# RIVER OTTER (*LONTRA CANADENSIS*) HOME RANGE, HABITAT USE, OVERNIGHT MOVEMENT, AND SURVIVAL IN THE PLATTE RIVER OF NEBRASKA

**by**

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River otters (*Lontra canadensis*) are native to Nebraska but were extirpated by the early 1900s. The Nebraska Game and Parks Commission (NGPC) reintroduced river otters during 1986–1991 to restore the species in the state but little is known regarding the habitat needs and status of this high profile threatened species. To provide information for management I conducted research to determine home range, habitat use, overnight movement distance, and annual survival of river otters in the central Platte River of Nebraska.

I trapped, implanted telemetry transmitters, and tracked 18 river otters during 2006–2009. I obtained 996 locations and constructed 13 annual home ranges. Mean home range size using the 95% fixed kernel (FK) method was 3,711.6 ha (*SD* = 2,995.4) and 1,361.0 ha (*SD* = 1,075.2) using the 95% minimum convex polygon method (MCP). Male home ranges were larger than females for both FK (*P* = 0.02) and MCP methods (*P* = 0.02). Habitat use was determined by comparing used versus available habitats using compositional analysis. Open water was used more than any other habitat type in all three comparisons tested.

I recorded 19 overnight movements (465 total telemetry locations) for four river otters during 2007–2008. Mean distance moved overnight was 3.5 km (*SD* = 3.0). Movements during Jan–Feb when NGPC conducts bridge surveys were lower than during the rest of the year (*P* = 0.03). Annual survival was 100% as no river otter mortalities were detected during the study (Oct 2006–Dec 2009). The mean number of days that a marked river otter was known to be alive was 470.5 (*SD* = 168.8).

River otters in the central Platte River select open water over other habitat types, exhibit reduced movements during winter months, and have high annual survival. This information will be used by the Nebraska Game and Parks Commission to assess the status of river otters in Nebraska and direct management efforts for the species.

# DEDICATION

To my loving wife Sarah who encouraged me and cared for our children while I was away sloshing through the river and working late nights. Her love and support will always be with me and her hard work made this project possible.

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Lastly I would like to thank technicians Kent Fricke and Dave Rempel for all of their hard work and dedication. I also appreciate the considerable efforts of Amy Williams who conducted her graduate research concomitantly with my project and fulfilled the role of wildlife technicians as well.

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## INTRODUCTION

River otters (*Lontra canadensis*) are a high profile threatened species in Nebraska. Information regarding their home range and habitat use is needed to inform conservation efforts that will take place in the central Platte River over the coming decades. River otters are identified as a Tier 1 at-risk species in the Nebraska Comprehensive Wildlife Conservation Strategy and the central Platte River has been identified as a Biologically Unique Landscape (BUL) (Schneider et al. 2005). This statewide conservation strategy guides management of BULs that have important habitat characteristics and at-risk species. The importance of the Platte River to river otters is illustrated by the fact that 53% of the confirmed sightings recorded between 1987 and 2002 occurred within 1 km of the Platte River and 63% occurred within 3 km (Bischof 2003). Despite their reintroduction and status as a state threatened species, information is needed to guide management of this species in Nebraska.

River otters were found throughout the state of Nebraska prior to European settlement and were frequently documented by early explorers on the Missouri and Platte rivers (Jones 1964). Conversion of habitat for agricultural production and unregulated harvest led to the extirpation of the species by the early 1900s. No river otters were documented in the state between 1916 and 1977 (Farney and Jones 1978). A female river otter trapped on Sappa Creek in Furnas County in 1977 represented the first documented occurrence in more than 60 years (Farney and Jones 1978). This confirmation occurred

after the reintroduction of river otters in Colorado in 1976 (Tischbein 1976) and may represent a transient animal from that release or a member of an undetected remnant population (Farney and Jones 1978). Between 1980 and 1985 four subsequent confirmations were made in the Republican River Basin **(**F. Andelt and R. Lock, Nebraska Game and Parks Commission, unpublished data); however, no confirmed presence was documented in this area between 1986 and 2010.

Many Midwestern states experienced a similar river otter decline and they were extirpated or rare in 15 states by the mid 1900s (Toweill and Tabor 1982). During the 1970s and 1980s ten states initiated reintroductions (Raesly 2001), including Nebraska. To restore river otters throughout the state, the Nebraska Game and Parks Commission released 159 river otters between 1986 and 1991 at seven release sites in five of the major river basins (Andelt 1988; Andelt 1992; Bischof 2003). The majority of those animals were trapped in Louisiana ($n$ = 68) and Alaska ($n$ = 62) (Bischof 2003). Post-release expansion of river otter distribution and an increase in the number of river otters incidentally trapped provide evidence that the population is growing (Bischof 2003; Hoffman and Genoways 2005). Williams (2011), who conducted research concomitantly with this project, found that the density of river otters in the central Platte River was higher than had previously been documented anywhere in North America. By 2003, river otter distribution had expanded into the Middle Loup and Nemaha rivers, which were not part of the original releases (Bischof 2003; Hoffman and Genoways 2005). River otters have subsequently been documented in the Missouri and Republican River basins, and are currently found in 9 of the 13 major river basins in Nebraska (S.P. Wilson, Nebraska Game and Parks Commission, unpublished data). Similar population growth and range

expansion has been reported by other states where river otters were reintroduced (Raesly 2001) including neighboring Iowa, Kansas, and Missouri where harvest seasons have been established.

River otters are highly adaptable and historically had one of the largest distributions of any North America mammal (Toweill and Tabor 1982). Melquist and Hornocker (1983) found that river otters avoid areas with high levels of human disturbance; although, like Gallant et al. (2009), they found that river otters respond primarily to the presence of appropriate habitat and prey and secondarily to human activities or disturbance. River otters are efficient predators that prey primarily on fish and crayfish but can also prey on insects, amphibians, birds, and mammals (Melquist et al. 2003). Prey items are selected based on their availability although slower swimming fish may be preferred when they are encountered (Ryder 1955; Toweill 1974).

Riparian areas and wetlands have been shown to be an important component of river otter habitat (Melquist and Hornocker 1983; Melquist and Dronkert 1987; Melquist et al. 2003) although they are not required. Riparian areas may be of increased importance due to the presence of beaver (*Castor canadensis*). Beaver dams create ponds in streams and waterways that provide habitat for river otters and their prey (Tumlison et al. 1982). This relationship between river otters and beavers has been described as commensalism by Tumlison et al. (1982) and partial commensalism by Reid et al. (1988). River otter dens are typically constructed by other animals or consist of natural features such as root structures, according to Melquist and Hornocker (1983), who identified 38% of river otter den or resting sites as beaver dens or lodges. Beaver dens may be of

additional importance in Nebraska and other Prairie Plains states where natural den sites such as rock overhangs are rare or absent.

River otter home range size varies and is likely influenced by prey densities, habitat quality, and other requirements (Melquist et al. 2003). Home ranges as large as 200 $km^2$ for males and 70 $km^2$ for females were documented by Reid et al. (1994) in Alberta, Canada; home ranges as small as 303 ha were documented by Foy (1984) in southeastern Texas. Adult river otters have larger home ranges than juveniles, and males typically have larger home ranges than females (Melquist and Hornocker 1983; Blundell et al. 2000). Blundell et al. (2000) suggested that larger home ranges of males were related to the spacing of female home ranges and not caused by a greater need for food or habitat resources. Both male and female river otters in Idaho exhibited overlapping home ranges (Melquist and Hornocker 1983). Route and Peterson (1988) found that female river otter home ranges in Minnesota showed little overlap. More recently, Gorman et al. (2006) found considerable overlap and described river otters in Minnesota as social rather than territorial. River otter home ranges can be linear in areas where habitat is limited to a river, stream or coastline (Blundell et al. 2001).

While home range and characteristics of habitat use have been determined for river otters in other areas of North America, no information specific to the Northern Prairie Plains states (NE, SD, ND) exists that can provide information for management in this unique landscape. To gather critical information needed for the creation of a river otter management plan and to guide conservation efforts in the Central Platte River BUL, the objectives of this study were to: 1) determine the home ranges of male and female

river otters in the central Platte River and 2) determine habitat use by river otters in the central Platte River.

## MATERIALS AND METHODS

### Study Area

I conducted this research from 2006 through 2009 on the Big Bend reach of the central Platte River in south central Nebraska. Trapping and telemetry efforts occurred primarily on a 32-km stretch of the Platte River and adjacent tributaries, wetlands, and lakes, between the Shelton and Grand Island exits of Interstate 80 (Figure 1.1). The boundaries of the study area used to assess habitat use were defined as the north and south channel of the Platte River and the easternmost and westernmost river otter locations buffered by 100 meters (Figure 1.1). The 100 meter buffer was selected because the majority of river otter movements have been shown to be within 100 meters of the interface between land and water (Woolington 1984). The Platte River in my study area is a complex braided river system consisting of broad and shallow sandy bottomed channels that may be separated by more than two kilometers of land, sandbars that are created and altered with seasonal flooding, and large islands dominated by riparian forests. The Platte originates in Colorado and flows through Wyoming and across the length of Nebraska. Flow rates vary by year and within years but are typically between 0 and 6,500 cubic feet per second. The Platte River presently supports a growing river otter population and appears to be critical to the establishment of this species in Nebraska (Bischof 2003). This area is also the focus of state, federal, and nongovernmental conservation efforts for federally endangered whooping cranes (*Grus americana*), interior

least terns (*Sternula antillarum athalassos*), pallid sturgeons (*Scaphirhynchus albus*), and federally threatened piping plovers (*Charadrius melodus*). In 1997, Nebraska, Colorado, Wyoming, and the U.S. Department of the Interior formed a partnership that created the Platte River Recovery Implementation Program (PRRIP). This program has a primary focus of restoring and maintaining habitats in the Big Bend reach of the Platte River to benefit threatened and endangered species and people in this area. Habitat restoration projects initiated by PRRIP will affect 10,000 acres of habitat between 2007 and 2019. Nongovernmental conservation organizations such as The Whooping Crane Trust, The Nature Conservancy, and the National Audubon Society own or manage more than 12,000 acres in the Big Bend reach and conduct or facilitate wildlife and habitat research projects. This combination of confirmed presence of river otters, previous and ongoing conservation efforts, and intense habitat management at this site made it ideal for this study.

**Capture and Radiotelemetry Implantation**

I captured river otters using modified No. 11 double jaw, double long-spring Sleepy Creek foothold traps (Sleepy Creek Manufacturing, Berkeley Springs, WV), which are recommended by Blundell et al. (1999) because of low rates of injury and escape. A small number (<5) of Onieda Victor No. 1.5 soft-catch coil spring traps (Oneida Victor Inc., Cleveland, Ohio) were used during the first trapping season. A shock spring and three swivels were added to the chain of each trap to allow freedom of movement and reduce injury. Traps were anchored in sand or soil using earth anchors consisting of two-inch washers with a heavy-duty six gauge j-hook in the center that was

attached to a 60 cm segment of 3/32 inch galvanized aircraft cable. Trapping was conducted during late summer through early winter to avoid trapping female river otters with dependent young and to avoid problems associated with thermal regulation by trapped otters. All traps were checked daily before noon to minimize stress to the captured animals associated with being restrained.

Traps were set in areas where river otter sign was present, such as latrine sites or crossover trails between adjacent water bodies. Areas where trapping occurred were cleared of brush, branches, or other material that could become entangled with the trap or chain and further restrict movement by the trapped animal (Serfass et al. 1996). Traps were set on land or in the water. When possible, traps were anchored so the river otter could choose to be submerged or on dry land as needed for thermoregulation. To reduce incidental capture of non-target species like raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*) that are abundant in the study area, traps were not baited and no scent lures were used.

I transferred trapped river otters to a transport container that consisted of a 75 liter plastic barrel with a sliding Plexiglas door on the front (Serfass et al. 1993). They were transported in the container to the University of Nebraska Animal Research Facility in Lincoln, NE. The river otters and transport containers were weighed and the tare container weight was subtracted from the total weight to determine the correct dose of anesthetic. The river otters were then restrained in a squeeze box (McCullough et al. 1986) and anesthetized with a mixture of ketamine (16 mg/kg) and midazolam (0.25 mg/kg) by a veterinarian. The combination of ketamine and midazolam has been shown

to provide a large margin of safety (Belfiore 2008) as well as a longer anesthetic effect with fewer complications than when only ketamine is used (Spelman et. al 1993). Each river otter was examined by a veterinarian to determine overall health status, gender, and weight and to document any trap related injuries. Sterilized Advanced Telemetry Systems M1250B radiotransmitters (Advanced Telemetry Systems Inc., Isanti, MN) equipped with activity and mortality sensors were implanted into the abdominal cavity following procedures similar to those outlined by Hernandez-Divers et al. (2001). Intra-peritoneal transmitters are effective for river otter research (Melquist and Hornocker 1983) and do not impede reproduction by females (Reid et al. 1986). A veterinarian administered meloxicam at a ratio of 0.1 mg/kg to control pain, penicillin benthazine to prevent infection, and Lactated Ringer's solution (200 cc) subcutaneously to replenish fluids and electrolytes. A passive integrated transponder tag was implanted subcutaneously under the base of the tail by a veterinarian to allow the river otters to be identified if the radiotransmitter failed (Bowyer et al. 2003; Helon et al. 2004).

Following these procedures, river otters were placed in clean transport containers and monitored by a veterinarian to assure a normal recovery from surgery and anesthesia. Each river otter was released at the location it was trapped as soon as possible (typically within five hours) after recovery from the anesthesia (Testa et al. 1994). All protocols used were approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee (UNL–IACUC Protocol #06–09–35D).

**Radiotelemetry**

Locations of river otters were determined by radiotelemetry 2–4 times per week until the batteries failed (batteries were warranted for 571 days) or until the project concluded in December 2009. Monitoring was accomplished primarily by tracking on the ground using a Communications Specialists R–1000 receiver (Communications Specialists Inc., Orange, CA), truck-mounted omni-directional antenna, and 3-element Yagi antenna. Telemetry from fixed-wing aircraft and canoes was used periodically to relocate animals because some transmitters could not be detected from >100 meters on the ground. Exact locations were determined whenever possible by homing in on the telemetry signal until the location was determined and recording the location using a Garmin GPS 72 (Garmin International, Inc., Olathe, KS) global positioning system. When safety considerations or lack of permission to enter property did not allow for an exact location to be determined, locations were determined by biangulation or triangulation. Bearings were taken within five minutes to reduce error associated with movements by the study animal (White and Garrott 1990). When mortality signals were detected, an immediate attempt was made to determine if it represented a true mortality or a false signal. False signals were determined by motion signals from the transmitter or movements upstream or over land typical of live river otters.

**Statistical Analysis**

I estimated locations for river otters collected by biangulation and triangulation using Location of Signal software (Version 4.0; Ecological Software Solutions LLC. Hegymagas, Hungary). Estimated locations with a mean receiver distance >700 m, error

ellipse >5 ha, or an inter-bearing angle <20° or >160° (Gese et al. 1988) were not used for home range or habitat selection analysis to minimize error due to inaccurate location estimates. Telemetry estimates and exact locations were used to create annual home ranges for all river otters with ≥30 locations in a given year (Seaman et al. 1999).

Home ranges were constructed using the 95% and 50% minimum convex polygon (MCP) method that has been shown to provide conservative area estimates and contiguous home ranges for species that have fragmented home ranges (Gerht et al. 2009). Minimum convex polygon has been the most widely used home range estimator so use of this method allows for comparison to previous studies if differences in sample size and habitat factors are accounted for. Home ranges were also constructed using the 95% and 50% fixed kernel method (Worton 1989) using ad hoc bandwidth selection (Berger and Gese 2007; Jacques et al. 2009; Kie et al. 2010). The fixed kernel method was selected for my analysis because it has been shown to be unbiased and able to estimate accurate home ranges with low sample sizes (Borger et al. 2006), and it has been identified as more appropriate than MCP or Jennrich-Turner ellipse methods for species like river otters that use linear habitats (Boege-Tobin 2005). Fixed kernel methods were identified by Gorman et al. (2006) as preferable to total linear length estimates for river otters in habitats that contain islands and upland natal den sites. Fixed kernel home ranges are also unlikely to be affected significantly by telemetry error if adequate sample sizes are used (Moser and Garton 2007). Ad hoc bandwidth selection allows for the reference bandwidth ($hr_{ef}$) to be reduced until the smallest home range with a contiguous polygon is determined. This reduces over-smoothing and unnecessary fragmentation of home ranges (Berger and Gese 2007; Jacques et al. 2009; Kie et al. 2010).

Fixed kernel and MCP home range estimates were calculated using Home Range Tools for ArcGIS (Rodgers et al. 2007) in ArcGIS 9.3 (ESRI, Redlands, CA). Locations of river otters that were tracked for more than one year were tested for independence using Multiple Response Permutation Procedures (MRPP) in the program BLOSSOM, version 2008.04.02 (Fort Collins Science Center, U. S. Geological Survey, CO). MRPP tests whether two sets of locations come from a common distribution. Separate home ranges were created for each year if locations in separate years were determined to be independent. The home range data did not meet assumptions of normality so I used a Wilcoxon rank-sum test to detect differences ($P < 0.05$) between male and female home range sizes and to test for differences in home range size between years. All statistical analyses were performed using the statistical software R, version 2.12.1 (R Development Core Team, 2012).

I used a 2009 GIS land cover layer created by the Great Plains GIS Partnership (Great Plains GIS Partnership, U.S. Fish and Wildlife Service, Grand Island, NE) to identify habitat types in my study area. I reclassified the original 24 habitat classifications present in my study area, into five habitat types (Table 1.1): riparian, river channel, open water, wet meadow, and agricultural/other. Geographic information system analysis for home range and habitat use was conducted using ArcGIS 9.3.

Arbitrary delineation of a study area, such as using political boundaries, has been identified as a weakness for determining available habitat (Johnson 1980; Aebischer et al. 1993). To address this I used telemetry locations of the study animals as recommended by McClean et al. (1998) and physical boundaries of the river to identify my study area.

Johnson (1980) described the selection of a home range from a larger area as second order selection and the use of habitat within the home range as third order selection. I examined habitat use at three levels using a modification of second and third order selection described by Johnson (1980): 1) I compared the proportion of each habitat in the 95% MCP home range for each river otter to the proportion available in the study area. 2) I compared the proportion of locations in each habitat to the proportion available in the 95% MCP home range for each river otter. 3) I compared the proportion of locations in each habitat for each river otter to the available habitat in the study area. Contiguous home ranges are important for estimating the area available for use within a home range (Gehrt et al. 2009). I used the 95% MCP home ranges in my habitat use analysis because I was unable to produce contiguous home ranges for all river otters using the fixed kernel method without expanding the home range size (Gehrt et al. 2009) to include large portions of unsuitable habitat such as stretches of Interstate 80. The proportion of each habitat type for the 95% MCP home ranges and the study area were calculated using ArcGIS 9.3. The total number of locations in each habitat type was calculated for each river otter using Hawth's Analysis Tools for ArcGIS, version 3.27 (Beyer 2004).

I used compositional analysis (Aebischer et al. 1993) to assess habitat selection using the package adehabitat (Calenge 2006) in R. Relative rankings of habitat types used, simplified ranking matrices of log ratio differences (Aebischer et al. 1993), and preference profile tables (Johnson 1980; Calenge 2006) for the 5 habitat types were constructed for each of the three comparisons. Significance was determined at $P < 0.05$ using randomization to eliminate distributional assumptions (Manly 1991). I chose

compositional analysis in part because it alleviates problems associated with the unit sum constraint, where avoidance of one habitat type leads to the appearance of a preference for others (Aebischer et al. 1993), and because it provides consistent and reliable estimates of resource use compared to the more recent Euclidian distances method (Bingham et al. 2010). I reclassified the original 24 habitat types to five habitat types for my analysis to reduce the number of unused habitat types by river otters. Habitat classifications with large numbers of habitat types are more likely to include habitats where the study animals were never located; which has been identified as problematic for compositional analysis (Aebischer et al. 1993; Thomas and Taylor 2006) and has been shown to increase Type I error rates (Bingham and Brennan 2004). Aebischer et al. (1993) suggest replacing the zero for available but unused habitats with a value smaller than the smallest nonzero proportion; in my case I replaced zero values with 0.01. I could not test for differences between genders or years due to the small sample size, so my analysis of habitat selection used locations from all 11 river otters and pooled 95% MCP home ranges for river otters that were tracked for more than one year ($n$ = 2). I assumed minimal differences in habitat use occurred between years due to relatively stable temperature, rainfall, and river level patterns over the duration of the study compared to previous years.

## RESULTS

### Capture and radio implantation

I trapped and implanted radiotelemetry transmitters in 18 river otters (10 male, 8 female) during the three trapping seasons: five in 2006 (three male, two female), seven in

2007 (three male, four female), and six in 2008 (four male, two female). None of the river otters trapped during my study exhibited any serious trap-related injuries. The majority of river otters were released on the same day they were captured to reduce stress related to being held in captivity.

**Monitoring**

I collected 996 total telemetry locations during the three-year telemetry phase of the study (January 1, 2007–December 31, 2009). Exact locations where the river otter was tracked to a den or resting site made up 58% of the total. I was able to collect ≥30 locations from three river otters during 2007 (one male, two female), five river otters during 2008 (two male, three female), and five river otters during 2009 (two male, three female) for 13 total river otter seasons (Table 1.2). Of those river otters, two females were tracked during more than one season. Locations for both females (056F and 113F) were spatially independent between years ($P < 0.01$) so separate home ranges were constructed for each year. I recorded 699 locations for the river otters that met the requirement for ≥30 locations in a season (Figure 1.1) after locations that did not meet the error criteria were removed. Of the 699 locations, 433 (62%) were exact locations. These 699 locations were used to analyze home range and habitat use for the 11 river otters represented. Natal dens were identified for three female river otters in the study and were used between mid-March and mid-May.

**Home range**

I constructed 13 annual home ranges for river otters using telemetry location data (Table 1.3; Appendix A). Mean home range size for all river otters using the 95% MCP method was 1,361.0 ha (*SD* = 1,075.2); 850.2 ha (*SD* = 724.5) for females (*n* = 8); and 2,178.4 ha (*SD* = 1,092) for males (*n* = 5). Using the 95% fixed kernel method, mean home range size for all river otters was 3,711.6 ha (*SD* = 2,995.4); 2,092.8 ha (*SD* = 1,883.3) for females; and 6,301.8 ha (*SD* = 2,661.3) for males.

Mean core home range size for all river otters using the 50% MCP method was 440.7 ha (*SD* = 583.6); 196.2 ha (*SD* = 232.7) for females; and 832.0 ha (*SD* = 784.8) for males. Using the 50% fixed kernel method, mean core home range size for all river otters was 722.1 ha (*SD* = 582.6); 433.3 ha (*SD* = 450.4) for females; and 1,184.1 ha (*SD* = 479) for males.

The 95% MCP home ranges of male river otters were larger than the female home ranges ($P = 0.02$); the 50% MCP home ranges of male river otters were not larger than the female home ranges ($P = 0.22$). The 95% fixed kernel home ranges of male river otters were larger than the female home ranges ($P = 0.02$) and the 50% fixed kernel home ranges of male river otters were also larger than the female home ranges ($P = 0.02$). Home range size did not vary between years ($P > 0.05$).

**Habitat use**

Habitat use by the 11 river otters in the analysis was different than expected based on availability at all three levels: 1) comparing the proportion of each habitat in the 95%

MCP home range for each river otter to the proportion available in the study area (Wilks' Lambda = 0.19, $P = 0.03$), 2) comparing the proportion of locations in each habitat to the proportion available in the 95% MCP home range for each river otter (Wilks' Lambda = 0.01, $P < 0.01$), 3) comparing the proportion of locations in each habitat for each river otter to the proportion available habitat in the study area (Wilks' Lambda = 0.01, $P < 0.01$). Rank of habitat types at the first level was open water > river channel > riparian > wet meadow > agricultural/other. River otters selected open water more than all other habitat types, river channel more than riparian and agricultural/other, and riparian and wet meadow more than agricultural/other (Table 1.4; Table 1.5).

Rank of habitat types at the second level was open water > riparian > river channel > agricultural/other > wet meadow. River otters selected open water more than all other habitat types and riparian more than river channel. River otters selected agricultural/other and wet meadow less than all other habitat types (Table 1.4; Table 1.6).

Rank of habitat types at the third level was open water > riparian > river channel > agricultural/other > wet meadow. River otters selected open water more than all other habitat types. Riparian was selected more than river channel, agricultural/other, and wet meadow; and river channel was selected more than agricultural/other and wet meadow (Table 1.4; Table 1.7).

## DISCUSSION

Radiotelemetry has provided detailed home range and habitat use information for river otters since Melquist and Hornocker's seminal study in Idaho. Subsequent studies

have been carried out in multiple states where reintroductions took place (Melquist et al. 2003) but river otter home range and habitat use has not been previously documented in the Northern Prairie Plains states (NE, SD, ND) other than assessment of river otter use of invasive *Phragmites australis* by Williams (2011), who conducted research concomitantly with this project. The mean 95% fixed kernel home range size observed in my study (3,711.6 ha) was similar to the mean 95% fixed kernel home range size for males (~2,000 ha) and females (~550 ha) reported in neighboring Missouri by Boege-Tobin (2005). Gorman et al. (2006) in Minnesota and Williamson (2009) in Kentucky also used the 95% fixed kernel method and reported similar mean home ranges of 2,049 ha and 5,580 ha respectively. The mean 95% MCP home range size observed in this study (1,361.0 ha) was similar to estimates for males (~1,900 ha) and females (~300 ha) in Missouri (Boege-Tobin 2005) and estimates from Texas (982 ha) by Foy (1984). The 95% MCP estimates for river otters using fresh water habitats in Alaska (3,400 ha) by Blundell et al. (2000) were larger but were based on a small sample size ($n$ = 4). Overall my home range size estimates fell within previously reported ranges for both the fixed kernel and MCP estimates. This suggests resources and habitat available to river otters in my study area are similar to previous studies.

The complex multi-channel structure of the Platte River did not allow for calculation of total length of waterways or shoreline to quantify home ranges as had been reported by Melquist and Hornocker (1983), Bowyer et al. (1995), and recommended by Blundell et al. (2001). Like Gorman et al. (2006), I believe that the fixed kernel home range estimate was appropriate for my study because it included islands, wetlands, temporary open water, and seasonal river channels that may be important to river otters

but may have been missed by using estimates of linear home ranges. Additionally, the fixed kernel method allowed for the identification of core areas of use. Burt (1943) defined home range as the area traversed by the individual in its normal activities of food gathering, mating, and caring for young. I recognize that the fixed kernel estimates may contain portions of unused habitat such as sections of Interstate 80, where river otters may cross but would not be critical to the animal's home range under this definition. To address this problem I used the more conservative MCP home ranges for analysis of habitat use. None of the MCP home ranges included portions of Interstate 80, which runs a few hundred meters to the north of the Platte River for most of the study area.

Recent advances in home range estimators such as the local convex hull (LoCoH) nonparametric kernel method (Getz et al. 2007) may be able to address the problem of unused habitats included in river otter home ranges, due to the ability of LoCoH to identify hard boundaries and exclude them from the estimate. The LoCoH method has the additional advantage of converging to the true distribution as the number of locations increase (Getz et al. 2007). This method would appear to provide advantages over the fixed kernel and MCP methods used in this study if a large set of locations (like those typical of GPS-based location data) could be gathered to allow the unused areas to be easily identified.

I assessed habitat use by river otters at three levels: 1) selection of a home range from within the study area, 2) use of habitat within the home range, 3) use of habitat within the study area. Compositional analysis showed that open water habitat was ranked higher than all other habitat types at all three levels. Riparian and river channel habitats

were also used in greater proportion than would be expected based upon their availability at all three levels. Wet meadow and agricultural/other were the lowest ranked habitat types at all three levels. Melquist and Dronkert (1987) described riparian habitat adjacent to lakes, streams, and wetlands as a key component of river otter habitat, and this description generally applies to the habitat used by river otters in my study area. In Kansas, Jeffress et al. (2011) found that the probability of river otter occupancy along waterways or shorelines increased with increasing adjacent woodland cover and decreasing agricultural cover at the local scale. My results are generally similar in that river otters used open water, riparian, and river channel in greater proportion than available and used agricultural/other and wet meadow in lesser proportion than available. Helon et al. (2004) also used compositional analysis to assess habitat use by river otters in Ohio and reported marsh as the highest ranked habitat type and open water as the lowest ranked habitat type. I believe the differences between our rankings are partly explained by differences in the definitions of open water. In my study, open water habitat may contain aquatic vegetation and be bounded by emergent marsh vegetation including cattails (*Typha* spp) and bulrush (*Schoenoplectus* spp); whereas, the open water category described by Helon et al. included deep water habitats with no vegetation. The top ranked marsh category from that study, which included an association of floating aquatics and emergent vegetation with standing water, may be more closely related to the open water category in my study.

Further, open water habitat may be of increased importance during winter months when the shallow river channel is partially frozen (Figure 1.2) and during summer months in periods of drought when the river channel does not contain water (Figure 1.3).

Year round open water habitat that does not freeze has been identified as a critical component for river otter distribution (Reid et al. 1994). Melquist and Hornocker (1983) observed that the use of lakes, reservoirs, and ponds was greatest in the winter in Idaho, and that airspace under ice creates ideal conditions for river otters. River otters have been documented retreating from high altitude habitat during winter months in Idaho (Melquist and Hornocker 1983) and from marshland to permanent water during dry seasons in Florida (Humphrey and Zinn 1982). The shallow and broad channels of the Platte River are prone to freezing in winter months, reducing the availability of river channel habitat for foraging. In my study area, open water habitats consist of manmade sand/gravel mining lakes, stock ponds, and natural or manmade warm water sloughs. These open water habitats – especially former sand and gravel mines which do not entirely freeze – provide deep water and reliable foraging habitat for river otters during the winter months. Open water habitats are likely equally important during periods of drought when the Platte River in my study area dries out completely, as happened during the summer months over a four year stretch (2002–2005) ending at the beginning of this study. Seasonal flooding events, as happened during the summer of 2011, also likely reduce the utilization of river channel habitat due to increased flow rates and turbidity.

Melquist and Hornocker (1983) described specific areas of increased use as “activity centers” and noted that river otters remained in these areas for as long as 40 days. McDonald (1989) also reported that river otters used open water habitats for extended periods of time in Ohio. I believe open water habitats such as sandpits and warm water sloughs function as activity centers, fulfilling needs of river otters in the study area with varying importance depending upon the season. I observed a male river

otter using a five hectare sandpit lake for 43 consecutive days during January and February of 2007, when freezing temperatures reduced available habitats in shallow water. McDonald (1989) observed that river otters used riverine habitat as a travel corridor between open water habitats. I also believe that river otters use the Platte River as a travel corridor between open water activity centers, especially during winter months when the river is partially frozen and during periodic droughts when the river is dry and therefore provides limited habitat for foraging.

The complex braided system of the Platte River in the study area made locating river otters difficult because of the limited distance that the implanted transmitters could be detected and the inaccessibility of much of the study area. Unlike previous studies in rivers or streams with a single channel that may be at most a few hundred meters wide, the Platte River in my study area has multiple channels that change with seasonal flooding or droughts and may be separated by more than two kilometers of agricultural ground (Figure 1.4). The Platte River also contains a complex of islands and sandbars that are often dominated by riparian forests which further inhibit telemetry signals. Furthermore, the shallow nature of the Platte River, locally described as “a mile wide and an inch deep”, limits the use of propeller driven boats and even canoes or kayaks. Due to these factors, it was common to have river otters that could not be located for days or weeks at a time. This inability to reliably locate river otters in my study area limited assessment of differences in habitat use between genders, seasons, and years. I encourage future research projects using radiotelemetry implants to consider these factors and to find alternative methods to locate study animals.

Telemetry searches from fixed wing aircraft were effective in the study area but were prohibitively expensive. I suggest the use of stationary telemetry receivers and data loggers at narrow sections of river systems, both upstream and downstream from the study area, may be useful to determine whether river otters remain within the study area or area searched. If records from the data loggers indicate that the river otter has passed outside the search area, efforts could be made to relocate that animal beginning at the data logger. This system may save time and money searching for river otters that have moved beyond the search area and may reduce the number of animals that are lost from the study. I also encourage the development of a GPS-based transmitter for river otters that will allow an increase in the number and accuracy of locations while simultaneously reducing the time required by research technicians to locate each river otter. A GPS-based transmitter would also allow for better use of home range estimators like LoCoH that may be suited to animals like river otters that have large areas of unused habitats within home ranges created using MCP and kernel methods.

**Management implications**

The importance of open water, riparian, and river channel habitats to river otters should be taken into consideration when management decisions are made in the Platte River basin. I suggest that land managers in the study area should focus on preserving existing habitats similar to those identified as “activity centers” in my study. These areas were generally open water habitats consisting of sandpits and warm water sloughs that were within established riparian areas and adjacent to the river channel (<200 m). Preservation of these areas may mitigate removal of riparian forest along sections of the

Platte River that may occur to promote use by sandhill cranes (*Grus canadensis*) and whooping cranes. The creation of new manmade open water areas, or water released into the Platte River to promote the creation of natural open water areas would also be beneficial. Water levels in the Platte River are highly variable with some seasonal flooding and frequent periods of drought where no water is present in the river channel. This variability makes year round open water habitats particularly important for otters on the Platte. The creation of new lakes, sloughs, and ponds would provide additional important river otter habitat particularly if they are created within established riparian areas where roots and partially submerged fallen trees provide den and resting sites and foraging areas for river otters and prey species (Melquist and Dronkert 1987). River otters have a commensal relationship with beaver (Tumlison et al. 1982) and Gallant et al. (2009) identified beaver ponds as the most important habitat factor for river otters in their study area in Canada. I also documented frequent use of beaver dens and ponds in my study area, with beaver dens accounting for more than half (54%) of all dens sites identified. Allowing beavers to create ponds and dens in appropriate areas would encourage use by river otters and increase available habitat.

River otter populations have expanded since their reintroduction and it appears that current habitat levels have been sufficient for population restoration in my study area. To maintain current levels and support further expansion in other areas of the Platte River open water habits that presently exist should be preserved, new open water habitats should be created through management of river flows or direct construction, and established riparian areas should be preserved if they are adjacent to open water habitats. My results provide new information to public and private landowners who are making

land management decisions along the Platte River. They also provide home range and habitat use information that will be used by the Comprehensive Wildlife Conservation Strategy in an effort to recover river otter populations throughout Nebraska.

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Table 1.1. River otters were trapped and implanted with radiotelemetry transmitters in the central Platte River of Nebraska during 2006–2008 to assess habitat use. The original 2009 GIS land cover layer created by the Great Plains GIS Partnership contained 24 habitat classifications in the study area. These 24 habitat types were reclassified into five general habitat types to allow for assessment of habitat use by river otters.

| Reclassified Habitat Type | Original Land Cover Layer Habitat Type |
|---|---|
| Riparian | Riparian Canopy |
| | Exotic Riparian Shrubland |
| | Native Riparian Shrubland |
| River Channel | River Channel |
| | Unvegetated Sandbar |
| Open Water | Pit |
| | Stock Pond |
| | Warmwater Slough |
| Wet Meadow | Wet Meadow |
| Agricultural/other | Alfalfa |
| | Corn |
| | Sorghum |
| | Soybeans |
| | Wheat |
| | Other Roads |
| | Rural Developed |
| | Two-lane Roads |
| | Urban/suburban |
| | Forest/woodland |
| | Mixedgrass |
| | Sandhills Grasslands |
| | Cropland |
| | CRP |
| | Badlands |

Table 1.2. Eighteen river otters were trapped and implanted with radiotelemetry transmitters in the central Platte River of Nebraska during 2006–2008 to assess home range and habitat use. The unique identification number, gender, year trapped, number of telemetry locations, and ad hoc proportion of the reference bandwidth ($h_{ad\ hoc}$) used to calculate fixed kernel home ranges are provided. Thirteen home ranges were created for the 11 river otters with ≥30 locations in a given year.

| River Otter | Gender | Year | Locations | ($h_{ad\ hoc}$) |
|---|---|---|---|---|
| 212 | Male | 2007 | 52 | 1 |
| 113 | Female | 2007 | 107 | 1 |
| 275 | Female | 2007 | 130 | 1 |
| 113 | Female | 2008 | 42 | 1 |
| 135 | Female | 2008 | 43 | 1 |
| 056 | Female | 2008 | 37 | 0.6 |
| 175 | Male | 2008 | 37 | 0.8 |
| 395 | Male | 2008 | 32 | 0.6 |
| 056 | Female | 2009 | 33 | 1 |
| 684 | Female | 2009 | 47 | 0.6 |
| 626 | Male | 2009 | 57 | 0.4 |
| 596 | Female | 2009 | 35 | 0.6 |
| 556 | Male | 2009 | 48 | 0.4 |

Table 1.3. River otters were tracked using radiotelemetry in the central Platte River of Nebraska during 2007–2009 to assess home range size. Mean minimum convex polygon (MCP) and fixed kernel (FK) home ranges at the 95% and 50% level are given in hectares by year and gender for the 13 river otter home ranges represented. Standard deviation (SD) is given where applicable.

| Year | Sex | n | 95% MCP | SD | 50% MCP | SD | 95% FK | SD | 50% FK | SD |
|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | F | 2 | 1,418.20 | 961.24 | 235.25 | 299.18 | 2,917.05 | 2,364.49 | 563.30 | 553.81 |
| 2007 | M | 1 | 892.70 | | 0.80 | | 4,117.10 | | 488.90 | |
| 2007 | All | 3 | 1,243.03 | 744.34 | 157.10 | 251.15 | 3,317.07 | 1,809.82 | 538.50 | 393.95 |
| 2008 | F | 3 | 378.60 | 358.58 | 97.33 | 72.17 | 958.33 | 662.41 | 204.73 | 155.34 |
| 2008 | M | 2 | 1,838.15 | 914.93 | 436.65 | 379.79 | 7,879.72 | 4,208.87 | 1,534.44 | 402.11 |
| 2008 | All | 5 | 962.42 | 955.33 | 233.06 | 270.56 | 3,726.89 | 4,361.16 | 736.61 | 763.49 |
| 2009 | F | 3 | 943.07 | 759.70 | 268.93 | 339.79 | 2,677.70 | 2,460.93 | 575.13 | 637.95 |
| 2009 | M | 2 | 3,161.55 | 338.63 | 1,643.00 | 20.51 | 5,816.20 | 626.07 | 1,181.45 | 165.25 |
| 2009 | All | 5 | 1,830.46 | 1,339.30 | 818.56 | 790.10 | 3,933.10 | 2,465.99 | 817.66 | 566.22 |
| 2007–2009 | F | 8 | 850.18 | 724.45 | 196.16 | 232.71 | 2,092.78 | 1,883.27 | 433.28 | 450.36 |
| 2007–2009 | M | 5 | 2,178.42 | 1,091.96 | 832.02 | 784.79 | 6,301.79 | 2,661.33 | 1,184.13 | 479.01 |
| 2007–2009 | All | 13 | 1,361.04 | 1,075.16 | 440.72 | 583.58 | 3,711.63 | 2,995.38 | 722.07 | 582.55 |

Table 1.4. Eleven river otters were tracked using radiotelemetry in the central Platte River of Nebraska during 2007–2009 to assess habitat use. Compositional analysis was used to compare habitat use at three levels: 1) proportion of habitat types in the 95% minimum convex polygon (MCP) home ranges to the proportion available in the study area, 2) proportion of locations in each habitat to the proportion available in the 95% MCP home ranges, 3) proportion of locations in each habitat for each river otter to the proportion of available habitat in the study area. Preference profile tables based on mean differences between used and available log-ratios are given for each pair-wise habitat comparison. Habitat types connected by a common line are not different at $P = 0.05$.

| Level 1 | | | | | |
|---|---|---|---|---|---|
| | Most Preferred | | | | Least Preferred |
| | Open Water | River Channel | Riparian | Wet Meadow | Agricultural other |
| Open Water | ---------- | | | | |
| River Channel | | ---------- | | ---------- | |
| Riparian | | | ---------- | | |
| Wet Meadow | | ---------- | | ---------- | |
| Agricultural/other | | | | | ---------- |

| Level 2 | | | | | |
|---|---|---|---|---|---|
| | Most Preferred | | | | Least Preferred |
| | Open Water | Riparian | River Channel | Agricultural other | Wet Meadow |
| Open Water | ---------- | | | | |
| Riparian | | ---------- | | | |
| River Channel | | | ---------- | | |
| Agricultural/other | | | | ---------- | |
| Wet Meadow | | | | ---------- | |

| Level 3 | | | | | |
|---|---|---|---|---|---|
| | Most Preferred | | | | Least Preferred |
| | Open Water | Riparian | River Channel | Agricultural other | Wet Meadow |
| Open Water | ---------- | | | | |
| Riparian | | ---------- | | | |
| River Channel | | | ---------- | | |
| Agricultural/other | | | | ---------- | |
| Wet Meadow | | | | ---------- | |

Table 1.5. Ranking matrices comparing habitat use at level one (the proportion of habitat types in the 95% minimum convex polygon home ranges to the proportion available in the study area) for 11 river otters tracked in the central Platte River of Nebraska during 2007–2009 are provided. Mean differences between used and available log-ratios are given for each pair-wise habitat comparison. Ranking matrices show habitat used in greater (+) or lesser (-) proportion than expected. Deviation from random at $P$ <0.05 is shown by "+++" or "---". Habitat types are ranked from least selected (0) to most selected (4).

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other |
|---|---|---|---|---|---|
| Riparian | | -0.272 | -0.724 | 0.241 | 1.044 |
| River Channel | 0.272 | | -0.451 | 0.513 | 1.316 |
| Open Water | 0.724 | 0.452 | | 0.964 | 1.768 |
| Wet Meadow | -0.241 | -0.513 | -0.964 | | 0.804 |
| Agricultural/other | -1.044 | -1.316 | -1.768 | -0.804 | |

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other | Rank |
|---|---|---|---|---|---|---|
| Riparian | | --- | --- | + | +++ | 2 |
| River Channel | +++ | | --- | + | +++ | 3 |
| Open Water | +++ | +++ | | +++ | +++ | 4 |
| Wet Meadow | - | - | --- | | +++ | 1 |
| Agricultural/other | --- | --- | --- | --- | | 0 |

Table 1.6. Ranking matrices comparing habitat use at level two (the proportion of locations in each habitat to the proportion available in the 95% minimum convex polygon home ranges) for 11 river otters tracked in the central Platte River of Nebraska during 2007–2009 are provided. Mean differences between used and available log-ratios are given for each pair-wise habitat comparison. Ranking matrices show habitat used in greater (+) or lesser (-) proportion than expected. Deviation from random at $P$ <0.05 is shown by "+++" or "---". Habitat types are ranked from least selected (0) to most selected (4).

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other |
|---|---|---|---|---|---|
| Riparian | | 0.656 | -0.912 | 2.281 | 1.945 |
| River Channel | -0.656 | | -1.568 | 1.625 | 1.289 |
| Open Water | 0.912 | 1.568 | | 3.193 | 2.857 |
| Wet Meadow | -2.281 | -1.625 | -3.193 | | -0.336 |
| Agricultural/other | -1.945 | -1.289 | -2.857 | 0.336 | |

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other | Rank |
|---|---|---|---|---|---|---|
| Riparian | | +++ | --- | +++ | +++ | 3 |
| River Channel | --- | | --- | +++ | +++ | 2 |
| Open Water | +++ | +++ | | +++ | +++ | 4 |
| Wet Meadow | --- | --- | --- | | - | 0 |
| Agricultural/other | --- | --- | --- | + | | 1 |

Table 1.7. Ranking matrices comparing habitat use at level three (the proportion of locations in each habitat type for each river otter to the available habitat in the study area) for 11 river otters tracked in the central Platte River of Nebraska during 2007–2009 are provided. Mean differences between used and available log-ratios are given for each pair-wise habitat comparison. Ranking matrices show habitat used in greater (+) or lesser (-) proportion than expected. Deviation from random at $P$ <0.05 is shown by "+++" or "---". Habitat types are ranked from least selected (0) to most selected (4).

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other |
|---|---|---|---|---|---|
| Riparian | | 0.656 | -0.912 | 2.281 | 1.945 |
| River Channel | -0.656 | | -1.568 | 1.625 | 1.289 |
| Open Water | 0.912 | 1.568 | | 3.193 | 2.857 |
| Wet Meadow | -2.281 | -1.625 | -3.193 | | -0.336 |
| Agricultural/other | -1.945 | -1.289 | -2.857 | 0.336 | |

| | Riparian | River Channel | Open Water | Wet Meadow | Agricultural other | Rank |
|---|---|---|---|---|---|---|
| Riparian | | +++ | --- | +++ | +++ | 3 |
| River Channel | --- | | --- | +++ | +++ | 2 |
| Open Water | +++ | +++ | | +++ | +++ | 4 |
| Wet Meadow | --- | --- | --- | | - | 0 |
| Agricultural/other | --- | --- | --- | + | | 1 |

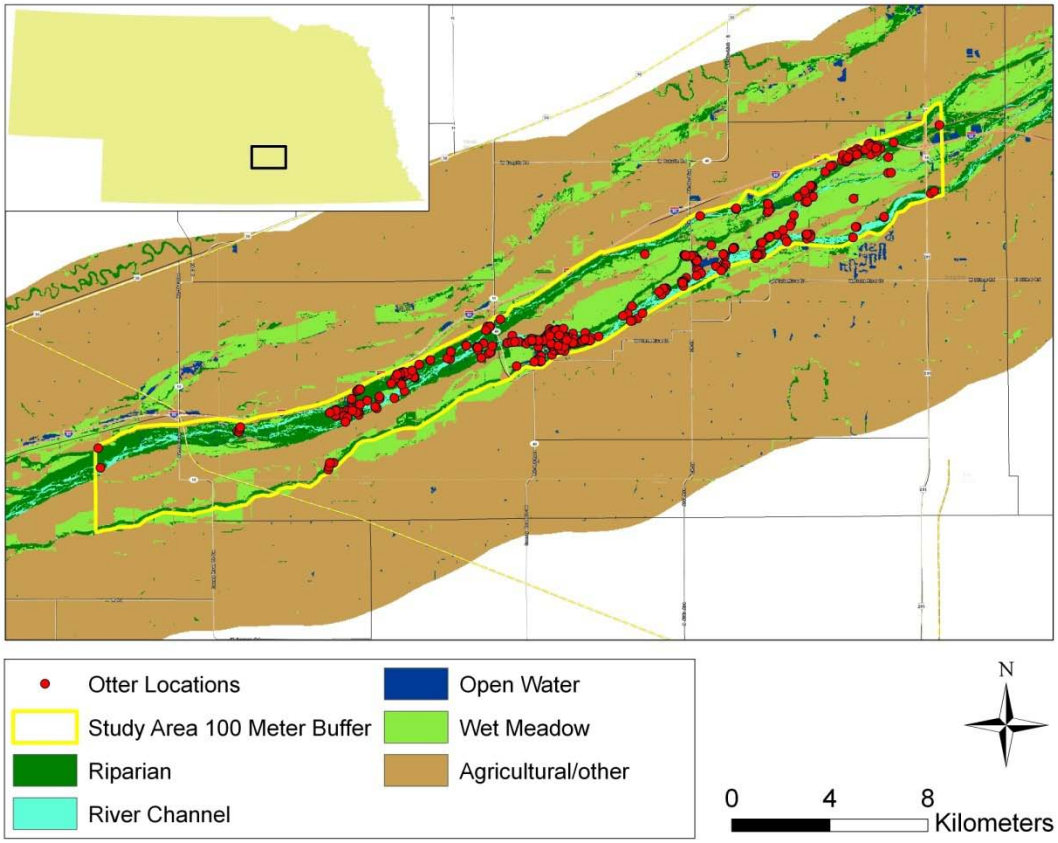


Figure 1.1. River otters were tracked using radiotelemetry during 2007–2009 on the central Platte River in south central Nebraska to assess home range and habitat use. Trapping and telemetry efforts primarily occurred on a 32-km stretch of the Platte River and adjacent tributaries, wetlands, and lakes, south of the Shelton and Grand Island exits of Interstate 80. The boundaries of the study area used to assess habitat use were defined as the north and south channel of the Platte River and the easternmost and westernmost river otter locations buffered by 100 meters. River otter telemetry locations, the study area boundary, and the habitat types in the study area are provided.

Figure 1.2. The central Platte River of Nebraska, frozen during winter, 2007.

Figure 1.3. The central Platte River of Nebraska with no flowing water due to drought, 2004. Photo courtesy of NEBRASKAland Magazine/Nebraska Game and Parks Commission.

Figure 1.4. The multi-braided channels of the central Platte River of Nebraska, 2002. Photo courtesy of NEBRASKAland Magazine/Nebraska Game and Parks Commission.

# CHAPTER 2: OVERNIGHT MOVEMENT, DISPERSAL, AND SURVIVAL OF RIVER OTTERS (*LONTRA CANADENSIS*) IN THE CENTRAL PLATTE RIVER OF NEBRASKA

## INTRODUCTION

River otter (*Lontra canadensis*) populations have been expanding in Nebraska since their reintroduction in the late 1980s and early 1990s (Bischof 2003). The Nebraska Game and Parks Commission (NGPC) collects carcasses and conducts sign surveys at bridges during winter to estimate changes in river otter distribution and population size but these methods are limited. Information regarding river otter movement, dispersal, and annual survival is needed to assess the effectiveness of present surveys, connectivity between release sites, and expansion of reintroduced otters. This critical information will be used by NGPC to assess the status of river otters in Nebraska and will guide conservation efforts of this high profile threatened species.

River otters are native to the state of Nebraska and were found in all major waterways of the state prior to European settlement (Jones 1964). Habitat alteration, unregulated harvest, and pollution led to the extirpation of the species from the state by the early 1900s (Jones 1964). River otters experienced a similar fate throughout much of the Midwest and 15 states reported river otters as extirpated or rare by the mid 1900s (Toweill and Tabor 1982). River otter reintroductions were initiated in Colorado in 1977 (Tishbein 1976) and by 1998, 21 states had implemented river otter reintroduction projects (Raesly 2001). In Nebraska, the Nebraska Game and Parks Commission released 159 river otters between 1986 and 1991 at seven release sites in five of the major river

basins to reestablish the species throughout the state (Andelt 1988; Andelt 1992; Bischof 2003).

River otter distribution in Nebraska has expanded since these releases, and the population appears to be stable or growing (Bischof 2003; Hoffman and Genoways 2005). Expanding populations typically have age distributions skewed toward younger age classes. Age data for 24 river otters that were opportunistically collected by NGPC between 2001 and 2004 show that 71% were age one or two (Figure 2.1), which suggests that the population was expanding at that time. River otters had expanded into the Nemaha and Middle Loup rivers by 2003 (Bischof 2003; Hoffman and Genoways 2005) and have since been documented in the Missouri and Republican rivers (S. P. Wilson, Nebraska Game and Parks Commission, unpublished data).

Expanding river otter distribution in Nebraska may be explained in part by immigration from neighboring states (Hoffman and Genoways 2005). River otter populations in the adjacent states of Iowa and Missouri have fully recovered since their reintroduction (Pitt et al. 2003; D. Hamilton, Missouri Department of Conservation, personal communication), and dispersing river otters from these states may be the source of those found in the Missouri and Nemaha rivers where no reintroductions took place. River otter reintroductions have been largely successful with populations now present in all of the conterminous United States other than New Mexico (Raesly 2001).

River otter reintroductions have been successful in part because of high annual survival rates for adult river otters (Raesly 2001). Annual survival rates reported for adult river otters range from 73% for females in Oregon with legal harvest (Tabor and Wright

1977) to 91% for river otters reintroduced to Great Smoky Mountain National Park in Tennessee with no legal harvest (Griess 1987). Annual survival rates in neighboring Missouri and Iowa were estimated at 81% and 86% respectively before harvest seasons were allowed (Erickson and McCullough 1987; Pitt et al. 2003).

Predators native to Nebraska that have been documented preying upon river otters include bald eagles (*Haliaeetus leucocephalus*), coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), bobcats (*Lynx rufus*), and mountain lions (*Puma concolor*); however, predation events typically involve young otters or vulnerable adults (Melquist et al. 2003) such as those on land (Melquist and Hornocker 1983) or caught in traps. Predation, parasites, and disease have not been shown to have a major influence on river otter populations (Melquist et al. 2003). Human activities are a primary source of mortalities for river otters, with vehicle collisions, domestic dogs, firearms, and trapping among the specific causes of human induced mortalities (Melquist and Hornocker 1983). Bischof (2003) found that accidental trapping by beaver trappers accounted for 86% of known river otter mortalities in Nebraska and vehicle collisions accounted for 5%.

River otters are highly mobile and capable of traveling long distances over land and by water when searching for mates, exploring, or dispersing (Melquist and Hornocker 1983). Andelt (1988) documented long-distance movements of 1,138 km and 324 km by reintroduced river otters in Nebraska. Melquist and Hornocker (1983) found maximum distances traveled between consecutive days ranged from seven to 42 kilometers. Mean distances traveled between consecutive days or over a 24-hour period range from 0.6 km documented by McDonald (1989) during the summer and fall in Ohio

to 3.6 km documented by Foy (1984) in coastal Texas. River otter movements vary seasonally and are restricted during winter months in temperate areas (Melquist and Hornocker 1983; Reid et al. 1994). Female river otter movements may increase dramatically while searching for a natal den and then decrease after giving birth (Reid et al. 1994).

The seven reintroduction sites in Nebraska (Figure 2.2) are geographically distant with the closest two sites separated by a Euclidean distance of ~52 km and a distance of ~261 km by river. Dispersal and movement information for river otters in Nebraska is needed to assess connectivity between populations and expansion from the release sites. Sign surveys conducted at bridges during the winter – searching for tracks, scat, and slides on snow and ice – have been used to assess expansion of river otter distribution since 2000 (Bischof 2003). Crowley et al. (2012) found that the probability of detecting river otter tracks on snow increases as daily movement distances increase, and river otter movements in winter are known to be restricted in northern climates (Melquist and Hornocker 1983; Reid et al. 1994); therefore, information regarding seasonal differences in daily movements is needed to assess the validity of these winter sign surveys. Movement information is also needed to assess the availability of habitats adjacent to or outside the major river systems in Nebraska. In addition, information regarding river otter survival rates is needed to assess the growth of the population since its reintroduction and to make determinations regarding the recovery of the species in Nebraska. To gather information regarding movement and survival needed to assess current survey techniques and expansion of river otter populations in Nebraska, my objectives were to: 1) determine overnight movements for river otters in the central Platte River and detect differences

during winter months and the remainder of the year, 2) identify and describe dispersal by river otters in the central Platte River, and 3) determine annual survival for river otters in the central Platte River.

## MATERIALS AND METHODS

### Study Area

This project was conducted from 2006 through 2009 on the Platte River in south central and eastern Nebraska. Trapping efforts primarily occurred on a 32-km stretch of the Platte River and adjacent tributaries, wetlands, and lakes between the Shelton and Grand Island exits of Interstate 80 (Figure 2.3). Telemetry searches were primarily conducted on a 180-km stretch of the Platte River south of the towns of Gibbon and Schuyler (Figure 2.4). ). The Platte River in my study area is a complex braided river system consisting of broad and shallow sandy bottomed channels that may be separated by more than two kilometers of land, sandbars that are created and altered with seasonal flooding, and large islands dominated by riparian forests. The Platte originates in Colorado and flows through Wyoming and across the length of Nebraska. Flow rates vary by year and within years but are typically between 0 and 6,500 cubic feet per second. The Platte River presently supports a growing river otter population and appears to be critical to the establishment of this species in Nebraska (Bischof 2003). Two of the seven original reintroduction sites were on the Platte River, and four rivers with reintroduction sites drain into it. The Platte River passes through public property and private property owned by non-governmental organizations such as the Whooping Crane Trust, The Nature Conservancy, and The National Audubon Society, all of which facilitated the

search for study animals. The combination of established river otter presence, connectivity to other river systems in Nebraska, and access to large stretches of river made this the ideal site for this study.

**Capture and Radiotelemetry Implantation**

I captured river otters using modified No. 11 double jaw, double long-spring Sleepy Creek foothold traps (Sleepy Creek Manufacturing, Berkeley Springs, WV), which are recommended by Blundell et al. (1999) for the capture of river otters because of low escape rates and low rates of trap-related injuries. A small number (<5) of Onieda Victor No. 1.5 soft-catch coil spring traps (Oneida Victor Inc., Cleveland, Ohio) were used during the first trapping season. A shock spring and three swivels were added to the chain of each trap to allow freedom of movement and reduce injury. Traps were anchored in sand or soil using earth anchors consisting of two-inch washers with a heavy-duty six gauge j-hook in the center that was attached to a 60 cm segment of 3/32 inch galvanized aircraft cable. Trapping was conducted during late summer through early winter to avoid trapping female river otters with dependent young and problems associated with thermal regulation by trapped river otters. All traps were checked daily before noon to minimize stress to the captured animals associated with being restrained.

Traps were set in areas where river otter sign was present, such as latrine sites or crossover trails between adjacent water bodies. Areas where trapping occurred were cleared of brush, branches, or other material that could become entangled with the trap or chain and further restrict movement by the trapped animal (Serfass et al. 1996). Traps were set on land or in the water. When possible, traps were anchored so the river otter

could chose to be submerged or on dry land as needed for thermoregulation. To reduce incidental capture of non-target species like raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*) that are abundant in the study area, traps were not baited, and no scent lures were used.

Trapped river otters were transferred to a transport container that consisted of a 75 liter plastic barrel with a sliding Plexiglas door on the front (Serfass et al. 1993). They were transported in the container to the University of Nebraska Animal Research Facility in Lincoln, NE. The river otters and transport containers were weighed and the tare container weight was subtracted from the total weight to determine the correct dose of anesthetic. The river otters were then restrained in a squeeze box (McCullough et al. 1986) and anesthetized with a mixture of ketamine (16 mg/kg) and midazolam (0.25 mg/kg) by a veterinarian. The combination of ketamine and midazolam provides a large margin of safety (Belfiore 2008) as well as a longer anesthetic effect with fewer complications than when only ketamine is used (Spelman et. al 1993). Each river otter was examined by a veterinarian to determine overall health status, gender, and weight and to document any trap-related injuries. River otters above 6.25 kg were assumed to be sub-adults or adults and were retained for surgery. Sterilized Advanced Telemetry Systems M1250B radio transmitters (Advanced Telemetry Systems Inc., Isanti, MN) equipped with activity and mortality sensors were implanted into the abdominal cavity following procedures similar to those outlined by Hernandez-Divers et al. (2001). Intra-peritoneal transmitters are effective for river otter research (Melquist and Hornocker 1983) and do not impede reproduction by females (Reid et al. 1986). River otters were administered meloxicam at a ratio of 0.1 mg/kg to control pain, given penicillin

benthazine to prevent infection, and given Lactated Ringer's solution (200 cc) subcutaneously to replenish fluids and electrolytes. A passive integrated transponder tag was implanted subcutaneously under the base of the tail to allow the river otters to be identified if the radio transmitter failed (Bowyer et al. 2003, Helon et al. 2004).

Following these procedures, river otters were placed in clean transport containers and monitored by a veterinarian to assure a normal recovery from surgery and anesthesia. Each river otter was released at the location where it was trapped as soon as possible (typically within five hours) after recovery from the anesthesia (Testa et al. 1994). All protocols used for this project were approved by the University of Nebraska–Lincoln Institutional Animal Care and Use Committee (UNL–IACUC Protocol #06–09–35D).

**Radiotelemetry**

Dispersal movements and survival were determined by locating river otters by radiotelemetry 2–4 times per week until the batteries failed (batteries were warranted for 571 days) or until the project concluded in December 2009. Monitoring was accomplished primarily by tracking on the ground using a Communications Specialists R–1000 receiver (Communications Specialists Inc., Orange, CA), truck-mounted omni-directional antenna, and 3-element Yagi antenna. Telemetry from fixed-wing aircraft and canoes was used periodically to relocate animals because some transmitters could not be detected from >100 meters on the ground. Exact locations were determined whenever possible by homing in on the telemetry signal until the location was determined and then recording the location using a Garmin GPS 72 (Garmin International, Inc., Olathe, KS) global positioning system. When safety considerations or lack of permission to enter

property did not allow for an exact location to be determined, locations were determined by biangulation or triangulation. Bearings were taken within five minutes to reduce error associated with movements by the study animal (White and Garrott 1990). When a mortality signal was detected, an immediate attempt was made to determine if it represented a true mortality or if it was a false signal. A false signal was indicated by motion signals from the transmitter or by movements either upstream or over land typical of live river otters.

River otters often remain in dens during the day and are generally considered crepuscular or nocturnal (Larivière and Walton 1998). To determine the extent of overnight movements I periodically tracked river otters by locating them in dens during late afternoon using radiotelemetry and following them on foot or by vehicle until they reentered a den the following morning. Locations were taken every half hour or as needed to keep track of the individual being followed. If extreme weather conditions or other factors prevented the river otter from being tracked from 30 minutes before sunset to 30 minutes after sunrise it was not included in the analysis. I conducted tracking sessions throughout the year on all river otters that could be located. Individual river otters were not tracked overnight more than once per month to avoid causing stress to the tracked animals. At least five overnight tracking sessions were conducted during each of two biologically important time periods when river otter movement may vary: 1) winter months (January–February) when bridge surveys are conducted and movements may be reduced and 2) natal and breeding seasons (March–May).

**Statistical Analysis**

Locations for river otters collected by biangulation and triangulation were estimated using Location of Signal software (Version 4.0; Ecological Software Solutions LLC. Hegymagas, Hungary). Estimated and exact locations were mapped using ArcGIS 9.3 (ESRI. Redlands, CA). Overnight movement distances were determined by measuring the Euclidean distance between consecutive locations recorded for each river otter using Home Range Tools for ArcGIS (Rodgers et al. 2007) or ArcGIS 9.3. Overnight movement data did not meet assumptions of normality; therefore, a Wilcoxon rank-sum test was used to detect differences ($P < 0.05$) between overnight movements during January and February when bridge surveys are conducted and the rest of the year. All statistical analyses were performed using the statistical software R, version 2.12.1 (R Development Core Team, 2012).

Natal dispersal for river otters is defined by Blundell et al. (2002) as a permanent movement of >20 km from the natal range. I used this definition to identify dispersers and distinguish between true dispersal and exploratory movements in which the river otter eventually returns to its natal range. Dispersal distances were calculated as the distance from the location where the river otter was trapped to the most distant location recorded for that river otter. River otters may have been in the process of dispersing when trapped, so dispersal distances represent a conservative estimate.

Annual survival was calculated for each river otter using the Kaplan-Meier staggered-entry model described by Pollock et al. (1989). I assumed that capture and implantation of transmitters did not affect survival after the first week post-surgery. River

otters that died or could not be located within the first week of their release were left-censored as these events were considered to have been caused by trauma related to surgical implantation or transmitter failure. I assumed that river otters captured were representative of the population, that implantation of transmitters did not influence survival, that individuals that could no longer be located by telemetry did not have a higher probability of death, and that the fates of study animals were independent of one another (Bunck 1987; Pollock et al. 1989). Survival was also quantified by calculating the number of days each river otter was known to be alive.

## RESULTS

### Capture and Radiotelemetry Implantation

I trapped and implanted radiotelemetry transmitters in 18 river otters (10 male, 8 female): five in 2006 (three male, two female), seven in 2007 (three male, four female), and six in 2008 (four male, two female) (Table 2.1). None of the river otters trapped during the study exhibited any serious trap-related injuries. The majority of river otters were released on the same day they were captured to reduce stress related to being held in captivity.

### Monitoring

I collected 996 total telemetry locations during the three-year telemetry phase of the study (January 1, 2007–December 31, 2009). Exact locations where a river otter was tracked to a den or resting site comprised 58% of the sample of locations.

**Overnight Movements**

I recorded 19 overnight movements consisting of 465 total telemetry locations for four river otters (two male, two female) from January 2007 to January 2008 (Table 2.2). Mean distance moved overnight was 3.49 km (*SD* = 2.99). Mean overnight movement for female river otters (*n* = 14) was 4.14 km (*SD* = 3.24) and for male river otters (*n* = 5) was 1.67 km (*SD* = 0.699). Mean overnight movements during the natal/breeding season (March–May) were 5.93 km (*SD* = 3.35). Mean overnight movements during the winter months of January and February were 2.18 km (*SD* = 3.07) and were lower than movements during the rest of the year (*P* = 0.03). One female river otter (113F) that was monitored during February 2007 did not leave her den. Overnight movement distances for all river otters ranged from 0–10.13 km; which is also the range for female river otter movements. The range for male river otter overnight movement distances was 0.83–2.48 kilometers.

**Dispersal**

Two male river otters were identified as dispersers using the criteria of movement >20 km from site of capture without known return (Figure 2.5). A male river otter (032M) moved a Euclidean distance of 140 km or a distance of 149 km by river over a period of 183 days during 2006 and 2007. I was only able to acquire three locations for this animal with the last location determined from a telemetry-equipped fixed-wing aircraft. The second dispersing male river otter (195M) remained in the area where it was trapped for 46 days after being released in October 2006. It then moved a Euclidean distance of 84 km or a distance of 86 km by river over a period of 92 days in early 2007.

A home range was established by the river otter at this new site where it remained for the next 11 months until the battery in the transmitter expired.

**Survival**

Annual survival for the river otters in the study was 100% as no river otter mortalities were detected during the three years of the study (October 2006–December 2009). Eleven river otters were confirmed alive throughout the year that they were monitored for survival analysis; six were right-censored before the end of the monitoring period because they could no longer be located. One river otter (576M) was left-censored because I could not locate it within the first week after being released. The remaining 17 river otters were confirmed alive by telemetry for a combined total of 7,999 days (Figure 2.6). The mean number of days that river otters were tracked with no mortalities detected was 470.53 (*SD* = 168.84). Four river otters were known to be alive 45–316 days beyond the warranted battery life of the transmitters (571 days). Thirteen of 17 river otters were known to be alive for at least one year after they were released. All 17 river otters were known to be alive for at least 182 days (~half a year) after they were released.

**DISCUSSION**

Movement, dispersal, and survival information for river otters has been documented in multiple areas in North America (Tabor and Wight 1977, Melquist and Hornocker 1983, Foy 1984) but there is no published information for the Northern Prairie Plains states (NE, SD, ND). Many previous telemetry studies took place during reintroductions efforts (Erickson and McCullough 1987; Griess 1987; Johnson and

Berkley 1999; Pitt el al. 2003; Spinola et al. 2008) and may not represent movement and survival data typical of established populations. The movement, dispersal, and survival information gathered here supports the observation by Bischof (2003) that the population of reintroduced river otters in Nebraska is expanding in distribution and size.

Mean overnight movements of 3.49 km for the river otters in my study are at the higher end of previously reported daily movements, which range from 0.6–3.6 kilometers (McDonald 1989; Foy 1984). The longer movements recorded in my study can be explained in part by variations in the methods used to calculate daily or 24-hour movements. Foy (1984) observed larger movements when locating river otters hourly over a 24-hour period than when locating them only once every six hours, and suggested hourly fixes provide a better estimate. Woolington (1984) and McDonald (1989) reported daily movements as the distance between locations taken on consecutive days, which Woolington noted should be considered a minimum distance moved. I located river otters every 30 minutes to estimate overnight movements in part so I could capture a better representation of the true distance moved; however, the overnight movement estimates are still likely an underestimation.

Variation in overnight movements and the implications this has for detectability during surveys is evident in the difference in distances traveled by female river otter 113F during consecutive tracking sessions. During February 2007 otter 113F remained in a den at a sandpit lake or under the ice within 100 meters of the den during an entire overnight tracking session. The following month during an overnight tracking session 113F traveled 10.13 km, which was the longest distance recorded in the study. Reduced winter

movements have been documented for river otters in northern climates (Melquist and Hornocker 1983; Reid et al. 1994), and movements during January and February were shorter than during the rest of the year in my study. Melquist and Hornocker (1983) noted that airspace under ice creates ideal conditions for river otters, and open water habitats such as the sandpit lake that 113F was using were identified in the habitat use phase of this study as activity centers of particular importance during the winter months. Sandpit lakes with surface ice such as this provide protection from extreme weather, unfrozen deep water, accessible prey, and den sites if beaver are present.

The combination of reduced movements during Jan–Feb and this observation of a female with no measurable overnight movement cast doubt upon the validity of sign surveys at bridges for detecting river otter presence. The detection probability for the sign surveys has not been determined for the study area, but it is likely low as river otter sign was only identified at one out of nine bridges in 2008 (the only year the survey was run at the study site during the project). Each of the nine bridges surveyed was located within one or more resident river otter home ranges, as identified during the home range portion of this study. Additionally, Williams (2011), who conducted research concomitantly with this project, estimated the density of river otters in the central Platte River was 0.99-1.13 otters/kilometer, which is higher than any previous estimates anywhere in North America. This further illustrates the inadequacy of present sign survey methods. Data from winter sign surveys at bridges should be interpreted with caution.

The two river otters that were identified as dispersers were both males and both dispersed downstream in the Platte River. The long distances these animals traveled

provide evidence that reintroduced river otter populations are unlikely to be genetically isolated. As populations at reintroduction sites increase and expand over time they are likely to be more connected genetically as a larger number of dispersing animals become available and higher densities of river otters force a larger proportion of animals to disperse. River otter 195M dispersed and then set up a stable home range in a section of the Platte River where the presence of only a single river otter had been previously confirmed.

There are no previous studies that tracked a similar number of river otters over a similar time period without detecting a single mortality. Annual survival of adult river otters is high, but many of the prior survival estimates have either come from areas that allowed harvest or from monitoring efforts of translocated individuals. River otters had been established for >15 years when this study began, so the study animals were not subject to the same mortality factors as river otters that were translocated and exploring new habitat. Additionally, there is no legal harvest of river otters in Nebraska, and many of the fur harvesters in the study area have learned to avoid trapping otters. True annual survival for adult river otters in the region of my study area is less than 100%, but the information gathered during my research suggests annual survival for adults is very high.

Male river otter 195M was incidentally trapped in December 2010 and turned in to the Nebraska Game and Parks Commission as required by law. This individual was tracked by telemetry for 470 days and could not be located after February 2008. This is the only river otter from my study where the cause of death is known. He was trapped in the same general area where he set up his home range after dispersing, which suggests

that his transmitter either failed before the 571-day warranted period or became too weak to detect. This river otter survived for 1,516 days after being implanted with a transmitter (including the monitored and not monitored period), which provides additional evidence that annual survival is high in my study area. I do not know whether other river otters that could not be located represent mortalities, transmitter failures, or movements beyond my search area.

**Management Implications**

Dispersal information from this project shows that river otters from the central Platte River are establishing home ranges outside of previously recognized river otter distribution. The annual sign surveys conducted by the Nebraska Game and Parks Commission are meant to document changes in river otter distribution, but a decrease in river otter movements during winter and low detection of river otters that were known to be present suggest that new techniques for determining river otter distribution should be developed. Assessing geographic distribution and status of river otters in Nebraska may be best accomplished with trail cameras, which have proven effective for research with river otters (Stevens and Serfass 2008) and are not dependent on specific weather conditions as are sign surveys conducted at bridges during winter (ice and light snow). Sign searches and occupancy modeling has proven effective for assessing river otter distribution in neighboring Kansas (Jeffress et al. 2011) and likely provides better distribution information than bridge surveys. Suitability and accessibility of the Republican, Blue, and Little Blue rivers, and lakes in the Sandhills region of Nebraska

should be assessed because these areas may provide considerable habitat that is not currently known to be occupied.

The high annual survival documented during this project and the high density estimates documented by Williams (2011) suggest that river otters are fully recovered in the region of my trapping study area in the central Platte River. The statewide population of river otters is expanding and the population in the central Platte River provides a source for natural expansion throughout Nebraska. The central Platte River could also provide a source for river otters that could be translocated to unoccupied habitat to establish river otter populations throughout the state and promote the full recovery of this species.

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Table 2.1. Eighteen river otters were trapped on the central Platte River of Nebraska and implanted with radiotelemetry transmitters during 2006–2008 to assess overnight movement, dispersal, and survival. The unique identification number, gender, and year trapped are provided for each river otter.

| River Otter | Gender | Year Trapped |
|---|---|---|
| 195 | Male | 2006 |
| 212 | Male | 2006 |
| 113 | Female | 2006 |
| 032 | Male | 2006 |
| 275 | Female | 2006 |
| 135 | Female | 2007 |
| 056 | Female | 2007 |
| 175 | Male | 2007 |
| 014 | Female | 2007 |
| 294 | Male | 2007 |
| 254 | Female | 2007 |
| 395 | Male | 2007 |
| 233 | Male | 2008 |
| 576 | Male | 2008 |
| 556 | Male | 2008 |
| 684 | Female | 2008 |
| 626 | Male | 2008 |
| 596 | Female | 2008 |

Table 2.2. Nineteen overnight tracking sessions were conducted on four river otters (two male, two female) during 2007– 2008 to assess overnight movements of river otters in the central Platte River of Nebraska. Tracking sessions consisted of locating a river otter using radiotelemetry every 30 minutes between sunset and sunrise. Overnight movement distances were calculated as the total linear distance between consecutive telemetry locations. The unique identification number, gender, overnight movement distance in kilometers, and date of the tracking session are provided for each of the four river otters tracked.

| River Otter | Gender | Overnight Movement (km) | Month and Year |
|---|---|---|---|
| 275 | Female | 8.92 | January 2007 |
| 212 | Male | 1.08 | January 2007 |
| 113 | Female | 1.19 | January 2007 |
| 275 | Female | 0.14 | February 2007 |
| 113 | Female | 0 | February 2007 |
| 212 | Male | 1.82 | February 2007 |
| 113 | Female | 10.13 | March 2007 |
| 113 | Female | 2.56 | April 2007 |
| 275 | Female | 7.76 | April 2007 |
| 212 | Male | 2.48 | May 2007 |
| 275 | Female | 6.75 | May 2007 |
| 275 | Female | 1.88 | June 2007 |
| 113 | Female | 2.63 | June 2007 |

| | | | |
|---|---|---|---|
| 275 | Female | 3.58 | July 2007 |
| 113 | Female | 3.02 | July 2007 |
| 212 | Male | 0.83 | August 2007 |
| 275 | Female | 3.22 | September 2007 |
| 275 | Female | 6.16 | October 2007 |
| 395 | Male | 2.14 | January 2008 |

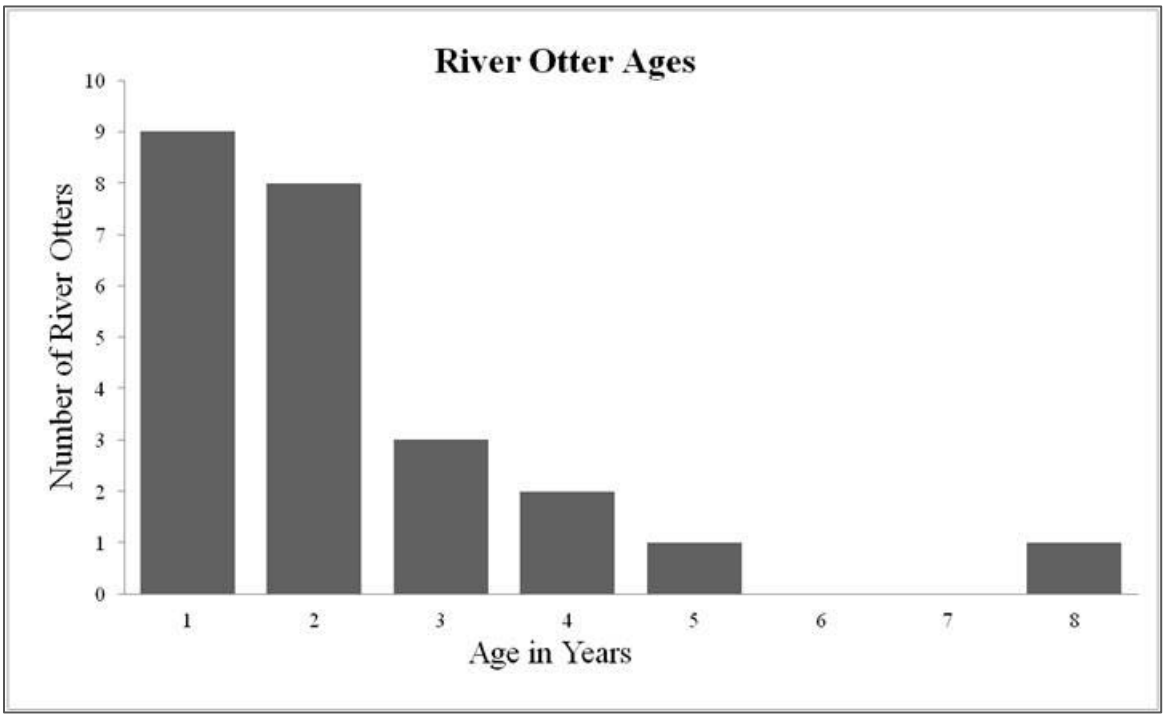


Figure 2.1. Carcasses of 24 river otters that were killed by vehicles or accidentally caught in beaver traps were collected by the Nebraska Game and Parks Commission between 2001 and 2004, with the majority collected from the central Platte River. These river otters were aged using cementum annuli counts of lower canine teeth to assess the age distribution of the population. The number of river otters in each age category and the estimated age are provided.

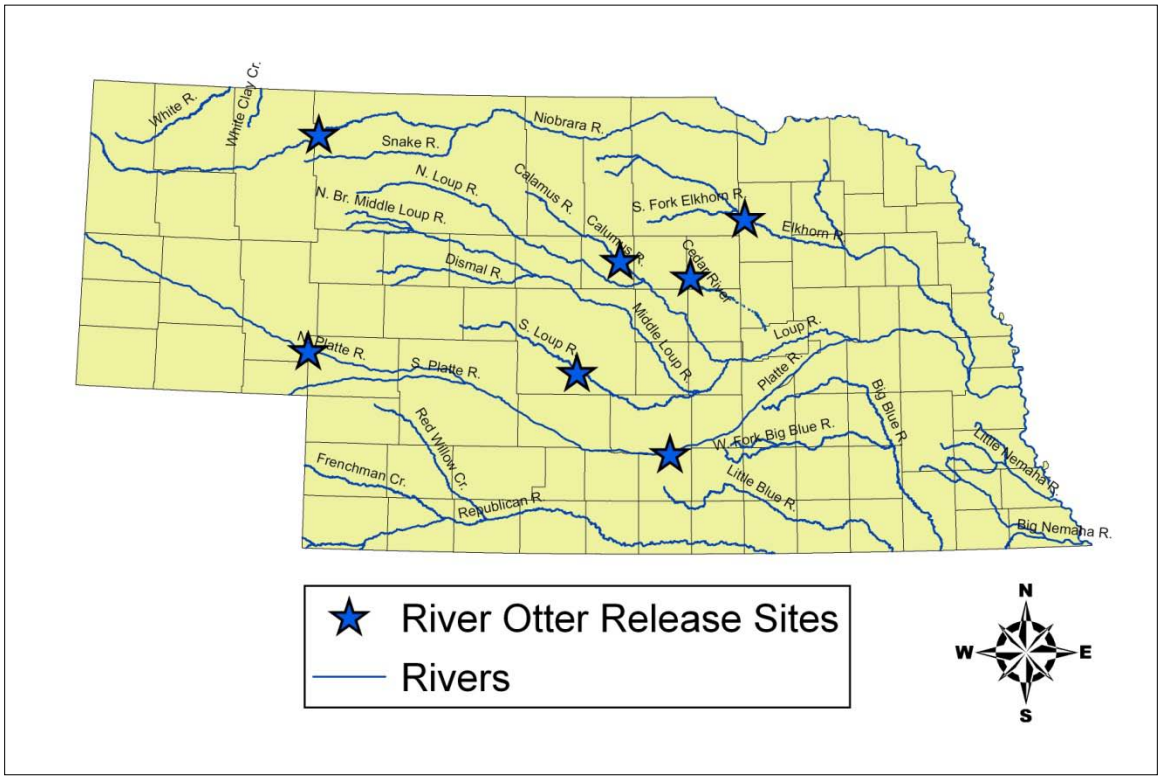


Figure 2.2. River otters were extirpated from Nebraska by the early 1900s. The Nebraska Game and Parks Commission reintroduced river otters at seven sites between 1986 and 1991 to reestablish the species in Nebraska.

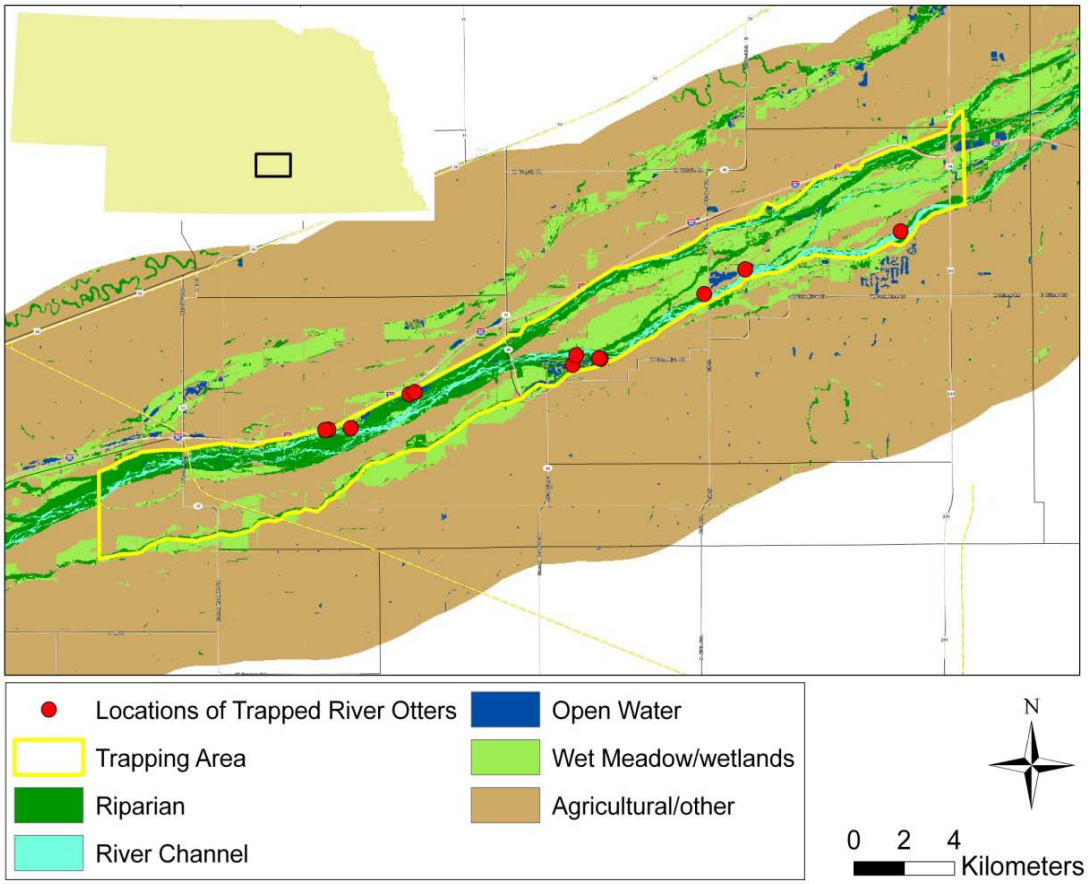


Figure 2.3. River otters were trapped and implanted with radiotelemetry transmitters in the central Platte River of Nebraska during 2006–2008 to gather overnight movement, dispersal, and survival information. Trapping efforts were focused on the Platte River and adjacent water bodies south of Interstate 80 between the Shelton and Grand Island exits.

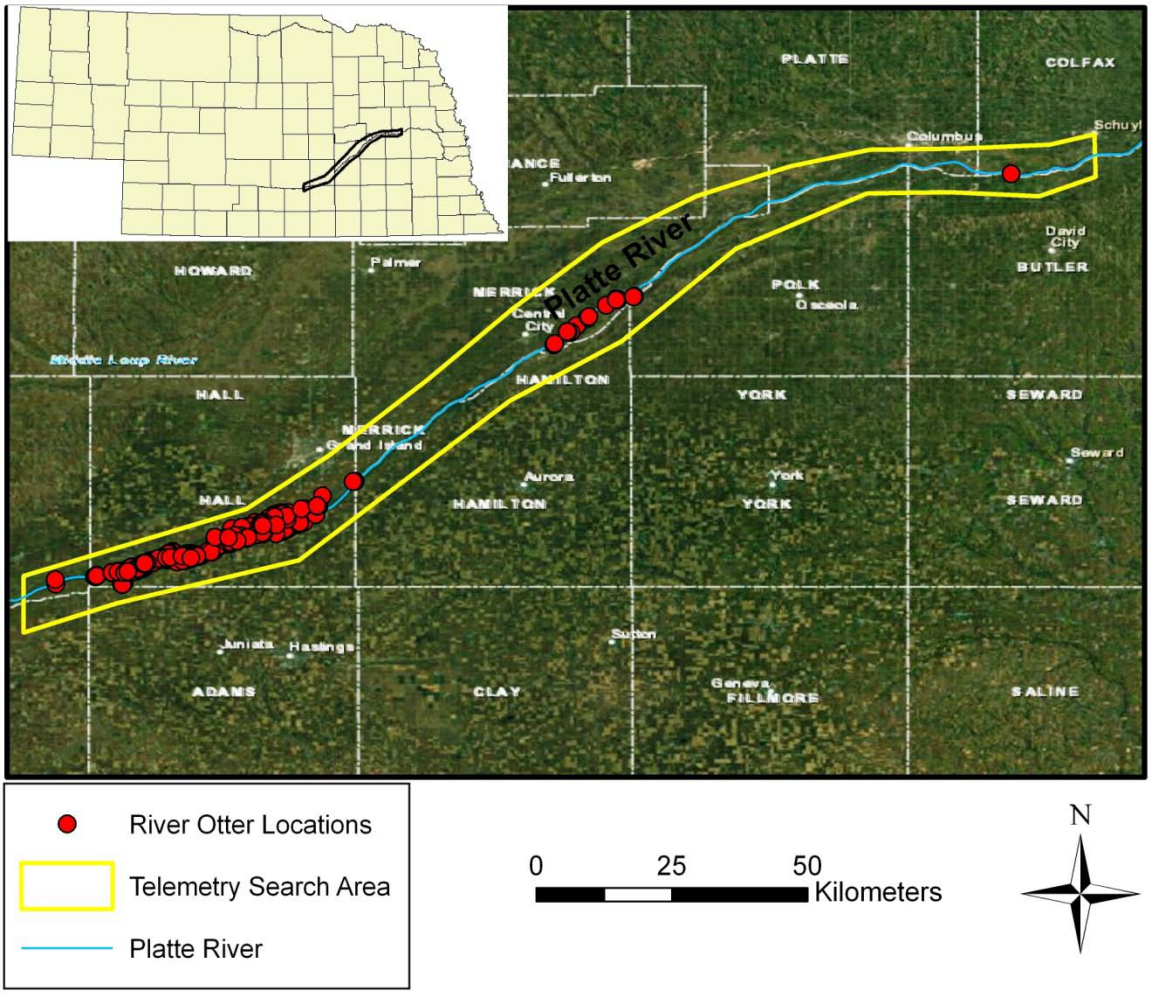


Figure 2.4. Eighteen river otters were located using radiotelemetry on the Platte River and adjacent water bodies south of the towns of Gibbon and Schuyler during 2006–2009 to gather overnight movement, dispersal, and survival information.

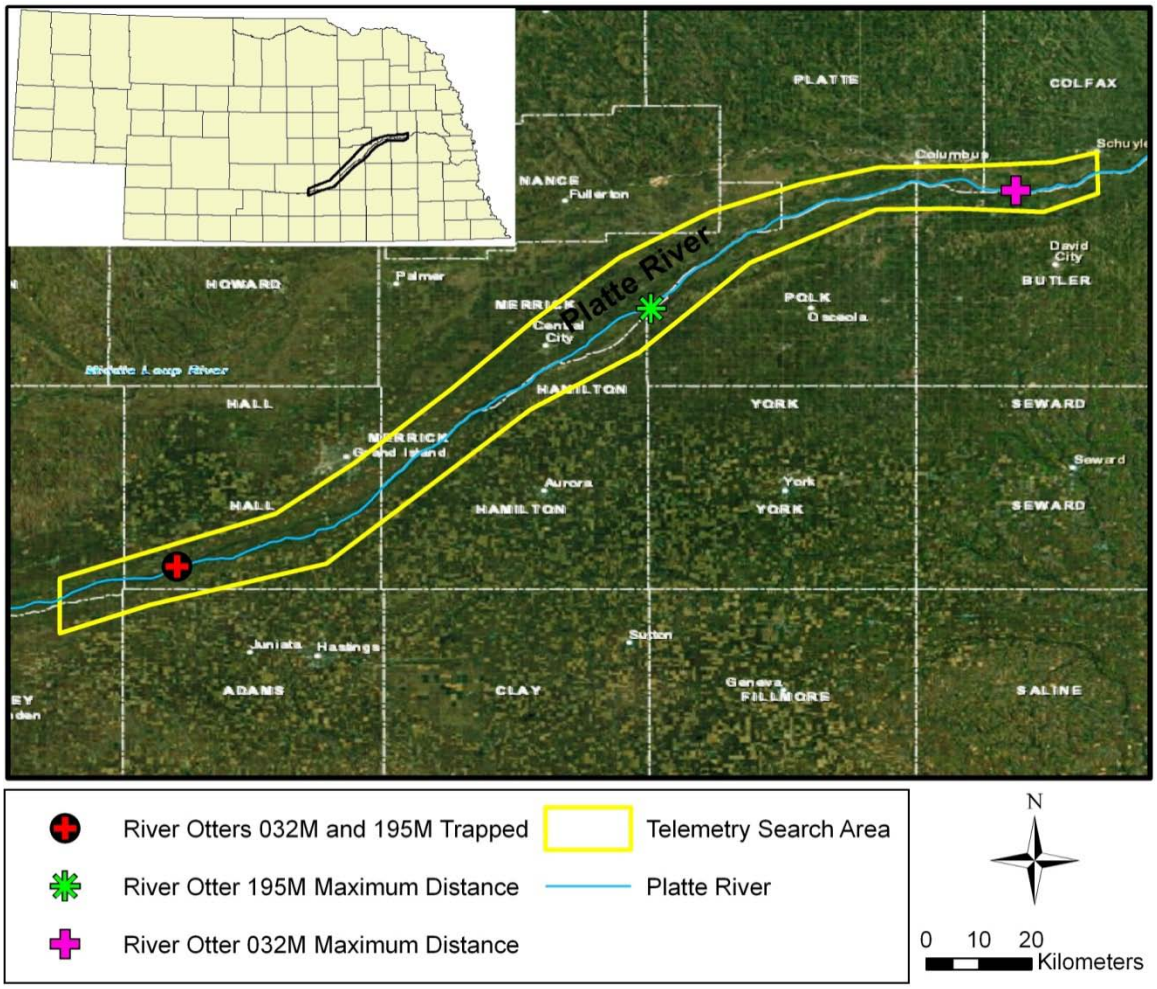


Figure 2.5. Dispersal by two male river otters (032M and 195M) was documented using radiotelemetry on the Platte River of Nebraska in 2006 and 2007. Dispersal was defined as a permanent movement of >20 km from the location where the river otter was trapped. The locations provided are the maximum distances these river otters were detected from the location where they were originally trapped.

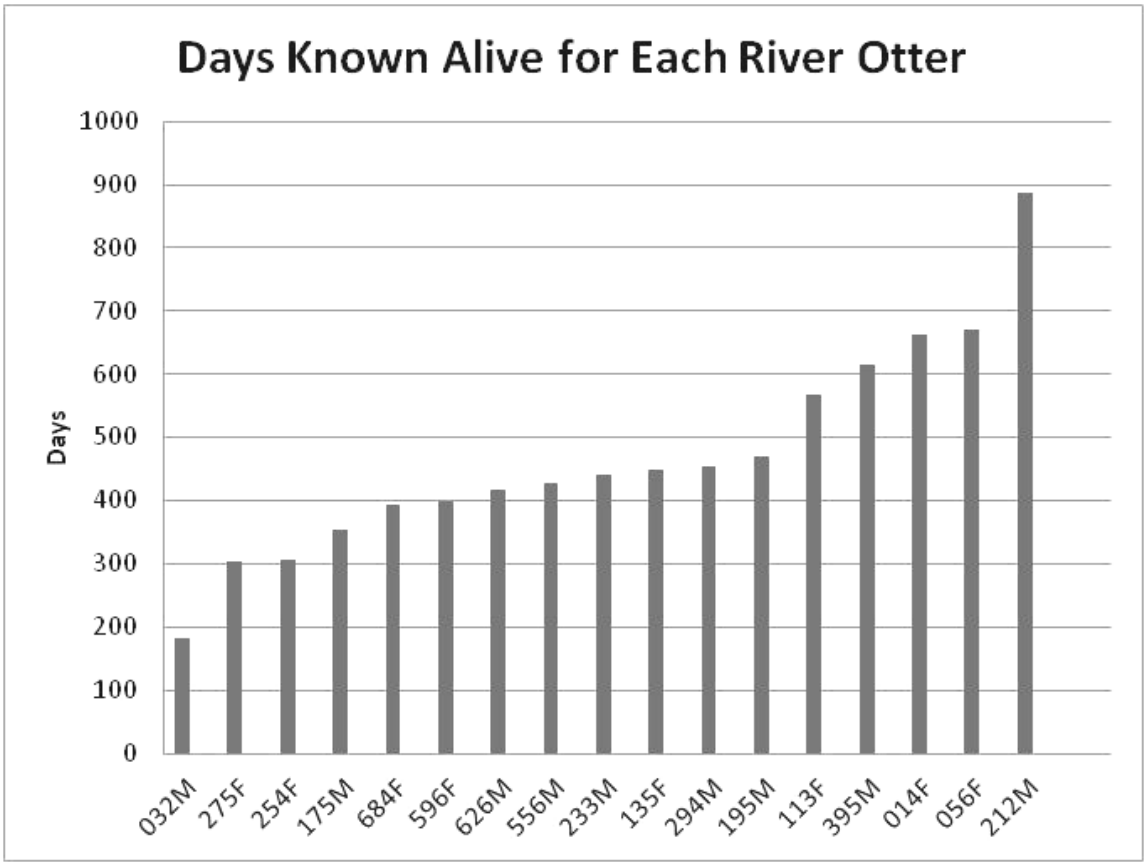


Figure 2.6. Eighteen river otters were trapped and implanted with radiotelemetry transmitters equipped with a mortality signal during 2006–2008 to assess annual survival of adult river otters in the central Platte River of Nebraska. No mortalities were detected during the telemetry phase of the study (2007–2009). The total number of days each river otter was known to be alive is provided.

Appendix A. Fixed kernel home ranges at the 95% and 50% level for all river otters with ≥30 locations in a given year, collected on the central Platte River of Nebraska during 2007–2009.

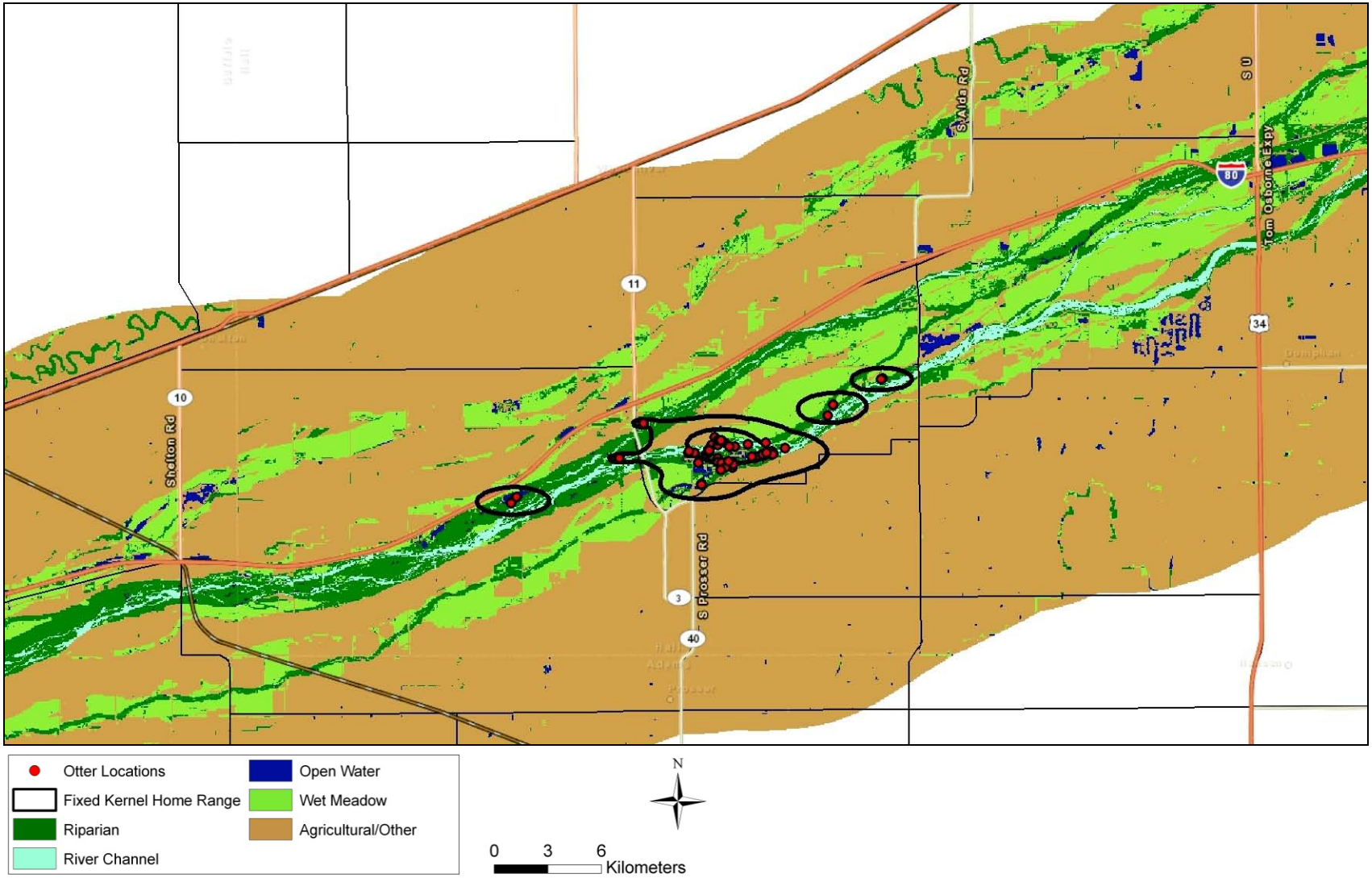


Figure A.1. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 113 during 2007.

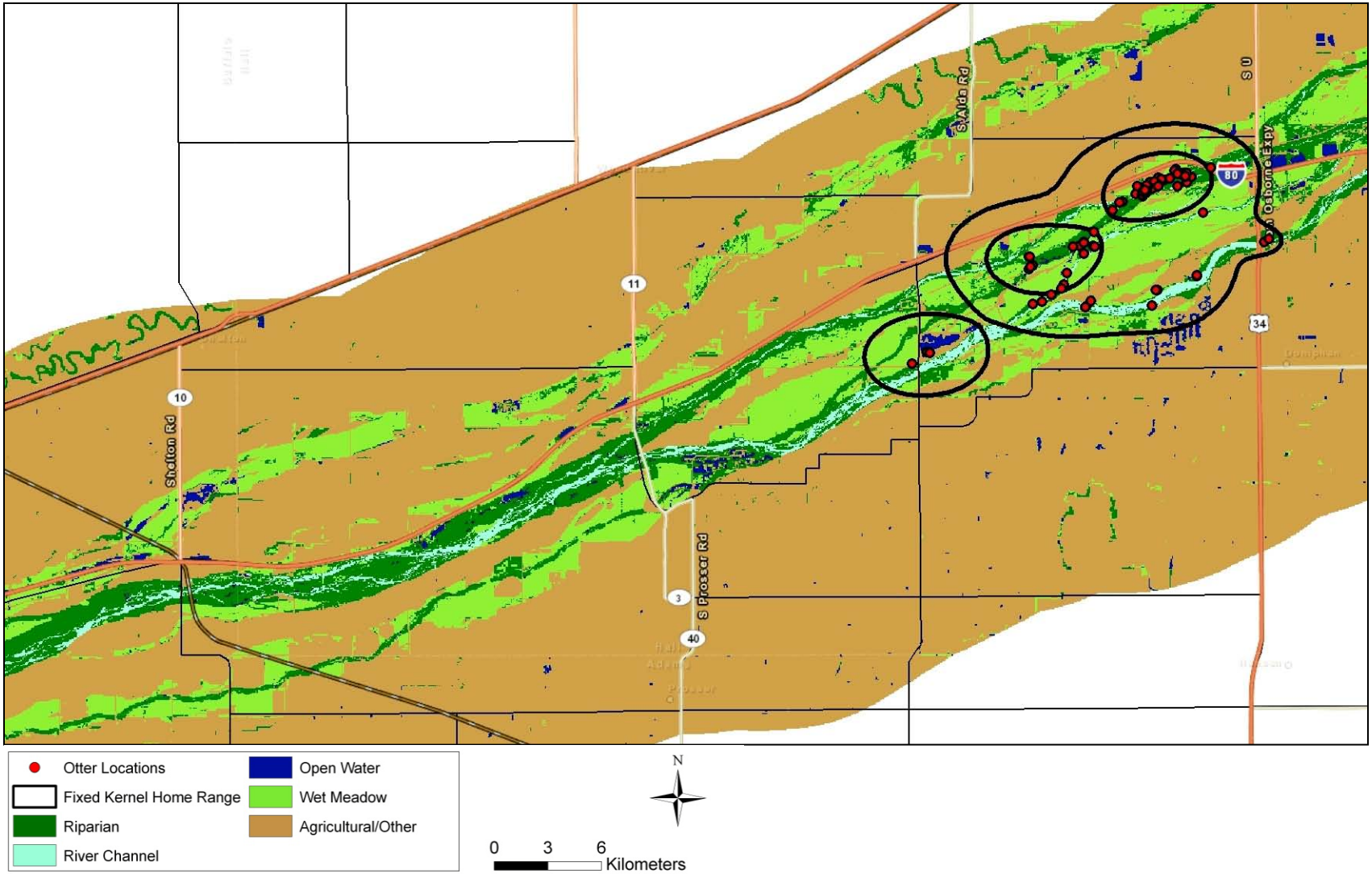


Figure A.2. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 275 during 2007.

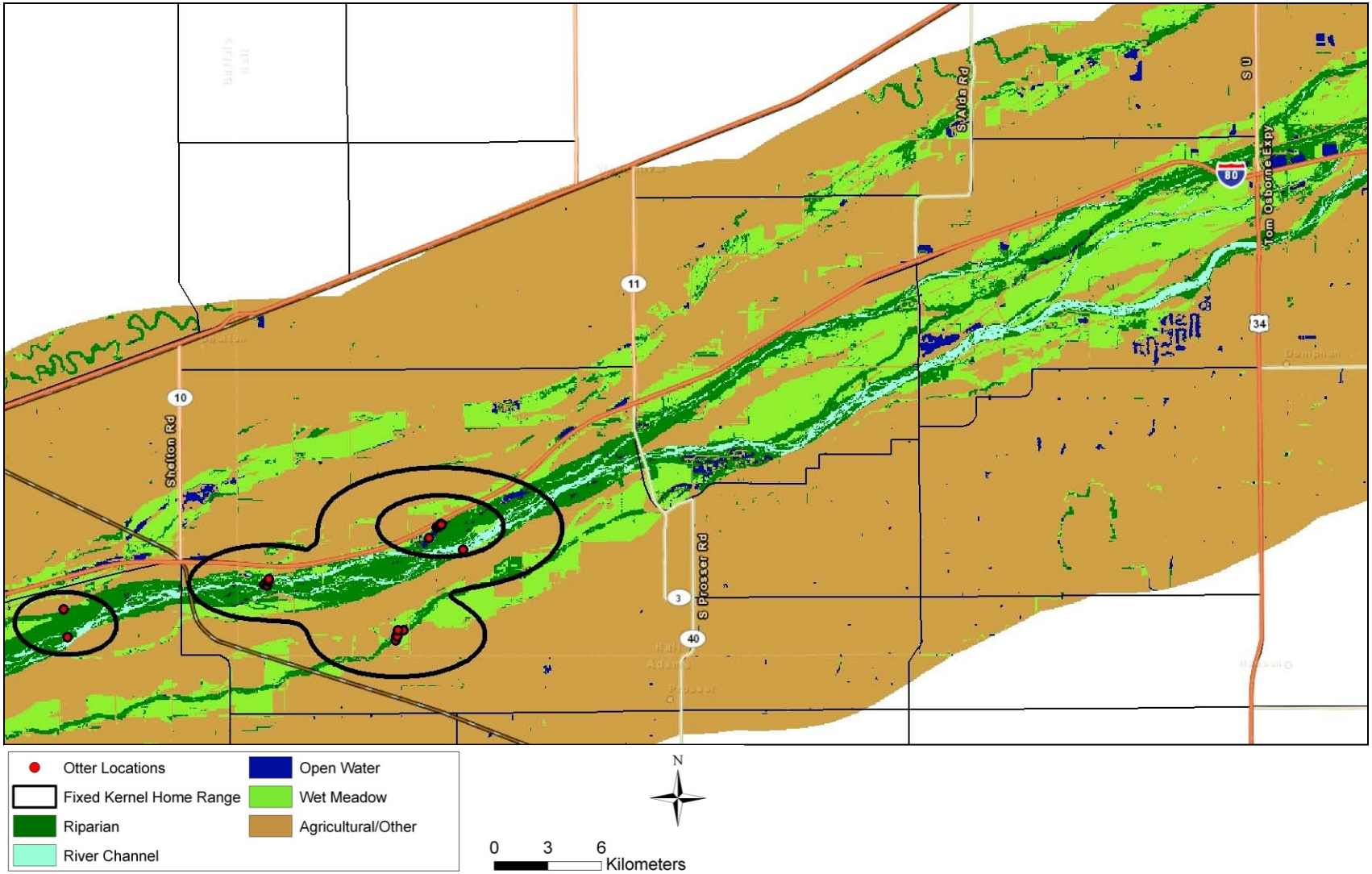


Figure A.3. Locations and fixed kernel home range at the 95% and 50% levels for male river otter 212 during 2007.

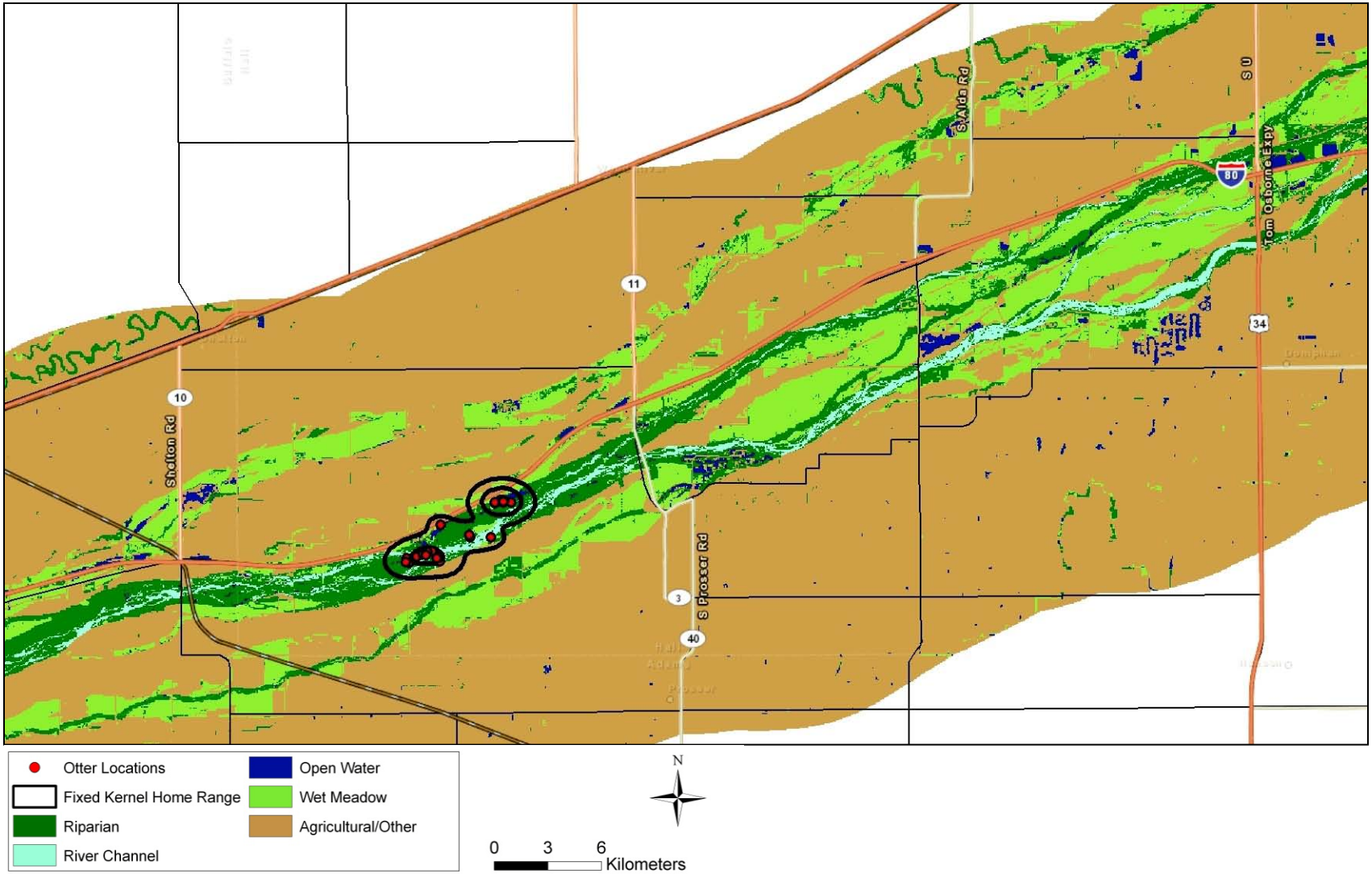


Figure A.4. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 056 during 2008.

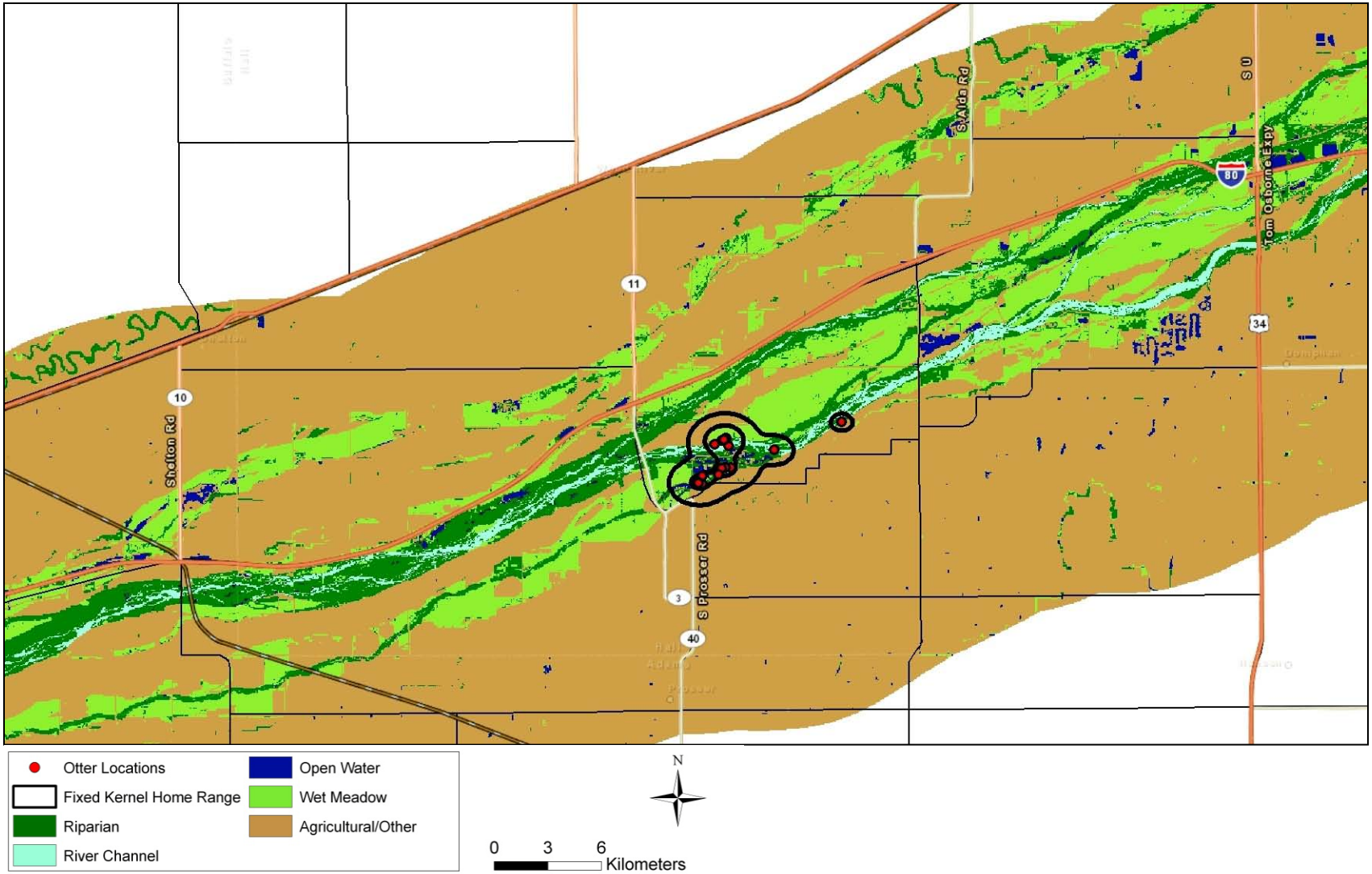


Figure A.5. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 113 during 2008.

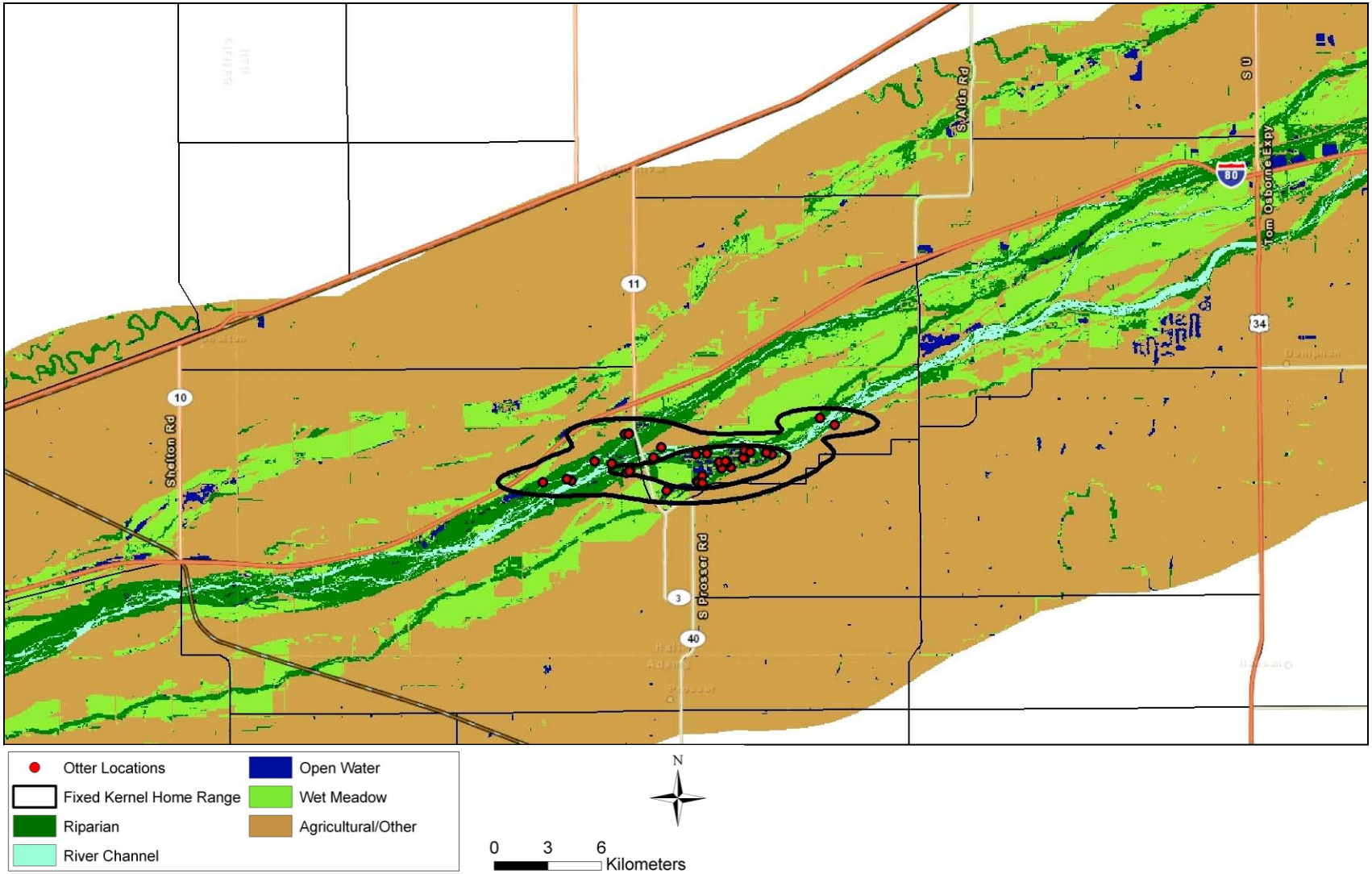


Figure A.6. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 135 during 2008.

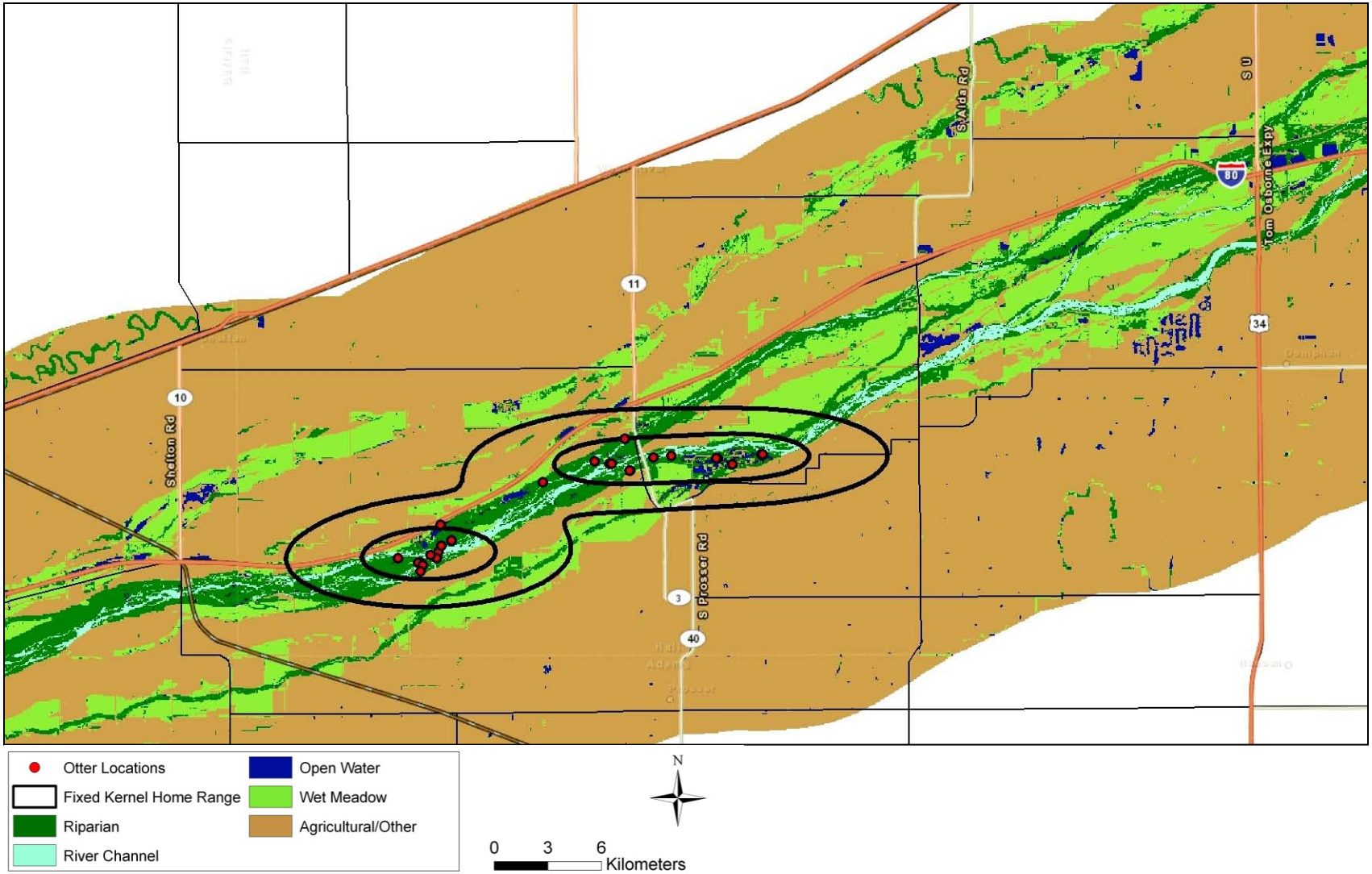


Figure A.7. Locations and fixed kernel home range at the 95% and 50% levels for male river otter 175 during 2008.

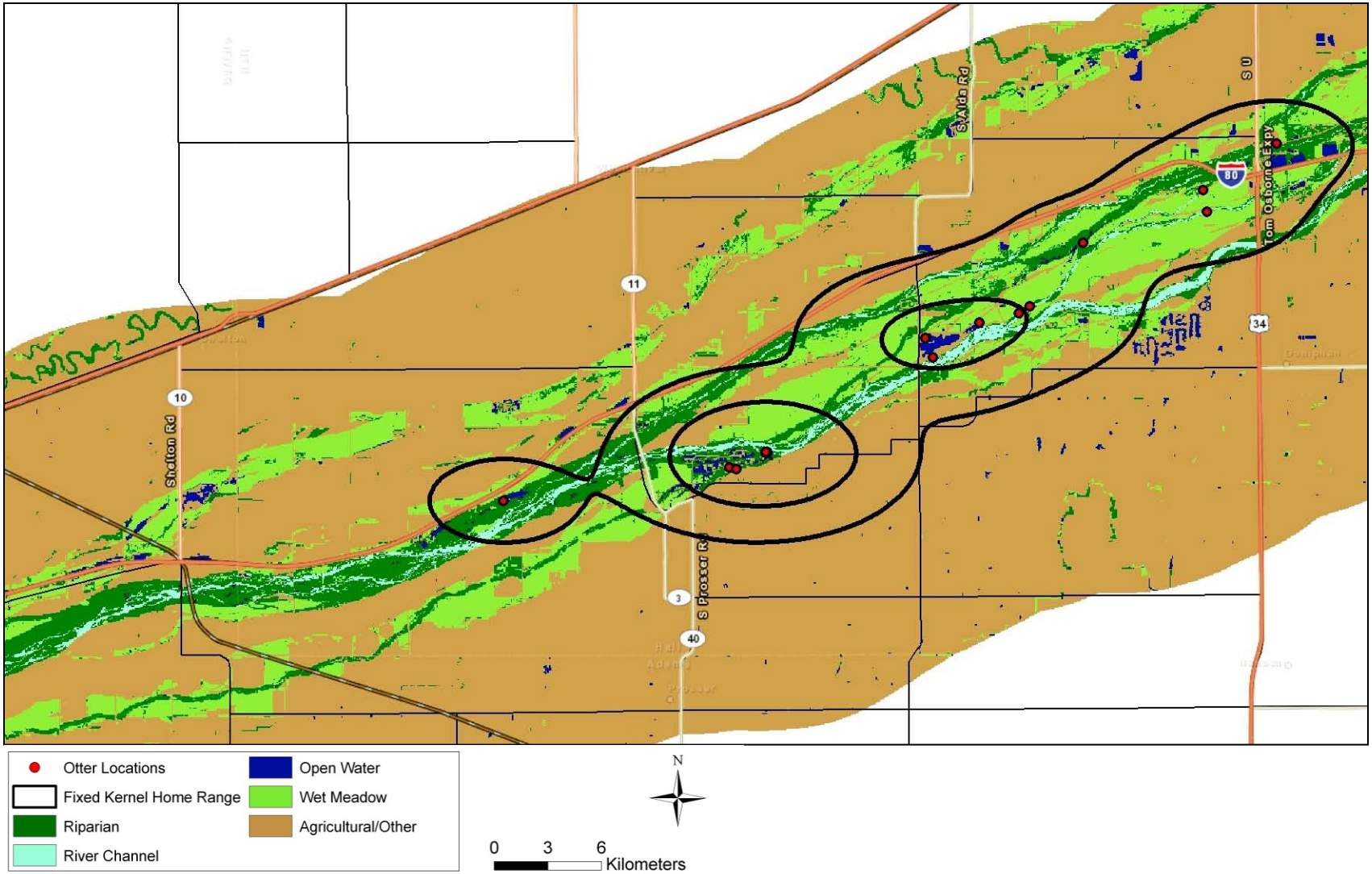


Figure A.8. Locations and fixed kernel home range at the 95% and 50% levels for male river otter 395 during 2008.

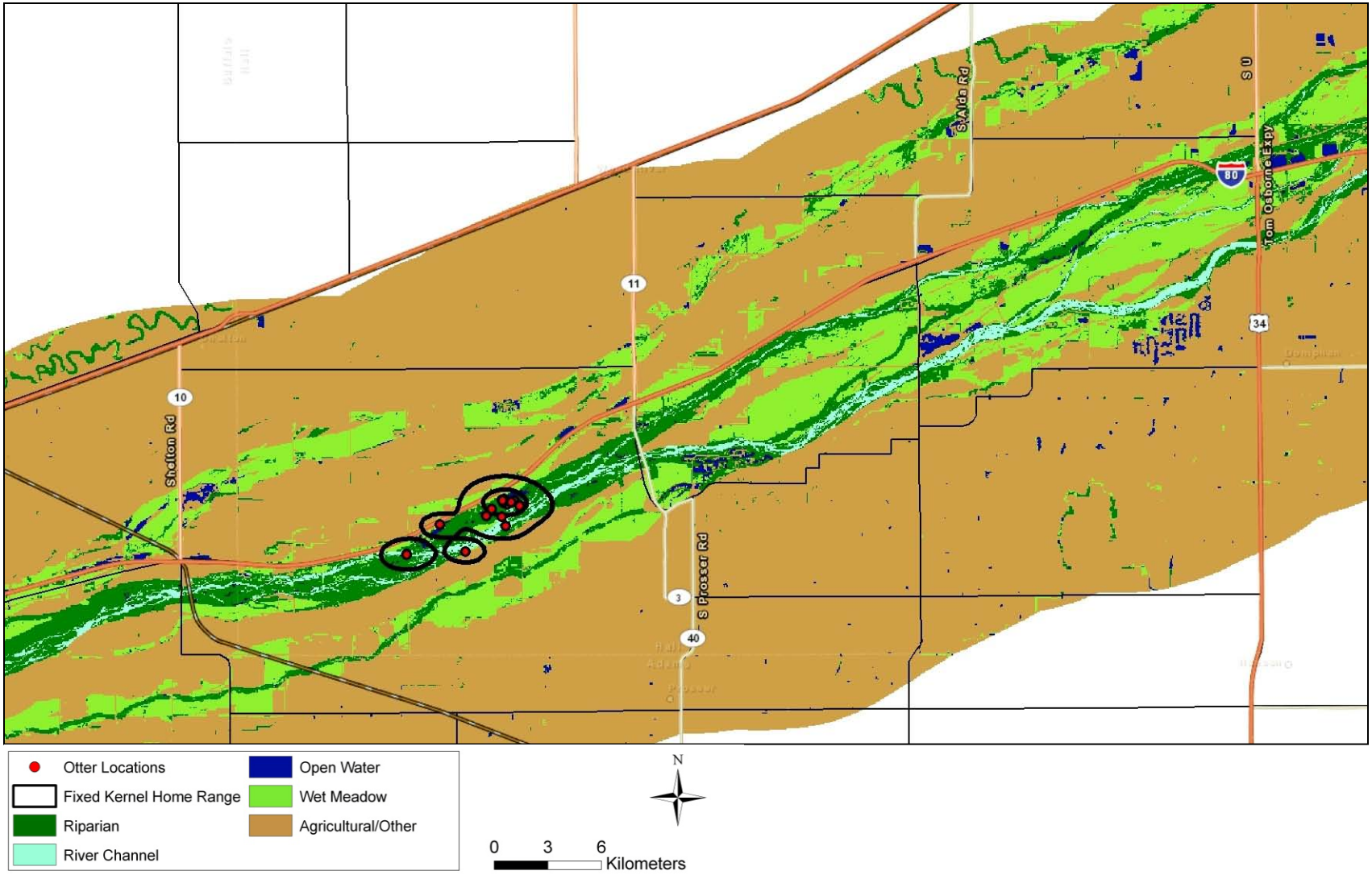


Figure A.9. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 056 during 2009.

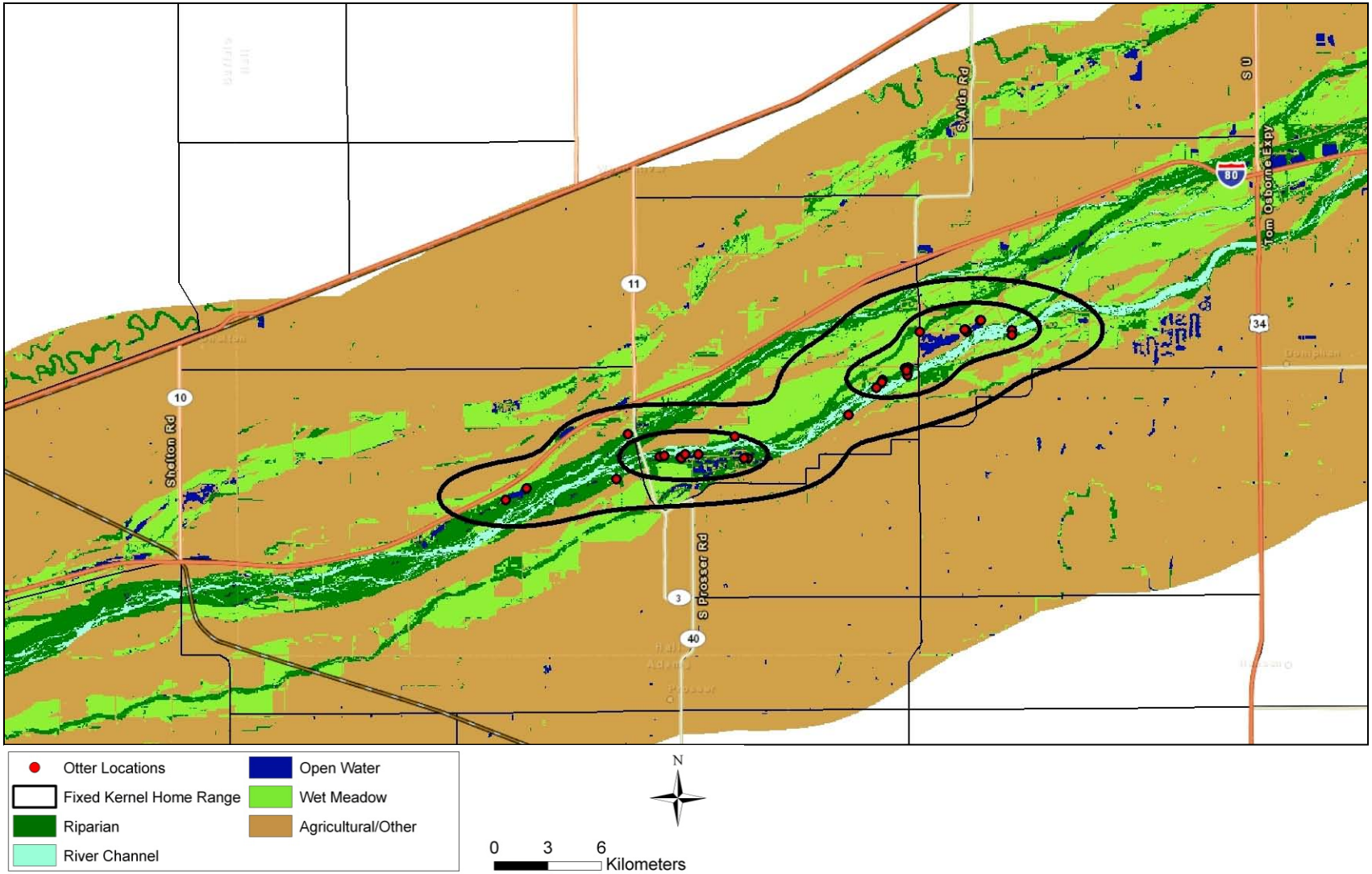


Figure A.10. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 596 during 2009.

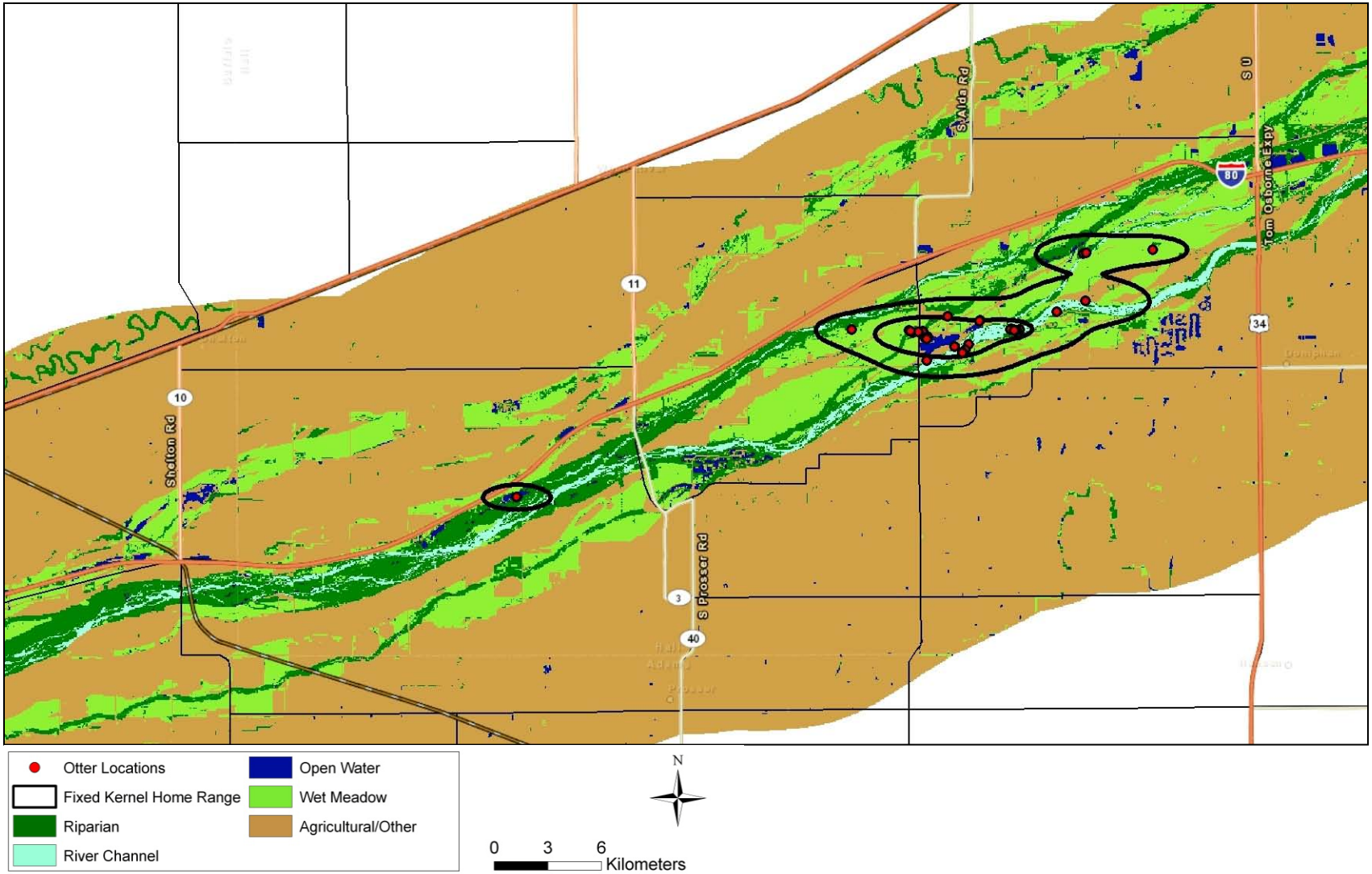


Figure A.11. Locations and fixed kernel home range at the 95% and 50% levels for female river otter 684 during 2009.

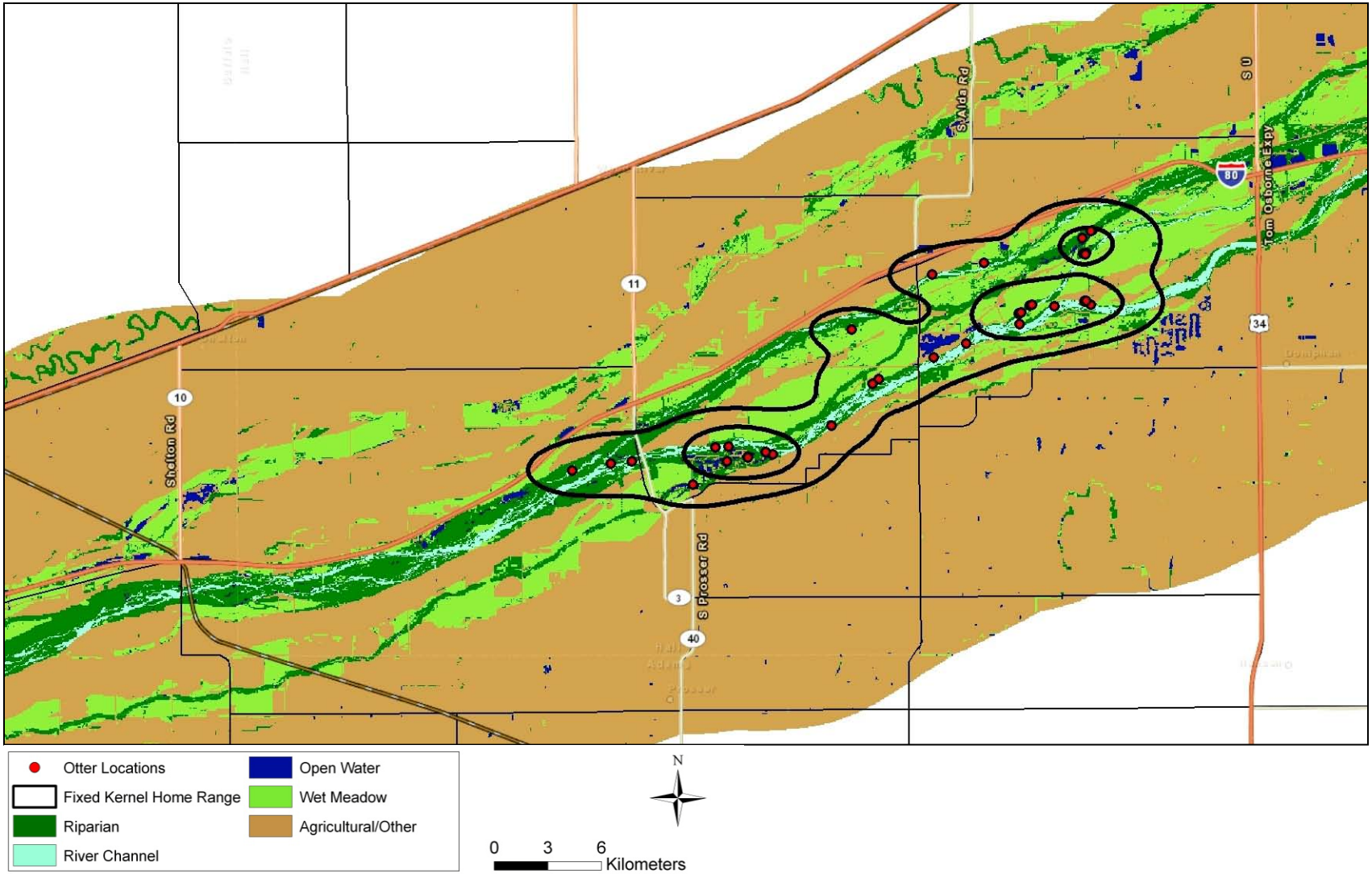


Figure A.12. Locations and fixed kernel home range at the 95% and 50% levels for male river otter 556 during 2009.

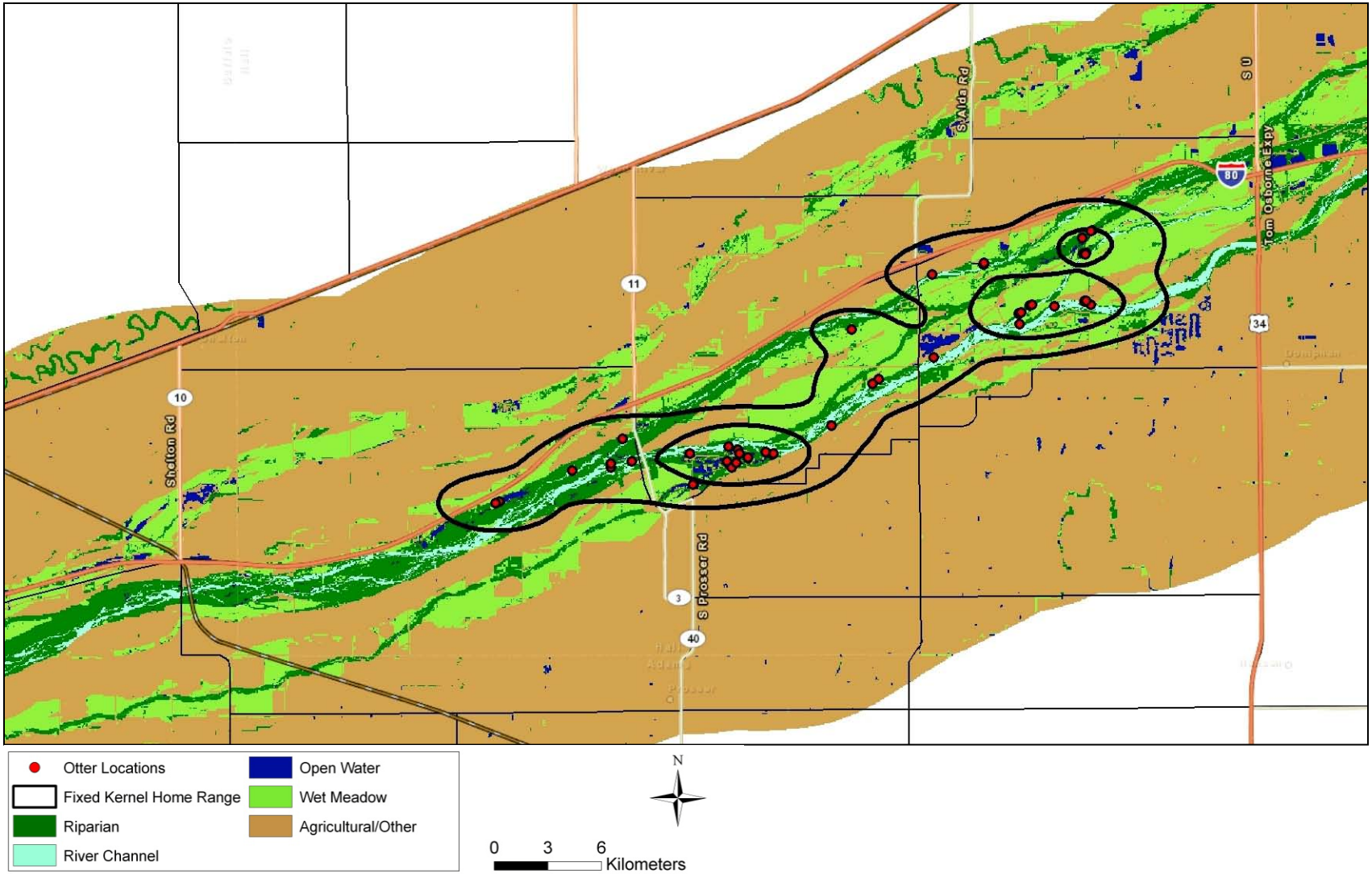


Figure A.13. Locations and fixed kernel home range at the 95% and 50% level for male river otter 626 during 2009.

Appendix B. Minimum convex polygon home ranges at the 95% level for 11 river otters with ≥30 locations in a given year which were used to assess habitat use, collected on the central Platte River of Nebraska during 2007–2009.

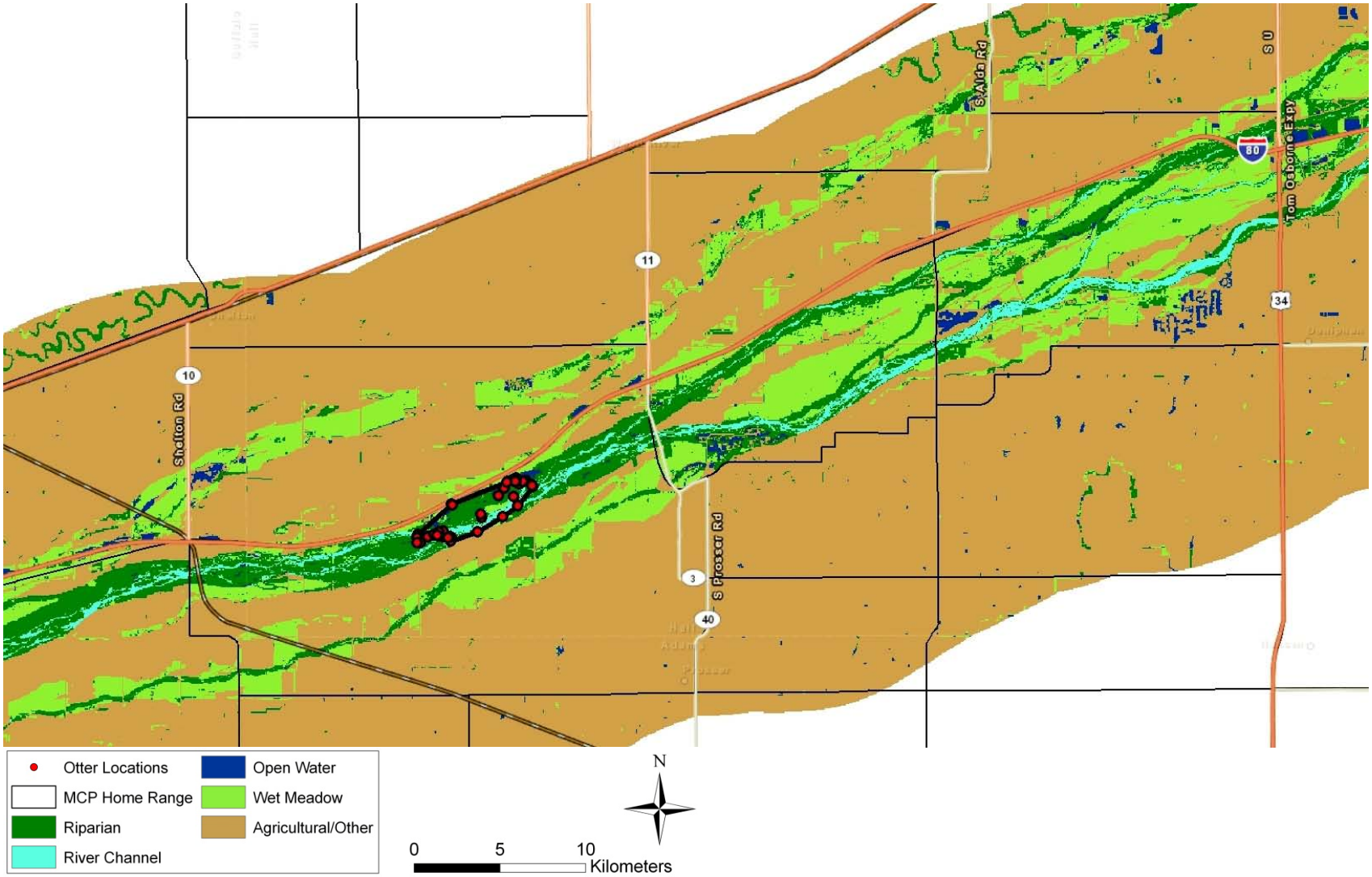


Figure B.1. Locations and minimum convex polygon home range at the 95% level for male river otter 056 used for habitat analysis.

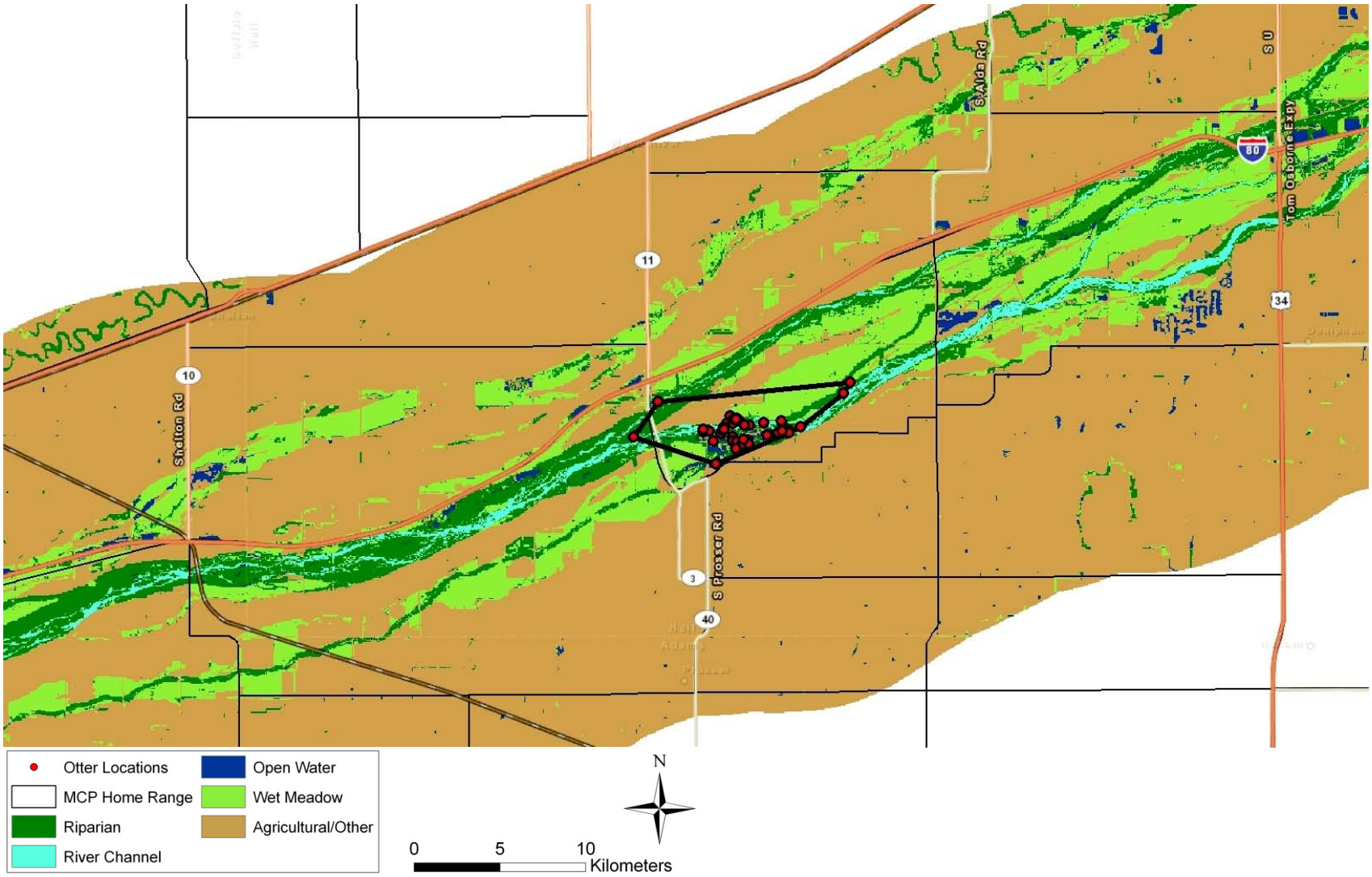


Figure B.2. Locations and minimum convex polygon home range at the 95% level for female river otter 113 used for habitat analysis.

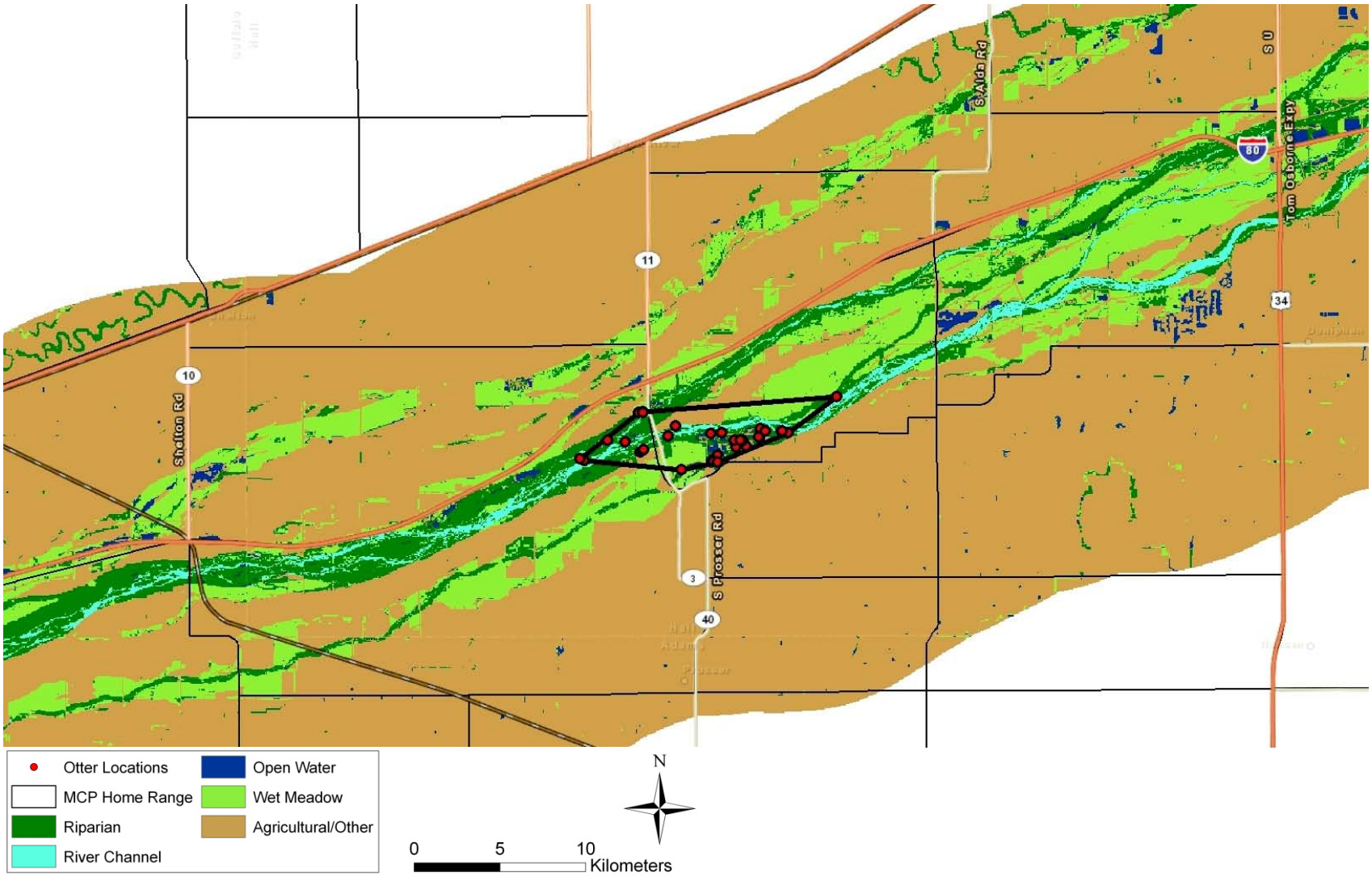


Figure B.3. Locations and minimum convex polygon home range at the 95% level for female river otter 135 used for habitat analysis.

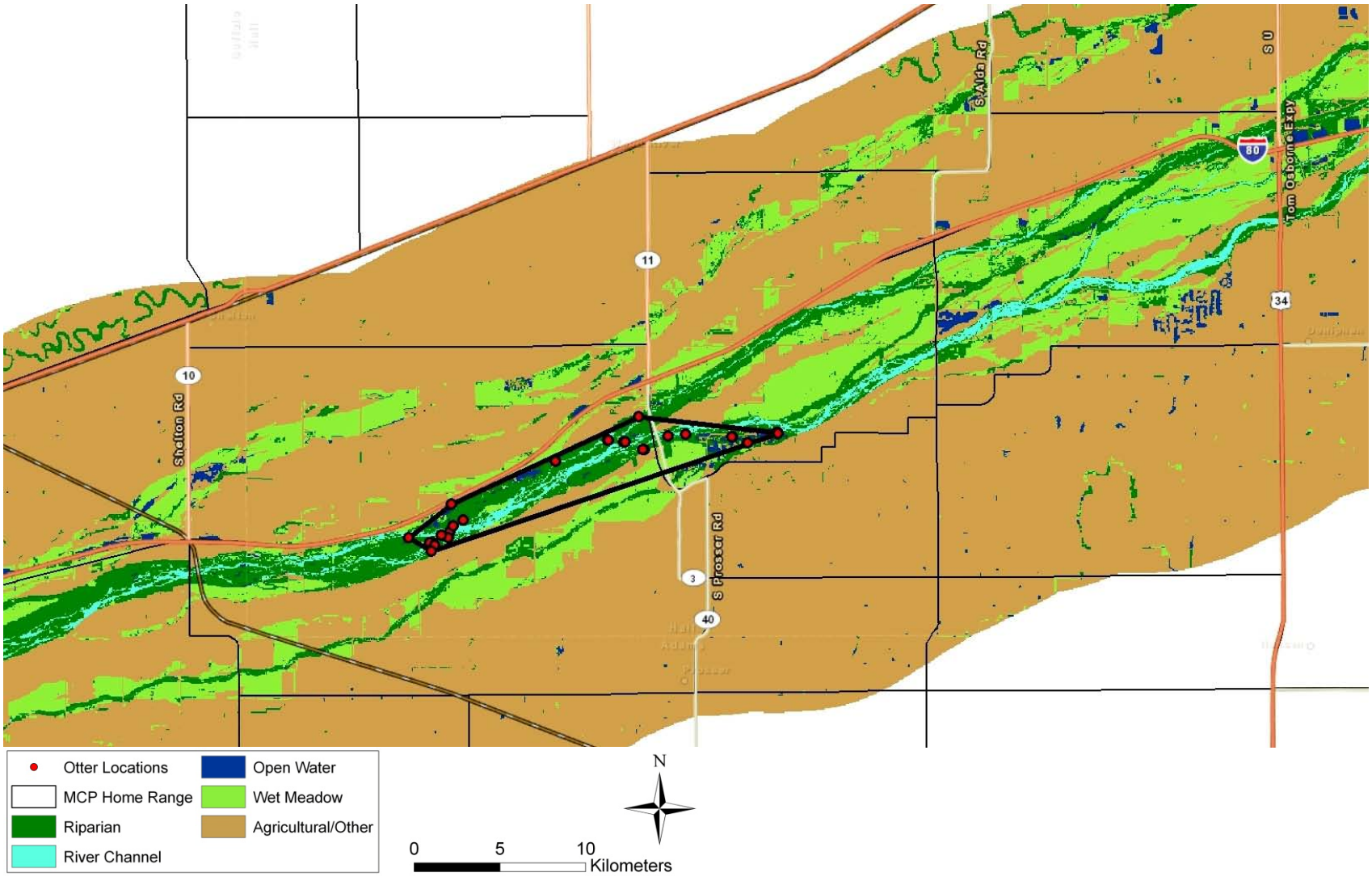


Figure B.4. Locations and minimum convex polygon home range at the 95% level for male river otter 175 used for habitat analysis.

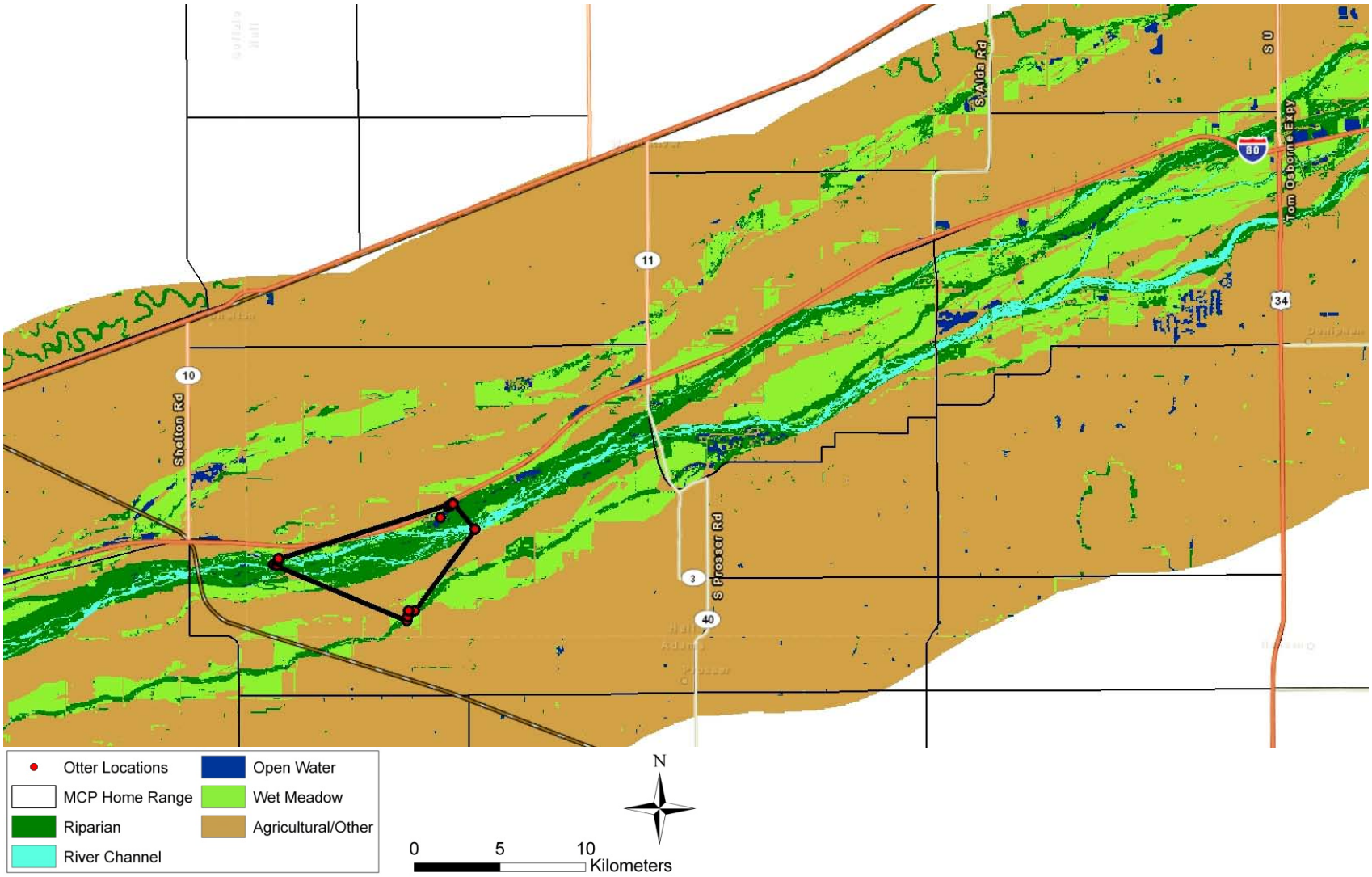


Figure B.5. Locations and minimum convex polygon home range at the 95% level for male river otter 212 used for habitat analysis.

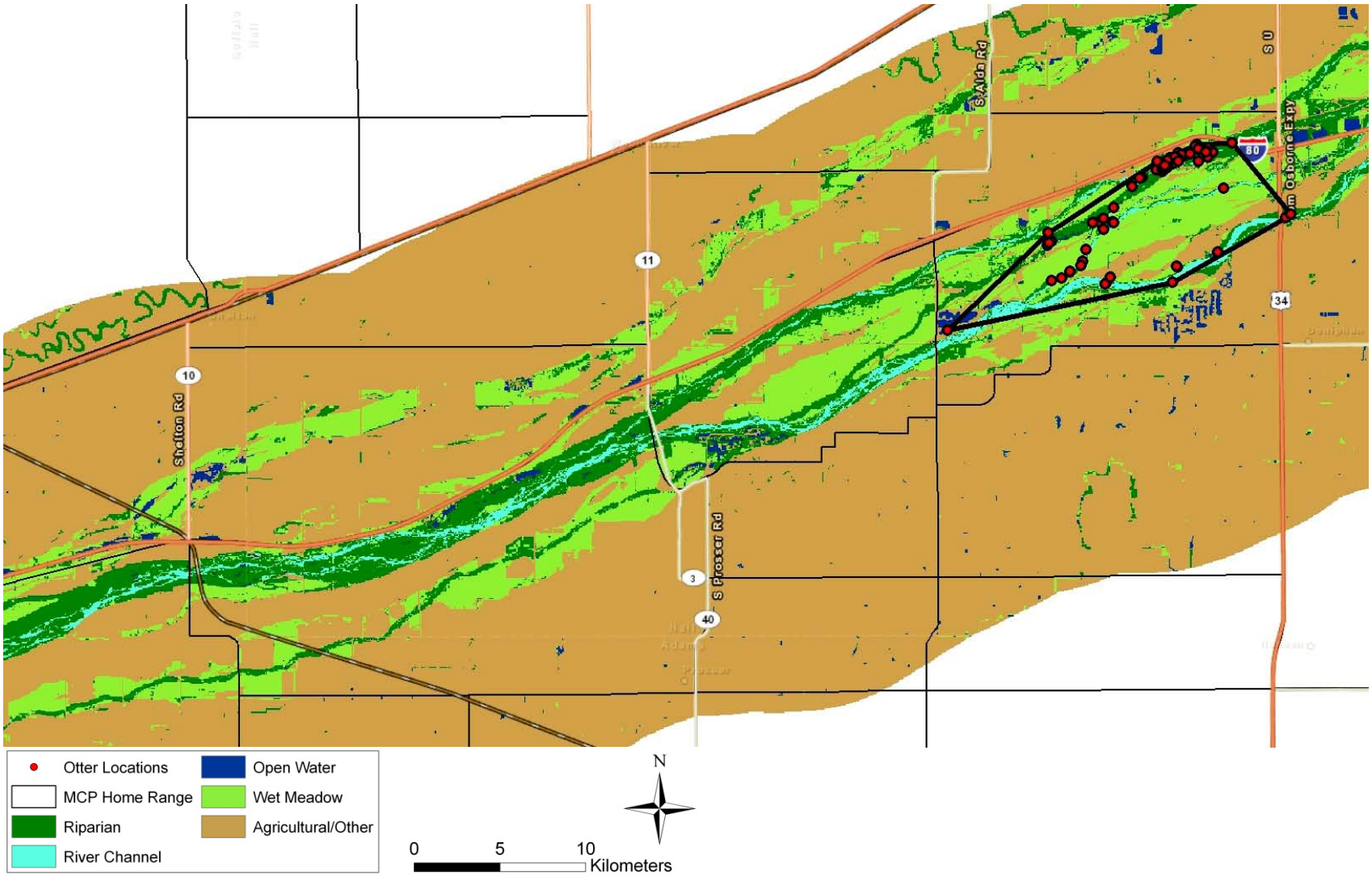


Figure B.6. Locations and minimum convex polygon home range at the 95% level for female river otter 275 used for habitat analysis.

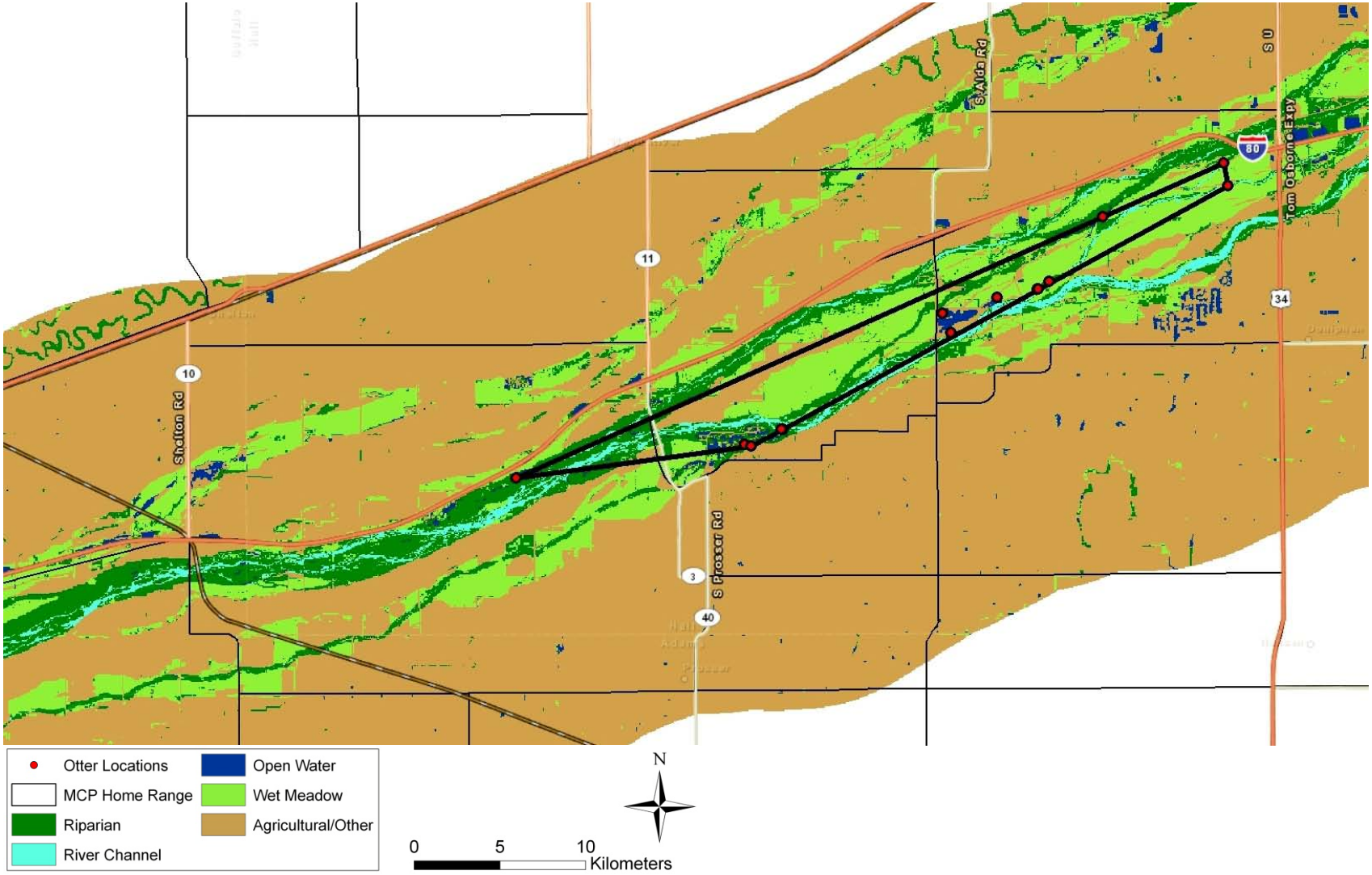


Figure B.7. Locations and minimum convex polygon home range at the 95% level for male river otter 395 used for habitat analysis.

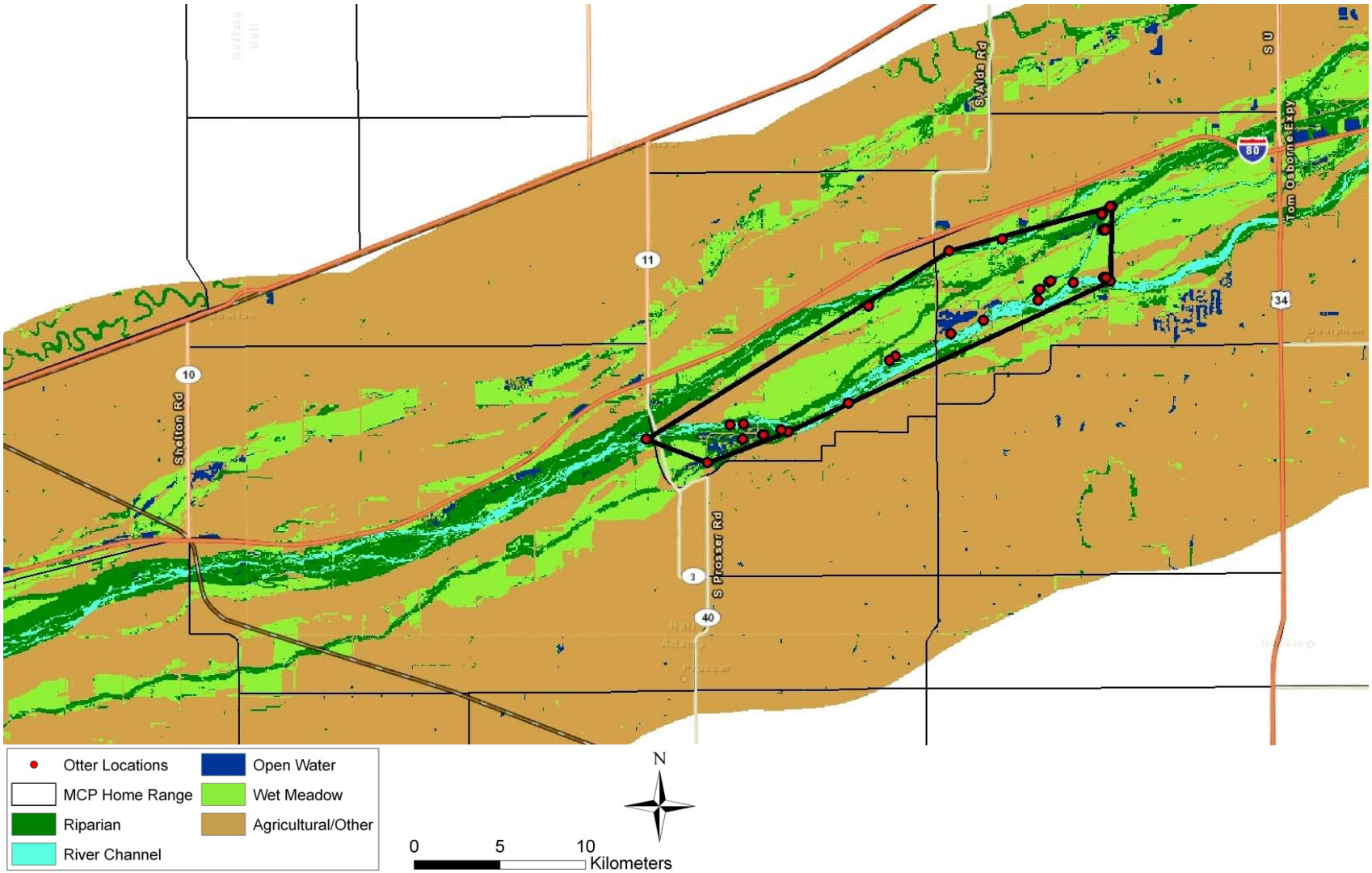


Figure B.8. Locations and minimum convex polygon home range at the 95% level for male river otter 556 used for habitat analysis.

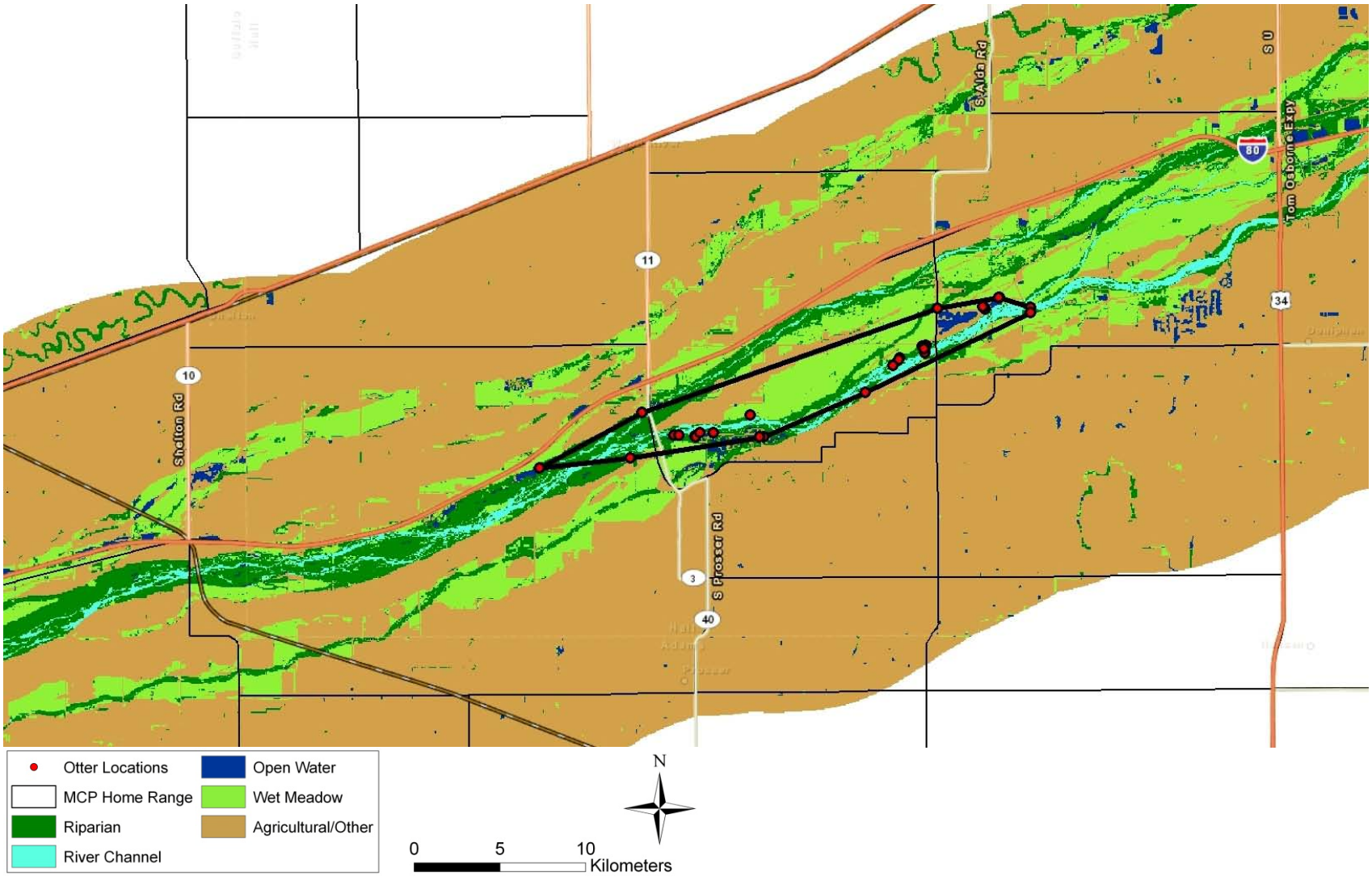


Figure B.9. Locations and minimum convex polygon home range at the 95% level for female river otter 596 used for habitat analysis.

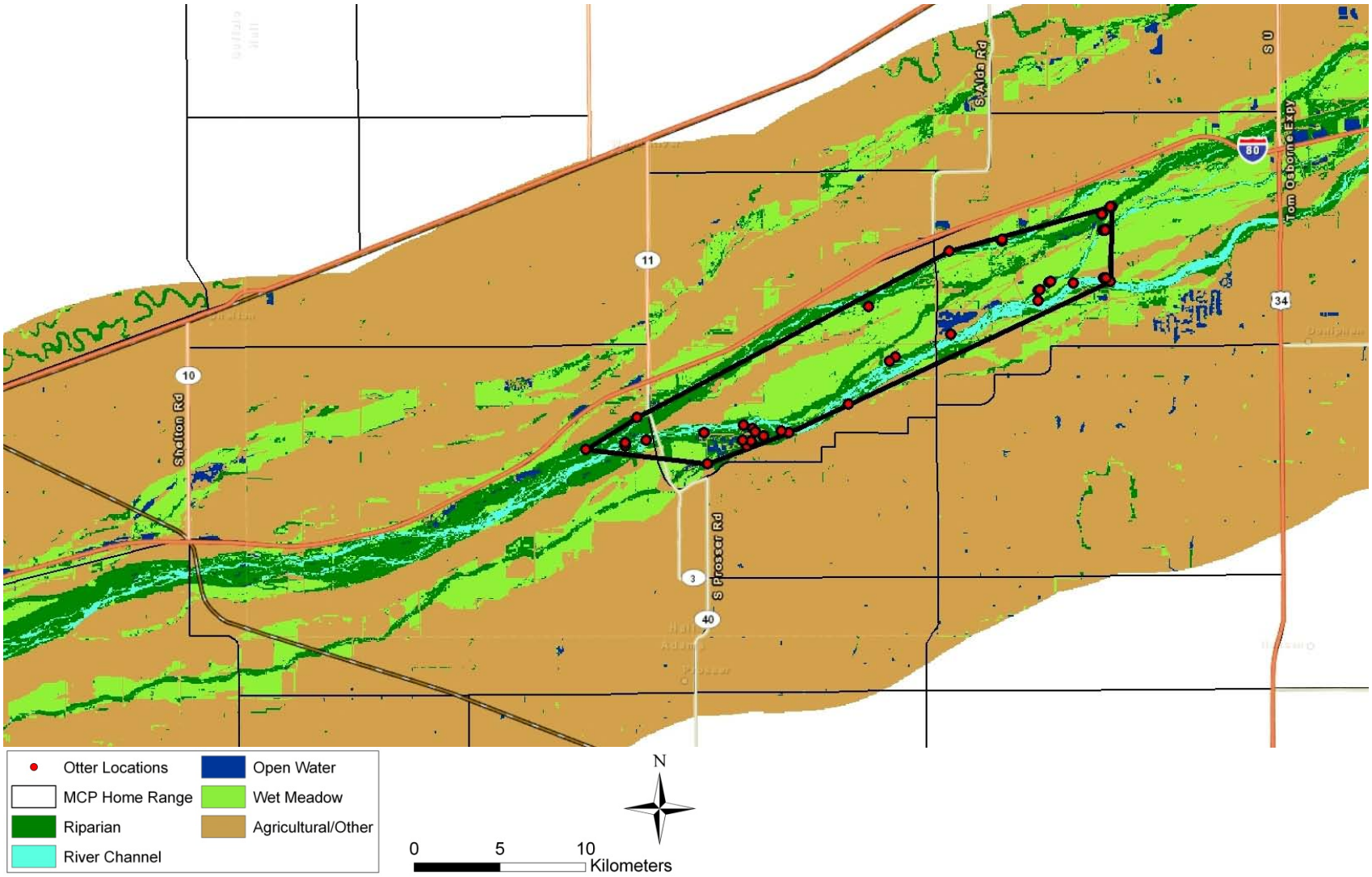


Figure B.10. Locations and minimum convex polygon home range at the 95% level for male river otter 626 used for habitat analysis.

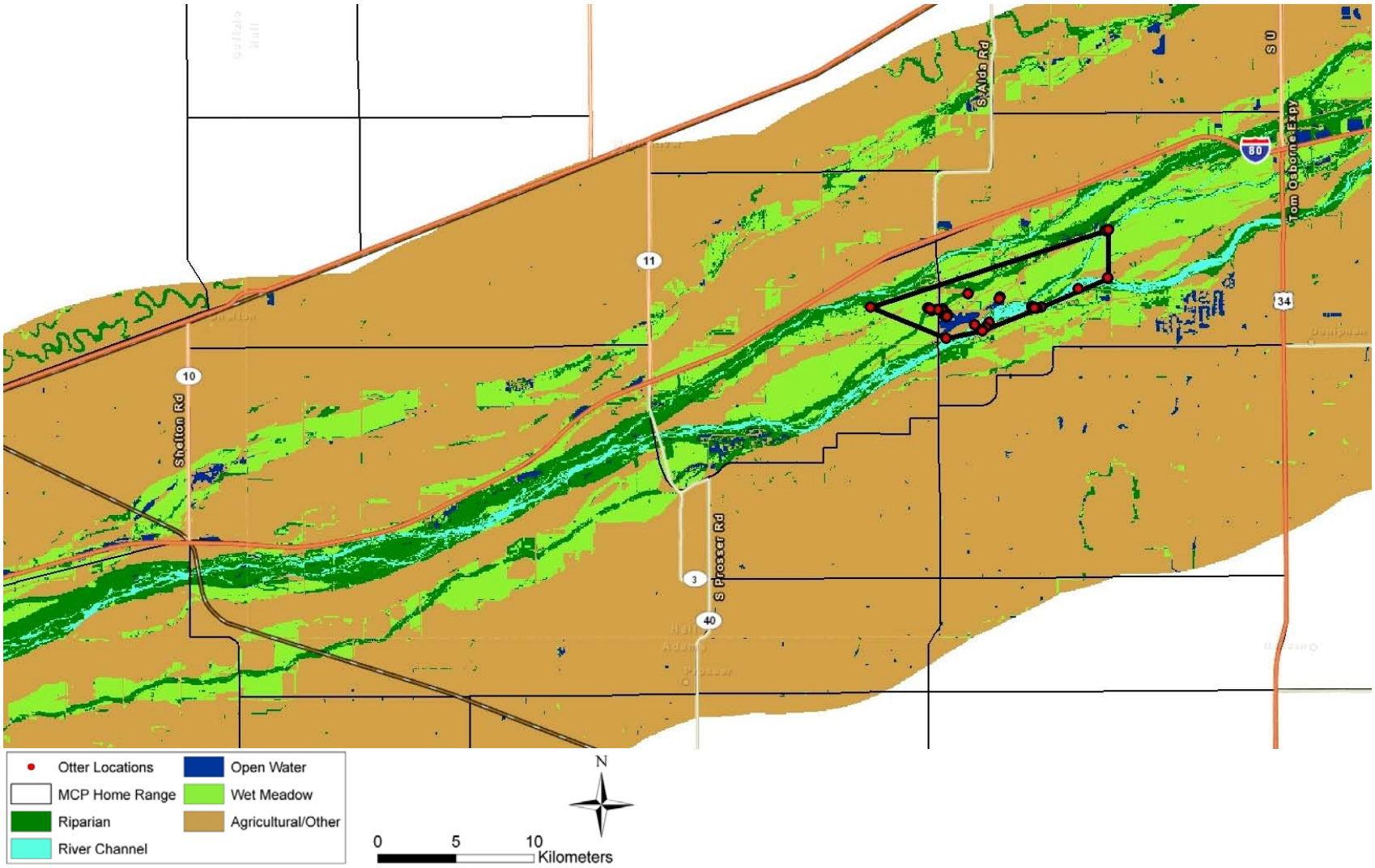


Figure B.11. Locations and minimum convex polygon home range at the 95% level for female river otter 684 used for habitat analysis.