12/2006	NW	n/a	33.95423186	-94.48495539
Mountian Fork	Mountain Fork	4/10/2006	A	No sign	34.64170173	-94.45736309
	Luksuklo Creek	4/12/2006	A	No sign	34.05987888	-94.57982554
	Mountain Fork	4/10/2006	P	Latrine	34.48699283	-94.51472481
	Big Eagle Creek	4/11/2006	P	Latrine	34.52728573	-94.71856649
	Buffalo Creek	4/11/2006	P	Latrine	34.38128388	-94.5473574
	Boktuklo Creek	4/11/2006	P	Latrine	34.45378927	-94.73305729
	Mountain Fork	4/11/2006	P	Latrine	34.38882608	-94.69591205
		4/11/2006	P	Latrine	34.13787542	-94.68760433
Pecan-Waterhole Creek	Red River	4/13/2006	A	No sign	33.68688527	-94.69442728
	McKinney Creek	4/12/2006	P	Latrine	33.73603667	-94.51078439
	Push Creek	4/13/2006	P	Latrine	33.73325178	-94.64187099
	Waterfall Creek	4/13/2006	P	Latrine	33.80863904	-94.79252354
		4/13/2006	P	Latrine	33.84126971	-94.90284456

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Pecan-Waterhole Creek	Red River	4/13/2006	P	Latrine	33.86139784	-95.03142991
	Clear Creek	4/13/2006	P	Tracks	34.01405116	-95.15592305
Poteau River	James Fork	4/17/2006	A	No sign	35.16156823	-94.50596379
	Sugar Loaf Creek	4/18/2006	A	No sign	34.99192874	-94.48029254
	Brazil Creek	4/19/2006	A	No sign	35.09871704	-94.88181948
		4/19/2006	A	No sign	35.01457614	-94.96299393
	Rock Creek	4/20/2006	A	No sign	35.00924877	-95.06246558
	Unknown Creek	4/17/2006	P	Latrine	35.27809303	-94.46560375
	Riddle Creek	4/17/2006	P	Latrine	35.08514011	-94.46766998
	Morris Creek	4/18/2006	P	Latrine	34.94947348	-94.61381667
	Poteau River	4/18/2006	P	Latrine	34.85864583	-94.56604628
	Big Creek	4/18/2006	P	Latrine	34.74553239	-94.52760503
	Black Fork	4/18/2006	P	Latrine	34.77332233	-94.61003719
	Holson Creek	4/18/2006	P	Latrine	34.82346875	-94.87644567
	Fouche Maline	4/20/2006	P	Latrine	34.9148998	-94.93534941
		4/24/2006	P	Latrine	34.96063591	-95.35326306
	Bandy Creek	4/24/2006	P	Latrine	34.90202487	-95.26142984
	Caston Creek	4/25/2006	P	Latrine	34.96273491	-94.82233923
Upper Little River (Southeastern OK)	Mud Creek	1/10/2007	P	Latrine	33.89533432	-94.70509426
	Yanubbe River	1/10/2007	P	Observation	34.02651815	-94.71150172
	Yashaua Creek	1/10/2007	P	Latrine	34.09400093	-94.77168353
	Lukfata Creek	1/11/2007	P	Latrine	34.08400241	-94.81933541
	Glover River	1/11/2007	A	No sign	34.13775916	-94.90094044
		1/11/2007	P	Latrine	34.2550898	-94.91481266

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Upper Little River	Coon Creek	1/11/2007	P	Latrine	34.35574053	-94.87213276
(Southeastern OK)	West Fork of the Glover River	1/11/2007	P	Latrine	34.36805363	-94.92507211
	Cypress Creek	1/25/2007	P	Latrine	34.17301923	-95.03919985
	Long Creek	1/25/2007	A	No sign	34.22931712	-95.0449029
	Terrapin Creek	1/25/2007	P	Latrine	34.25552784	-95.09843887
	Little River	1/26/2007	P	Latrine	34.32574145	-95.19852432
	Cloudy Creek	1/26/2007	A	No sign	34.2805816	-95.32289232
	Pickens Creek	1/27/2007	P	Latrine	34.41258408	-95.11896187
	Little River	1/27/2007	P	Latrine	34.47363359	-95.1867247
		1/27/2007	P	Latrine	34.52908206	-95.01512527
		1/27/2007	P	Latrine	34.53970151	-94.84763397
	Lukfata Creek	2/19/2007	P	Latrine	33.96816627	-94.7656028
	Little River	2/20/2007	A	No sign	34.06982769	-95.04650242
Kiamichi River	Billy Creek	1/28/2007	A	No sign	34.68482033	-94.73696946
	Kiamichi River	1/28/2007	A	No sign	34.68270583	-94.88537299
	Unknown Stream A	1/28/2007	A	No sign	34.70969179	-94.99868433
	Buck Creek	2/7/2007	A	No sign	34.52898667	-95.75621056
	West Fork Anderson Creek	2/8/2007	A	No sign	34.713237	-95.41028338
	Kiamichi River	1/27/2007	P	Latrine	34.63740416	-94.65336987
	North Jack Fork	1/28/2007	P	Tracks	34.66035658	-95.54959338
	Cedar Creak	2/5/2007	P	Latrine	34.05125432	-95.36508506
	Frazier Creek	2/5/2007	P	Latrine	34.16698351	-95.36896496
	Northfork Creek	2/6/2007	P	Tracks	34.07390842	-95.50430864
	Dumpling Creek	2/6/2007	P	Latrine	34.18528263	-95.60836142

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Kiamichi River	Rock Creek	2/06/007	P	Latrine	34.24321381	-95.38906074
	Big Waterhole Creek	2/6/2007	P	Latrine	34.25525148	-95.46356161
	Big Cedar Creek	2/6/2007	P	Latrine	34.33000532	-95.48146184
		2/7/2007	P	Latrine	34.45273574	-95.34659777
	Kiamichi River	2/7/2008	P	Tracks	34.42728519	-95.57823904
		2/7/2007	P	Tracks	34.54014458	-95.4647961
	Jack Fork Creek	2/8/2007	P	Latrine	34.60523006	-95.33446345
	Buffalo Creek	2/8/2007	P	Latrine	34.72864327	-95.23543739
Lower Washita River	Cumberland Cut	2/21/2007	P	Tracks	34.09633311	-96.55412626
	Washita River	2/21/2007	P	Tracks	34.21786945	-96.80245933
		2/21/2007	A	No sign	34.23042253	-96.90969514
	Pennington Creek	2/27/2007	P	Latrine	34.31987495	-96.70587433
		2/27/2007	P	Latrine	34.42068410	-96.75854570
	Rock Creek	2/28/2007	P	Latrine	34.28864105	-96.74537715
	Mill Creek	2/28/2007	P	Latrine	34.38897243	-96.84560451
Clear Boggy Creek	Clear Boggy Creek	3/21/2007	P	Latrine	34.10009055	-95.88604096
		3/21/2007	P	Latrine	34.16799411	-96.05089028
		3/21/2007	P	Latrine	34.25144006	-96.20507975
		3/21/2007	P	Latrine	34.36451378	-96.32065899
	Delaware Creek	3/21/2007	P	Latrine	34.3900096	-96.49616724
	Clear Boggy Creek	3/22/2007	P	Latrine	34.61520108	-96.57218398
	Goose Creek	3/22/2007	P	Latrine	34.54570044	-96.44304165
Deep Fork	Unknown Stream A	3/1/2007	A	No sign	35.53662462	-95.67645047
	Unknown Steram B	3/1/2007	A	No sign	35.44178163	-95.87988705

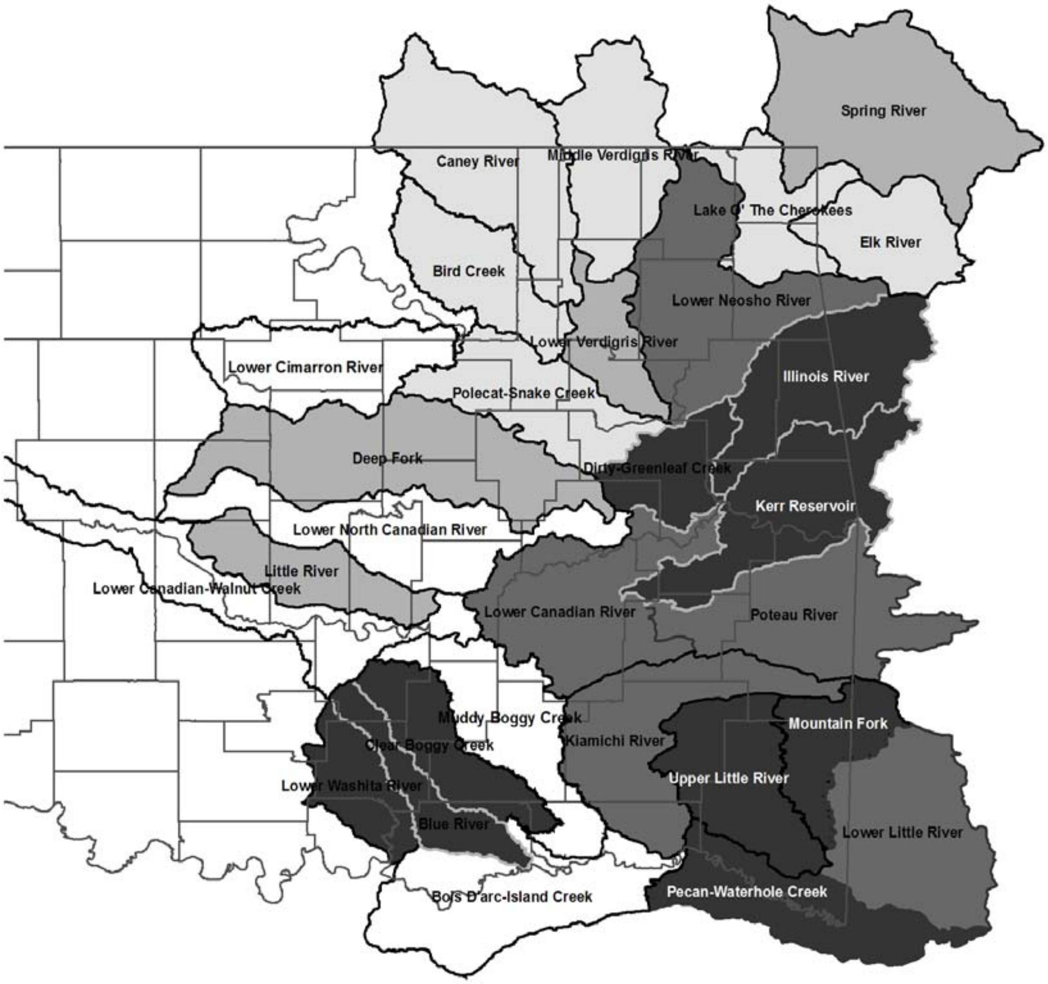
Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Deep Fork	Deep Fork	3/1/2007	A	No sign	35.61332121	-96.02300134
	Cussetah Creek	3/8/2007	P	Latrine	35.61557570	-95.90871602
	Deep Fork	3/8/2007	P	Tracks	35.70428875	-96.13958540
	Adams Creek	3/8/2007	P	Latrine	35.72638839	-96.05977208
	Nuyaka Creek	3/15/2007	A	No sign	35.59516920	-96.21099637
	Hilliby Creek	4/17/2007	A	No sign	35.62458373	-96.53277922
	Deep Fork	4/17/2007	P	Tracks	35.68530156	-96.66257861
		4/17/2007	P	Latrine	35.64272946	-96.82227490
		4/17/2007	A	No sign	35.67942359	-96.98176618
		4/23/2007	A	No sign	35.70149364	-97.15898300
	Coffee Creek	4/23/2007	A	No sign	35.66296874	-97.35368136
Blue River	Blue River	3/19/2007	P	Latrine	33.98290736	-96.24547466
	Bokchito Creek	3/19/2007	P	Tracks	34.01177631	-96.12288262
	Blue River	3/20/2007	P	Latrine	34.06347253	-96.34214893
		3/20/2007	P	Latrine	34.25055502	-96.54919887
		3/20/2007	P	Latrine	34.36179075	-96.5889187
	Unknown Steam A	3/20/2007	NW	n/a	34.54933693	-96.69244551
	Blue River	3/20/2007	P	Latrine	34.45518804	-96.63611175
Lower Cimarron River	Cimarron River	3/16/2007	A	No sign	36.06045954	-96.59367652
	House Creek	3/16/2007	A	No sign	36.17502918	-96.48182111
Illinois River (2007)	Illinois River	4/4/2007	P	Latrine	35.58849905	-95.06197491
	Caney Creek	4/4/2007	P	Latrine	35.78497974	-94.85590146
	Baron Fork	4/4/2007	P	Latrine	35.92157702	-94.83733177
		4/4/2007	P	Latrine	35.94791832	-94.68877553

Appendix C. Continued

Watershed	Stream	Date	Sign	Type of Sign	Latitude	Longitude
Illinois River (2007)	Baron Fork	4/4/2007	P	Latrine	35.90886720	-94.56204677
	Illinois River	4/4/2007	P	Latrine	35.92618212	-94.92384215
		4/4/2007	P	Latrine	36.03181455	-94.91103292
		4/5/2007	P	Latrine	36.10431458	-94.78290849
	Flint Creek	4/5/2007	P	Latrine	36.21880836	-94.63852577
	Ballard Creek	4/5/2007	P	Latrine	36.09142707	-94.58899417
Muddy Boggy Creek	McGee Creek	4/10/2007	P	Tracks	34.50665460	-95.83011883
	Muddy Boggy Creek	4/10/2007	P	Tracks	34.35323283	-96.00521084
	North Boggy Creek	4/10/2007	P	Tracks	34.43921976	-96.06768846
Little River (Central OK)	Little River	5/21/2007	P	Tracks	34.96552809	-96.51222571
		5/21/2007	A	No sign	35.11263753	-96.63178668
		5/21/2007	A	No sign	35.15847338	-96.75599442
		5/21/2007	A	No sign	35.17264366	-96.93178355
	Salt Creek	5/22/2007	A	No sign	35.04771207	-96.67002015
		5/22/2007	A	No sign	35.10222847	-96.87941409
	Little River	5/22/2007	P	Latrine	35.22237249	-97.21364214
Middle Washita River	Caddo Creek	6/12/2007	P	Tracks	34.28342038	-97.28271338
		6/12/2007	A	No sign	34.35776224	-97.43963267
	Rock Creek	6/12/2007	A	No sign	34.48962282	-96.99069835

Appendix D. Watersheds of eastern Oklahoma.



Appendix E. River otter death report (2005).

1. Date of capture (MM/DD/YYYY): ___________________

2. Sex: ☐ Male ☐ Female

3. Approximate age: ☐ Juvenile ☐ Adult

4. Local town: _________________; distance from local town: __________ miles; coordinates if available: ___________________________________

5. Locate the capture site on the map below, mark with a dot and a "C."

7. What type of trap was in use when the otter was captured?

- ☐ Leg hold trap
- ☐ Conibear trap
- ☐ Snare
- ☐ Live trap
- ☐ Other: _______________

8. Which of the following best describes the trapper who captured the otter? Check all that apply.

- ☐ Recreational trapper
- ☐ Professional trapper/Contractor
- ☐ ODWC employee
- ☐ USDA APHIS, Wildlife Services employee
- ☐ USFWS
- ☐ Other: _______________

Appendix F. Stable istotope signatures ($\delta^{13}C$, $\delta^{15}N$) of river otter liver, muscle, toenail, and teeth from pre- and post-1996 counties (2005–2007).

	Pre-1996		Post-1996	
Tissue	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Liver	-26.43	13.95	-24.41	15.89
	-24.09	13.94	-26.00	15.03
	-24.18	12.73	-24.24	11.21
	-23.55	13.63	-24.29	11.34
	-28.77	13.39	-22.81	12.35
	-28.49	13.24	-22.07	13.30
	-28.75	12.12	-21.80	13.41
	-28.36	11.31	-21.49	13.31
	-25.18	12.37	-21.13	14.21
	-26.32	13.82	-26.51	10.71
	-22.32	16.50	-26.29	9.89
	-25.52	14.86	-27.43	11.50
Muscle	-25.03	12.20	-25.31	14.35
	-26.52	13.53	-23.44	11.36
	-27.69	10.65	-23.67	10.90
	-26.85	11.08	-26.63	12.60
	-27.64	8.98	-25.74	11.85
	-26.21	10.02	-25.73	9.85
	-25.89	12.73	-26.08	12.10
	-28.38	10.48	-25.28	10.02
	-27.90	11.99	-	-
	-25.08	11.99	-	-
	-23.88	11.70	-	-
	-24.74	14.03	-	-
	-24.87	14.65	-	-
	-26.86	12.22	-	-

Appendix F. Continued

	Pre-1996		Post-1996	
Tissue	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Muscle	-26.81	13.04	-	-
	-25.69	11.19	-	-
	-25.64	12.95	-	-
Toenail	-22.58	13.32	-22.56	15.97
	-22.33	14.13	-24.35	13.75
	-22.04	14.16	-20.74	12.22
	-26.58	10.38	-19.31	12.33
	-22.26	15.07	-23.04	13.54
	-24.28	13.42	-23.76	12.09
	-25.20	14.10	-23.45	10.79
	-21.65	14.10	-23.28	14.08
	-22.25	13.14	-22.65	11.61
	-26.75	10.85	-23.00	11.49
	-22.46	11.17	-20.99	12.34
	-24.95	12.23	-20.88	12.38
	-26.08	12.14	-22.56	13.29
	-24.88	10.76	-24.72	13.1
	-26.90	10.74	-22.20	11.21
	-23.18	10.36	-22.90	14.06
	-24.74	10.50	-20.69	12.49
	-23.58	13.19	-19.83	13.46
	-22.36	12.50	-22.19	14.22
	-21.96	13.77	-	-
	-22.91	13.22	-	-
	-22.76	18.04	-	-
	-22.84	13.07	-	-
	-23.93	13.92	-	-
	-20.24	16.52	-	-
	-21.10	15.95	-	-
	-22.31	13.46	-	-
	-22.94	13.11	-	-
	-21.85	14.23	-	-

Appendix F. Continued

	Pre-1996		Post-1996	
Tissue	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Toenail	-22.02	14.39	-	-
Teeth	-22.35	13.57	-23.28	18.94
	-22.31	19.30	-20.85	14.54
	-21.99	15.75	-20.19	16.91
	-23.79	14.28	-22.16	13.67
	-24.01	14.71	-22.06	14.15
	-23.90	13.76	-20.53	17.63
	-23.09	13.68	-22.55	13.32
	-23.75	11.48	-23.39	12.39
	-23.89	14.87	-22.54	14.98
	-21.91	13.42	-24.02	14.36
	-20.94	13.23	-22.65	13.68
	-24.19	14.63	-23.68	13.31
	-22.97	12.56	-22.45	12.72
	-21.92	14.46	-24.17	13.77
	-22.13	13.67	-23.68	11.58
	-23.11	12.96	-23.97	16.23
	-21.98	15.09	-	-
	-24.78	12.22	-	-
	-24.12	13.27	-	-
	-22.90	10.24	-	-
	-25.57	12.50	-	-
	-23.42	14.56	-	-
	-25.00	12.54	-	-
	-24.83	11.07	-	-
	-22.72	13.87	-	-
	-22.71	13.71	-	-
	-21.76	15.87	-	-
	-22.47	16.00	-	-
	-20.10	17.33	-	-
	-20.59	16.45	-	-

Appendix F. Continued

	Pre-1996		Post-1996	
Tissue	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
Teeth	-21.58	16.32	-	-
	-22.23	16.34	-	-
	-23.31	15.02	-	-
	-23.00	16.80	-	-
	-24.06	13.62	-	-
	-21.25	14.79	-	-

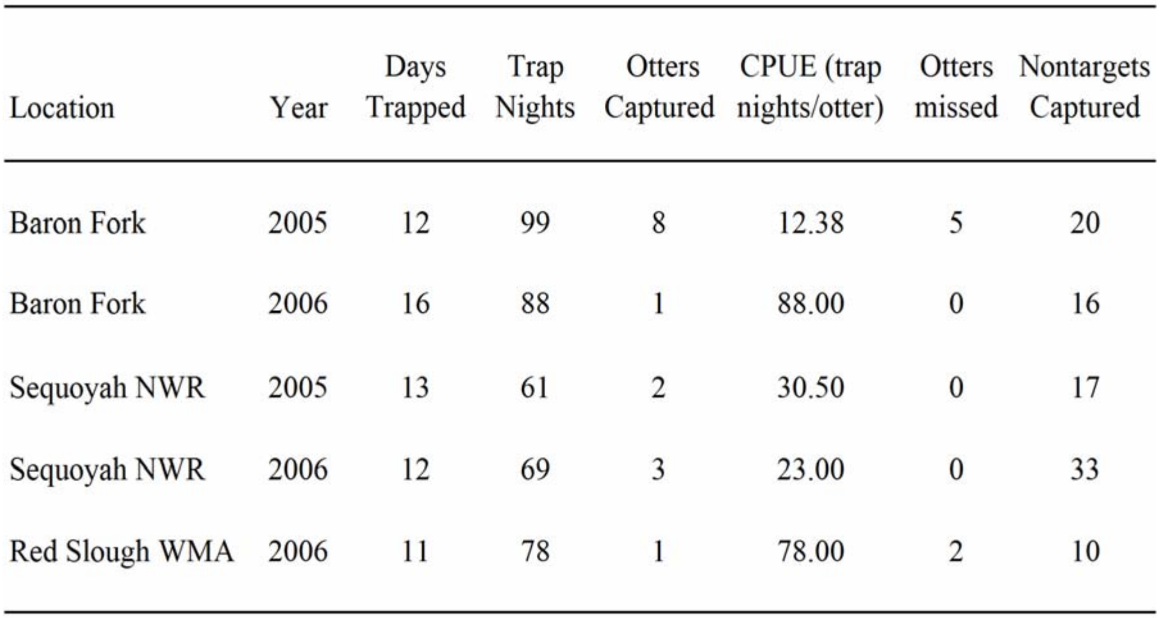
Appendix G. Stable isotope signatures ($\delta^{13}C$, $\delta^{15}N$) of river otter toenails and teeth from 4 watersheds (Illinois River Watershed [ILRW], Arkansas River Watershed [ARRW], Canadian River Watershed [CRW], Red River Watershed [RRW]) in eastern Oklahoma (2005–2007).

	Toenail		Teeth	
Watershed	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
ILRW	-23.58	13.19	-22.72	13.87
	-22.36	12.5	-22.71	13.71
	-21.96	13.77	-21.76	15.87
	-22.91	13.22	-22.47	16
	-22.76	18.04	-20.1	17.33
	-22.84	13.07	-20.59	16.45
	-23.93	13.92	-21.58	16.32
	-20.24	16.52	-22.23	16.34
	-21.1	15.95	-	-
	-22.31	13.46	-	-
	-22.94	13.11	-	-
	-21.85	14.23	-	-
	-22.02	14.39	-	-
ARRW	-22.56	15.97	-23.28	18.94
	-22.58	13.32	-22.35	13.57
	-22.33	14.13	-22.31	19.3
	-22.04	14.16	-21.99	15.75
	-26.58	10.38	-23.79	14.28
	-22.26	15.07	-24.01	14.71
	-24.28	13.42	-23.9	13.76
	-25.2	14.1	-23.09	13.68
	-21.65	14.1	-23.75	11.48
	-22.25	13.14	-23.89	14.87
	-24.35	13.75	-21.91	13.42
	-26.75	10.85	-20.94	13.23

Appendix G. Continued

	Toenail		Teeth	
Watershed	$\delta^{13}C$	$\delta^{15}N$	$\delta^{13}C$	$\delta^{15}N$
ARRW	-	-	-24.19	14.63
	-	-	-22.97	12.56
	-	-	-21.92	14.46
	-	-	-23.97	16.23
	-	-	-22.13	13.67
	-	-	-23.11	12.96
CRW	-20.74	12.22	-20.85	14.54
	-19.31	12.33	-21.98	15.09
	-23.04	13.54	-20.19	16.91
	-23.76	12.09	-22.16	13.67
	-	-	-22.06	14.15
	-	-	-20.53	17.63
RRW	-23.45	10.79	-22.55	13.32
	-23.28	14.08	-23.39	12.39
	-22.65	11.61	-22.54	14.98
	-23	11.49	-24.02	14.36
	-20.99	12.34	-22.65	13.68
	-20.88	12.38	-23.68	13.31
	-22.56	13.29	-22.45	12.72
	-24.72	13.1	-24.17	13.77
	-22.2	11.21	-23.68	11.58
	-22.9	14.06	-24.78	12.22
	-20.69	12.49	-24.12	13.27
	-19.83	13.46	-22.9	10.24
	-22.19	14.22	-25.57	12.5
	-22.46	11.17	-23.42	14.56
	-24.95	12.23	-25	12.54
	-26.08	12.14	-24.83	11.07
	-24.88	10.76	-	-
	-26.9	10.74	-	-
	-23.18	10.36	-	-
	-24.74	10.5	-	-

Appendix H. River otter capture data from eastern Oklahoma (2006, 2007).



Location	Year	Days Trapped	Trap Nights	Otters Captured	CPUE (trap nights/otter)	Otters missed	Nontargets Captured
Baron Fork	2005	12	99	8	12.38	5	20
Baron Fork	2006	16	88	1	88.00	0	16
Sequoyah NWR	2005	13	61	2	30.50	0	17
Sequoyah NWR	2006	12	69	3	23.00	0	33
Red Slough WMA	2006	11	78	1	78.00	2	10

Appendix I. Comparison of capture data (catch per unit effort) by state; river otters were captured using leg-hold traps unless noted.

Author	State or Province	Trap Type	Trap Nights	Otters Captured	CPUE (trap nights/otter)	Otters Missed
Present study	Oklahoma	leg-hold	395	15	26.3*	7
Gorman (2004)	Minnesota	leg-hold	200**	39	0.57–1.2***	n/a
G. Blundell, unpublished data (1999)	Alaska	leg-hold, Hancock	779	54	14.4*	n/a
Gallagher (1999)	Missouri	n/a	n/a	461	29.0****	n/a
Serfass et al. (1996)	Pennsylvania	leg-hold	1,749	29	60.3	22
Penak and Code (1987)	Ontario	Bailey, Hancock	1219	45	122.0****	n/a
Shirley et al. (1983)	Louisiana	leg-hold	6,609	30	220.3	n/a

*Trap nights/otter among all sample sites
**Days of trapping
***Per 100 trap nights
****Mean trap nights/otter

VITA

Dominic Alan Barrett

Candidate for the Degree of

Master of Science

Thesis: STATUS AND POPULATION CHARACTERISTICS OF THE NORTHERN RIVER OTTER (*LONTRA CANADENSIS*) IN CENTRAL AND EASTERN OKLAHOMA

Major Field: Natural Resource Ecology and Management

Biographical:

Personal Data: Born in Chickasha, Oklahoma, on May 6, 1981, the son of Vance Barrett and Olga Pollock.

Education: Graduated from Duncan High School, Duncan, Oklahoma, in May 2000; received a Bachelor of Science in Fisheries and Wildlife Conservation from Southeastern Oklahoma State University, in Durant, Oklahoma, in December 2004; completed requirements for Master of Science in Natural Resource Ecology and Management at Oklahoma State University in May 2008.

Experience: Graduate Research Assistant for Oklahoma Cooperative Fish and Wildlife Research Unit, 2005–2007; Creel Clerk for Oklahoma Department of Wildlife Conservation, 2003 and 2004; Laboratory Teaching Assistant for Southeastern Oklahoma State University, 2001–2004; Fisheries Intern for US Fish and Wildlife Service King Salmon Fisheries Resource Office, 2004; Research Technician for USDA National Wildlife Research Center Logan Field Station, 2003; Research Technician for Oklahoma Cooperative Fish and Wildlife Research Unit, 2002; and Research Technician for Southeastern Oklahoma State University, 2001.

Professional Memberships: American Society of Mammalogists, Oklahoma Chapter of The Wildlife Society

Name: Dominic Alan Barrett Date of Degree: May, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: STATUS AND POPULATION CHARACTERISTICS OF THE
NORTHERN RIVER OTTER (*LONTRA CANADENSIS*) IN CENTRAL
AND EASTERN OKLAHOMA

Pages in study: 114 Candidate for the Degree of Master of Science

Major Field: Natural Resource Ecology and Management

In 1984 and 1985, the Oklahoma Department of Wildlife Conservation reintroduced 17 northern river otters (*Lontra canadensis*) in southeastern Oklahoma. In the past, distributional data have been limited to incidental harvest by state and federal trappers and roadkills collected opportunistically. Our goal was to determine the precise distribution of river otters via sign surveys and mail surveys and examine river otter age structure and isotopic (δ^{13}C, δ^{15}N) signatures in Oklahoma. During winter and spring of 2006 and 2007, we visited 340 bridge sites within 28 different watersheds and identified river otter sign in 11 counties where river otters were not previously documented. Approximately 300 (27%) mail surveys were returned by state and federal natural resource employees, private organizations, and professional and recreational trappers. Mail surveys revealed the possibility of river otters occurring in 8 additional counties where they were not documented previously by published literature, USDA Animal and Plant Health Inspection Service records, or by sign survey efforts. From 2005–2007, we salvaged river otter carcasses from APHIS and ODWC employees and live-captured river otters using leg hold traps. Seventy-two river otters were sampled, and sex ratios were skewed toward females (1F:0.8M). Teeth were removed from salvaged and live-captured river otters (n = 63) for aging. One year olds represented the largest age class (30.2%). Proportion of juveniles within Oklahoma (19.0%) was less than proportions in some states but higher in others where river otters occur. Mean age of river otters decreased from east-to-west in the Arkansas River and its tributaries. Populations in extreme eastern Oklahoma (Arkansas River Watershed) had an older age structure and lower proportion of juveniles than colonizing populations further west (Canadian River Watershed). Tissue δ^{13}C values were less in western areas, which probably resulted from allochthonous inputs of C_3 and C_4 plants and water velocity differences. Tissue δ^{15}N values decreased in western areas and probably resulted from less suitable habitat and/or older age structures further east.

Advisor's Approval: David M. Leslie, Jr.