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# River Otter (*Lontra canadensis*) Distribution and Habitat Suitability in Nebraska

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**RIVER OTTER (*LONTRA CANADENSIS)* DISTRIBUTION AND HABITAT SUITABILITY IN NEBRASKA**

**By**

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The river otter (*Lontra Canadensis)* was once common in Nebraska, but by the early 1900's they were extirpated. In 1986, the Nebraska Game and Parks Commission (NGPC) began reintroducing otters back into Nebraska rivers. Following reintroductions, the otter was listed as a tier-1 at-risk species providing protection to the incipient population. With increasing otter populations, NGPC is evaluating a de-listing plan. In order to inform de-listing efforts, I surveyed Nebraska's navigable waterways documenting otter sign and used modeling techniques to estimate otter distribution and habitat suitability in Nebraska.

Otter sign surveys were conducted primarily on the Platte, Elkhorn, Niobrara, Big Blue, Republican, Missouri, and Loup River systems. Occupancy modeling techniques were used to examine patterns in otter detections related to habitat characteristics. The most supported model incorporated the distance to the nearest otter release site, beaver occupancy, and river flow rate. In addition to predicted occupancy in areas where otters were detected, occupancy estimates of >0.10 were predicted in the southern Loup River system. Occupancy estimates between 0.05 and 0.10 were predicted in areas of the southern Loup River system, Platte, Elkhorn, Republican, and Niobrara rivers.

Presence-only data collected by NGPC were used to examine patterns among historical otter locations. Maxent modeling identified the Platte, northern Elkhorn, southern Loup River system, sections of the western and eastern Niobrara, and small sections of rivers in southern Nebraska as areas most likely to be occupied. Maxent habitat suitability modeling identified the Platte, eastern Niobrara, southern Elkhorn, and southern Loup River system as areas with the best otter habitat. The distance to a release site and river flow rate had the strongest impact on the fit of the models.

The results of my analyses are consistent with distribution estimates prepared by NGPC, and spatial correspondence between occupancy estimation methods was high. Future efforts to translocate or reintroduce more otters should be focused on areas identified by habitat suitability modeling and areas with high occupancy estimates but where few occurrence records exist.

## ACKNOWLEDGEMENTS

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**CHAPTER 1: INTRODUCTION**

The North American River Otter (*Lontra canadensis)* was once a common mammal in Nebraska ranging throughout most of the state's rivers (Swenk 1908) especially the Missouri and Platte Rivers (Jones 1964). Similar to several other Midwestern states, otter numbers began to dwindle during the latter half of the 19$^{th}$ century. The primary reasons for otter decline throughout their distribution appear to have been unregulated trapping for fur, human encroachment, and habitat degradation (Melquist and Dronkert 1987). By the early 1900's, the river otter was extirpated in the state of Nebraska.

Only infrequent accounts of otters surfaced through the late 1800's and early 1900's. An individual was reported near Beatrice on the Big Blue River in 1897 (Swenk 1918). One individual was taken in Seward County, Nebraska in 1916, and this was perhaps the last otter record in the state for the next 50 or more years (Jones 1964). Then in the late 1960's and early 1970's, specimens turned up on the Missouri River near Council Bluffs, Iowa and near Beaver City, Nebraska (Hoffman and Genoways 2005).

Beginning in 1986 and continuing through 1991, the Nebraska Game and Parks Commission (NGPC) began reintroducing river otters back into the state. They released 159 animals, which came from Alaska, Louisiana, Idaho, British Colombia, Wisconsin, Ontario, and Michigan (Bischof 2003; Table 1.1) and were released at seven sites on the Niobrara, Elkhorn, Platte, South Loup, Calamus and Cedar Rivers (Figure 1.1). With the reintroductions, the otter was listed as a tier-1 at-risk species in the state of Nebraska

(Bischof 2003; Wilson 2012; Schneider et al. 2005). During the five years when releases were taking place, otters were reported on the Platte River as far west as Bridgeport, NE and nearly so far east as the junction with the Elkhorn River. There were several reports ranging throughout the South Loup and northern Elkhorn rivers, many reports near the Calamus Reservoir on the Calamus River, and a few records from the northern Cedar River and southern Middle and North Loup rivers. One report exists of an otter on the Little Nemaha River near Nemaha, NE and there was one report near the Harlan County Lake on the Republican River during this time period (Figure 1.2). The majority of early reports came from trappers who had inadvertently captured otters while targeting other species. Winter bridge survey efforts by NGPC also contributed to local otter records during early expansion years (Bischof 2002).

In 2006, graduate work at the University of Nebraska- Lincoln began to determine river otter density in the Big Bend area of the Platte River (between Overton, NE and Chapman, NE), the size of their home ranges, mortality rates, dispersal characteristics, and habitat associations. Eighteen otters were trapped and implanted with VHF transmitters so that they might be tracked throughout the Big Bend study area. It was found that the mean home range size was 3,711 ha using a fixed kernel method, and 1,361 ha using minimum convex polygons, and males tended to have larger home ranges than females. During the study, otters were most commonly found using open water habitats (Wilson 2012). Associations with the invasive plant *Phragmites* were also examined, and it was found that otters used *Phragmites* proportional to its availability, but females tended to use *Phragmites* more than expected and more often than males (Williams 2011). Genetic analyses of scat collected around the Big Bend suggested an otter density of 0.99-1.13 otters/km, which exceeds any known density in North America (Williams 2011). No mortalities were recorded in the radio-marked animals during the study (Wilson 2012).

Reports from trappers, bridge surveys, and graduate work have suggested that the distribution of otters in Nebraska is expanding from the seven initial release sites, that otters are establishing home ranges, occurring locally at high densities, and experiencing low mortality rates. NGPC is now in the process of considering whether or not it is appropriate to de-list otters in Nebraska. This is a significant management decision that will require all of the most current available information, and one piece of information that is currently missing is a complete picture of otter distribution in the state and of habitat suitability for otters in Nebraska.

Many tools exist for estimating species distribution and habitat suitability, among them occupancy models and maximum entropy models. In the next 2 chapters, I detail the use of occupancy modeling techniques to estimate river otter occupancy along the state's major rivers and to explore some of the factors influencing site occupancy. I then consider maximum entropy models, which provide information about habitat suitability and estimates of site occupancy, in order to compare patterns in occupancy and habitat suitability. I also consider spatial correspondence between modeling methods and create a composite distribution estimate using the results of both methods. These models will help improve otter distribution estimates in Nebraska and identify areas with suitable habitat that are not currently within these distribution estimates.

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Table 1.1

Over the course of six years, 159 otters were released into Nebraska's rivers ending nearly a century of absence from the state. These animals came from seven donor states and provinces: Louisiana, Alaska, Idaho, British Columbia, Ontario, Wisconsin, and Michigan.

| **Source** | **Count** |
|---|---|
| Louisiana | 68 |
| Alaska | 62 |
| Idaho | 11 |
| British Columbia | 9 |
| Ontario | 4 |
| Wisconsin | 4 |
| Michigan | 1 |
| Total | 159 |

Figure 1.1

River otters were released at seven sites between 1986 and 1991. Release sites included the western Niobrara, northern Elkhorn, North Platte, central Platte, Cedar, South Loup, and Calamus rivers.

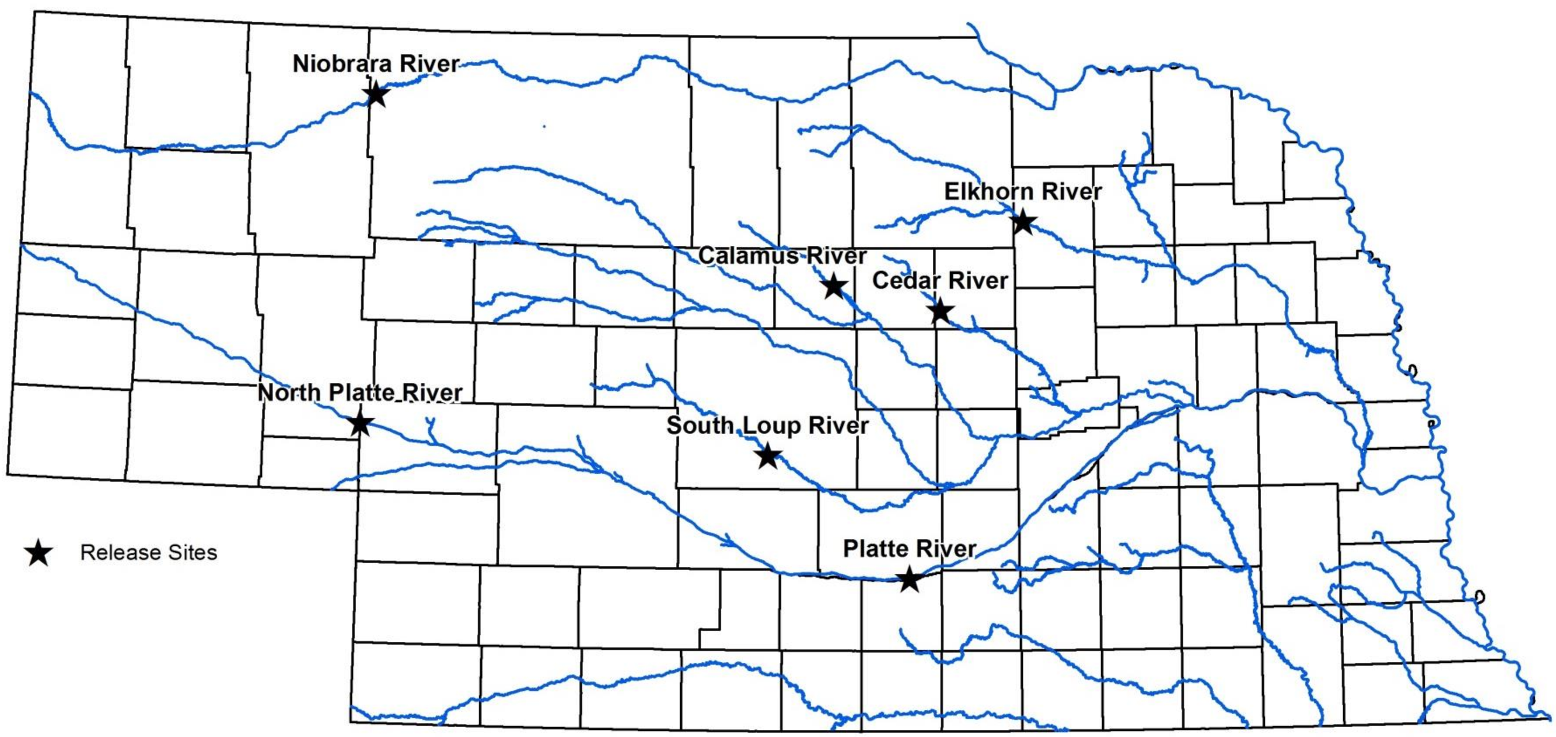
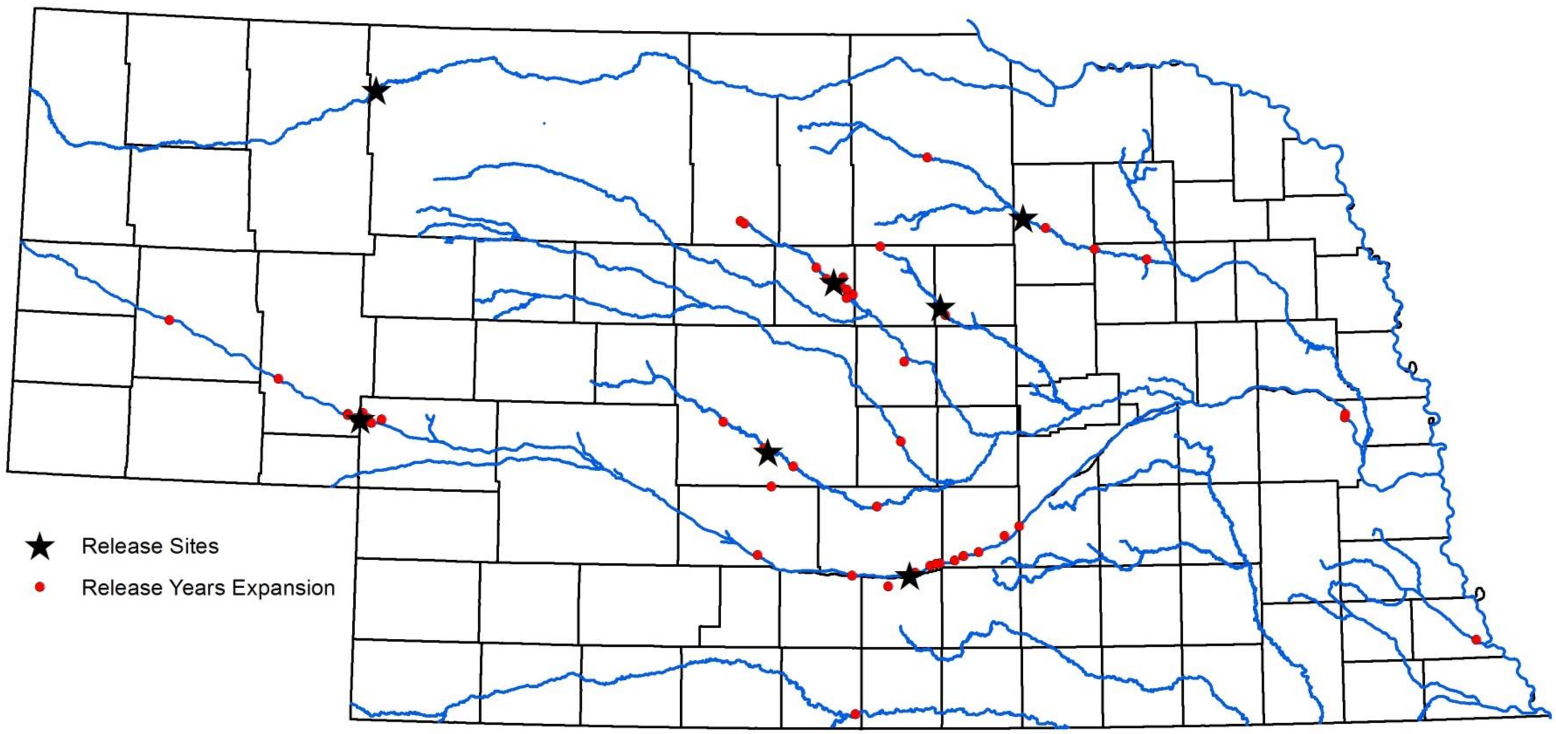


Figure 1.2

During the release period from 1986 to 1991, reports of river otters around the state began to increase. The majority of reports came from nearby release sites, but otters were also reported on the Little Nemaha, Republican, and eastern Platte rivers.



## CHAPTER 2: RIVER OTTER (*LONTRA CANADENSIS)* DISTRIBUTION IN NEBRASKA: USING PRESENCE-ABSENCE DATA TO ESTIMATE SITE OCCUPANCY

### INTRODUCTION

The North American river otter (*Lontra canadensis)* was once a common mammal in Nebraska ranging throughout all of the state's major rivers (Swenk 1908), particularly in the Missouri and Platte rivers (Jones 1964). By the early 1900's, however, unregulated fur-trapping and changes in land use practices had eliminated otters from Nebraska's rivers (Melquist and Dronkert 1987). In the late 1800's through the early 1900's, reports of otters were very infrequent with a report on the Big Blue River in 1897 (Swenk 1918) and a report from Seward County, Nebraska in 1916 (Jones 1964) being among the last that would occur for nearly 50 years. Two specimens were reported coming from the Missouri River near Council Bluffs, Iowa and Beaver City, Nebraska in the late 1960's and early 1970's (Hoffman and Genoways 2005).

In 1986, the Nebraska Game and Parks Commission (NGPC) began releasing otters back into Nebraska rivers, and by 1991 NGPC had released 159 otters at seven release sites throughout the state (Figure 2.1; Bischof 2003). With the reintroductions, the otter was listed as a tier-1 at-risk species in the state of Nebraska (Bischof 2003; Wilson 2012; Schneider et al. 2005). Early efforts to monitor the reintroduced otters were limited primarily to winter bridge surveys by NGPC (Bischof 2002), incidental take reported to NGPC, and to graduate work along the Big Bend of the Platte River (Wilson 2012; Williams 2011).

To date, no systematic effort to survey Nebraska's waterways has been made, and it is unknown what the current distribution of river otters is in the state. In a brief summary of reports from accidental captures, bridge surveys, and observations from 1992 to 2002, Richard Bischof of the NGPC noted that there appeared to be a few common areas where a bulk of otter reports were coming from, and these included the Big Bend area of the Platte River, the northern Elkhorn River, the Platte River west of Lake McConaughy, the Cedar and Calamus rivers near the release sites there, and a small area on the Little Nemaha River (Bischof 2003). This indicates that otters were being reported primarily in areas near release sites, though reports from the Niobrara and South Loup were lacking in his report. The lack of reports from these areas may not reflect absence as the Niobrara River was not included in winter bridge surveys, and reports from trappers may be less common in these more remote areas of the state. Other NGPC records indicate incidental otter take occurring along the Niobrara River as far west as Gordon, NE and east to the convergence with the Missouri. Between 1992 and 2014, 29 otters were reported from the Niobrara, and 12 of these reports were confirmed with carcass collection. Seven otters, five confirmed by carcass collection, were reported from the South Loup River between 1986 and 2001 with no existing recent reports. A distribution estimate produced by the Nebraska Natural Heritage Program, NGPC in 2012, which was constructed considering expert opinion and known locations, suggests that river otters occur in nearly all of the Platte and Elkhorn rivers as well as large sections of the Niobrara, Loup system, Missouri, Republican, and Little Nemaha rivers (Simpson and Schneider 2014).

Efforts to survey for otters typically consist of identifying tracks, scats, and latrines (Mowry 2011; Barrett and Leslie 2010; Shardlow 2009; Gallant 2008), collecting data from trappers (Bischof 2003; Rolley 2013), or a multi-faceted approach (Bischof 2003). Oftentimes, bridges are used as convenient water access points where otter sign may be scouted (Shackelford and Whitaker1997; Gallant 2008; Kiesow 2005; Jeffress et al. 2011). The "standard method" developed in England and employed by several other studies recommends searching 400m belt-transects on either side of bridges for otter sign (Fourth 2002).

Systematically surveying for and estimating the distribution of uncommon species presents several difficulties (MacKenzie 2005a; Mackenzie 2005b). First, it may be desired that inference be drawn to very large areas, yet for practical reasons, it may be possible only to survey smaller areas. Second, it is highly unlikely that all individuals are encountered by or noticed by surveyors (Bailey 2005; MacKenzie 2005a; Mackenzie 2005b). Techniques to estimate site occupancy were developed by MacKenzie et al. (2002) that allow for site occupancy estimates despite imperfect detection rates. The method proposed assumes that site occupancy and detection likelihoods are constant between visits, all observations are independent, and no false detections occur (MacKenzie 2002; Powell and Gale 2015). By conducting multiple surveys of each site, a detection probability may be estimated. Incorporating covariate data then allows one to consider the attributes of each site as well as the detection probability in determining the likelihood that any given site is occupied (MacKenzie 2002; Powell and Gale 2015).

Estimating species distribution at the state level also presents a unique set of challenges. In order to provide the most accurate estimate, it is necessary for the data set to provide very broad geographical coverage. The ability to obtain this data is limited by funding, time, available labor, land accessibility, and conditions within the survey areas. When data are obtained through directly surveying the study area and the focal species is largely aquatic, river conditions may not be suitable for survey during the late fall and winter as waters begin to ice and into the spring as water levels remain at levels unsafe for travel or at levels that obscure available tracking substrate.

Over the course of two field seasons, I collected presence and absence data consisting of otter tracks, scats, and visual locations throughout Nebraska's river systems. These data were collected to be used in occupancy models to determine: 1) the extent of otter distribution in Nebraska and 2) which rivers are more likely to have otter populations.

## MATERIALS AND METHODS

### Study Area

This study focused on the navigable rivers of Nebraska, in particular the Platte, Niobrara, Elkhorn, Loup, Republican, Big Blue, and Missouri rivers, but including some smaller rivers, the Big Nemaha, Little Nemaha, Little Blue, Dismal, and Cedar rivers (Figure 2.2). These rivers were chosen because they allowed for relatively easy navigation and survey by kayak, and because they included the rivers chosen as reintroduction points during the otter reintroduction efforts.

The Platte River is a braided river spanning approximately 985km west to east across central Nebraska until it junctions with the Missouri River. It occurs primarily within the Western High Plains and Central Great Plains ecoregions, and is characterized by highly seasonal flow rates and divergent channels. Vegetation cover is primarily cultivated crops along the central and eastern Platte, and uncultivated herbaceous vegetation along the western Platte.

The Niobrara River runs approximately 740km west to east through the northern counties of Nebraska until it junctions with the Missouri River. It occurs primarily within the Northwestern Great Plains, Northwestern Glaciated Plains, and Nebraska Sandhills ecoregions, and vegetation cover along the river is primarily uncultivated herbaceous plants.

The Missouri River marks the eastern boundary of Nebraska running approximately 935km north to south where its course is primarily within the Western Corn Belt Plains ecoregion. Along the northern border of Nebraska, the Missouri River is sandy, broad, and relatively slow-moving. As the river continues south, it has been channelized and currents are much swifter. Vegetation cover along the river is primarily cultivated crops.

The Loup River system is comprised of several large branches and smaller rivers including the North Loup, Middle Loup, South Loup, Dismal, Calamus, and Cedar rivers. These rivers occur primarily within the Nebraska Sandhills ecoregion in their northern extent and the Central Great Plains ecoregion in their southern extent. The system runs north to south to its junction with the Platte River. The Loup River system comprises over 2,325km over of river within Nebraska. The Loup River system is surrounded primarily by uncultivated herbaceous vegetation, mostly grasslands in the northern reaches and woodland/grassland in the southern reaches.

The Big Blue River flows approximately 900km north to south within the Central Great Plains and Western Corn Belt Ecoregion in southeast Nebraska where it eventually flows into the Kansas River in northeastern Kansas. Cultivated crops dominate the landscapes around the Big Blue.

The Elkhorn River runs north to south approximately 855km through the Northwestern Glaciated Plains, Nebraska Sandhills, and Western Corn Belt Plains ecoregions where it joins with the Platte River. The northern reaches of the Elkhorn are surrounded primarily by uncultivated herbaceous vegetation and the southern reaches by cultivated croplands.

The Republican River flows approximately 515km west to east through the southern counties of Nebraska where it then flows south into Kansas and meets with the Kansas River. It occurs almost entirely within the Central Great Plains ecoregion and the surrounding lands are a mixture of cropped lands and uncultivated vegetation.

**Sign Surveys**

Data were collected July into October 2014 and 2015. Surveys were conducted with 2 to 3 observers surveying each location on the same day. I chose locations based on ease of access, need for coverage on each water body, and availability of lodging reasonably close by. When possible, surveys were spaced along rivers with gaps roughly the same length as the surveys in order to provide maximum river coverage. Prior to surveying, each surveyor spent at least one day on a river gaining experience identifying common mammal tracks with an experienced tracker. Each surveyor was also provided with a field guide highlighting common mammals of the area with special focus being placed on aquatic furbearing mammals.

Surveys typically began and ended at bridges, which offered the best opportunities to launch kayaks. When other public access points were available, such as wildlife management areas or public parks, these were used as well. Surveyors were instructed to stay within distant view of one another while paddling to ensure that observations recorded were independent between observers. While paddling, each observer made note of any sign of river otter, beaver, muskrat, or mink encountered, and they recorded UTM coordinates for any sign encountered. If otter sign was encountered, surveyors attempted to estimate the number of animals present based on the apparent number of track sets as well as scat sizes and amounts. Though mink and muskrat records were not used in the final analyses, their inclusion may have been valuable towards keeping surveyors focused during long paddles and in improving track identification skills. I also deployed remote-sensing cameras on smaller rivers that could not be surveyed by kayak in an effort to document otters in these areas. Cameras were positioned near game trails, over-looking sandbars, and at creek inlets.

**Sampling Units**

In order to create discrete sampling units with which to associate presence and absence sign data as well as covariate data, I constructed a grid of 6x6km grid cells using ESRI's ArcMap program (Esri 2011) covering the state. I extracted all grid cells that contained focal survey rivers such that each remaining grid cell constituted one sampling unit (Figure 2.3). I chose the 6x6km resolution as this 36km$^2$ area represents a conservative estimate of home range size for river otters on the Platte River of Nebraska (Wilson 2012). Home range estimates from other parts of the country suggest that otters in Nebraska have a somewhat larger home range (Gorman et al. 2006; Helon et al. 2004). By choosing a resolution that was approximately the home range size of an otter in Nebraska, I assumed that animals detected in neighboring cells were different animals, and thus the data were structured for rough abundance estimation in the future.

Each sampling unit had associated with it detection histories for each possible observer where a "1" indicated detection, a "0" indicated non-detection, and a dash indicated a null value for a site where the observer did not survey. Each sampling unit also had a set of covariate data associated with it. A sampling unit was considered to have been surveyed if >1km of river had been surveyed within it.

**Survey-specific Covariates**

Survey-specific covariates included the period in which the survey was conducted and the numbers of days since the last heavy rainfall. Surveys conducted July, August, and September of 2014 were considered periods 1, 2, and 3 respectively. Surveys conducted July, August, September, and October 2015 were considered periods 4, 5, 6, and 7 respectively. A rainfall was considered heavy if >2cm of rain fell in a 24 hour period. These covariates were included to capture seasonal variation in detection probabilities as well as variation from the most relevant climatic event to animal tracking, heavy rainfall, which may obscure or erase tracks and other sign.

**Site-specific Covariates**

Site-specific covariate data were collected *post hoc* and included the distance to the nearest otter release site (km), the amount of non-river channel wetland area, the long-term median flow rate of the river ($ft^3/s$), the probability of beaver occupancy, the dominant vegetative land cover, and whether or not the river had gone dry in the last five years. Because there was such a large range of values amongst continuous variables, values for these covariates were standardized by calculating z-scores.

I included the distance to a release site covariate in order to gain some idea of how otters had dispersed outward from the reintroduction points and whether or not sufficient time had elapsed since reintroduction for the otters to disperse to all habitable areas. The distance to the nearest release site was measured from the center of a given sampling unit in a straight line to the nearest release site (Figure 2.4). This method supposes that river otters are able to travel over land in addition to along waterways, though travel by waterways is preferred (Melquist and Hornocker 1983).

I considered wetland area as a covariate as it could represent habitat outside of the main river channel that an otter would use while traveling over land (Simpson and Schneider 2007; Tranl and Chapman 2007). Wetland area data was derived from a wetland layer made available through the USDA (United States Department of Agriculture) NRCS (Natural Resources Conservation Service) Geospatial Data Gateway (Figure 2.5). Only wetlands >0.5 acres in size were selected so as to avoid including ephemeral or very small wetlands. River channels were removed from the layer in order that only wetland area beyond the river channel would be considered. In the event that a reservoir occurred along the river, the area covered by the reservoir was not included as so large a contiguous waterbody along the river did not seem to match the functionality of a wetland area, despite the water area being additional to the main river channel.

I considered the river flow rate covariate because the size of a river may have implications for how much forage is available within the river, and because otters may prefer rivers with larger and deeper pools and open water sections (Wilson 2012; Tranl and Chapman 2007).The information for long-term median flow rates was provided by the USGS (United State Geological Survey) National Water Information System (NWIS) flow meters established throughout the state of Nebraska. Due to a relatively limited number of these meters existing, it was necessary to extrapolate flow rate values in many sampling units that did not contain flow meters (Figure 2.6). This was accomplished using linear regression and contextual information provided by aerial imagery and on-the-ground knowledge of the rivers.

I considered beaver presence as a covariate due to the frequent use of beaver lodges by river otters (Swimley 1999; Melquist and Hornocker 1983; Jackson 2014). Naïve occupancy, that is the proportion of sites found to be occupied through surveys, was used during the model selection process, but because presence/absence data for beaver would not be available for unsurveyed grid cells, it was necessary to estimate beaver occupancy (Figure 2.7; Appendix A). This was done using occupancy modeling techniques explored later in this chapter.

I derived and simplified land cover data from land cover raster sets available through USDA NRCS Geospatial Data Gateway. Data was simplified to consist of the two dominant vegetation cover types because “cultivated crops” and “herbaceous” land covers dominated the study area, and all other land covers along the focal rivers existed in only a very small number of sampling units (Figure 2.8). In the event that some other uncommon land cover was present in a grid cell, the surrounding vegetation cover was chosen. A study by Jeffress (2011) found that land cover was an important consideration in otter occupancy at the local scale but he did not find evidence that it was important at larger scales.

The final covariate was an estimate of whether or not the river in a given sampling unit was likely to have gone dry in the last five years- dry history for short- which in most cases would have occurred during the 2012 drought if at all (Mallya et al. 2013; Figure 2.9). It is possible that if the river had gone dry, resident otters may have left the area and not yet returned. The information for this covariate was also derived from the USGS NWIS flow meters, and areas were considered to have gone dry if their flow rate during the previous five years dropped as low as 20ft$^3$/s of water for a period of one month. This flow rate is a high estimate for long-term median flow rates in the headwaters of smaller Nebraska rivers that typically are dry in the summer and fall.

I also considered combinations of covariates in four models. The “Global” model included all six of the considered covariates. The “Basic Needs” model included river flow rate and beaver occupancy as these covariates represent very basic needs for otters: beaver dens to lodge in and adequate river flow to support prey. The “Incomplete dispersal” model is similar to the “Basic Needs” model, but it also includes the distance to the nearest release site. This model supposes that an otter’s basics needs are met but that animals are more closely associated with release sites than would be expected if otters had completely colonized all available habitat. The “Wet Area” model includes wetland area, river flow rate, and whether or not the river had likely gone dry in the last 5 years. This model supposes that the amount of available water is the driving factor in otter occupancy.

**Statistical Analysis**

I defined eight detection models and ten site occupancy models *a priori* (Table 2.1;Table 2.2). I considered a null detection model in which detection rates were similar between observers as well as a model which accounted for differences in detection rates between observers. I added covariates to each of these models to examine the impact of recent heavy rains, the impact of the survey period, and the impact of a combination of these two on detection rates. I considered six occupancy models, which each considered otter occupancy to be a function of a single covariate, as well as four occupancy models, which considered otter occupancy to be a function of 2 or more covariates. I used correlation analyses to assess the independence of all covariates (Table 2.3). Covariates were considered to be strongly correlated at r or phi=0.50. If two covariates were strongly correlated, the covariate most relevant to the model in question would be retained. Occupancy analyses were conducted using Program PRESENCE and simple single-season models (Hines 2006).

I used Akaike's Information Criterion (AIC) to determine relative fit of competing models. Detection models of survey-specific covariates were first run using global site-specific covariates. The strongest detection model was then used while assessing further models incorporating the site-specific covariates. Model weights were summed top-down until the cumulative model weights exceeded 0.95 and this was considered to be the 95% confidence set. As this confidence set contained the global model for site-specific covariates, all covariates were retained (Burnham and Anderson 2002). Occupancy estimates from the best model were then imported into the appropriate sampling units in ArcGIS so that results could be displayed.

**RESULTS**

Approximately 1,630 kilometers were surveyed by kayak. Five remote-sensing cameras were deployed on the Little Blue River, five on the Little Nemaha River, and four on the Calamus River near the Calamus Reservoir River (Figure 2.10). Otter sign was detected on the Niobrara, Elkhorn, Platte, Loup, and Cedar rivers during kayak surveys. A total of 190 observations were made with records occurring in 52 of 324 surveyed grid cells, which equates to a naïve occupancy rate of 16% ((Figure 2.11; Appendix B).

On the Niobrara River, sign was detected from Cody, Nebraska east to Lynch. Otter sign on the Elkhorn was concentrated between O'Neill and Meadow Grove but was found as far south as Scribner. On the Platte River, sign was detected primarily on the North Platte west of the reservoir at Ogallala and along the Big Bend of the Platte River between Overton and Chapman. Sign was found sporadically and infrequently in the Loup River system with records occurring near Loup City on the Middle Loup, Cotesfield and Elba on the North Loup, and southwest of Dannebrog on the Loup River. One observation was made on the Cedar River of an animal spotted swimming across the river channel southeast of Cedar Rapids (Figure 2.10). There were some technical or configuration problems with the remote-sensing cameras that led to their data being discarded from the set.

The best detection model included different detection rates by observer and effects from both survey period and recent heavy rainfall (AIC weight=0.9983) (Table 2.4). The best occupancy model was the "Incomplete dispersal" model, which considered otter occupancy to be a function of the distance from the survey site to a release site, the presence of beaver in the area, and the long-term median flow rate of the river (AIC weight= 0.91). The only other model with more than 5% of the AIC weight was the global model, which accounted for the effects of all six site-specific covariates

(AIC weight=0.09) (Table 2.5). Beta estimates for the covariates in the best model suggest a strong positive effect of beaver occupancy on otter occupancy, a strong negative effect of the distance from the nearest release site on otter occupancy, and a weak negative effect of the river flow rate on otter occupancy (Table 2.6; Figure 2.12).

**Projected Distribution**

In addition to predicting occupancy in all areas where otter sign was found, occupancy estimates of 10-25% were predicted throughout much of the southern Loup River system. A lower occupancy estimate of 5-10% was predicted intermittently throughout the central and eastern Niobrara River, the central Elkhorn River, the southern Loup River system, the South Platte River, and the Republican River near the Harlan County Lake (Figure 2.13).

**DISCUSSION**

The current estimated distribution for river otters in the state is consistent with the findings of my study. Otters are found throughout the Niobrara from Cody, NE east to the Missouri, throughout the Elkhorn and Platte rivers, and in the southern Loup River system. In the Loup River system, I found occupancy estimates between 10% and 25% on the North Loup river from Brewster, NE south to the Loup River, between 5% and 25% on the Middle Loup river from Sargent, NE south to the Loup River, and between 10% and 25% in some sampling units on the South Loup river from Callaway, NE south to the Loup River. I estimated occupancy on the Cedar River to be 5% to 25% from Spalding, NE south to the Loup River. Occupancy estimates between 5% and 10%

around the Harlan County Lake on the Republican River suggest that there is an increased likelihood of otters occurring there.

My survey records indicate that the Niobrara River in Keya Peha County has resident otters, but this is an area that is not well-supported by historic records. Modeling results suggest otter occupancy estimates between 5-10% on the eastern Republican River. This area was within the NGPC distribution estimate, but only around Harlan County Lake (Figure 2.14). Surveys in this area failed to detect any otter presence, though compared to other surveyed rivers, the Republican had comparatively little exposed substrate to examine for tracks. The NGPC distribution estimate also considers the Little Nemaha River to be a part of otter distribution in the state, and several historical records exist from this area. I was unable to survey this area due to low river flow at the time of the surveys.

Though survey efforts were able to cover a very broad area and reach much of the navigable river water in Nebraska, there were areas that were not surveyed or that received limited coverage. Coverage on the Missouri River was limited as water conditions further south were unsafe for kayak surveys. The northernmost parts of the Elkhorn, Big Blue, South Loup, Middle Loup, and North Loup rivers, and the western North Platte, Niobrara, and Republican rivers were also not surveyed due to low water or inaccessibility. I would advise integrating other surveying approaches to better represent some of the smaller rivers, which could not be surveyed by kayak (e.g. northern Big Blue and western Republican Rivers), and to bolster detection rates on surveyed rivers. Remote sensing cameras have been used with some success in otter monitoring efforts (Stevens and Serfass 2008) and may be made more useful with bait stations (Zielinski and Kucera 1995). Fourteen cameras were deployed in my Nebraska surveying efforts, but they proved to be too unpredictable with over half of the cameras failing to function in the dark. A more extended trial period is recommended for those wishing to integrate cameras into their surveys.

My analyses corroborate that beaver presence (Swimley 1999; Melquist and Hornocker 1983; Jackson 2014) and flow rate (Wilson 2012; Tranl and Chapman 2007) are important contributors to otter occupancy. River otters in Nebraska also remain somewhat localized around release sites, which may suggest that they have not fully dispersed in the 25 years since reintroduction efforts began. The amount of wetland area available was not strongly supported in my modeling efforts as a driving factor in otter occupancy. This was an important consideration in Simpson and Schneider's distribution estimates (Simpson and Schneider 2014). It is worth noting that the amount of wetland area available was much higher along the central and eastern Platte River than it was anywhere else in the state, which may have impacted the performance of wetland area as a covariate. The dominant vegetative land cover and the dry history of the river were not supported as strong covariates.

Detection rates were variable between observers. Average detection rates by observer were 0.56, 0.59, 0.38, 0.43, and 0.36. An Oklahoma study using bridges as survey locations found variable detections rates of 30-50% and 7-17% during high otter abundance and low otter abundance years respectively (Shackelford and Whitaker 1997). A Missouri study showed 68% and 40% detection rates at random and bridge sites respectively (Crimmins et al. 2009). MacKenzie (2006) recommends surveying sites 3 or more times when detection probability is >0.5, but this is emphasized for studies where surveys are not done on the same day. With detection rates above or near 50% and all surveys being conducted on the same day, the 2 to 3 observers per site used were adequate.

**Management Implications**

Given the number of historical reports from the Little Nemaha River, I cannot disagree with the current belief that it should be included in distribution estimates for the state. Because the Missouri River is so large and channelized as it flows south, we did not feel it was safe to survey by kayak over much of its course, and the small area we did survey was too large to cover efficiently. NGPC does possess some historical records from the Missouri, and it was considered to be well-populated prior to their extirpation (Swenk 1908). Due to limited surveys coverage on the Missouri, however, I cannot recommend one way or the other if this river should be considered a part of the otter's distribution in Nebraska**.** Given the low occupancy estimates occurring in few cells on the Republican River near the Harlan County Lake, it is unlikely that there are resident otters in the lake or in that stretch of the river, and it would be worth reconsidering its inclusion if no new records occur in the next several years.

If further reintroduction or otter translocation efforts are considered in the future, I recommend focusing on areas of higher estimated otter occupancy but where records are lacking. These areas might include the eastern Republican, South Platte, and southern Elkhorn rivers as well as the southern Loup River system. These areas were identified as areas with elevated occupancy estimates, but otter records are almost entirely absent from these areas with only a few records from the Harlan County Lake area in 1980 and 2010 and few or no records from the South Platte, southern Elkhorn, and southern Loup River system.

The method of surveying employed in this chapter was beneficial in its broad coverage and ability to account for absences. It was, however, very labor intensive and only feasible during a short window of time when water levels were appropriate and rivers had not iced over. Future monitoring efforts would be most effective employing multiple survey methods. I suggest relying on the continued cooperation of fur trappers for information in the more populated regions of Nebraska. In less populated areas but where bridges are available, bridge surveys may be used. The more labor intensive sign surveys should be reserved for areas of special interest and remote areas of the state.

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Figure 2.1

Otters were released at seven sites throughout the state. These sites were centrally located in the Loup River system, the central and western Platte River, the western Niobrara River, and the northern Elkhorn River.

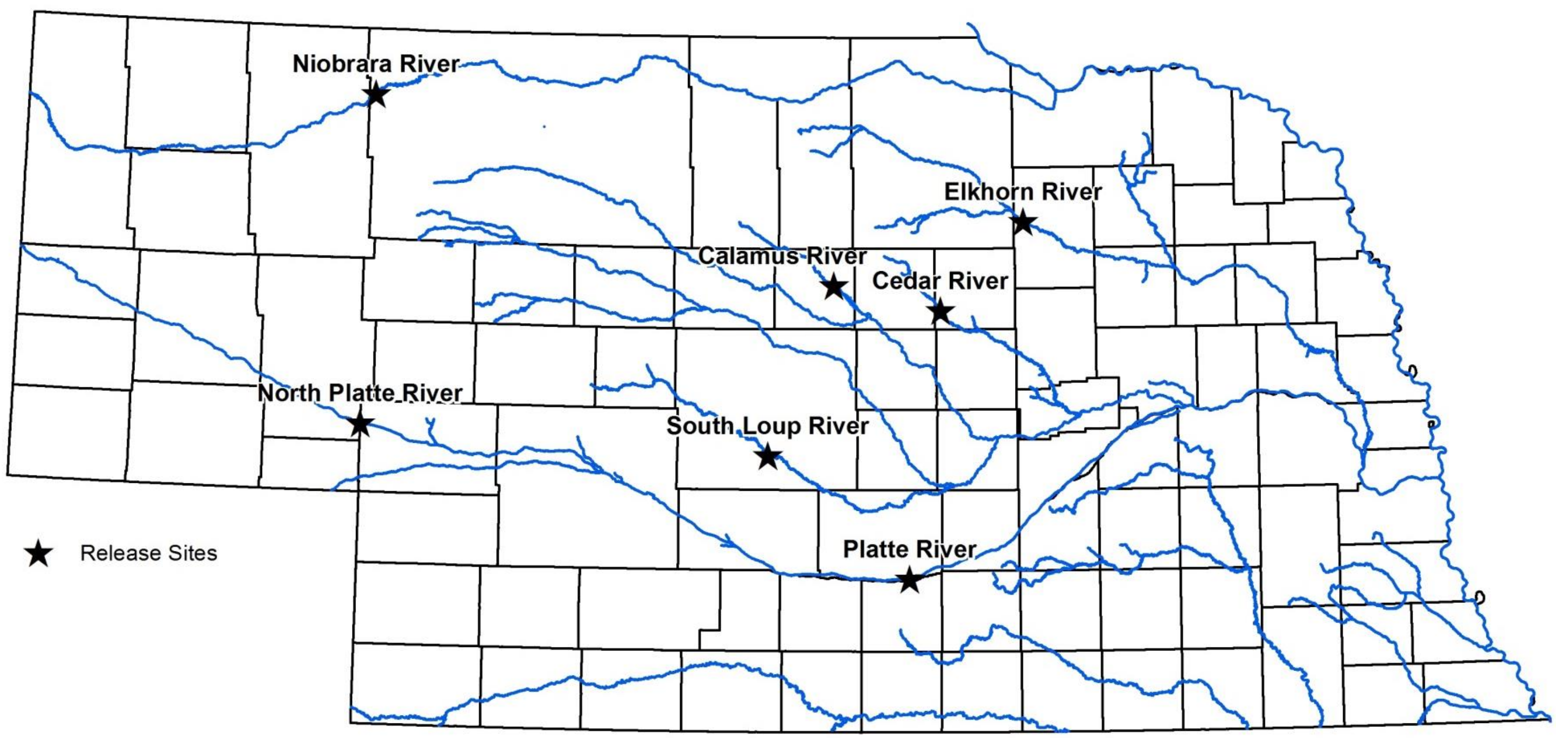

Figure 2.2

Nebraska is home to over 8,500km of river. Most of these are sandy rivers with meandering channels flowing west to east and draining into the Missouri River.

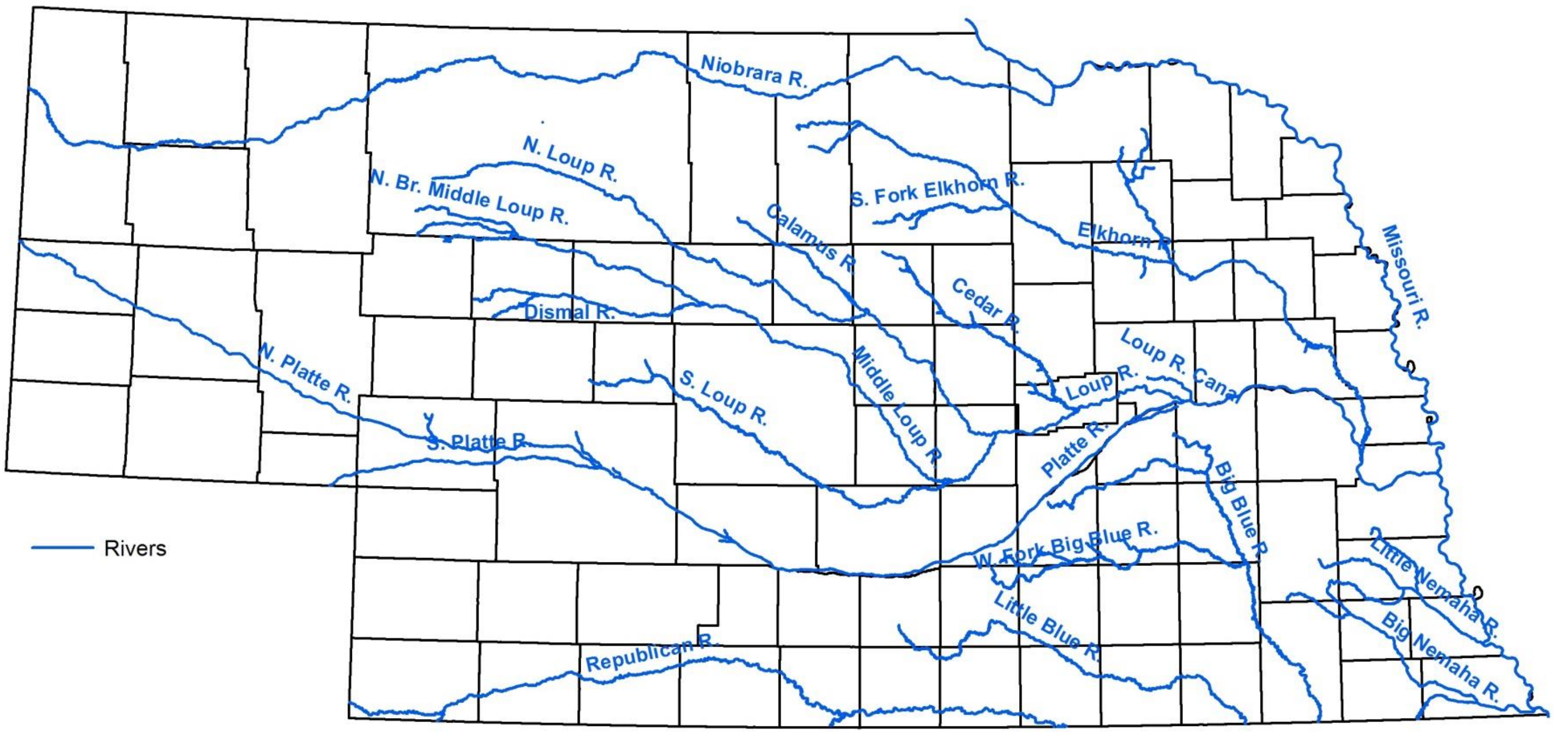

Figure 2.3

A grid of 6km x 6km grid cells was established overlaying the major rivers of Nebraska. Grid cells with focal river within them were extracted to serve as sampling units.

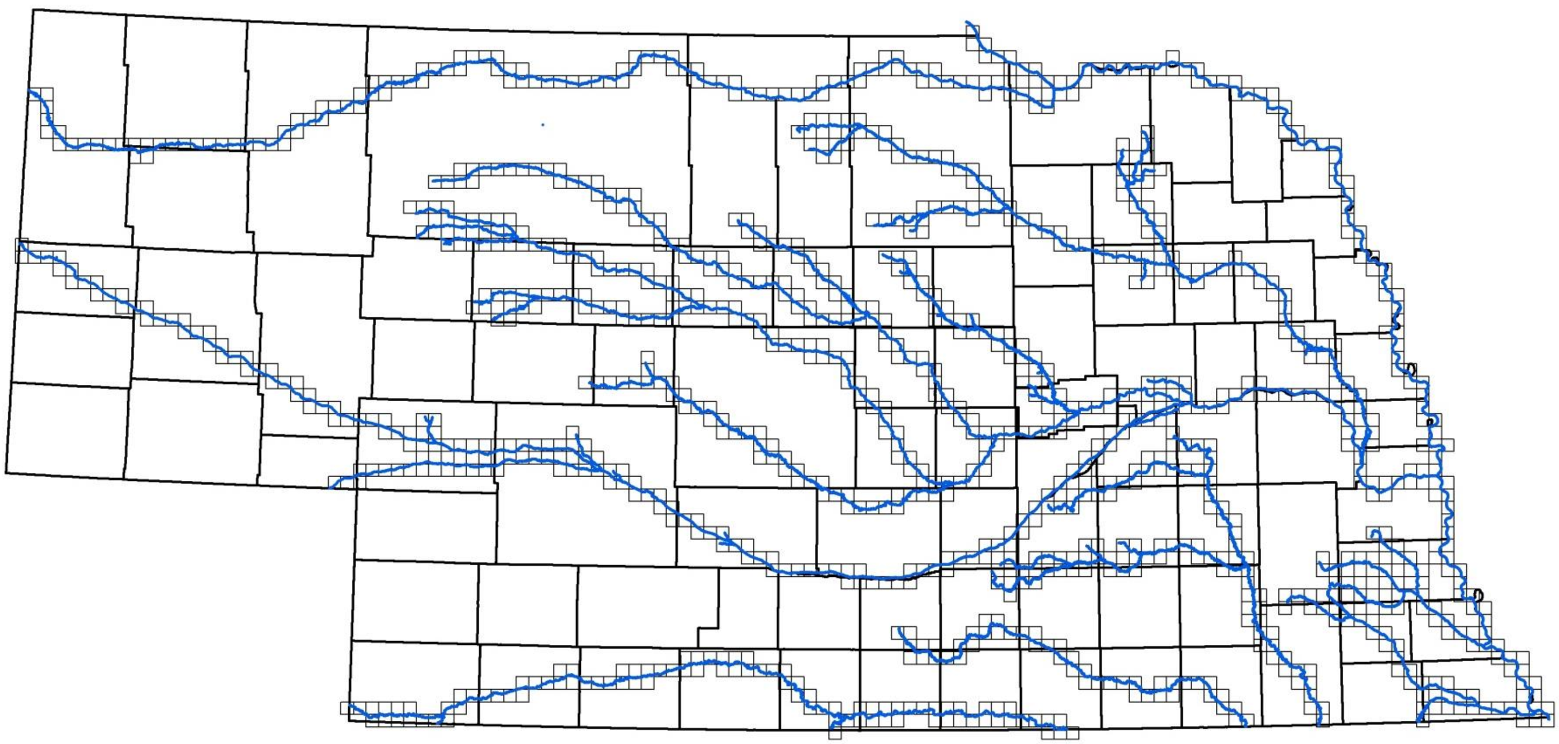

Figure 2.4

The distance to the nearest release site was measured from the center of a given sampling unit in a straight line to the nearest release site. This method supposes that river otters are able to travel over land in addition to along waterways.

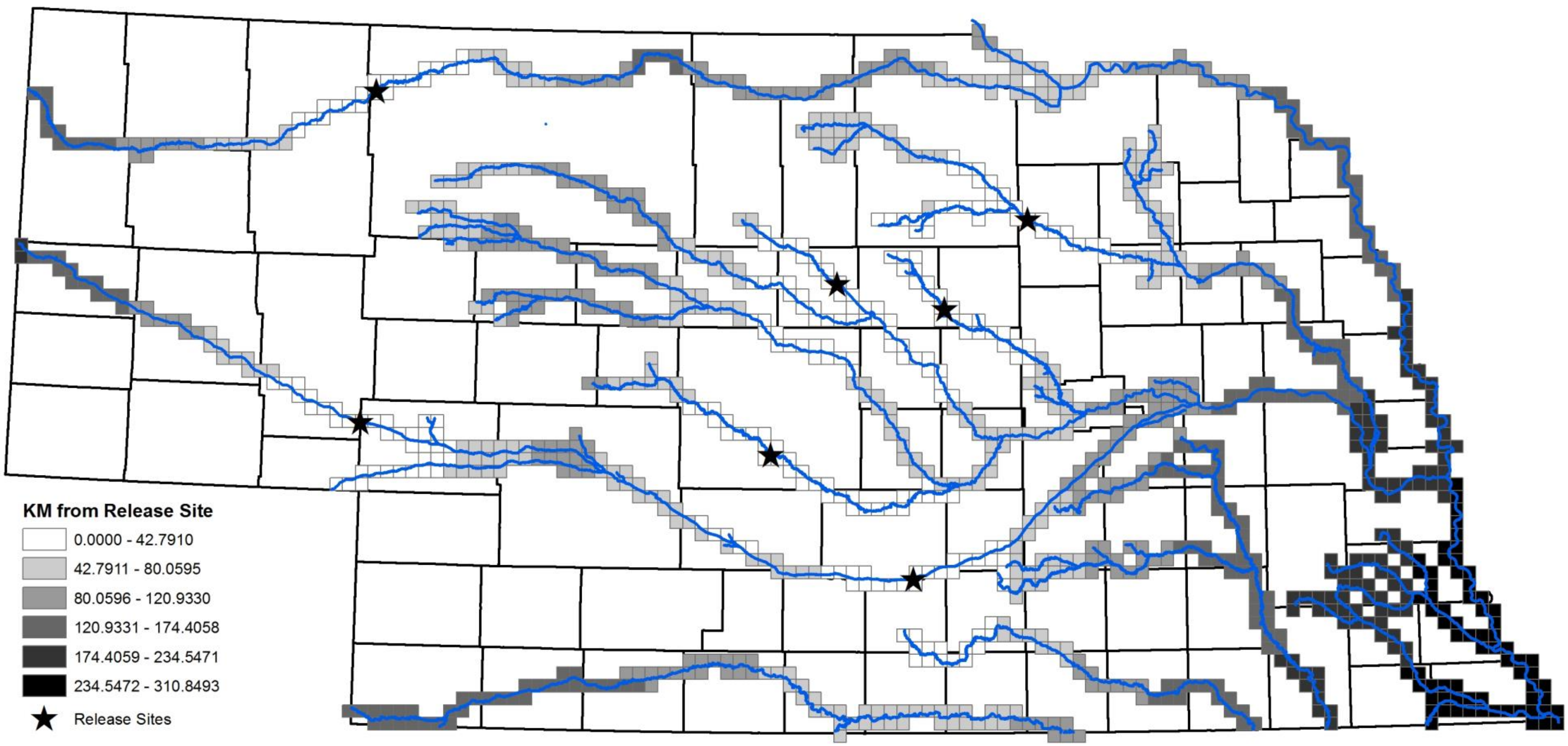

Figure 2.5

The amount of wetland area available in a sampling unit was highly variable across the state with the greatest total areas being found along the Platte River. Very little wetland area outside of the river channel was available along the Niobrara River as well as much of the Elkhorn and Missouri Rivers.

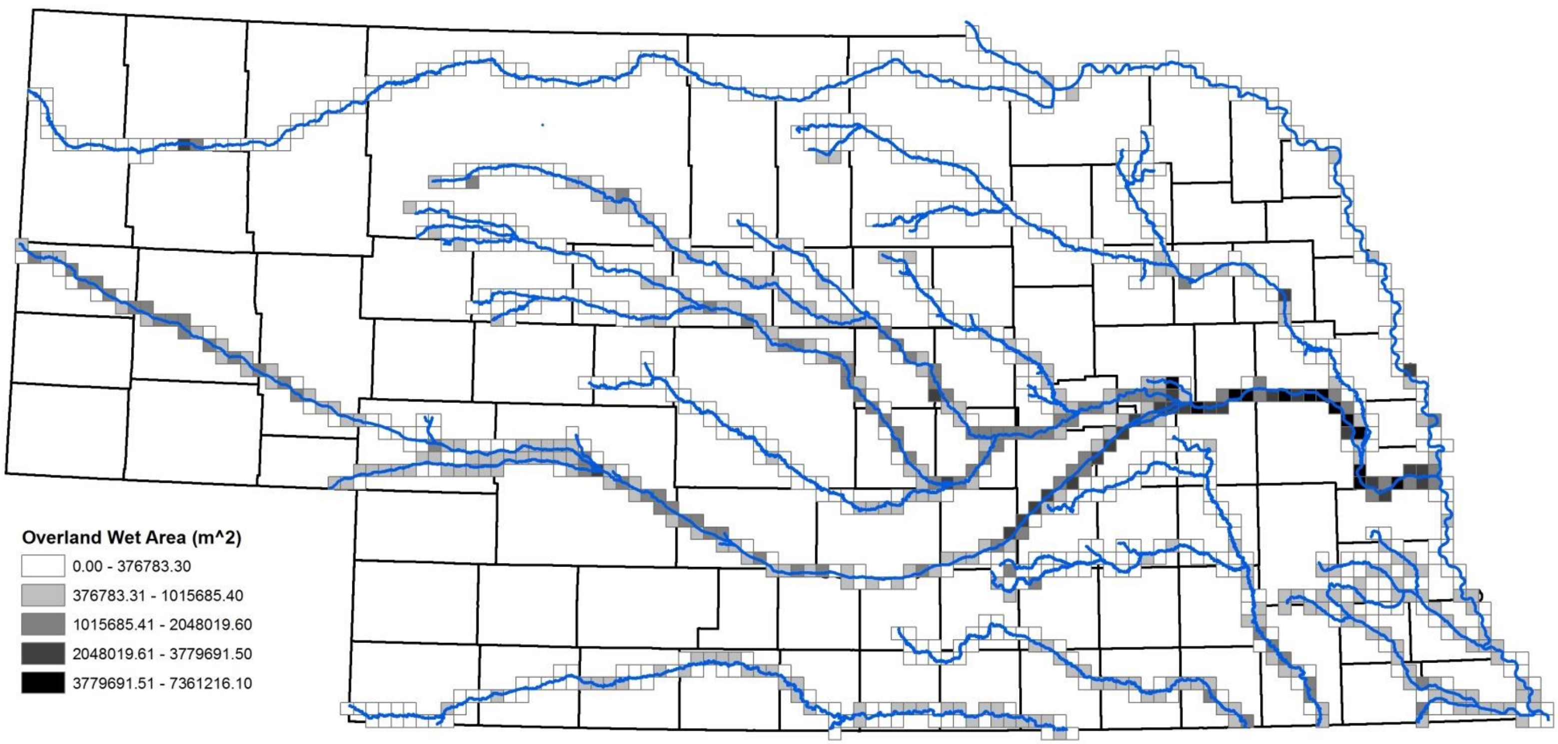

Figure 2.6

Flow rate was estimated using data from 49 flow meters scattered around the state’s waterways. Because these meters were widely spread, linear regression was used to estimate flow rates between meters. Aerial imagery and on-the-ground knowledge of river channels and water control structures were also used to inform flow estimates.

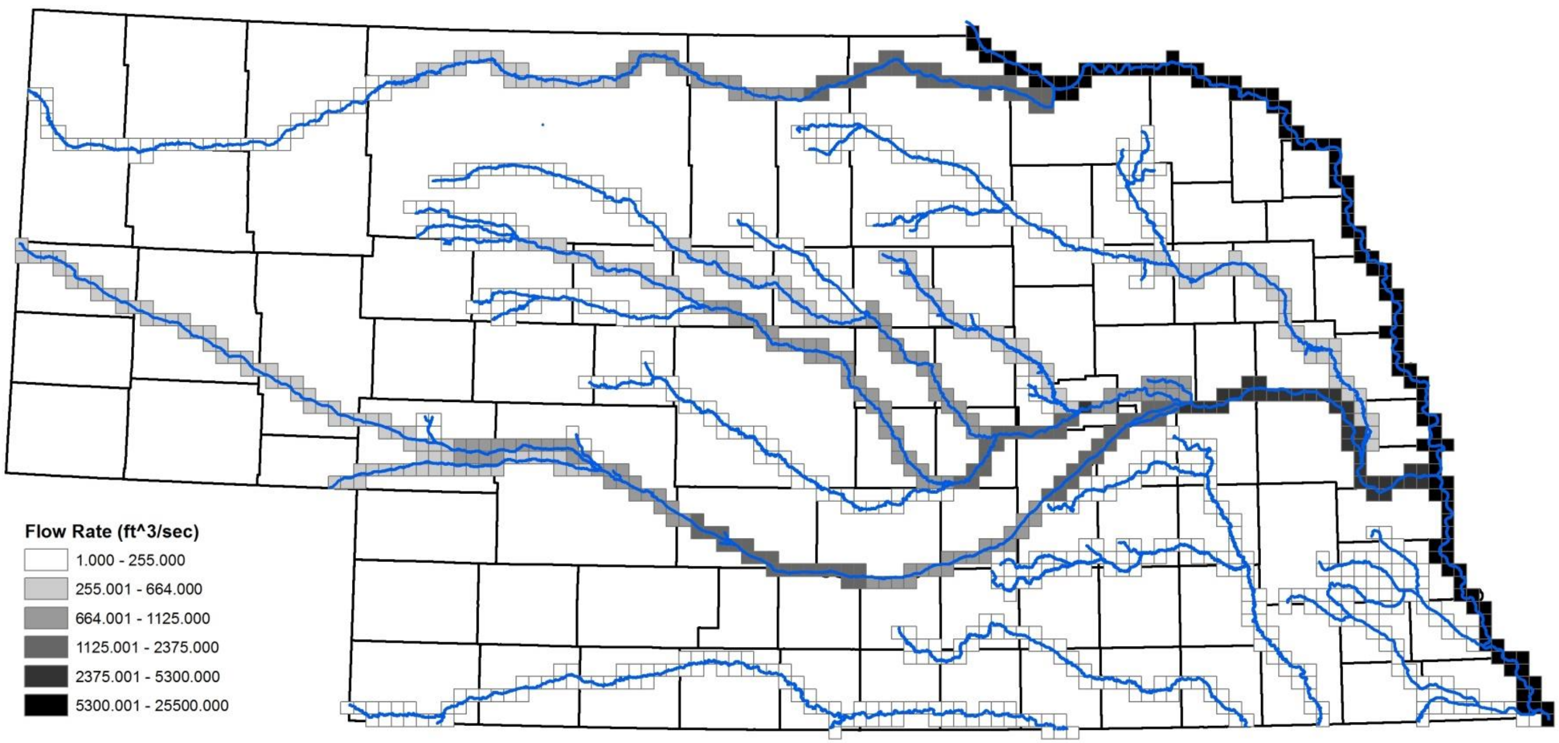

Figure 2.7

Beaver occupancy was very high across the state. There were few areas where occupancy <0.50, and these occurred primarily on the western Niobrara River, in the northern parts of the Loup River system, and on the southern Missouri River.

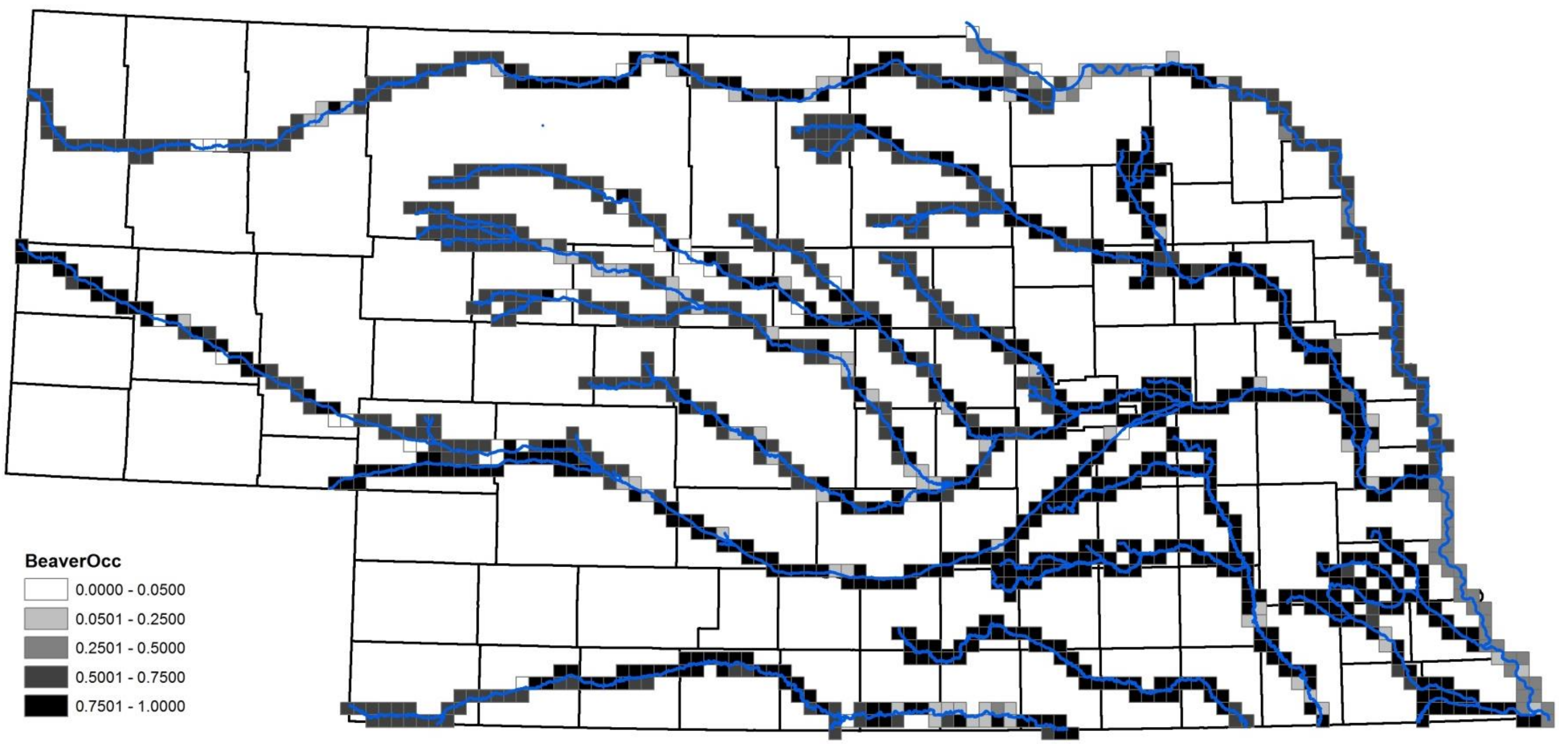

Figure 2.8

Dominant vegetation cover was considered as a possible covariate in estimating otter occupancy. Because there were very few sampling units containing land cover types besides cultivated crops and herbaceous vegetation, the vegetation cover surrounding these outliers was considered.

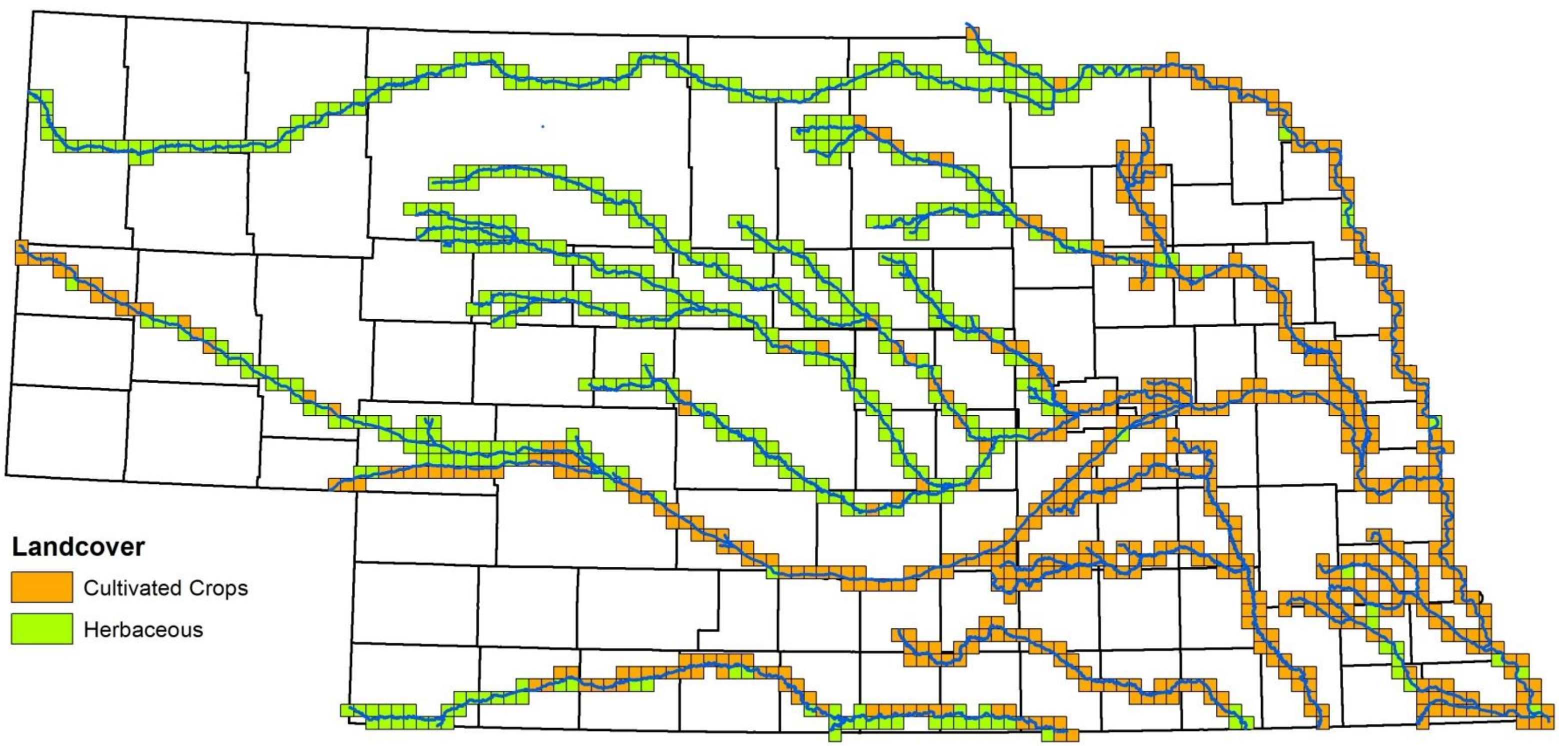

Figure 2.9

Whether or not a river was likely to have gone dry during the last five years, most likely during the 2012 drought, was determined using the five-year low reading on flow meters throughout the state. Because flow meters were widely spread, many sampling units contain estimates informed by the nearest meter and upstream or downstream orientation.

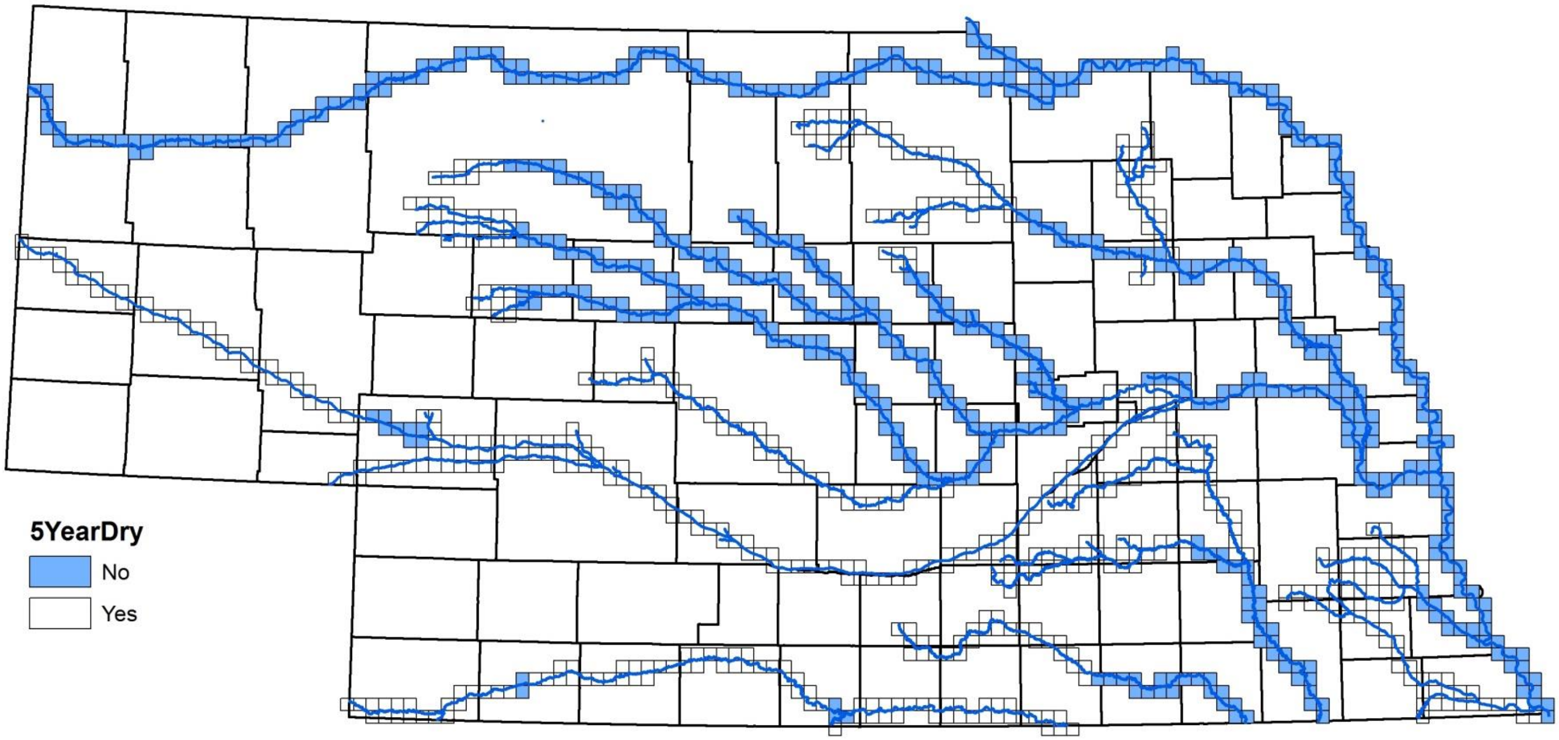

Figure 2.10

An estimated 1,630km were surveyed by kayak during the summers of 2014 and 2015. Remote sensing cameras were also deployed on the Little Nemaha, Little Blue, and Calamus rivers.

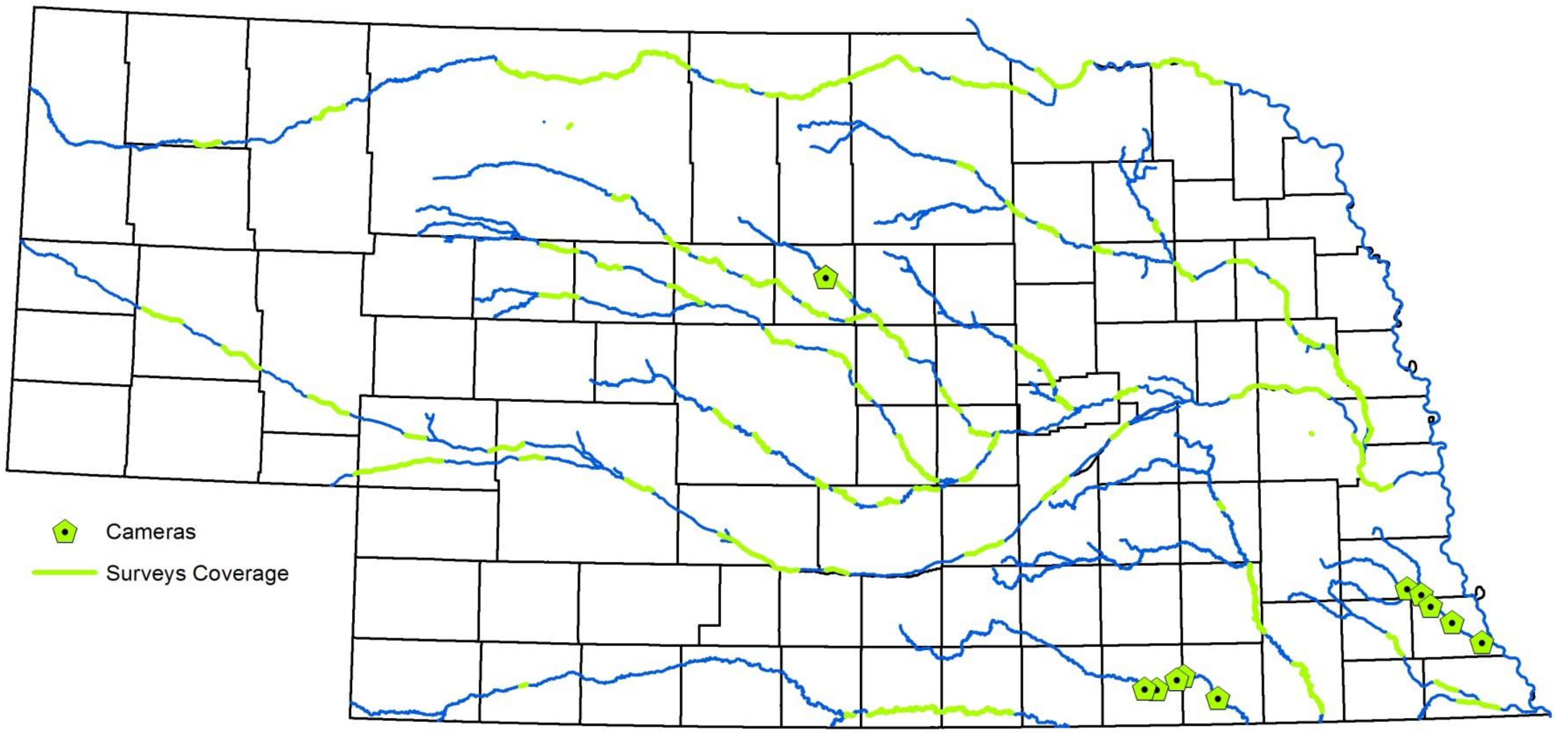

Figure 2.11

Three-hundred and twenty-four sampling units were considered to have been surveyed, and otter sign was found in 52 of these (naïve occupancy=16).

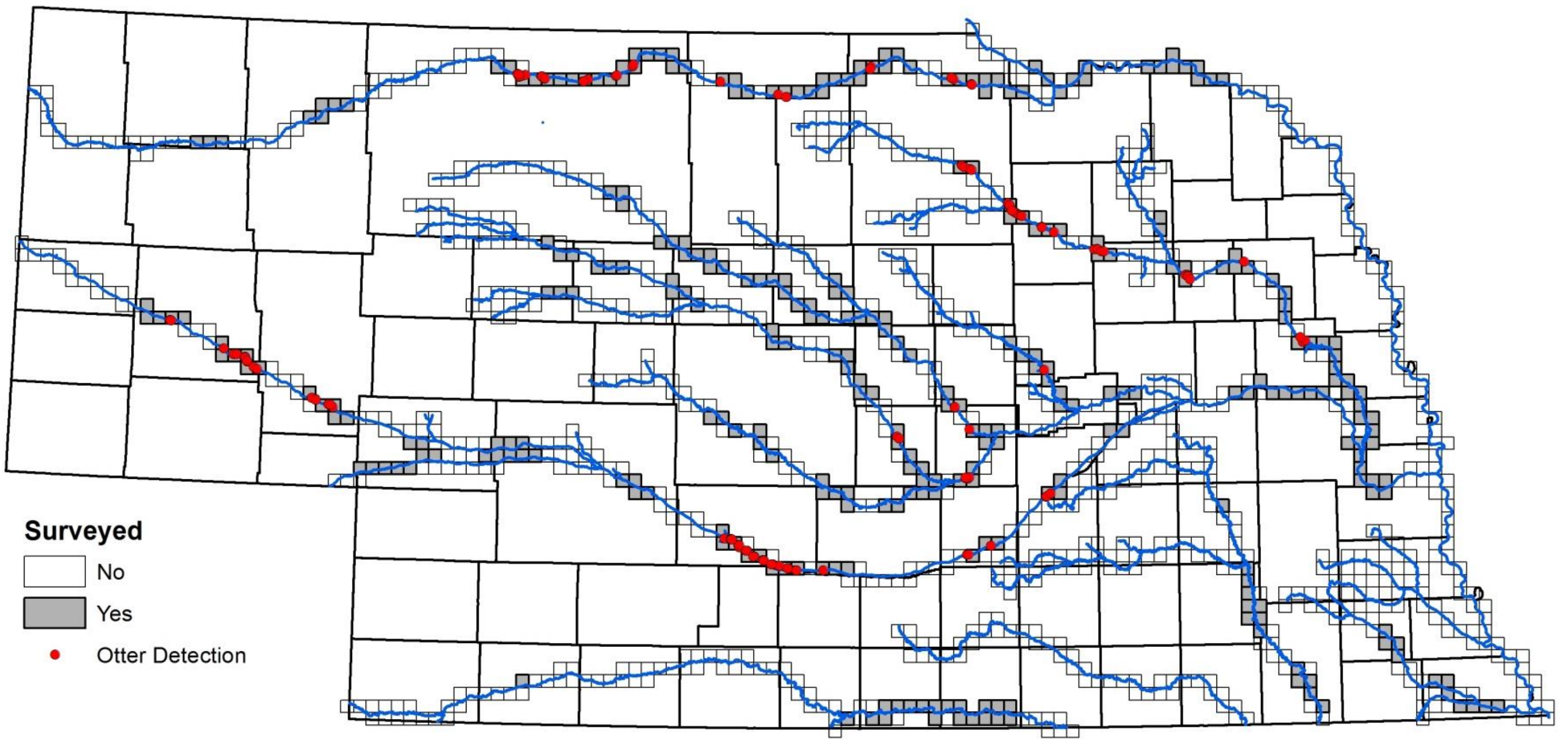

Figure 2.12

Plotting otter occupancy and each covariate illustrates the directionality of these relationships, most notably the negative relationship between otter occupancy and the distance to a release site and the positive relationship between otter occupancy and beaver occupancy. Beaver sign was recorded in every sampling unit where otter sign was recorded.

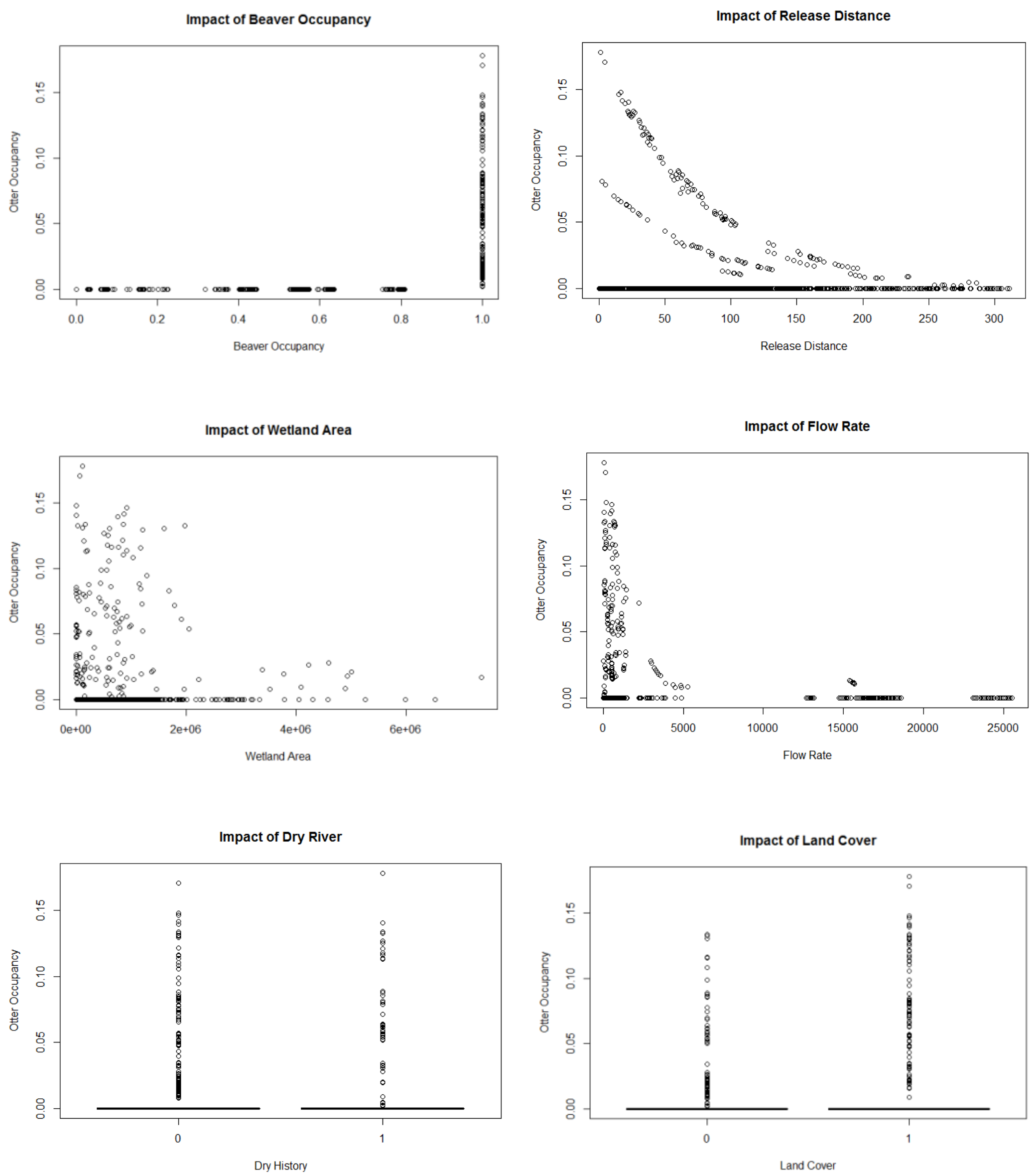

Figure 2.13

In addition to predicting occupancy in areas where otter sign was found, occupancy estimates of 10-25% occurred throughout the southern Loup River system. Occupancy estimates of 5-10% were common throughout the state, primarily on the Platte, Niobrara, Elkhorn, and eastern Republican rivers as well as the southern Loup River system.

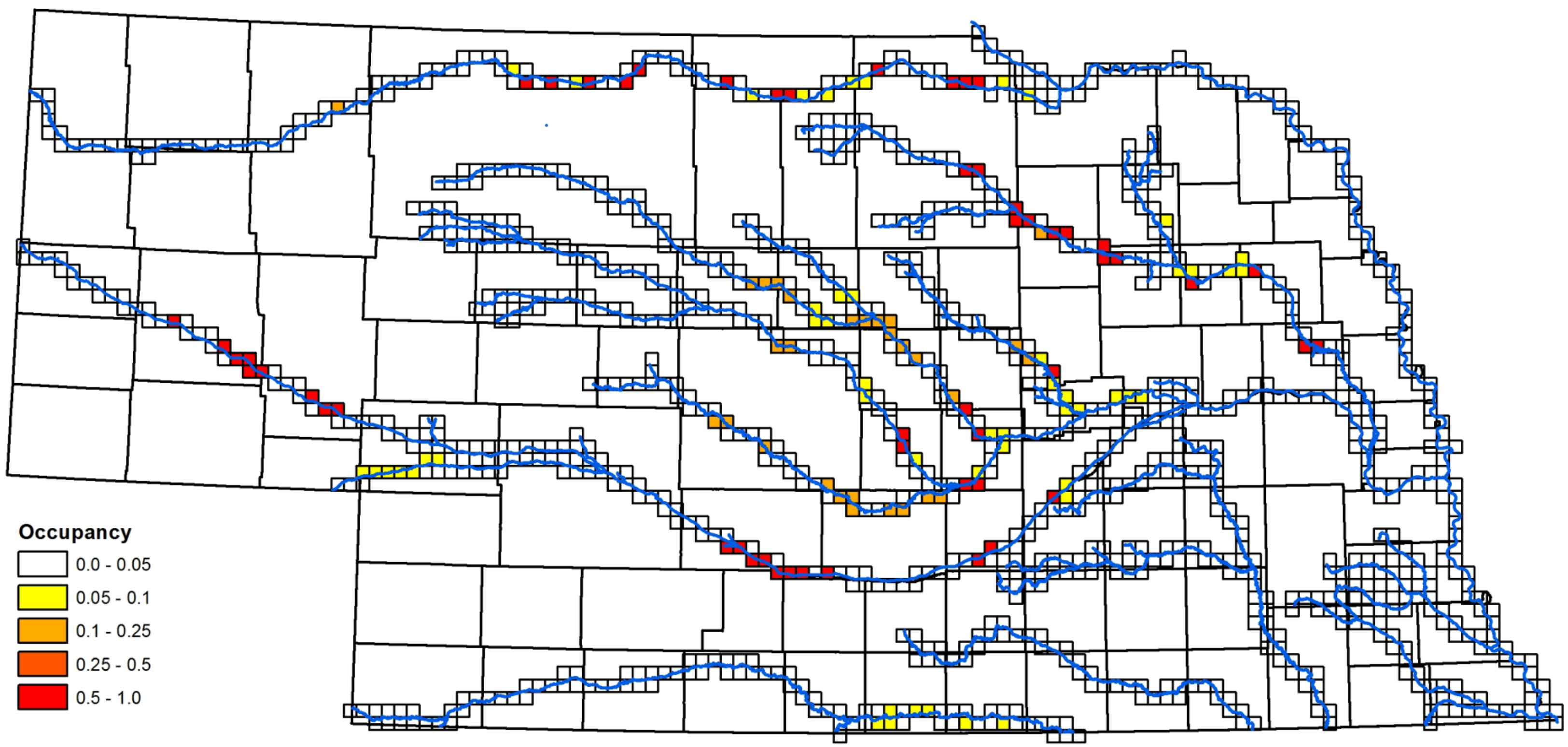

Figure 2.14

NGPC estimated otter distribution in the state considering reports of otters as well as suitable habitat nearby. Suitable habitat consisted of lake and sandpit lakes nearby to the river channel.

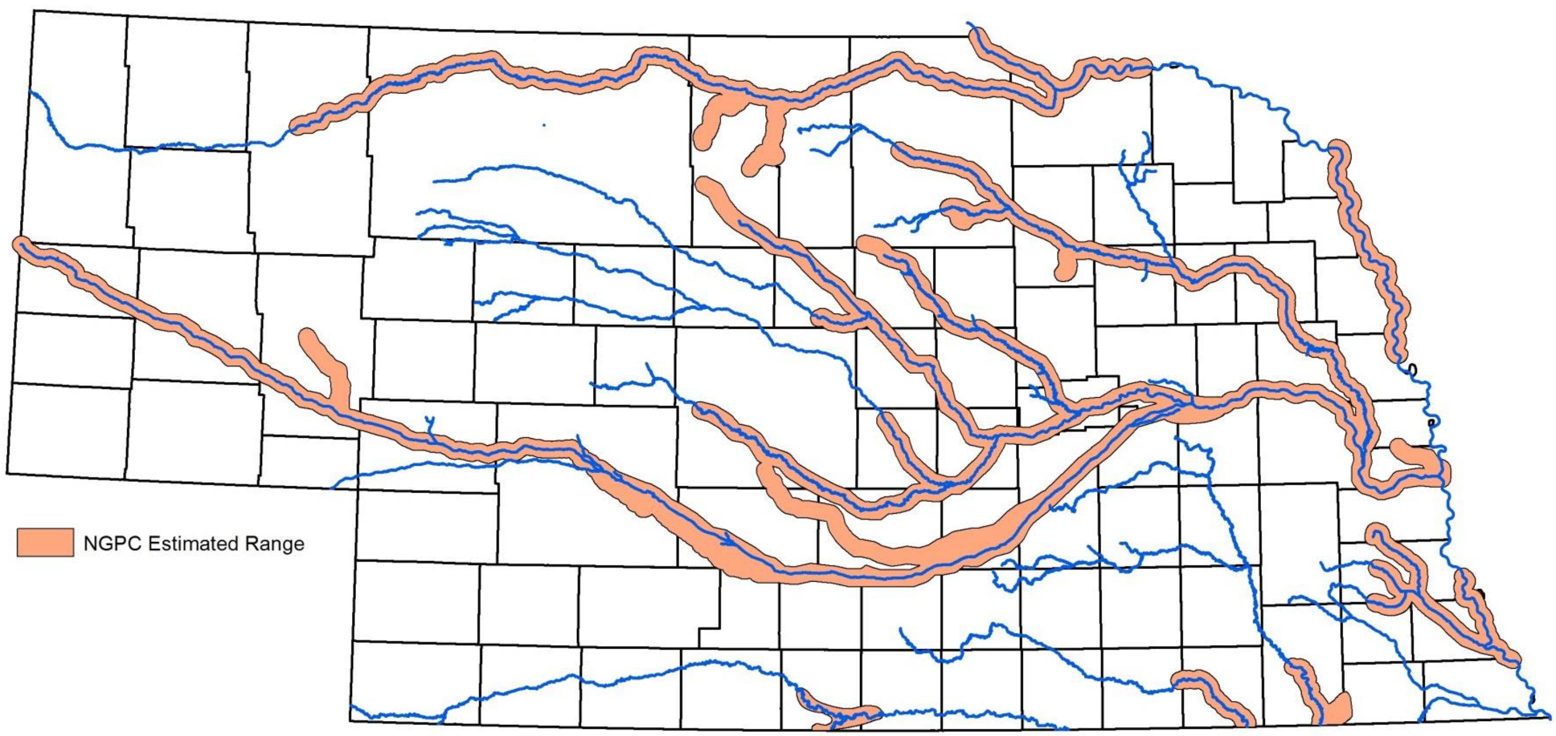

Table 2.1

Detection models included constant and observer-specific detection rates as well as information describing the amount of time since the last significant rainfall and the period of the project during which the survey took place.

| Name | Model |
|---|---|
| Constant | psi(GlobalSiteCovariates),p(.) |
| Observer-specific | psi(GlobalSiteCovariates),p(Observer) |
| Rain Days | psi(GlobalSiteCovariates),p(RainDays) |
| Survey Period | psi(GlobalSiteCovariates),p(SurveyPeriod) |
| Rain Days and Survey Period | psi(GlobalSiteCovariates),p(RainDays,SurveyPeriod) |
| Observer-specific Rain Days | psi(GlobalSiteCovariates),p(Observer,RainDays) |
| Observer-specific Survey Period | psi(GlobalSiteCovariates),p(Observer,SurveyPeriod) |
| Observer-Specific Rain Days and Survey Period | psi(GlobalSiteCovariates),p(Observer,RainDays,SurveyPeriod) |

Table 2.2

Ten occupancy models were defined a *priori*, and the best model was used to estimate otter occupancy in unsurveyed areas of the state.

| Name | Model |
|---|---|
| Global | psi(Global),p(TopDetectionCovariates) |
| Available Water | psi(WetlandArea, FlowRate, Dry),p(TopDetectionCovariates) |
| Basic Needs | psi(FlowRate, Beaver),p(TopDetectionCovariates) |
| Incomplete Dispersal | psi(ReleaseDist, FlowRate, Beaver),p(TopDetectionCovariates) |
| Beaver | psi(Beaver),p(TopDetectionCovariates) |
| Five Year Dry | psi(Dry),p(TopDetectionCovariates) |
| Flow Rate | psi(FlowRate),p(TopDetectionCovariates) |
| Land Cover | psi(LandCover),p(TopDetectionCovariates) |
| Release Distance | psi(ReleaseDist),p(TopDetectionCovariates) |
| Wetland Area | psi(WetlandArea),p(TopDetectionCovariates) |

Table 2.3

Correlation analyses determined that none of the covariates used in the analyses were offering the same information. A correlation coefficient of >0.50 was considered to indicate a strong correlation.

| Covariates | Release Distance | River Size | River Dry | Wetland Area | Beaver |
|---|---|---|---|---|---|
| River Size | 0.032 | - | - | - | - |
| River Dry | 0.142 | 0.272 | - | - | - |
| Wetland Area | 0.124 | 0.176 | 0.025 | - | - |
| Beaver | 0.017 | 0.141 | 0.039 | 0.108 | - |
| Land Cover | 0.426 | 0.08 | 0.038 | 0.283 | 0.138 |

Table 2.4

The best detection model included different detection rates by observer and effects from both survey period and recent heavy rainfalls.

| Model | AIC | deltaAIC | AIC wgt | Model Likelihood | no.Par. | -2*LogLike |
|---|---|---|---|---|---|---|
| psi(GlobalSiteCovariates),p(Observer, RainDays, SurveyPeriod) | 356.05 | 0 | 0.9983 | 1 | 22 | 312.05 |
| psi(GlobalSiteCovariates),p(Observer, SurveyPeriod) | 369.44 | 13.39 | 0.0012 | 0.0012 | 17 | 335.44 |
| psi(GlobalSiteCovariates),p(RainDays) | 373.29 | 17.24 | 0.0002 | 0.0002 | 9 | 355.29 |
| psi(GlobalSiteCovariates),p(RainDays, SurveyPeriod) | 373.61 | 17.56 | 0.0002 | 0.0002 | 10 | 353.61 |
| psi(GlobalSiteCovariates),p(Observer, RainDays) | 373.84 | 17.79 | 0.0001 | 0.0001 | 17 | 339.84 |
| psi(GlobalSiteCovariates),p(.) | 382.35 | 26.3 | 0 | 0 | 8 | 366.35 |
| psi(GlobalSiteCovariates),p(SurveyPeriod) | 383.55 | 27.5 | 0 | 0 | 9 | 365.55 |
| psi(GlobalSiteCovariates),p(Observer) | 384.64 | 28.59 | 0 | 0 | 12 | 360.64 |

Table 2.5

The best fit otter occupancy model was one that considered river flow rate, distance to a release site, and beaver occupancy. The only other model in the 95% confidence set was the global model.

| Model | AIC | deltaAIC | AIC wgt | Model Likelihood | no.Par. | -2*LogLike |
|---|---|---|---|---|---|---|
| psi(IncompleteDispersal),p(TopDetectionCovariates) | 351.51 | 0 | 0.905 | 1 | 19 | 313.51 |
| psi(Global),p(TopDetectionCovariates) | 356.05 | 4.54 | 0.0935 | 0.1033 | 22 | 312.05 |
| psi(BasicNeeds),p(TopDetectionCovariates) | 365.12 | 13.61 | 0.001 | 0.0011 | 18 | 329.12 |
| psi(Beaver),p(TopDetectionCovariates) | 367.28 | 15.77 | 0.0003 | 0.0004 | 17 | 333.28 |
| psi(ReleaseDist),p(TopDetectionCovariates) | 404.68 | 53.17 | 0 | 0 | 17 | 370.68 |
| psi(FlowRate),p(TopDetectionCovariates) | 416.21 | 64.7 | 0 | 0 | 17 | 382.21 |
| psi(Dry),p(TopDetectionCovariates) | 417.31 | 65.8 | 0 | 0 | 17 | 383.31 |
| psi(AvailableWater),p(TopDetectionCovariates) | 418.46 | 66.95 | 0 | 0 | 19 | 380.46 |
| psi(WetlandArea),p(TopDetectionCovariates) | 419.25 | 67.74 | 0 | 0 | 17 | 385.25 |
| psi(LandCover),p(TopDetectionCovariates) | 419.68 | 68.17 | 0 | 0 | 17 | 385.68 |

Table 2.6

Beta estimates for the covariates in the best model suggest a strong positive effect of beaver occupancy on otter occupancy, a strong negative effect of the distance from a release sites on otter occupancy, and a weak negative effect of the river flow rate on otter occupancy.

| Parameter | Estimate | Std.Error |
|---|---|---|
| psi | -70.615 | 0.679 |
| psi.ReleaseDist | -85.496 | 2.676 |
| psi.FlowRate | -0.642 | 0.683 |
| psi.Beaver | 36.540 | 1.028 |
| P[1] | 0.718 | 0.640 |
| P[2] | 3.696 | 1.892 |
| P[3] | 2.085 | 1.225 |
| P[4] | 8.582 | 3.445 |
| P[5] | 254.980 | 1.464 |
| P[1].RainDays | -0.174 | 0.050 |
| P[2].RainDays | 0.291 | 0.242 |
| P[3].RainDays | -0.107 | 0.088 |
| P[4].RainDays | -0.227 | 0.119 |
| P[5].RainDays | 1.288 | 1.496 |
| P[1].SurveyPeriod | 0.253 | 0.191 |
| P[2].SurveyPeriod | -2.198 | 1.128 |
| P[3].SurveyPeriod | -1.005 | 0.583 |
| P[4].SurveyPeriod | -1.489 | 0.597 |
| P[5].SurveyPeriod | -64.170 | 0.364 |

# CHAPTER 3: ESTIMATING RIVER OTTER DISTRIBUTION AND HABITAT SUITABILITY IN NEBRASKA USING PRESENCE-ONLY DATA FROM HISTORICAL RECORDS AND A COMPARISON OF OCCUPANCY ESTIMATION METHODS

## INTRODUCTION

The North American river otter (*Lontra canadensis)* was once a common mammal in Nebraska found in all of the state's major rivers (Swenk 1908), particularly in the Missouri and Platte rivers (Jones 1964). By the early 1900's, however, unregulated fur-trapping and changes in land use practices had eliminated otters from Nebraska's rivers (Melquist and Dronkert 1987). From the late 1800's through the early 1900's, reports of otters were very infrequent with a report on the Big Blue River in 1897 (Swenk 1918) and a report from Seward County, Nebraska in 1916 (Jones 1964) being among the last that would occur for nearly 50 years. Two specimens were reported coming from the Missouri River near Council Bluffs, Iowa and Beaver City, Nebraska in the late 1960's and early 1970's (Hoffman and Genoways 2005).

In 1986, the Nebraska Game and Parks Commission (NGPC) began releasing otters back into Nebraska rivers, and by 1991 had released 159 otters at seven sites throughout the state (Figure 3.1; Bischof 2003). With the reintroductions, the otter was listed as a tier-1 at-risk species in the state of Nebraska (Bischof 2003; Wilson 2012; Schneider et al. 2005). Early efforts to monitor the reintroduced otters consisted primarily of winter bridge surveys by NGPC (Bischof 2002), incidental take by fur trappers reported to NGPC, and to graduate work along the Big Bend of the Platte River (Wilson 2012; Williams 2011). These early efforts indicate that otters in Nebraska are reclaiming much of their lost distribution. There are, however, large gaps in the known otter occurrence data, and it is unclear whether some of these areas may be quality otter habitat with no corresponding records or whether they may be poor quality habitat.

Maximum-entropy modeling (maxent) is a method of estimating habitat suitability and species distribution that has become very widely used in recent years due to its effectiveness, the availability of the intuitive Maxent software that interfaces well with ArcGIS software (Merow 2013), and because it offers a means of analyzing presence-only data, which is common and relatively easy to obtain (Philips 2004). Reviews of presence-only species distribution modeling (SDM) methods have suggested that maxent performs favorably over many other SDM methods, particularly with smaller sample sizes and with complex model interactions (Elith et al. 2006, Elith et al. 2009; Hernandez et al. 2006).

The maxent method requires a set of georeferenced locations of species occurrence on a landscape grid where each cell has an associated set of environmental characteristics data. In a maxent analysis, models of the distribution of a species over all of the sites in a study area are created. These models represent probability distributions that account for relationships found between the available presence data and the environmental characteristics data subject to constraints, which are that the mean value of any environmental characteristic predicted by the model should be close to the mean value observed in the data. Of these probability distributions, we select the distribution with maximum entropy, or the most uniform distribution (Jaynes 1957; Philips 2006).

In this chapter, I use maxent analyses with presence-only data provided by NGPC gathered over a period of nearly 35 years. The sources of these data were incidental take reports from fur trappers and biologist observations. Performing these analyses will yield: 1) statewide estimates of habitat suitability and 2) statewide estimates of the distribution of river otters.

In providing a statewide species distribution estimate, multiple data sets may exist that are not compatible with a single method of analysis. The consideration of multiple data sets and analysis methods may allow for greater representation of the study area and for direct comparisons between methods. To conclude this chapter, I compare the results of presence-absence occupancy modeling to the results of presence-only maxent modeling in order to: 1) highlight areas of agreement between model outputs and 2) provide an estimate of otter distribution in Nebraska that considers the results of modeling with two different data sets and modeling techniques.

## MATERIALS AND METHODS

### Study Area

This study focused on the navigable rivers of Nebraska, in particular the Platte, Niobrara, Elkhorn, Loup, Republican, Big Blue, and Missouri rivers, but including some smaller rivers, the Big Nemaha, Little Nemaha, Little Blue, Dismal, and Cedar rivers (Figure 2.2). These rivers were chosen because they allowed for relatively easy navigation and survey by kayak, and because they included the rivers chosen as reintroduction points during the otter reintroduction efforts.

The Platte River is a braided river spanning approximately 985km west to east across central Nebraska until it junctions with the Missouri River. It occurs primarily within the Western High Plains and Central Great Plains ecoregions, and is characterized by highly seasonal flow rates and divergent channels. Vegetation cover is primarily cultivated crops along the central and eastern Platte, and uncultivated herbaceous vegetation along the western Platte.

The Niobrara River runs approximately 740km west to east through the northern counties of Nebraska until it junctions with the Missouri River. It occurs primarily within the Northwestern Great Plains, Northwestern Glaciated Plains, and Nebraska Sandhills ecoregions, and vegetation cover along the river is primarily uncultivated herbaceous plants.

The Missouri River marks the eastern boundary of Nebraska running approximately 935km north to south where its course is primarily within the Western Corn Belt Plains ecoregion. Along the northern border of Nebraska, the Missouri River is sandy, broad, and relatively slow-moving. As the river continues south, it has been channelized and currents are much swifter. Vegetation cover along the river is primarily cultivated crops.

The Loup River system is comprised of several large branches and smaller rivers including the North Loup, Middle Loup, South Loup, Dismal, Calamus, and Cedar rivers. These rivers occur primarily within the Nebraska Sandhills ecoregion in their northern extent and the Central Great Plains ecoregion in their southern extent. The system runs north to south to its junction with the Platte River. The Loup River system comprises over 2,325km over of river within Nebraska. The Loup River system is surrounded primarily by uncultivated herbaceous vegetation, mostly grasslands in the northern reaches and woodland/grassland in the southern reaches.

The Big Blue River flows approximately 900km north to south within the Central Great Plains and Western Corn Belt Ecoregion in southeast Nebraska where it eventually flows into the Kansas River in northeastern Kansas. Cultivated crops dominate the landscapes around the Big Blue.

The Elkhorn River runs north to south approximately 855km through the Northwestern Glaciated Plains, Nebraska Sandhills, and Western Corn Belt Plains ecoregions where it joins with the Platte River. The northern reaches of the Elkhorn are surrounded primarily by uncultivated herbaceous vegetation and the southern reaches by cultivated croplands.

The Republican River flows approximately 515km west to east through the southern counties of Nebraska where it then flows south into Kansas and meets with the Kansas River. It occurs almost entirely within the Central Great Plains ecoregion and the surrounding lands are a mixture of cropped lands and uncultivated vegetation.

**Presence-only Data**

I obtained presence-only data for historical otter records from NGPC. These records cover the timespan of November 5, 1977 through April 23, 2014 (Figure 3.3). Data consisted of geographic coordinates for the record, the date the record was made, whether or not a carcass was collected in association with the record, and in the case of a visual record, how many individuals were observed. A total of 380 records were collected with the number of records per year increasing steadily from the time the reintroductions began in 1986. Of these records, 352 had the necessary geographic coordinate data associated with them (Appendix C).

The primary sources of these records were fur trappers who incidentally trapped otters while targeting other species and subsequently turned the carcasses over to NGPC. There were 218 records associated with a collected carcass that also had geographic coordinate data. Of the remaining 134 records, 90 had an estimate of the number of animals present at the time of the record. These records were reports made by biologists in the field. The origin of the final 40 records was unclear as no carcass or otter count estimates were associated with them, only a location and a date.

**Sampling Units**

In order to create discrete sampling units with which to associate NGPC historic otter records as well as covariate data, I constructed a grid of 6x6km grid cells using ESRI's ArcMap program (Esri 2011) covering the state. I extracted all grid cells that contained focal survey rivers from the grid such that each remaining grid cell constituted one sampling unit along those rivers (Figure 3.4). I chose the 6x6km resolution as this 36km$^2$ area represents a conservative estimate of home range size for river otters on the Platte River of Nebraska (Wilson 2012). By choosing a resolution that was approximately the home range size of an otter in Nebraska, I assumed that animals detected in neighboring cells were different animals, and thus the data were structured for rough abundance estimation in future analyses. The geographic extent of the combined extracted grid cells defined the "bounding box" from which background samples were taken.

**Covariates**

Covariate data were collected *post hoc* and included the distance to the nearest otter release site (km), the amount of non-river channel wetland area, the long-term median flow rate of the river ($ft^3/s$), the probability of beaver occupancy, the dominant vegetative land cover, and whether or not the river had gone dry in the last five years. Because there was such a large range of values amongst continuous variables, values for these covariates were standardized by calculating z-scores.

I included the distance to a release site covariate in order to gain some idea of how otters had dispersed outward from the reintroduction points and whether or not sufficient time had elapsed since reintroduction for the otters to disperse to all habitable areas. The distance to the nearest release site was measured from the center of a given sampling unit in a straight line to the nearest release site (Figure 2.4). This method supposes that river otters are able to travel over land in addition to along waterways, though travel by waterways is preferred (Melquist and Hornocker 1983).

I considered wetland area as a covariate as it could represent habitat outside of the main river channel that an otter would use while traveling over land (Simpson and Schneider 2007; Tranl and Chapman 2007). Wetland area data was derived from a wetland layer made available through the USDA (United States Department of Agriculture) NRCS (Natural Resources Conservation Service) Geospatial Data Gateway (Figure 2.5). Only wetlands >0.5 acres in size were selected so as to avoid including ephemeral or very small wetlands. River channels were removed from the layer in order that only wetland area beyond the river channel would be considered. In the event that a reservoir occurred along the river, the area covered by the reservoir was not included as so large a contiguous waterbody along the river did not seem to match the functionality of a wetland area, despite the water area being additional to the main river channel.

I considered the river flow rate covariate because the size of a river may have implications for how much forage is available within the river, and because otters may prefer rivers with larger and deeper pools and open water sections (Wilson 2012; Tranl and Chapman 2007).The information for long-term median flow rates was provided by the USGS (United States Geological Survey) National Water Information System (NWIS) flow meters established throughout the state of Nebraska. Due to a relatively limited number of these meters existing, it was necessary to extrapolate flow rate values in many sampling units that did not contain flow meters (Figure 2.6). This was accomplished using linear regression and contextual information provided by aerial imagery and on-the-ground knowledge of the rivers.

I considered beaver presence as a covariate due to the frequent use of beaver lodges by river otters (Swimley 1999; Melquist and Hornocker 1983; Jackson 2014).

Naïve occupancy, that is the proportion of sites found to be occupied through surveys, was used during the model selection process, but because presence/absence data for beaver would not be available for unsurveyed grid cells, it was necessary to estimate beaver occupancy (Figure 2.7; Appendix A). This was done using occupancy modeling techniques explored later in this chapter.

I derived and simplified land cover data from land cover raster sets available through USDA NRCS Geospatial Data Gateway. Data was simplified to consist of the two dominant vegetation cover types because “cultivated crops” and “herbaceous” land covers dominated the study area, and all other land covers along the focal rivers existed in only a very small number of sampling units (Figure 2.8). In the event that some other uncommon land cover was present in a grid cell, the surrounding vegetation cover was chosen. A study by Jeffress (2011) found that land cover was an important consideration in otter occupancy at the local scale but he did not find evidence that it was important at larger scales.

The final covariate was an estimate of whether or not the river in a given sampling unit was likely to have gone dry in the last five years, which in most cases would have occurred during the 2012 drought if at all (Mallya et al. 2013; Figure 2.9). It is possible that if the river had gone dry, resident otters may have left the area and not yet returned. The information for this covariate was also derived from the USGS NWIS flow meters, and areas were considered to have gone dry if their flow rate during the previous five years dropped as low as 20ft$^3$/s of water for a period of one month. This flow rate is a high estimate for long-term median flow rates in the headwaters of smaller Nebraska rivers that typically are dry in the summer and fall.

**Statistical Analysis**

In program Maxent, I incorporated the five environmental variables and the distance to release site variable in a model of otter distribution, and the 5 habitat-related variables excluding the distance to release site in a model of habitat suitability (Phillips 2004). Presence-only data were formatted as CSV (comma delimited) files for import into the program. In order to avoid over-sampling bias, one record per sampling unit was retained in the analysis data set (Fourcade et al 2014). This removal left 170 records in the data set. I converted the environmental variable polygon-shapefiles to raster files in ArcGIS and then from raster to ASCII files for import into Maxent (ESRI 2011).

The data were run with 10,000 background samples, a regularization multiplier of 1, a random test percentage of 10, and a random seed for each replicate run. The replicate run type was cross-validation, and 10 replicates were run (Merow 2013). I set the default prevalence to 0.16, which is an estimate of occurrence probability obtained through occupancy modeling efforts detailed in chapter 2. The output format was 'cumulative' for the habitat suitability model, which is recommended when approaching problems of delineating species distribution and habitat suitability (Merow 2013). The output format was 'logistic' for the species distribution model, which is the format recommended for estimating relative occupancy (Merow 2013). I ran a jackknife test of variable importance to examine the relative impact of each environmental variable.

I used correlation analyses to assess the independence of all covariates (Table 3.1). Covariates were considered to be strongly correlated at r or phi=0.50. If two covariates were strongly correlated, the covariate most relevant to the model in question would be retained.

The fit of the maxent models was evaluated by the average test area under the curve (AUC) in the receiver operating characteristic (ROC) plot. An analysis of variable contribution was run with the model, which provided an estimate of the percentage contribution of each variable to the final maxent models. The jackknife analysis provided similar information on variable importance but provided additional information about the strength of a model where each variable was the sole variable in the model as well as a model where each variable was left out.

Habitat suitability, based on outputs from the final habitat suitability model, was ranked on a scale of 0 to 1 where the threshold at which a site is considered to be habitable to otters occurs somewhere between 0.01 to 0.2 depending on the level of predictions omitted by the user (Phillips 2005). Relative occupancy, based on outputs from the final species distribution model, was ranked on a scale of 0 to 1. These data were imported into ArcGIS software for display.

Occupancy estimates produced by the maxent species distribution model were compared to occupancy estimates produced using presence-absence occupancy modeling techniques in program PRESENCE described in chapter 2. Estimates of spatial correspondence were made by subtracting the presence-absence occupancy modeling estimates from the presence-only maxent occupancy estimates. A composite distribution estimate was produced by averaging the occupancy estimates derived from presence-absence occupancy and presence-only maxent analyses for each sampling unit.

## RESULTS

### Species Distribution Model

The maxent otter distribution model had an AUC value of 0.69 (SD= 0.062; Figure 3.11). Variable contributions were highest for the distance to release site and river flow rate variables (permutation importance= 41.8, 31.4). The amount of wetland area and beaver presence had permutation importance levels of 10.1% and 10.4% respectively, and the five year dry history of the river and the dominant vegetative land cover had permutation importance levels of 0.2% and 6.2%.

None of the models with single environmental variables omitted produced any gain over the model with all six variables, suggesting each variable provides at least some measure of non-redundant information. The variable that provided the greatest gain when used in isolation was the river flow rate, which suggests that this variable is the most informative on its own. This distance to a release site variable decreases the model gain the most when omitted, so I conclude that this variable provides the most information that is not accounted for by other variables (Figure 3.12).

This model identified as the areas with occupancy estimates between 0.1 and 0.5 the majority of the Platte River from Ogallala, NE east to the convergence with the Missouri River, the northern half of the Elkhorn River, the southern Loup River system, and sections in both the western and eastern Niobrara River (Figure 3.13). The greatest concentration of sampling units with occupancy estimates >0.25 occurred on the central Platte River around Kearney

**Habitat Suitability Model**

The maxent habitat suitability model had an AUC value of 0.65 (SD= 0.072; Figure 3.13). Variable contribution was highest for the river flow rate variable (permutation importance= 75.3). The amount of wetland area, beaver occupancy, river dry history, and dominant vegetative land cover had permutation importance levels of 4.5%, 14.8%, 2.9%, and 2.7% respectively.

None of the models with single environmental variables omitted produced any gain over the model with all five variables, suggesting each variable provides at least some measure of non-redundant information. The variable that provided the greatest gain when used in isolation was the river flow rate variable, which suggests that this variable is the most informative on its own. This variable also decrease the model gain the most when it is omitted, so I conclude that this variable provides the most information that is not accounted for by other variables (Figure 3.14).

This model identified the Platte River between North Platte and Columbus, NE as the area with the highest habitat suitability values, which were between 0.8 and 1.0.

The central and western Niobrara, southern Elkhorn, and southern Loup River system had habitat suitability values between 0.6 and 0.8. Lower values were found in the eastern Niobrara River, northern Elkhorn River, northern Loup River system, Republican River, and sections of smaller rivers in southeastern Nebraska (Figure 3.16).

**Comparisons with Presence-Only Occupancy Estimates**

Of the 1192 sampling units, 718 had less than a 0.1 difference in occupancy estimates between methods (Figure 3.17). The maxent method of occupancy estimation tended to produce more liberal estimates. There were 421 sampling units with positive spatial correspondence values >0.1. Only 54 sampling units had negative spatial correspondence values, and in only one of these was the higher presence-absence occupancy estimate not influenced by a “1” value, which reflects a known occurrence using that method.

The composite distribution estimate produced by averaging the outputs produced by the two occupancy estimation methods identified as the areas with occupancy estimates consistently between 0.1 and 0.5 the central Platte River, northern Elkhorn River, southern Loup River system, and the North and South Platte rivers near Ogallala, NE. Occupancy estimate between 0.1 and 0.5 occurred intermittently along the Niobrara River and in small localized areas of the eastern Platte River and the Republican River near the Harlan County Lake (Figure 3.18)

## DISCUSSION

### Variable Contributions

The variable that contributed most to the model fit in the species distribution maxent model was the distance to a release site. It may be that otters have not yet fully dispersed around the state so that they tend to be closely linked to release areas or it may be that the original release sites were ideally located to begin with such that a fully dispersed population would have localized around those sites regardless. River flow rate also contributed a large proportion of the information in each model with this variable accounting for 75.3% of the habitat suitability model fit and 31.4% of the species distribution model fit. This is in agreeance with the assertion that river otters tend towards larger open water areas (Wilson 2012; Tranl and Chapman 2007).

The amount of wetland area available, the river dry history, and the presence of beaver were of lesser importance in both models. The importance of beaver presence is suggested elsewhere as otters often use old or take over new beaver dens for pup rearing (Swimley 1999; Melquist and Hornocker 1983; Jackson 2014). The amount of wetland area is a difficult variable to consider in Nebraska, because the majority of sampling units had relatively low amounts of wetland area available when compared to the amounts seen along the Platte River. The dominant vegetative land cover had little influence on model fit. This was a categorical variable with only two levels, so it may be that on a statewide scale, there was simply not enough variability in the data to provide inference. At a smaller scale and with more detailed data, this variable may prove more impactful. Whether or not the river had gone dry in the past five years was of limited importance to model fits.Future efforts with this method of modeling might provide stronger results with more environmental variables included, a higher resolution than the 6x6km resolution used with these data, and with greater precision within the categorical variables.

**Species Distribution and Habitat Suitability**

The output of the maxent otter distribution model is very similar to the distribution estimate produced by NGPC (Simpson and Schneider 2014), however estimates using this method will vary greatly depending on what occupancy threshold is considered within the species' distribution. Areas such as the central Niobrara River, southern Elkhorn River, the Republican River near Harlan County Lake, the Missouri River, the southern Big Blue, Little Blue, or Little Nemaha rivers may not be supported if areas with occupancy estimates <0.1 are not considered.

When comparing distribution estimates produced using different data, such as those created by Simpson and Schneider 2014 as well as historic descriptions of river otter distribution in the state (Swenk 1908; Jones 1964), with the habitat suitability estimate produced by the cumulative habitat suitability model produced with maxent, there is a great deal of overlap (Figure 3.7; Figure 3.8). This could mean that the river otters in the state have nearly reached the bounds of their historic distribution in the state and that areas of suitable habitat that are currently not included in estimates may be areas that will be colonized in the near future.

**Management Implications**

The Platte River is to be considered critical habitat for river otters in the state and ought to be managed as such if extra efforts to maintain or increase populations are ever deemed necessary. The habitat suitability model identifies the Platte River as the most suitable habitat for otters in the state, and it is well-established the importance of the Platte River to river otters. Amy Williams in her graduate work at the University of Nebraska- Lincoln found the highest recorded otter density in North America on the Big Bend of the Platte River (Williams 2011) and the Platte has also been cited as a key area for otters authors describing their historic distribution in the state (Swenk 1908; Jones 1964).

The eastern Niobrara and main body of the Loup River were other areas identified as having ideally suited habitat for otters, but these areas were less strongly supported in the occupancy analysis. Furthermore, these areas are lacking historical records. Given the proximity of these areas to more established areas and the ability of otters to disperse long distances (Wilson 2012), I do not believe any action needs to be taken to facilitate the spread of otters to these areas.

The Republican River near the Swanson County Lake and the Middle and North Loup rivers were identified as areas with high habitat suitability that lack historical records and are more removed from established areas. I suggest that these are areas worth considering in future reintroduction or translocation efforts.

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Figure 3.1

Otters were released at seven sites throughout the state. These sites were centrally located in the Loup River system, the central and western Platte River, the western Niobrara River, and the northern Elkhorn River.

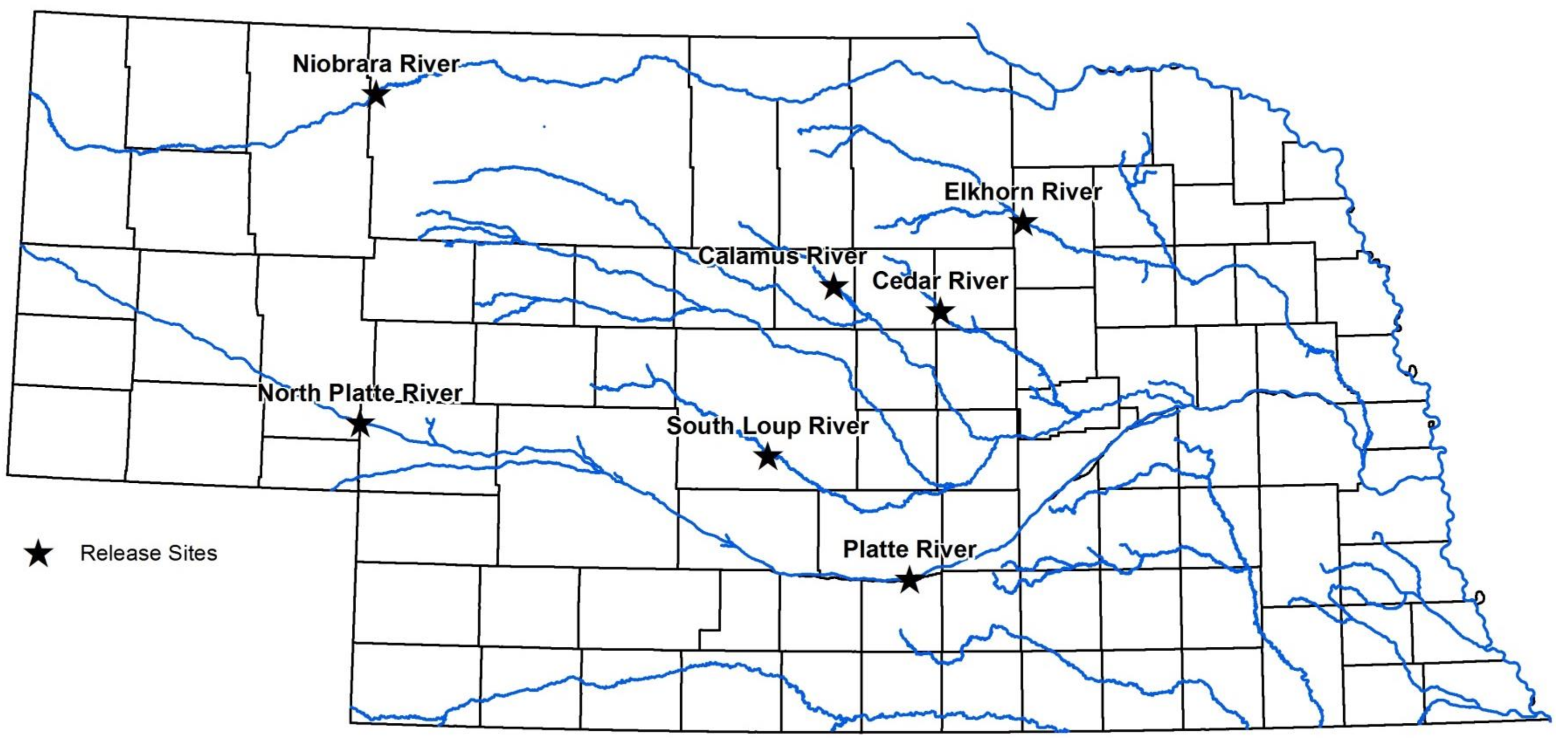

Figure 3.2

Nebraska is home to over 8,500km of river. Most of these are sandy rivers with meandering channels flowing west to east and draining into the Missouri River.

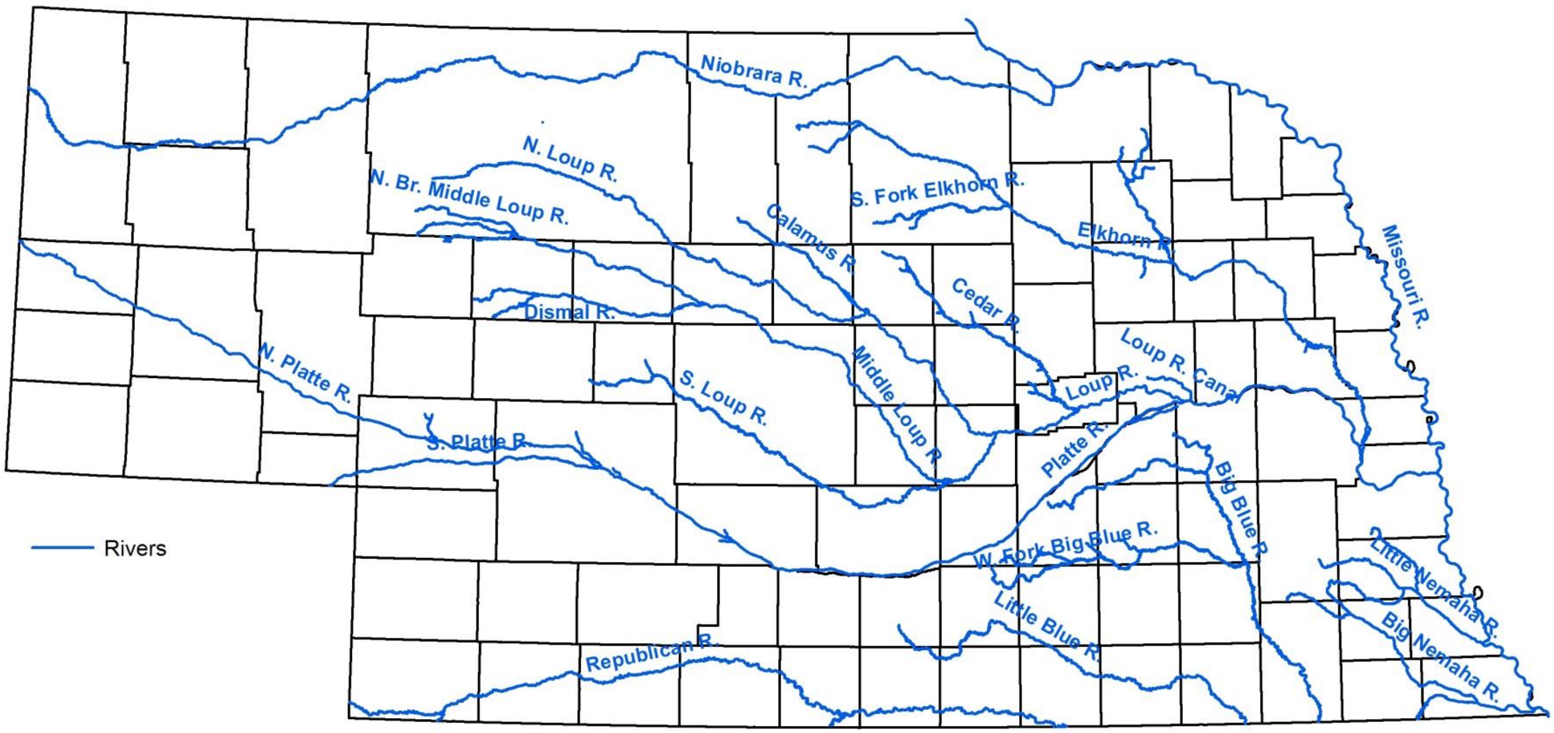

Figure 3.3

Nebraska Game and Parks collected records of otter occurrence from fur trappers and biologist sitings between 1977 and 2014.

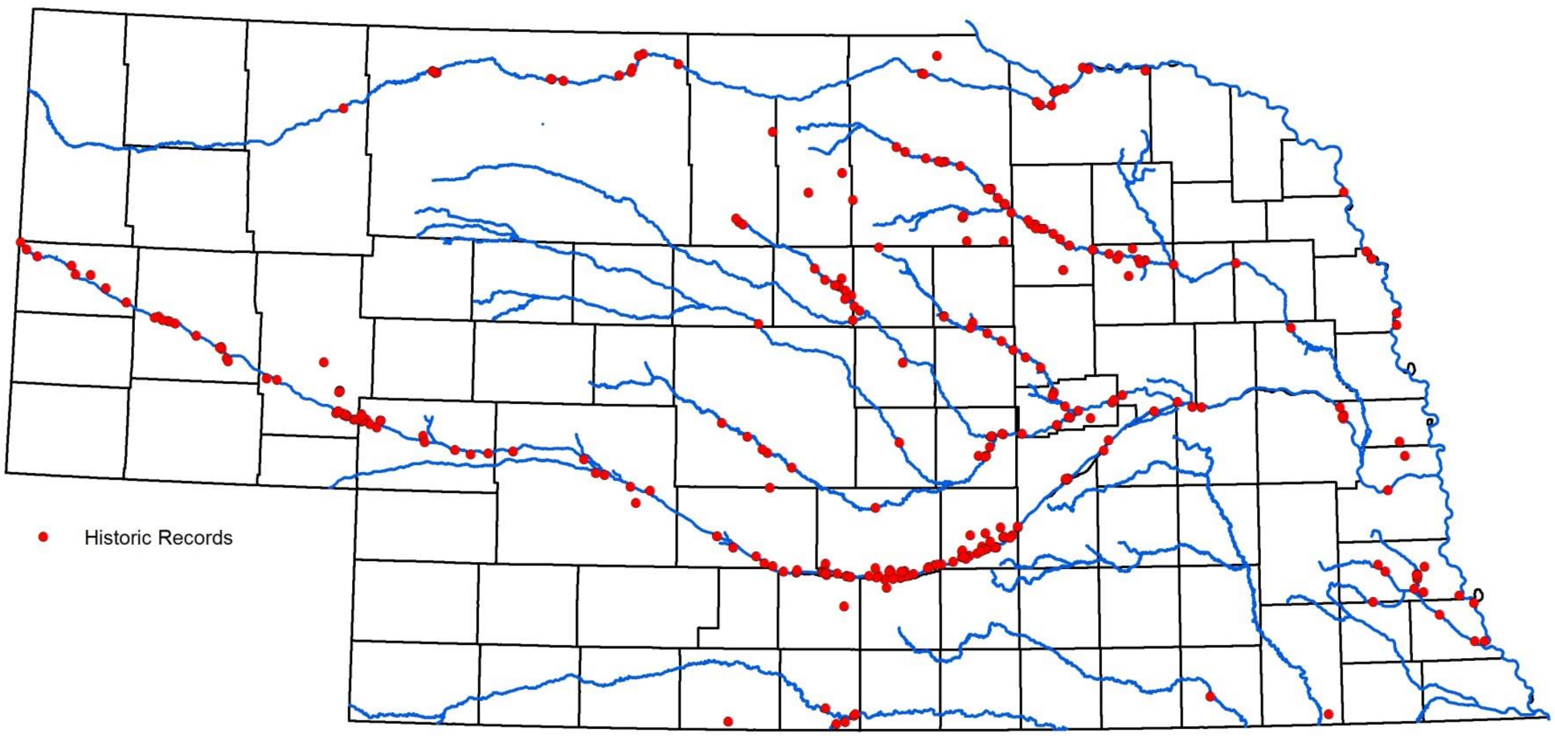

Figure 3.4

A grid of 6km x 6km grid cells was established overlaying the major rivers of Nebraska. Grid cells with focal river within them were extracted to serve as sampling units.

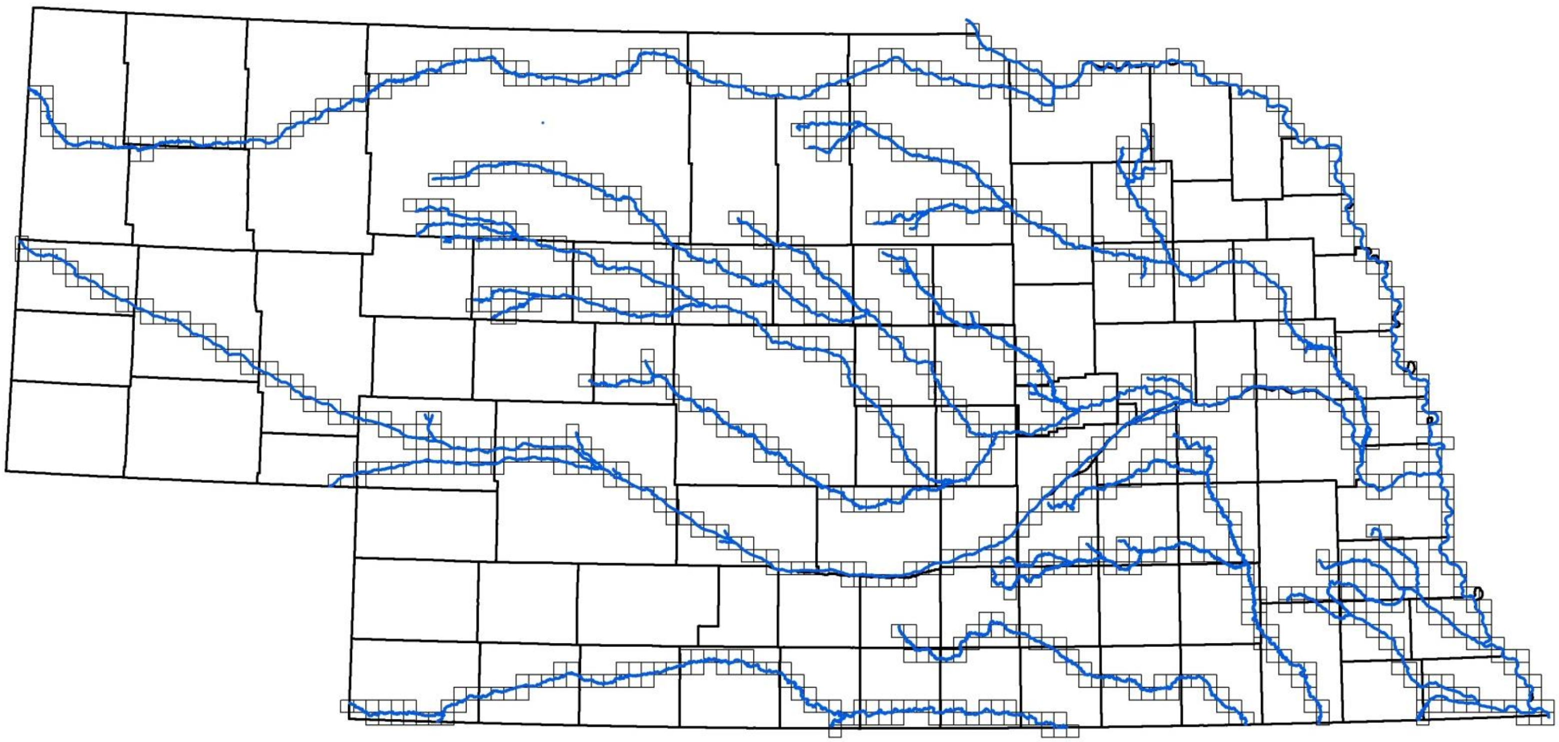

Figure 3.5

The distance to the nearest release site was measured from the center of a given sampling unit in a straight line to the nearest release site. This method supposes that river otters are able to travel over land in addition to along waterways.

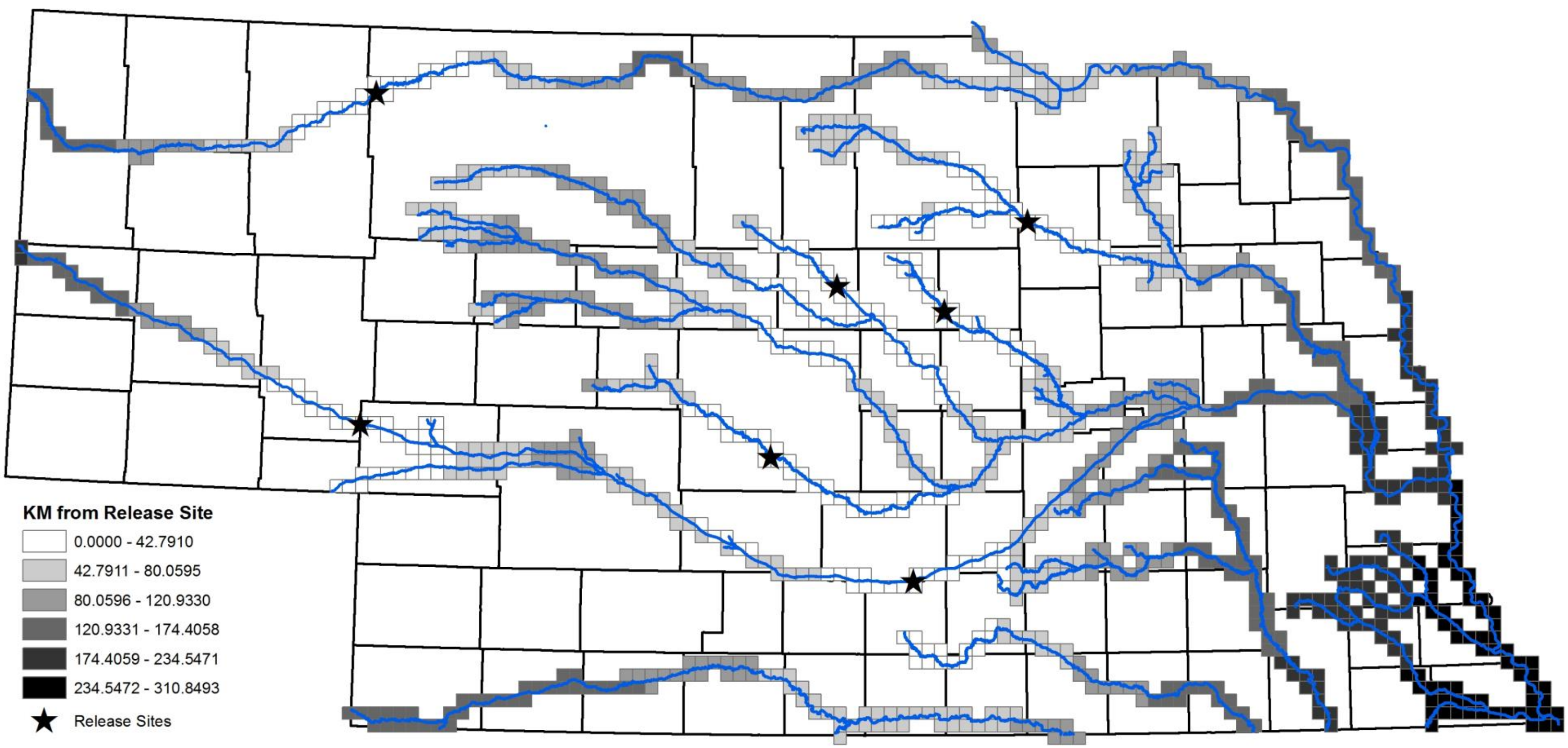

Figure 3.6

The amount of wetland area available in a sampling unit was highly variable across the state with the greatest total areas being found along the Platte River. Very little wetland area outside of the river channel was available along the Niobrara River as well as much of the Elkhorn and Missouri Rivers.

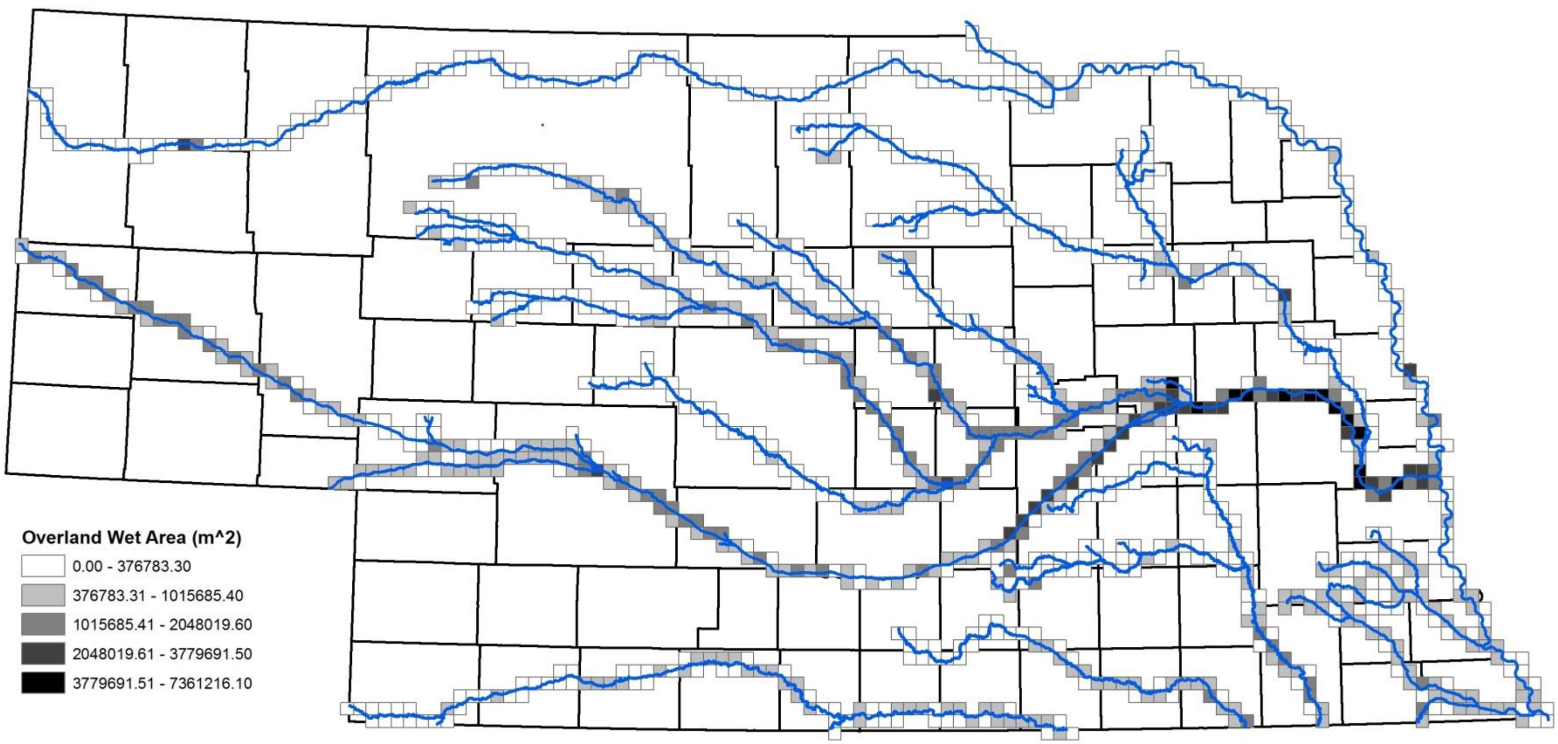

Figure 3.7

Flow rate was estimated using data from 49 flow meters scattered around the state's waterways. Because these meters were widely spread, linear regression was used to estimate flow rates between meters. Aerial imagery and on-the-ground knowledge of river channels and water control structures were also used to inform flow estimates.

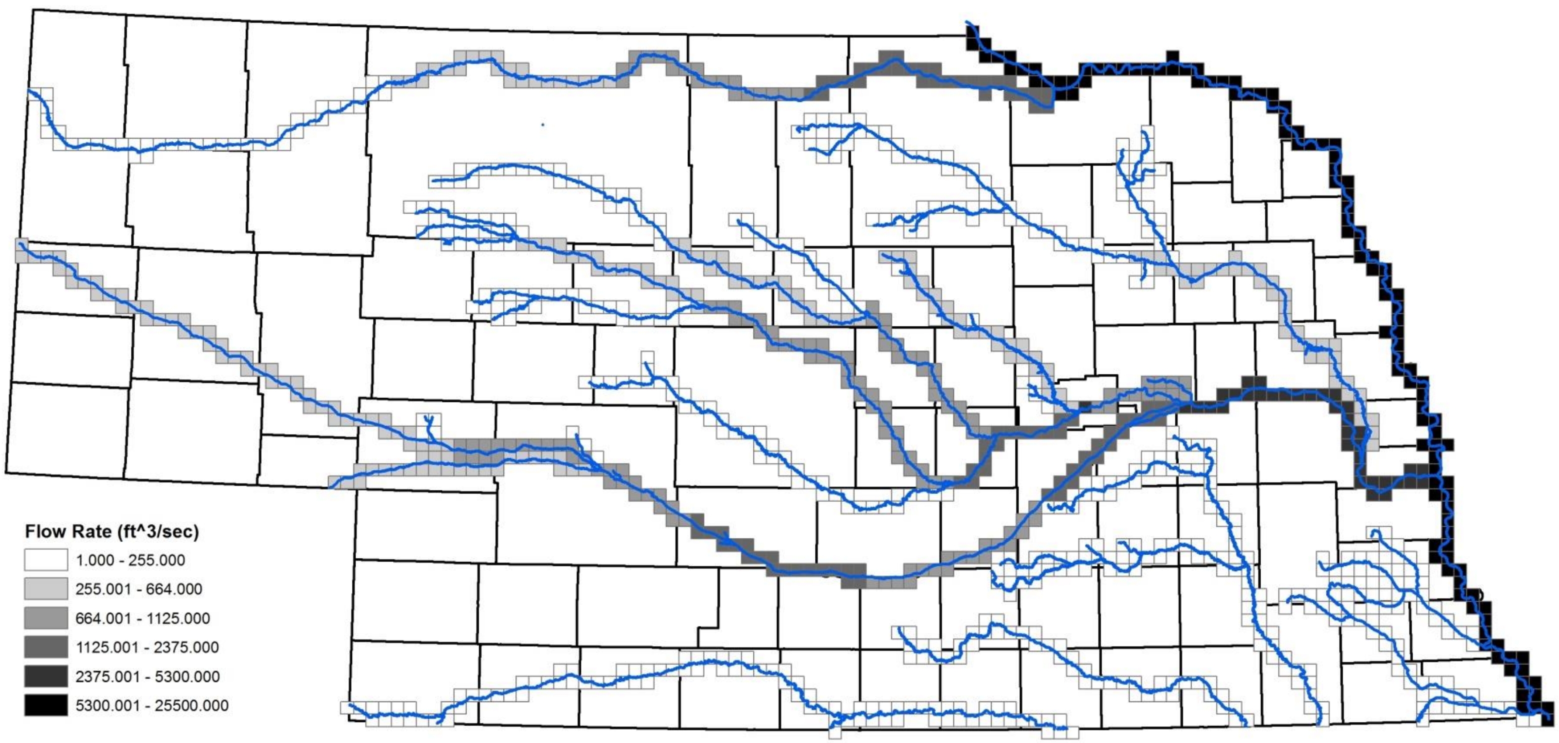

Figure 3.8

Beaver occupancy was very high across the state. There were few areas where occupancy <0.50, and these occurred primarily on the western Niobrara River, in the northern parts of the Loup River system, and on the southern Missouri River.

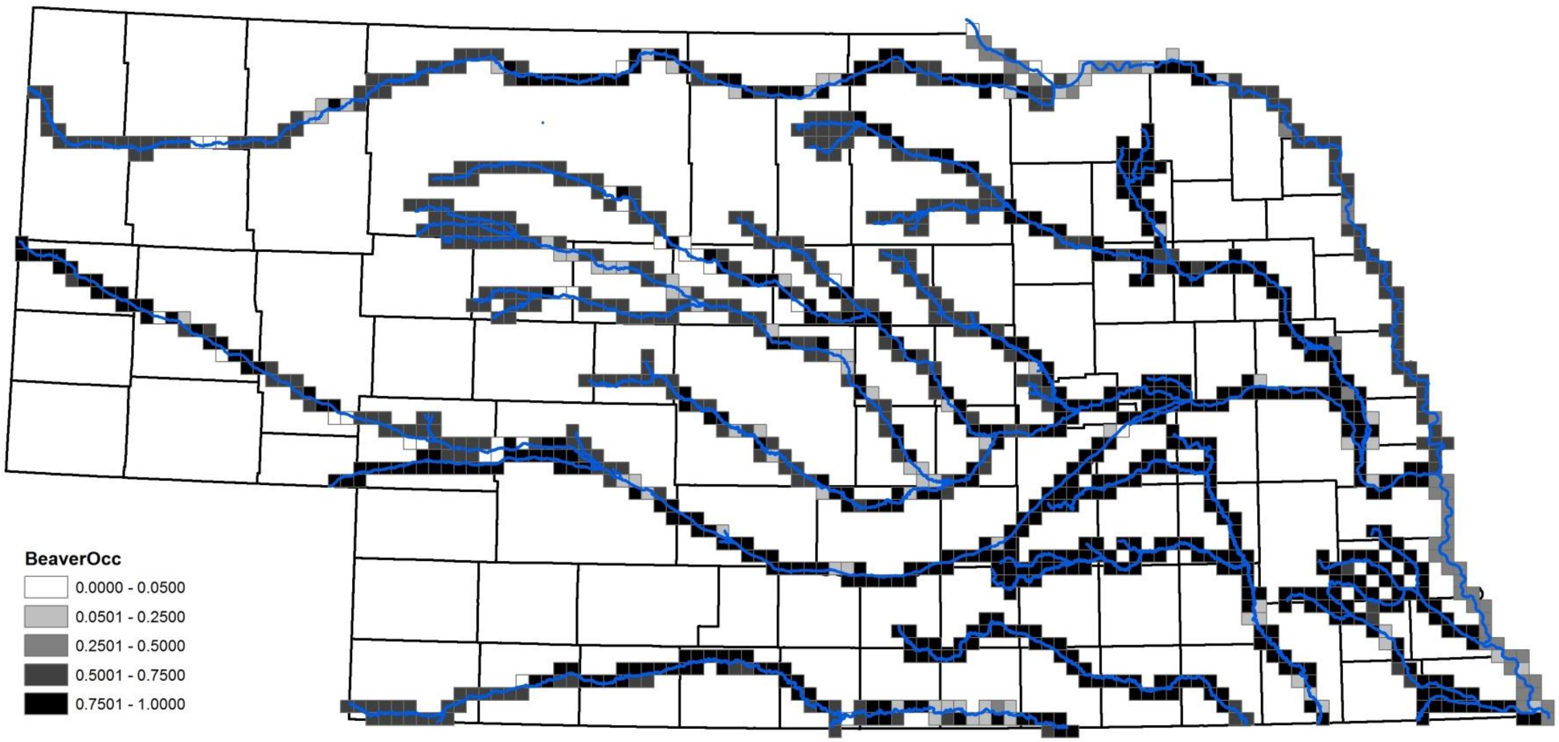

Figure 3.9

Dominant vegetation cover was considered as a possible covariate in estimating otter occupancy. Because there were very few sampling units containing land cover types besides cultivated crops and herbaceous vegetation, the vegetation cover surrounding these outliers was considered.

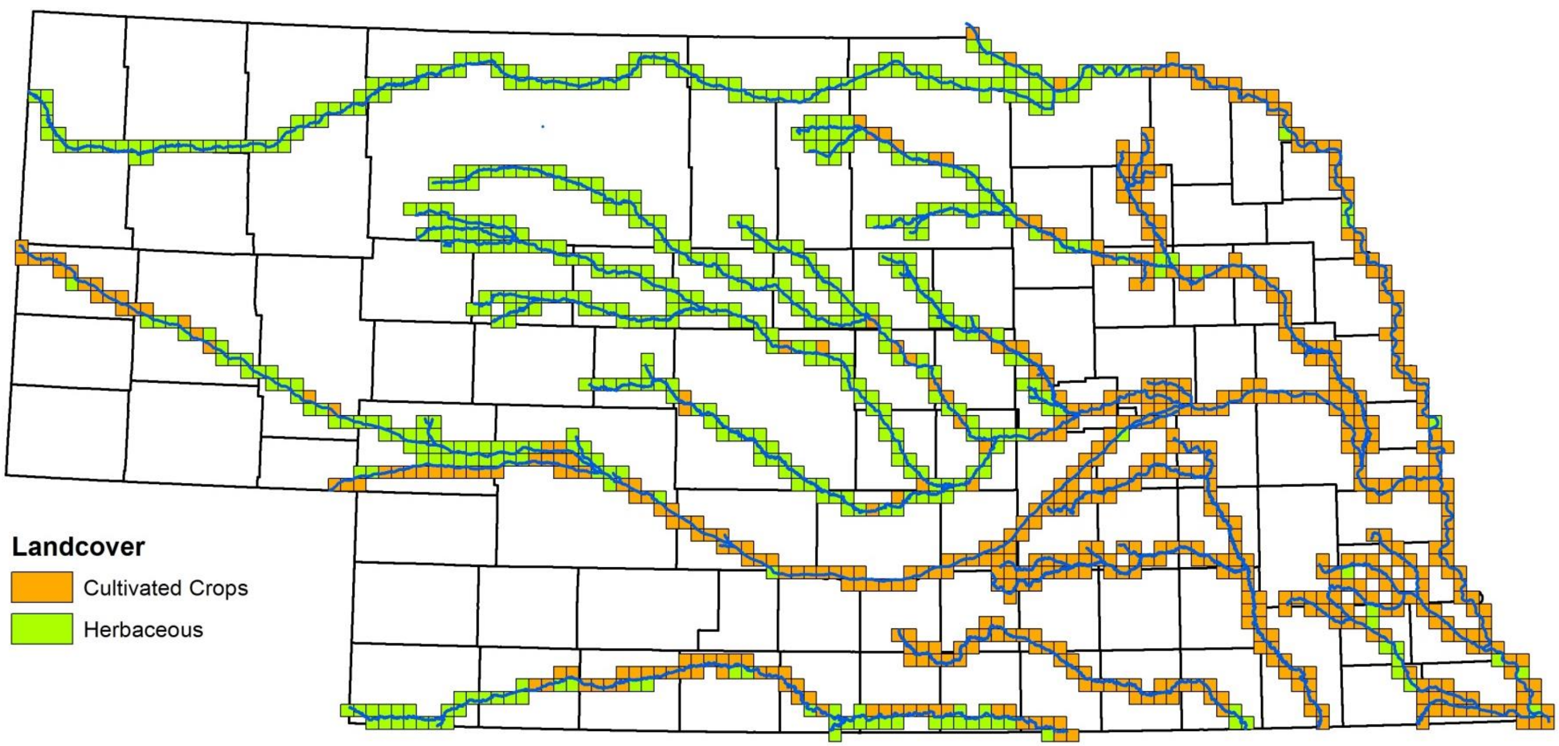

Figure 3.10

Whether or not a river was likely to have gone dry during the last five years, most likely during the 2012 drought, was determined using the five-year low reading on flow meters throughout the state. Because flow meters were widely spread, many sampling units contain estimates informed by the nearest meter and upstream or downstream orientation.

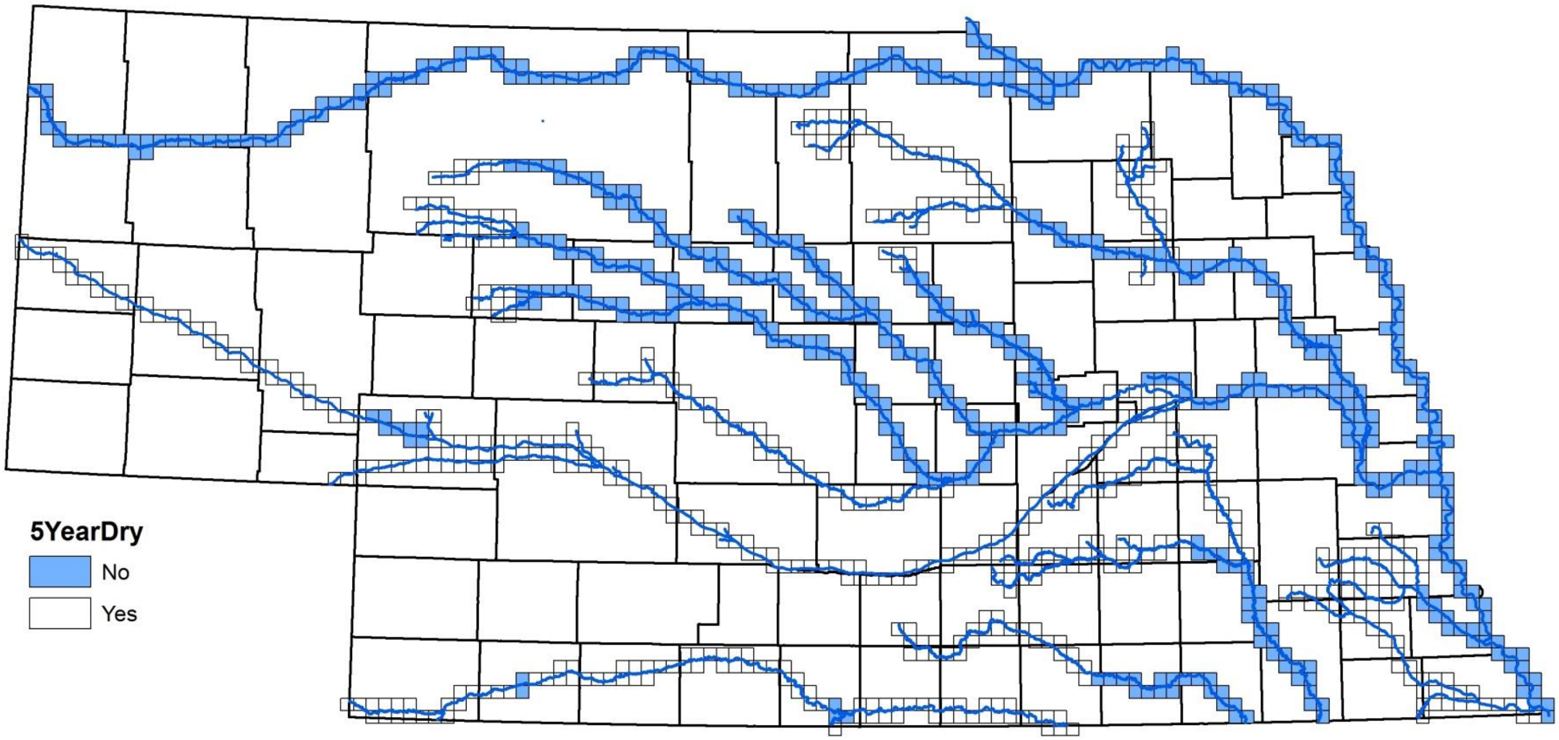

Figure 3.11

The fit of the maxent models were evaluated by the average test area under the curve (AUC) in the receiver operating characteristic (ROC) plot. The AUC for the species distribution maxent model indicated a fair fit to the data.

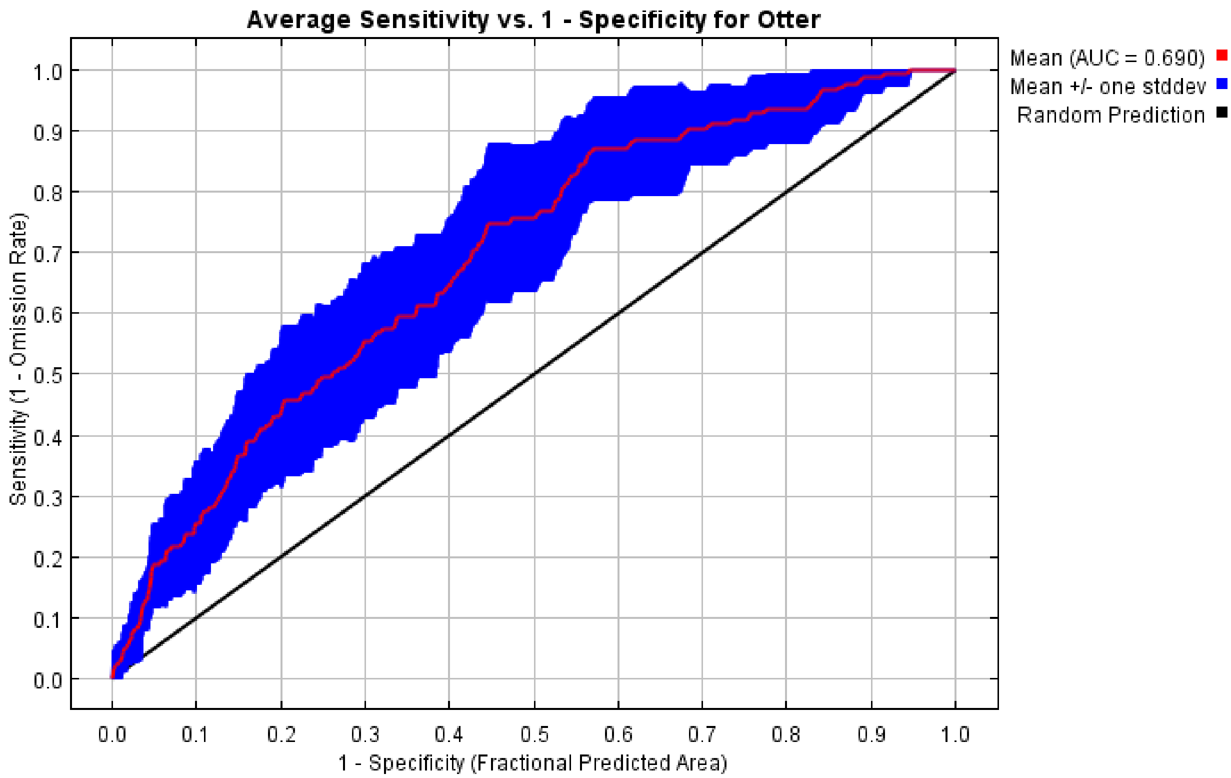

Figure 3.12

The variable that provided the greatest gain when used in isolation was the river flow rate, which suggests that this variable is the most informative on its own. This distance to a release site variable decreased the model gain the most when omitted, so I concluded that this variable provided the most information that is not accounted for by other variables

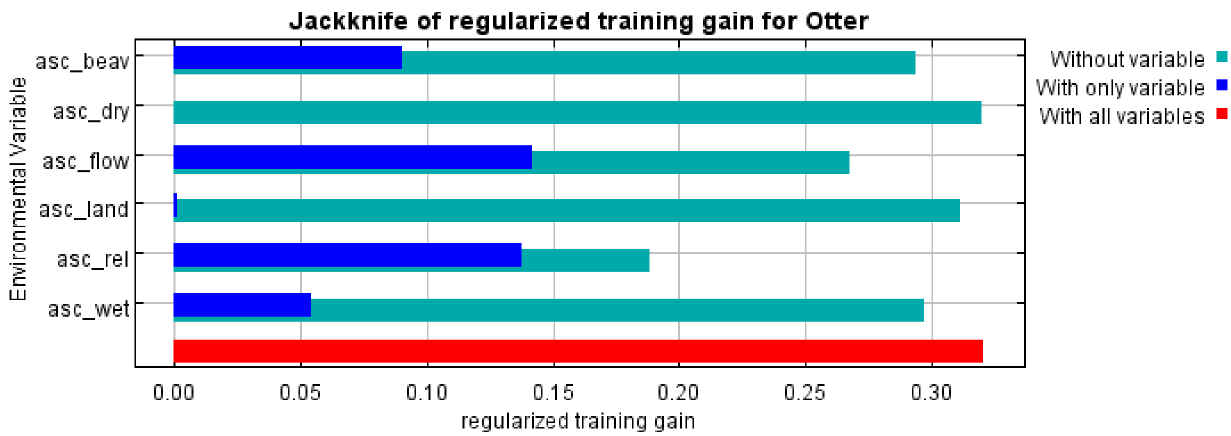

Figure 3.13

Maxent's logistic output suggests the areas most likely occupied by otters are along the Platte, northern Elkhorn, southern Loup system, and sections of the western and eastern Niobrara.

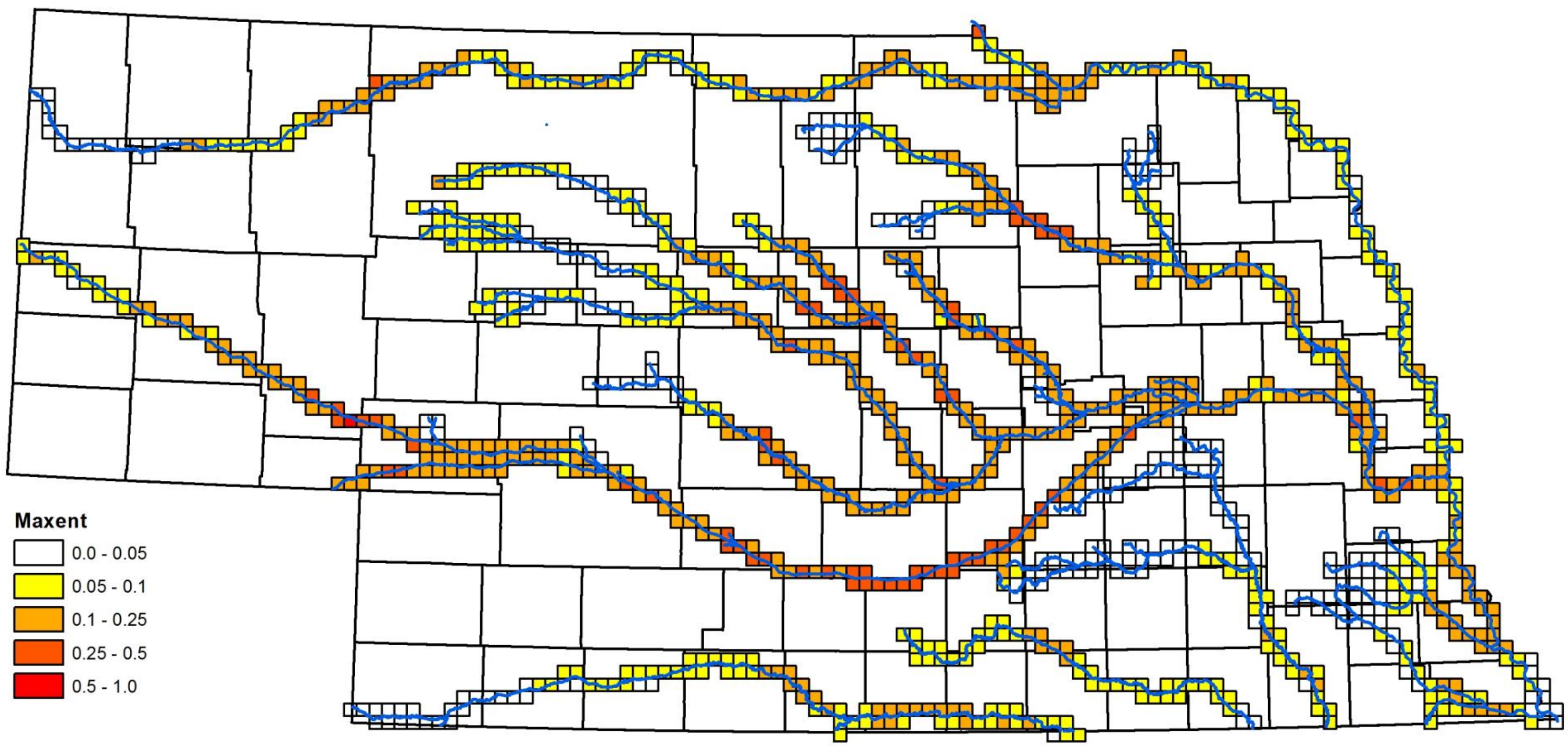

Figure 3.14

The fit of the maxent models were evaluated by the average test area under the curve (AUC) in the receiver operating characteristic (ROC) plot. The AUC for the maxent habitat suitability model indicated a fair fit to the data.

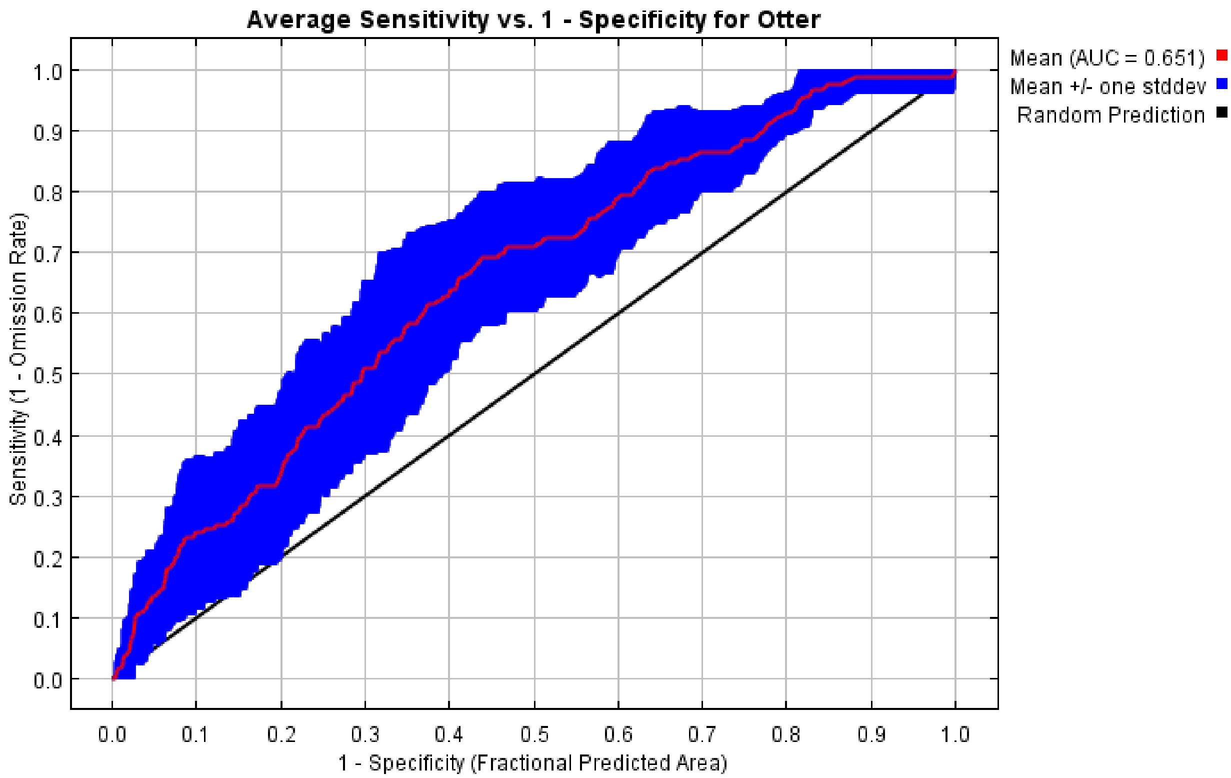

Figure 3.15

The river flow rate variable contributed the most to the maxent habitat suitability model fit and also provided the most non-redundant information.

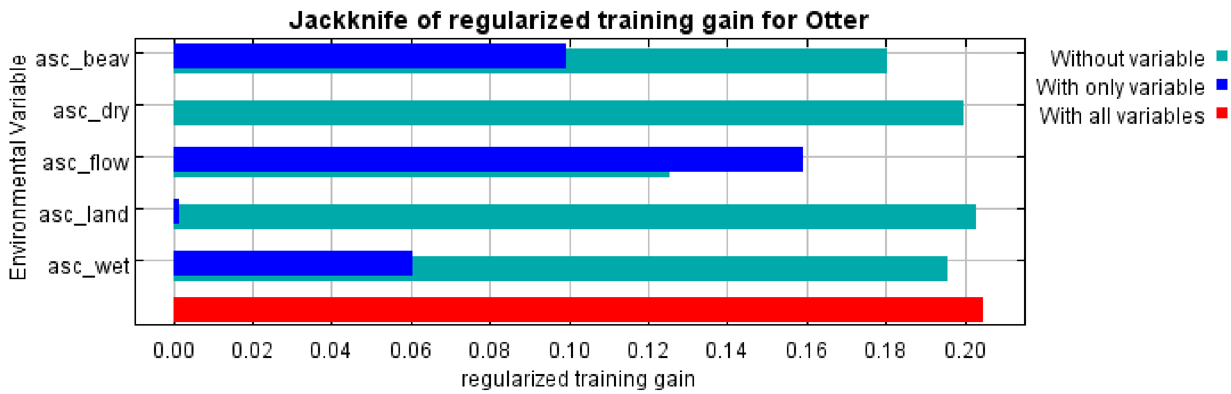

Figure 3.16

Habitat suitability estimation using Maxent's cumulative output suggests that the areas most suitable for otters in Nebraska are along the length of the Platte, the eastern Niobrara, and the main body of the Loup River.

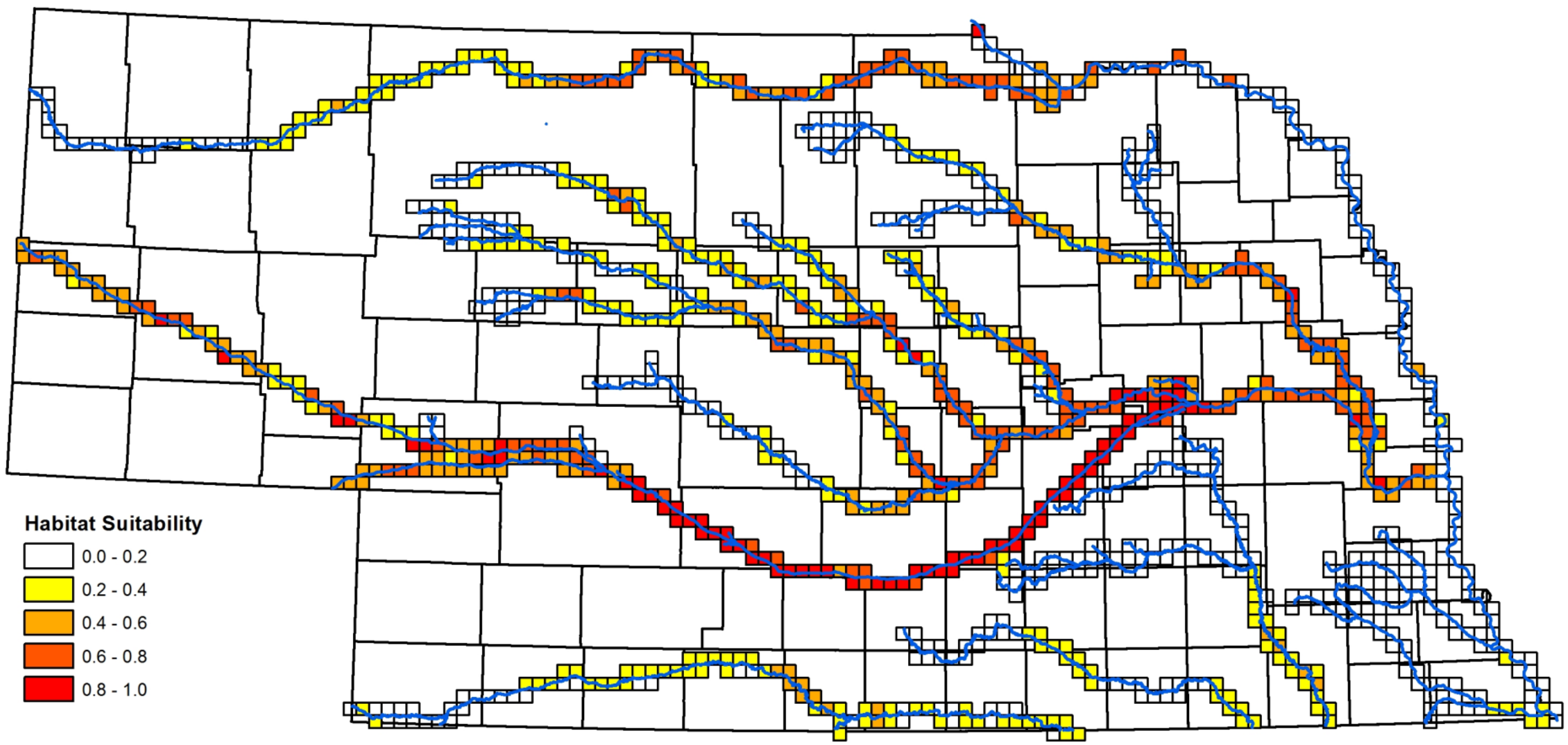

Figure 3.17

Though the areas identified as areas with elevated occupancy estimates were largely consistent between methods, occupancy modeling in PRESENCE produced much more conservative estimates than did maxent modeling. This may be due to the relatively large number of samples in the Nebraska Game and Parks dataset, which informed the maxent models. This resulted in much greater coverage and far fewer occupancy estimates of zero.

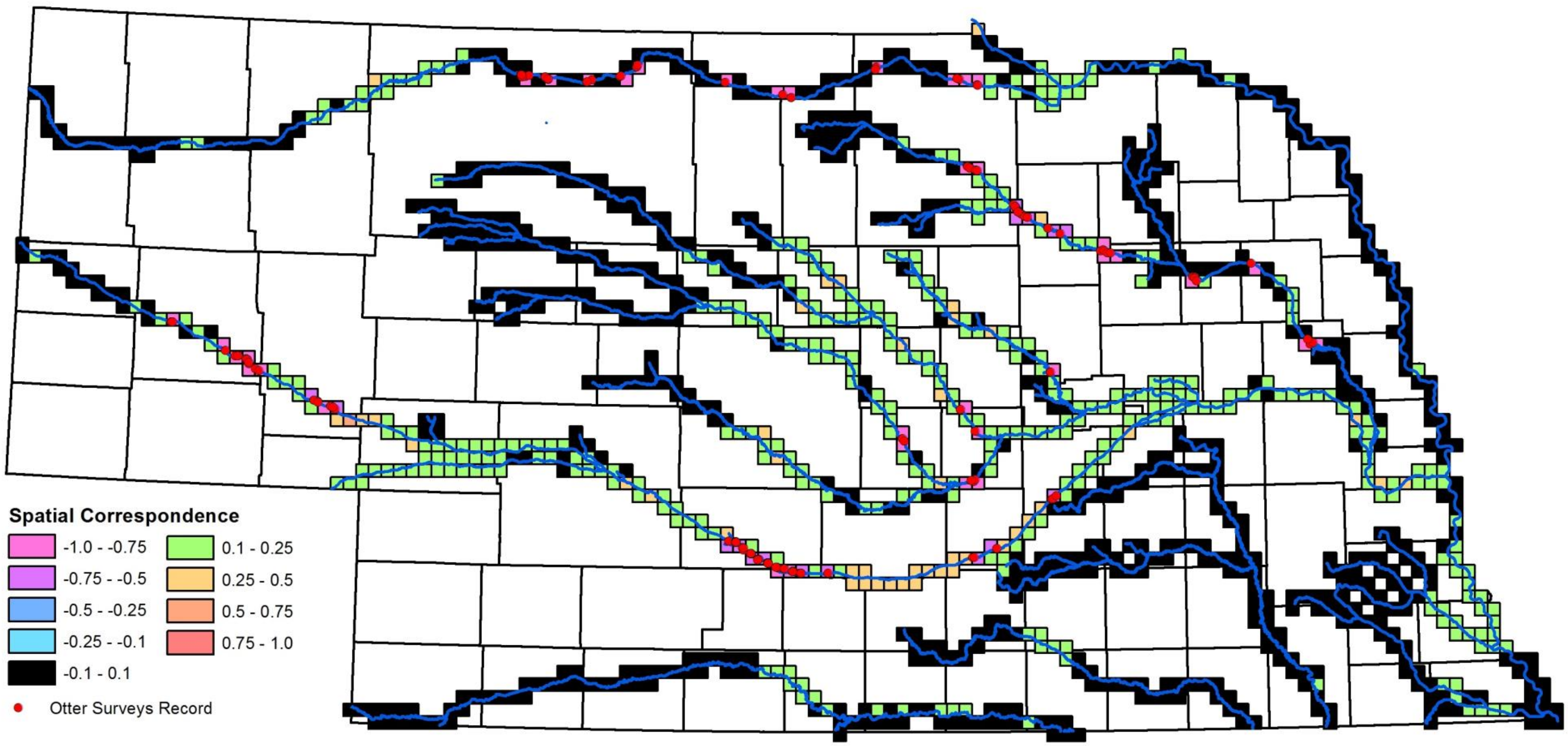

Figure 3.18

A composite distribution estimate was produced by averaging the occupancy estimates produced by presence-absence occupancy modeling and presence-only maxent modeling.

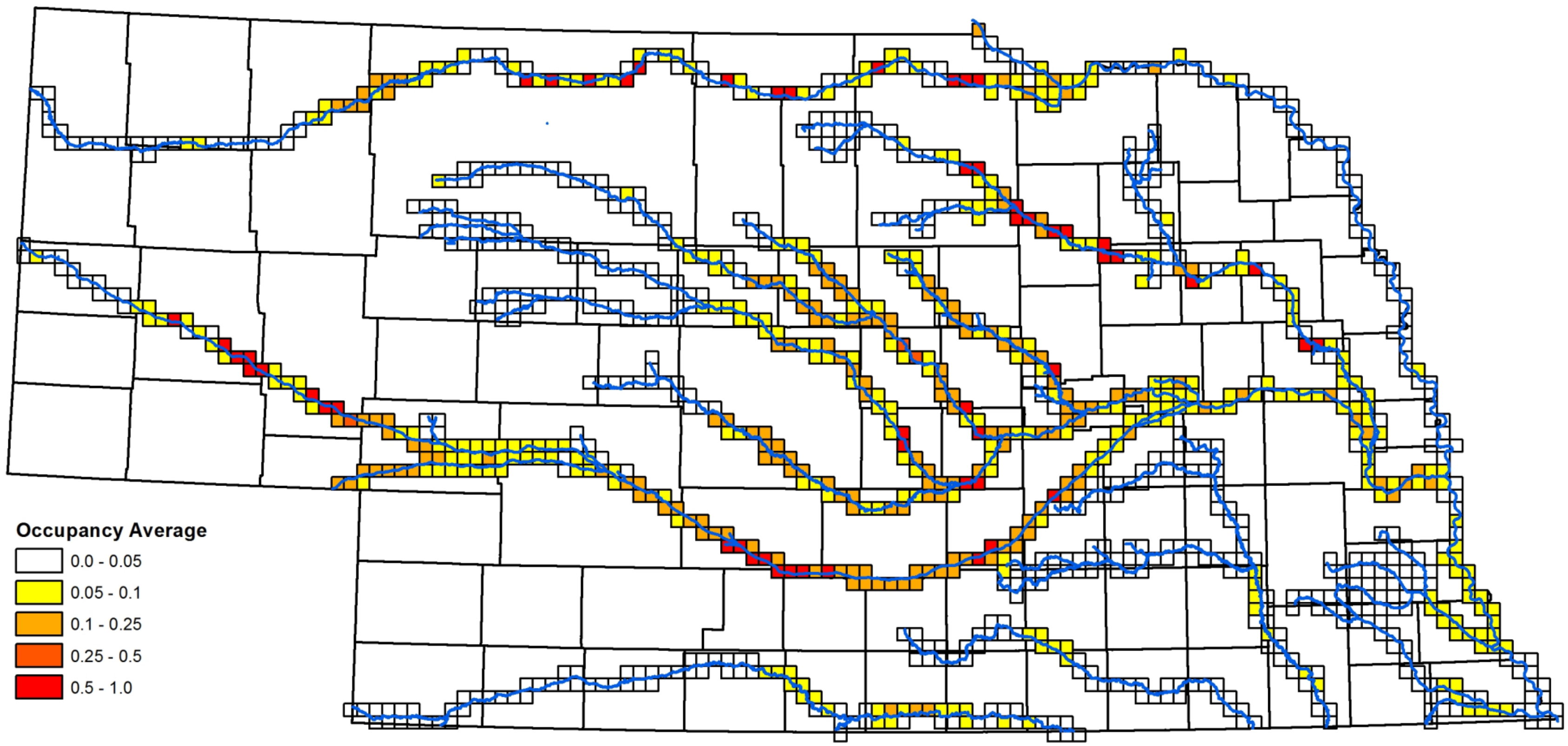

Figure 3.19

NGPC estimated otter distribution in the state considering reports of otters as well as suitable habitat nearby. Suitable habitat consisted of lake and sandpit lakes nearby to the river channel.

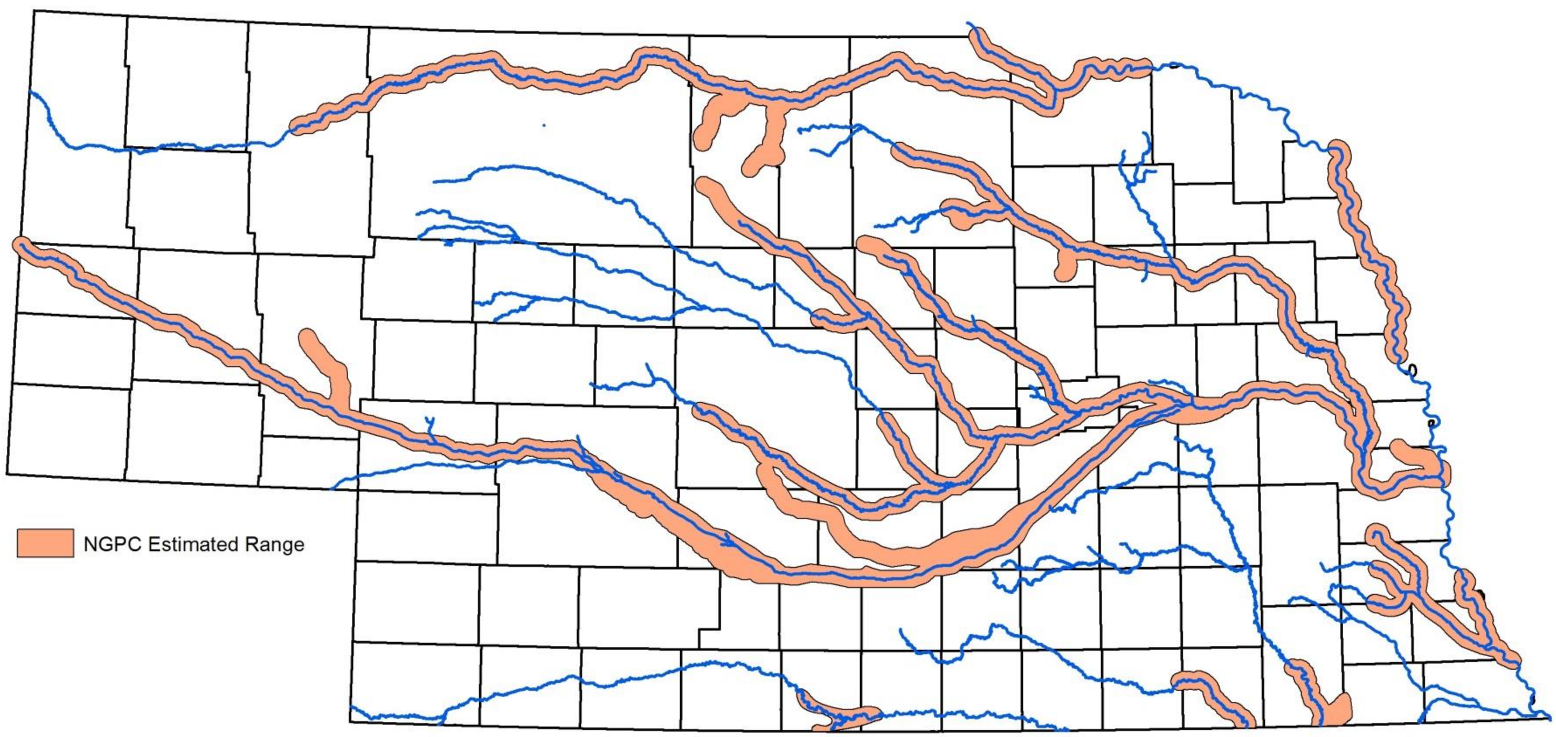

Table 3.1

Correlation analyses determined that none of the covariates used in the analyses were offering the same information. A correlation coefficient of >0.50 was considered to indicate a strong correlation.

| Covariates | Release Distance | River Size | River Dry | Wetland Area | Beaver |
|---|---|---|---|---|---|
| River Size | 0.032 | - | - | - | - |
| River Dry | 0.142 | 0.272 | - | - | - |
| Wetland Area | 0.124 | 0.176 | 0.025 | - | - |
| Beaver | 0.017 | 0.141 | 0.039 | 0.108 | - |
| Land Cover | 0.426 | 0.08 | 0.038 | 0.283 | 0.138 |

**CHAPTER 4: CONCLUSIONS**

In order to make sound and informed management decisions, particularly when working with rare species, it is critical to consider all aspects of a species' ecology and life history. After their reintroduction to Nebraska began in 1986, efforts to monitor the spread of river otters (*Lontra canadensis)* in Nebraska were limited to incidental take reports from trappers, winter bridge surveys, and graduate work on the Big Bend of the Platte River. Throughout the previous two chapters, I have described my efforts to broaden our knowledge of otter ecology in the state by providing a clearer picture of otter distribution and by identifying critical habitat areas. This information will aid the Nebraska Game and Parks Commission (NGPC) in their efforts to manage this recovering species.

In the first chapter, I documented the history of river otters in the state of Nebraska from their extirpation and reintroduction to our present knowledge of their recolonization of the state. I highlighted the importance of having as much information as possible when making decisions about species conservation listing and management, and I cited the current lack of information regarding otter distribution in the state and critical habitats for those otters.

In the second chapter, I described efforts to survey over 1,600km of Nebraska's rivers for otter sign. I made 190 records of otter presence during these surveys with sign occurring in 52 of our 324 sampling units (naïve occupancy=0.16). The bulk of detections occurred on the Niobrara River between Cody, NE and Lynch, NE, on the North Platte River, on the Big Bend area of the Platte River, and between O'Neill, NE and Meadow

Grove, NE on the Elkhorn River. More sporadic records were made throughout the southern Loup River system.

Using these data, I examined otter occupancy patterns throughout Nebraska and identified some of the variables that likely have strong influences on whether or not otters are present in a given area. I examined the impacts of several covariates: beaver presence, the distance to a release site, river flow rate, whether or not the river had run dry in the previous five years, the amount of wetland area in the sampling unit discounting the river channel, and the dominant vegetative land cover. The model that best described the patterns of otter detections was one that incorporated the distance to a release site, beaver presence, and the river flow rate. Beta estimates indicated a strong positive effect of beaver occupancy on otter occupancy, a strong negative effect of the distance to release site on otter occupancy, and a weak negative effect of the river flow rate on otter occupancy. This would suggest that our detections were associated with areas that had beaver present, were closer to release sites, and had lower river flow rates.

Applying this model to unsurveyed areas, I identified which parts of the state were most likely to be occupied by otters. I found that the central and eastern Niobrara River, central and northern Elkhorn River, southern Loup River system, central Platte River, and North Platte River were areas identified as most likely to be occupied. The Platte River, which prior work, anecdotal evidence, and our survey experiences suggest is well-populated was not well-represented by this model, perhaps due to the difficulty in accurately modeling a river with so many divergent channels.

In the third chapter, I detailed my use of maximum entropy modeling (maxent) and my efforts to use data consisting of historical otter locations collected NGPC with the Maxent software program to estimate relative occupancy for otters across the state's major rivers and to identify critical habitat areas. I also compared distribution estimate produced by presence-absence occupancy modeling and presence-only maxent modeling and created a composite distribution estimate using averages from the two methods. My efforts to examine site occupancy with maxent suggest that the Platte River, southern Loup River system, Elkhorn RIver, eastern Republican River, and small sections of the Big Nemaha River, Little Nemaha River, and western and eastern Niobrara River are the areas most likely to be occupied. The habitat suitability analysis with maxent identified the Platte River, southern Elkhorn River, parts of the southern Loup River system, main body of the Loup River, and eastern and central Niobrara River as the areas with habitat suitability values > 0.6. Areas identified with habitat suitability values between 0.4 and 0.6 included parts of the southern Loup River system, particularly in the Middle and North Loup and Cedar River, the central and northern Elkhorn River, and the Republican River around the Harlan County Lake. The western Niobrara, northern Loup River system, northern Elkhorn, Republican, Big Blue, Little Blue, Big Nemaha, and Little Nemaha rivers represent marginal habitat that is perhaps habitable in localized areas with preferred conditions.

Spatial correspondence between presence-absence occupancy analyses and presence-only maxent analyses was mapped, and of the 1,192 sampling units, 718 had less than a 0.1 difference in occupancy estimates between methods. Areas identified by both methods as areas with elevated occupancy estimates included the northern Elkhorn River, the southern Loup River system, and sections of the Niobrara and Platte rivers. The maxent method in chapter 3 more strongly supported the Platte River as a high occupancy area than did the occupancy method employed in chapter 2. This may be due to a broader coverage of that area in the NGPC presence-only data set as well as the difficulties inherent in modeling a river with many divergent channels. Though the areas identified as areas with elevated occupancy were largely consistent between methods, presence-only maxent modeling produced more liberal occupancy estimates than did presence-absence occupancy modeling. There were 421 sampling units with positive spatial correspondence values >0.1. Only 54 sampling units had negative spatial correspondence values, and in only one of these was the higher presence-absence occupancy estimate not influenced by a “1” value, which reflects a known occurrence using that method.

The Loup River was supported by both occupancy estimation methods as well as the habitat suitability analysis, yet relatively few historical records have come from the Loup River, and survey efforts detailed in chapter 2 yielded very few detections there. The southern sections of the Middle Loup and North Loup rivers were also supported as areas with highly suitable habitat. These rivers did not have otters released in them, but given the proximity to other areas with otter records and their suitable habitat, I feel these may be areas worthy of consideration if translocation or further reintroduction efforts are made.

Throughout these chapters, I have attempted to shed light on the current distribution of otters in the state. I found that my estimates, produced by two different methods and with two different datasets, agree with current prevailing thoughts on otter distribution in Nebraska. I have also identified areas with suitable habitat that may not currently be well-populated. It is my hope that these data and analyses will be used as NGPC moves forward with otter management in the state, and that my efforts would well-serve the continuing proliferation of otters throughout Nebraska's rivers.

**Appendix A.** Occupancy analysis results for beaver in Nebraska. Occupancy estimates for beaver were used as covariate data in otter occupancy analyses.

Beaver presence was considered as a covariate in the otter occupancy analyses in chapter 2 and the maxent analysis in chapter 3, so it was necessary to estimate and predict beaver occupancy so that unsurveyed sampling units would have values for this covariate. Long-term median flow rates, land cover, whether or not the river had gone dry in the last five years, and wetland area were considered as covariates in the beaver analyses. These covariates reflect the importance of woody vegetation and open water to beavers (Curtis and Jensen 2004). The best detection model accounted for different detection rates between observers and difference between survey periods. The best occupancy model incorporated land cover and river flow rates.

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**Appendix A. Continued.**

The best fit beaver detection model was one that considered different detection rates by observer and accounted for the effects of survey period on detection.

| Model | AIC | deltaAIC | AIC wgt | Model Likelihood | no.Par. | -2*LogLike |
|---|---|---|---|---|---|---|
| psi(GlobalSiteCovariates),p(Observer, SurveyPeriod) | 893.35 | 0 | 0.8755 | 1 | 15 | 863.35 |
| psi(GlobalSiteCovariates),p(Observer, RainDays, SurveyPeriod) | 897.73 | 4.38 | 0.098 | 0.1119 | 20 | 857.73 |
| psi(GlobalSiteCovariates),p(Observer) | 900.38 | 7.03 | 0.026 | 0.0297 | 10 | 880.38 |
| psi(GlobalSiteCovariates),p(Observer, RainDays) | 908.25 | 14.9 | 0.0005 | 0.0006 | 15 | 878.25 |
| psi(GlobalSiteCovariates),p(SurveyPeriod) | 926.26 | 32.91 | 0 | 0 | 7 | 912.26 |
| psi(GlobalSiteCovariates),p(RainDays, SurveyPeriod) | 927.95 | 34.6 | 0 | 0 | 8 | 911.95 |
| psi(GlobalSiteCovariates),p(.) | 931.44 | 38.09 | 0 | 0 | 6 | 919.44 |
| psi(GlobalSiteCovariates),p(RainDays) | 933.43 | 40.08 | 0 | 0 | 7 | 919.43 |

The best fit beaver occupancy model was one that considered river flow rate as well as the land cover. Though wetland area was the second strong single covariate, there was no (land cover + wetland area) model in the *a priori* model set.

| Model | AIC | deltaAIC | AIC wgt | Model Likelihood | no.Par. | -2*LogLike |
|---|---|---|---|---|---|---|
| psi(BasicNeeds; Flow, LandCover),p(TopDetectionCovariates) | 892.67 | 0 | 0.4101 | 1 | 13 | 866.67 |
| psi(Global),p(TopDetectionCovariates) | 893.35 | 0.68 | 0.2919 | 0.7118 | 15 | 863.35 |
| psi(LandCover),p(TopDetectionCovariates) | 894.40 | 1.73 | 0.1727 | 0.4211 | 12 | 870.4 |
| psi(Wetland),p(TopDetectionCovariates) | 896.62 | 3.95 | 0.0569 | 0.1388 | 12 | 872.62 |
| psi(AvailableWater; Flow, Wetland, Dry),p(TopDetectionCovariates) | 898.58 | 5.91 | 0.0214 | 0.0521 | 14 | 870.58 |
| psi(Flow),p(TopDetectionCovariates) | 902.00 | 9.33 | 0.0039 | 0.0094 | 12 | 878 |
| psi(Dry),p(TopDetectionCovariates) | 903.60 | 10.93 | 0.0017 | 0.0042 | 12 | 879.6 |

**Appendix B.** Otter locations gathered via kayak survey between July and September of 2014 and 2015 (n=190).

| Estimated # | Sign Type | Date | Observer | River | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | Tracks | 7/17/2014 | CLO | Platte | 37.5858 | -98.6029 |
| 1 | Tracks | 7/17/2014 | CLO | Platte | 40.7513 | -98.5715 |
| 1 | Tracks | 7/17/2014 | CLO | Platte | 40.7503 | -98.5623 |
| 1 | Tracks | 7/17/2014 | CLO | Platte | 40.7876 | -98.4357 |
| 1 | Tracks | 7/23/2014 | CLO | Loup | 41.2607 | -98.9693 |
| 1 | Tracks | 7/23/2014 | CLO | Loup | 41.2515 | -98.9573 |
| 1 | Tracks | 7/24/2014 | CLO | Loup | 41.2924 | -98.5546 |
| 1 | Visual, Tracks | 7/30/2014 | CLO | Cedar | 41.5442 | -98.1212 |
| 4 | Tracks, Scats | 8/12/2014 | CLO | Niobrara | 42.7947 | -101.0524 |
| 5 | Tracks, Scats | 8/12/2014 | CLO | Niobrara | 42.7890 | -101.0427 |
| 1 | Tracks | 8/16/2014 | CLO | Niobrara | 42.7780 | -100.8082 |
| 1 | Tracks | 8/16/2014 | CLO | Niobrara | 42.7873 | -100.7804 |
| 1 | Tracks | 9/9/2014 | CLO | Niobrara | 42.8014 | -98.6348 |
| 2 | Tracks | 9/9/2014 | CLO | Niobrara | 42.7797 | -98.5319 |
| 2 | Scats | 9/10/2014 | CLO | Niobrara | 42.8552 | -99.1204 |
| 1 | Tracks | 7/7/2014 | CLO | Platte | 40.8135 | -99.9138 |
| 3 | Tracks | 7/7/2014 | CLO | Platte | 40.8130 | -99.9129 |
| 1 | Tracks | 7/7/2014 | CLO | Platte | 40.8127 | -99.9119 |
| 1 | Tracks | 7/7/2014 | CLO | Platte | 40.8131 | -99.9107 |
| 2 | Tracks | 7/7/2014 | CLO | Platte | 40.7650 | -99.8260 |
| 1 | Tracks | 7/7/2014 | CLO | Platte | 40.7644 | -99.8252 |
| 4 | Tracks | 7/7/2014 | CLO | Platte | 40.7404 | -99.7856 |
| 1 | Tracks | 7/7/2014 | CLO | Platte | 40.7402 | -99.7831 |
| 2 | Tracks | 7/8/2014 | CLO | Platte | 40.7256 | -99.7291 |
| 2 | Tracks | 7/8/2014 | CLO | Platte | 40.7246 | -99.7286 |
| 2 | Tracks | 7/8/2014 | CLO | Platte | 40.7242 | -99.7266 |
| 5 | Tracks | 7/8/2014 | CLO | Platte | 40.7066 | -99.6808 |
| 1 | Tracks | 7/10/2014 | CLO | Platte | 40.6823 | -99.4890 |
| 1 | Tracks | 7/10/2014 | CLO | Platte | 40.6828 | -99.3878 |
| 1 | Tracks | 7/25/2014 | LTU | Loup | 41.3865 | -98.9606 |
| 3 | Tracks | 8/12/2014 | LTU | Niobrara | 42.7948 | -101.0523 |
| 6 | Scats | 8/12/2014 | LTU | Niobrara | 42.7948 | -101.0523 |
| 3 | Tracks | 8/12/2014 | LTU | Niobrara | 42.7872 | -101.0346 |
| 2 | Tracks | 8/14/2014 | LTU | Niobrara | 42.7926 | -101.1863 |
| 2 | Tracks | 8/14/2014 | LTU | Niobrara | 42.8025 | -101.1943 |
| 2 | Tracks | 8/14/2014 | LTU | Niobrara | 42.8009 | -101.1894 |
| 2 | Tracks | 8/16/2014 | LTU | Niobrara | 42.7782 | -100.8078 |
| 1 | Tracks | 9/9/2014 | LTU | Niobrara | 42.7777 | -98.5283 |

**Appendix B. Continued.**

| Estimated # | Sign Type | Date | Observer | River | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | Tracks | 9/25/2014 | LTU | Elkhorn | 41.6646 | -96.6444 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.8135 | -99.9138 |
| 3 | Tracks | 7/7/2014 | LTU | Platte | 40.8130 | -99.9129 |
| 4 | Tracks | 7/7/2014 | LTU | Platte | 40.8127 | -99.9119 |
| 4 | Tracks | 7/7/2014 | LTU | Platte | 40.8131 | -99.9107 |
| 3 | Tracks | 7/7/2014 | LTU | Platte | 40.8131 | -99.9095 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7888 | -99.8711 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7886 | -99.8674 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7650 | -99.8260 |
| 5 | Tracks | 7/7/2014 | LTU | Platte | 40.7644 | -99.8252 |
| 4 | Tracks | 7/7/2014 | LTU | Platte | 40.7645 | -99.8240 |
| 3 | Tracks | 7/7/2014 | LTU | Platte | 40.7646 | -99.8226 |
| 3 | Tracks | 7/7/2014 | LTU | Platte | 40.7646 | -99.8214 |
| 6 | Tracks | 7/7/2014 | LTU | Platte | 40.7404 | -99.7856 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7402 | -99.7831 |
| 3 | Tracks | 7/7/2014 | LTU | Platte | 40.7401 | -99.7817 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7406 | -99.7805 |
| 8 | Tracks | 7/8/2014 | LTU | Platte | 40.7256 | -99.7291 |
| 3 | Tracks | 7/8/2014 | LTU | Platte | 40.7246 | -99.7286 |
| 2 | Tracks | 7/8/2014 | LTU | Platte | 40.7243 | -99.7277 |
| 8 | Tracks | 7/8/2014 | LTU | Platte | 40.7242 | -99.7266 |
| 6 | Tracks | 7/8/2014 | LTU | Platte | 40.7066 | -99.6808 |
| 2 | Tracks | 7/8/2014 | LTU | Platte | 40.7070 | -99.6797 |
| 1 | Tracks | 7/8/2014 | LTU | Platte | 40.7070 | -99.6785 |
| 1 | Tracks | 7/8/2014 | LTU | Platte | 40.7070 | -99.6773 |
| 1 | Tracks | 7/8/2014 | LTU | Platte | 40.7056 | -99.6757 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7004 | -99.6386 |
| 1 | Tracks | 7/7/2014 | LTU | Platte | 40.7005 | -99.6362 |
| 5 | Tracks | 7/9/2014 | LTU | Platte | 40.6901 | -99.5893 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6901 | -99.5869 |
| 3 | Tracks | 7/9/2014 | LTU | Platte | 40.6897 | -99.5855 |
| 2 | Tracks | 7/9/2014 | LTU | Platte | 40.6895 | -99.5844 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6894 | -99.5833 |
| 4 | Tracks | 7/9/2014 | LTU | Platte | 40.6833 | -99.5467 |
| 4 | Tracks | 7/9/2014 | LTU | Platte | 40.6830 | -99.5455 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6827 | -99.5441 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6821 | -99.5431 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6823 | -99.5419 |
| 1 | Tracks | 7/9/2014 | LTU | Platte | 40.6825 | -99.5408 |

**Appendix B. Continued.**

| Estimated # | Sign Type | Date | Observer | River | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | Tracks | 7/17/2014 | NRB | Platte | 40.7877 | -98.4349 |
| 1 | Tracks | 7/25/2014 | NRB | Loup | 41.3860 | -98.6370 |
| 3 | Tracks | 8/12/2014 | NRB | Niobrara | 42.7946 | -101.0522 |
| 4 | Scats | 8/12/2014 | NRB | Niobrara | 42.7943 | -101.0517 |
| 3 | Tracks | 8/12/2014 | NRB | Niobrara | 42.7856 | -101.0354 |
| 2 | Tracks | 8/14/2014 | NRB | Niobrara | 42.8023 | -101.1945 |
| 1 | Tracks | 8/14/2014 | NRB | Niobrara | 42.8015 | -101.1897 |
| 3 | Tracks | 8/14/2014 | NRB | Niobrara | 42.7918 | -101.1865 |
| 5 | Tracks, Scats | 8/14/2014 | NRB | Niobrara | 42.7954 | -101.1682 |
| 1 | Tracks | 8/14/2014 | NRB | Niobrara | 42.8001 | -101.1473 |
| 2 | Tracks | 8/17/2014 | NRB | Niobrara | 42.8457 | -99.1249 |
| 1 | Tracks | 8/19/2014 | NRB | Niobrara | 42.7345 | -99.6647 |
| 1 | Tracks | 8/19/2014 | NRB | Niobrara | 42.7228 | -99.6166 |
| 4 | Scats | 8/19/2014 | NRB | Niobrara | 42.7229 | -99.6174 |
| 4 | Scats | 8/20/2014 | NRB | Niobrara | 42.7864 | -100.0024 |
| 5 | Scats | 8/24/2014 | NRB | Niobrara | 42.8037 | -100.6168 |
| 6 | Scats | 8/24/2014 | NRB | Niobrara | 42.8065 | -100.6110 |
| 5 | Scats | 8/24/2014 | NRB | Niobrara | 42.8460 | -100.5203 |
| 3 | Scats | 8/24/2014 | NRB | Niobrara | 42.8543 | -100.5149 |
| 2 | Tracks | 9/9/2014 | NRB | Niobrara | 42.8072 | -98.6497 |
| 4 | Tracks | 9/17/2014 | NRB | Elkhorn | 42.1616 | -98.1284 |
| 2 | Tracks | 9/17/2014 | NRB | Elkhorn | 42.1605 | -98.1269 |
| 1 | Tracks | 9/17/2014 | NRB | Elkhorn | 42.1384 | -98.0572 |
| 3 | Tracks | 9/25/2014 | NRB | Elkhorn | 41.6444 | -96.6306 |
| 1 | Tracks | 9/25/2014 | NRB | Elkhorn | 41.6435 | -96.6306 |
| 2 | Tracks | 9/25/2014 | NRB | Elkhorn | 41.6501 | -96.6157 |
| 1 | Tracks | 7/6/2014 | NRB | Platte | 40.8178 | -99.9513 |
| 1 | Tracks | 7/7/2014 | NRB | Platte | 40.8135 | -99.9138 |
| 2 | Tracks | 7/7/2014 | NRB | Platte | 40.8127 | -99.9119 |
| 4 | Tracks | 7/7/2014 | NRB | Platte | 40.8131 | -99.9107 |
| 2 | Tracks | 7/7/2014 | NRB | Platte | 40.8131 | -99.9095 |
| 1 | Tracks | 7/7/2014 | NRB | Platte | 40.7907 | -99.8728 |
| 3 | Tracks | 7/7/2014 | NRB | Platte | 40.7893 | -99.8680 |
| 3 | Tracks | 7/7/2014 | NRB | Platte | 40.7655 | -99.8269 |
| 1 | Tracks | 7/7/2014 | NRB | Platte | 40.7645 | -99.8240 |
| 1 | Tracks | 7/7/2014 | NRB | Platte | 40.7413 | -99.7797 |
| 4 | Tracks | 7/9/2014 | NRB | Platte | 40.6901 | -99.5893 |
| 1 | Tracks | 07/13/2015 | AVH | N. Platte | 41.6877 | -103.1592 |
| 1 | Tracks | 07/13/2015 | AVH | N. Platte | 41.6874 | -103.1551 |

**Appendix B. Continued.**

| Estimated # | Sign Type | Date | Observer | River | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 3 | Tracks | 07/14/2015 | AVH | N. Platte | 41.3791 | -102.3266 |
| 2 | Tracks | 07/14/2015 | AVH | N. Platte | 41.3717 | -102.3044 |
| 6 | Tracks | 07/14/2015 | AVH | N. Platte | 41.3553 | -102.2296 |
| 6 | Tracks | 07/14/2015 | AVH | N. Platte | 41.3523 | -102.2185 |
| 3 | Tracks | 07/19/2015 | AVH | N. Platte | 42.0943 | -102.7505 |
| 2 | Tracks | 07/19/2015 | AVH | N. Platte | 41.5406 | -102.7168 |
| 1 | Tracks | 07/19/2015 | AVH | N. Platte | 41.5241 | -102.7050 |
| 1 | Tracks | 07/19/2015 | AVH | N. Platte | 41.5024 | -102.6669 |
| 1 | Tracks | 09/06/2015 | AVH | Loup | 41.0815 | -98.5772 |
| 1 | Scats | 09/10/2015 | AVH | Elkhorn | 42.4285 | -98.5878 |
| 2 | Tracks | 09/10/2015 | AVH | Elkhorn | 42.4224 | -98.5780 |
| 2 | Tracks | 09/10/2015 | AVH | Elkhorn | 42.4136 | -98.5437 |
| 2 | Tracks | 09/10/2015 | AVH | Elkhorn | 42.4101 | -98.5353 |
| 5 | Tracks | 09/11/2015 | AVH | Elkhorn | 42.2552 | -98.3154 |
| 5 | Tracks | 09/11/2015 | AVH | Elkhorn | 42.2332 | -98.3006 |
| 3 | Tracks | 09/11/2015 | AVH | Elkhorn | 42.2084 | -98.2449 |
| 1 | Tracks | 7/13/2015 | HE | N. Platte | 41.6877 | -103.1592 |
| 1 | Tracks | 7/13/2015 | HE | N. Platte | 41.6874 | -103.1551 |
| 3 | Tracks | 7/14/2015 | HE | N. Platte | 41.3791 | -102.3266 |
| 2 | Tracks | 7/14/2015 | HE | N. Platte | 41.3756 | -102.3078 |
| 6 | Tracks | 7/14/2015 | HE | N. Platte | 41.3523 | -102.2185 |
| 6 | Tracks | 7/14/2015 | HE | N. Platte | 41.3432 | -102.2034 |
| 3 | Tracks | 07/19/2015 | HE | N. Platte | 41.5758 | -102.8425 |
| 4 | Tracks | 07/19/2015 | HE | N. Platte | 41.5439 | -102.7221 |
| 5 | Tracks | 07/19/2015 | HE | N. Platte | 41.5288 | -102.7075 |
| 1 | Tracks | 7/13/2015 | NRB | N. Platte | 41.6877 | -103.1592 |
| 1 | Tracks | 7/13/2015 | NRB | N. Platte | 41.6874 | -103.1551 |
| 3 | Tracks | 7/14/2015 | NRB | N. Platte | 41.3791 | -102.3266 |
| 2 | Tracks | 7/14/2015 | NRB | N. Platte | 41.3715 | -102.3040 |
| 6 | Tracks | 7/14/2015 | NRB | N. Platte | 41.3553 | -102.2296 |
| 6 | Tracks | 7/14/2015 | NRB | N. Platte | 41.3523 | -102.2185 |
| 4 | Tracks | 7/19/2015 | NRB | N. Platte | 41.5535 | -102.7865 |
| 2 | Tracks | 7/19/2015 | NRB | N. Platte | 41.5546 | -102.7705 |
| 3 | Tracks | 7/19/2015 | NRB | N. Platte | 41.5410 | -102.7166 |
| 5 | Tracks | 7/19/2015 | NRB | N. Platte | 41.5288 | -102.7075 |
| 2 | Tracks | 7/19/2015 | NRB | N. Platte | 41.4954 | -102.6480 |
| 1 | Tracks | 8/31/2015 | NRB | S. Loup | 41.0278 | -98.7526 |
| 3 | Tracks | 9/4/2015 | NRB | Platte | 40.9978 | -98.1190 |
| 3 | Tracks | 9/4/2015 | NRB | Platte | 41.0004 | -98.1145 |

**Appendix B. Continued.**

| Estimated # | Sign Type | Date | Observer | River | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 3 | Tracks | 9/4/2015 | NRB | Platte | 41.0128 | -98.0937 |
| 3 | Tracks | 9/6/2015 | NRB | M. Loup | 41.0812 | -98.5781 |
| 2 | Tracks | 9/6/2015 | NRB | M. Loup | 41.0794 | -98.5668 |
| 2 | Tracks | 9/6/2015 | NRB | M. Loup | 41.0777 | -98.5629 |
| 1 | Tracks | 9/6/2015 | NRB | M. Loup | 41.0844 | -98.5551 |
| 3 | Scats | 9/10/2015 | NRB | Elkhorn | 42.4311 | -98.5910 |
| 4 | Scats | 9/10/2015 | NRB | Elkhorn | 42.4282 | -98.5875 |
| 2 | Scats | 9/10/2015 | NRB | Elkhorn | 42.4250 | -98.5791 |
| 2 | Tracks | 9/10/2015 | NRB | Elkhorn | 42.4224 | -98.5780 |
| 2 | Tracks | 9/10/2015 | NRB | Elkhorn | 42.4095 | -98.5364 |
| 2 | Visual, Den | 9/11/2015 | NRB | Elkhorn | 42.2637 | -98.3237 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2548 | -98.3173 |
| 5 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2553 | -98.3151 |
| 1 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2528 | -98.3135 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2502 | -98.3127 |
| 3 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2449 | -98.3067 |
| 3 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2376 | -98.3029 |
| 4 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2332 | -98.3003 |
| 4 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2287 | -98.2886 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2246 | -98.2796 |
| 5 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2216 | -98.2783 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2100 | -98.2607 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2127 | -98.2591 |
| 2 | Tracks | 9/11/2015 | NRB | Elkhorn | 42.2105 | -98.2467 |
| 3 | Tracks | 9/12/2015 | NRB | Elkhorn | 41.9457 | -97.2983 |
| 3 | Tracks | 9/12/2015 | NRB | Elkhorn | 41.9446 | -97.2876 |
| 1 | Tracks | 9/12/2015 | NRB | Elkhorn | 41.9414 | -97.2841 |
| 3 | Tracks | 9/12/2015 | NRB | Elkhorn | 41.9385 | -97.2848 |
| 2 | Tracks | 9/12/2015 | NRB | Elkhorn | 41.9262 | -97.2742 |
| 1 | Tracks | 9/15/2015 | NRB | Elkhorn | 42.0619 | -97.8254 |
| 2 | Tracks | 9/15/2015 | NRB | Elkhorn | 42.0648 | -97.8098 |
| 2 | Tracks | 9/15/2015 | NRB | Elkhorn | 42.0611 | -97.8024 |
| 2 | Tracks | 9/15/2015 | NRB | Elkhorn | 42.0530 | -97.7838 |
| 1 | Tracks | 9/15/2015 | NRB | Elkhorn | 42.0525 | -97.7682 |
| 2 | Tracks | 9/16/2015 | NRB | Elkhorn | 41.9968 | -96.9579 |

**Appendix C.** Historical otter records reported to NGPC by fur trappers and biologists in the field (n=352).

| # Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| NA | YES | 11/05/77 | 1977 | Furnas | 40.0358 | -99.9189 |
| 1 | NO | 06/04/80 | 1980 | Harlan | 40.0653 | -99.2122 |
| 1 | NO | 12/13/86 | 1986 | Custer | 41.1958 | -99.7108 |
| 1 | NO | 03/21/87 | 1987 | Buffalo | 40.6747 | -98.8756 |
| NA | NO | 12/11/87 | 1987 | Loup | 41.9489 | -99.2897 |
| NA | NO | 11/30/87 | 1987 | Valley | 41.5858 | -98.9347 |
| NA | YES | 11/30/87 | 1987 | Custer | 41.1328 | -99.5694 |
| NA | YES | 11/30/87 | 1987 | Custer | 41.2100 | -99.7383 |
| NA | YES | 05/27/87 | 1987 | Dawson | 41.0442 | -99.6947 |
| NA | YES | 12/22/87 | 1987 | Douglas | 41.3167 | -96.4089 |
| NA | YES | 11/11/87 | 1987 | Loup | 41.8711 | -99.2606 |
| NA | YES | 11/11/87 | 1987 | Loup | 41.9142 | -99.3031 |
| NA | YES | 12/22/87 | 1987 | Saunders | 41.3306 | -96.4072 |
| 1 | NO | 01/13/88 | 1988 | Custer | 41.3228 | -99.9736 |
| 1 | NO | 01/09/88 | 1988 | Garden | 41.3142 | -102.1261 |
| 1 | NO | 08/17/88 | 1988 | Garden | 41.2989 | -102.0831 |
| 1 | NO | 09/21/88 | 1988 | Garden | 41.3167 | -102.1261 |
| 1 | NO | 12/03/88 | 1988 | Garden | 41.4583 | -102.5300 |
| 1 | NO | 01/13/88 | 1988 | Loup | 41.9917 | -99.4444 |
| 1 | NO | 03/25/88 | 1988 | Loup | 41.9417 | -99.3853 |
| 1 | NO | 03/27/88 | 1988 | Loup | 41.8764 | -99.2314 |
| NA | YES | 02/28/88 | 1988 | Brown | 42.1903 | -99.8872 |
| NA | YES | 12/12/88 | 1988 | Holt | 42.4667 | -98.8000 |
| NA | YES | 11/06/88 | 1988 | Keith | 41.3022 | -102.0100 |
| NA | YES | 11/06/88 | 1988 | Keith | 41.3236 | -102.0389 |
| NA | YES | 04/30/88 | 1988 | Loup | 41.8967 | -99.2653 |
| NA | YES | 11/30/88 | 1988 | Morrill | 41.6892 | -103.1711 |
| NA | YES | 11/29/88 | 1988 | Nemaha | 40.3378 | -95.7050 |
| 2 | NO | 09/11/89 | 1989 | Garden | 41.2994 | -102.0769 |
| 1 | NO | 12/25/89 | 1989 | Garden | 41.3142 | -102.1250 |
| NA | NO | 01/01/89 | 1989 | Kearney | 40.6161 | -99.0267 |
| 2 | NO | 09/21/89 | 1989 | Keith | 41.2989 | -101.9311 |
| 1 | NO | 10/14/89 | 1989 | Keith | 41.2842 | -101.9881 |
| 4 | NO | 11/10/89 | 1989 | Keith | 41.2947 | -102.0389 |
| 1 | NO | 12/14/89 | 1989 | Keith | 41.2919 | -102.0361 |
| 1 | NO | 08/26/89 | 1989 | Loup | 41.9200 | -99.3089 |
| NA | YES | 03/09/89 | 1989 | Buffalo | 40.9608 | -99.0908 |
| NA | YES | 04/10/89 | 1989 | Loup | 41.8606 | -99.2692 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| NA | YES | 01/25/90 | 1990 | Buffalo | 40.6628 | -99.2319 |
| NA | YES | 02/08/90 | 1990 | Dawson | 40.7489 | -99.7689 |
| NA | YES | 11/28/90 | 1990 | Garfield | 42.0822 | -99.0744 |
| NA | YES | 02/13/90 | 1990 | Hall | 40.7278 | -98.6483 |
| NA | YES | 02/18/90 | 1990 | Hall | 40.7633 | -98.5133 |
| NA | YES | 03/11/90 | 1990 | Hall | 40.7458 | -98.5994 |
| NA | YES | 03/11/90 | 1990 | Hall | 40.7461 | -98.5992 |
| NA | YES | 12/08/90 | 1990 | Merrick | 40.8736 | -98.2811 |
| 5 | NO | 07/16/91 | 1991 | Brown | 42.1797 | -99.8622 |
| 1 | NO | 03/24/91 | 1991 | Buffalo | 40.7044 | -98.7883 |
| 4 | NO | 12/11/91 | 1991 | Loup | 41.9194 | -99.3253 |
| 1 | NO | 07/04/91 | 1991 | Wheeler | 41.7861 | -98.6967 |
| NA | YES | 12/30/91 | 1991 | Antelope | 42.1603 | -98.1139 |
| NA | YES | 02/26/91 | 1991 | Buffalo | 40.7156 | -98.7331 |
| NA | YES | 12/31/91 | 1991 | Buffalo | 40.7136 | -98.7553 |
| NA | YES | 04/02/91 | 1991 | Hall | 40.8325 | -98.3667 |
| NA | YES | 12/02/91 | 1991 | Madison | 42.0667 | -97.8308 |
| NA | YES | 12/31/91 | 1991 | Madison | 42.0186 | -97.5278 |
| NA | YES | 12/31/91 | 1991 | Sherman | 41.2417 | -98.9544 |
| 1 | NO | 04/12/92 | 1992 | Antelope | 42.1769 | -98.1750 |
| NA | NO | 03/01/92 | 1992 | Cherry | 42.8058 | -101.6689 |
| 1 | NO | 05/06/92 | 1992 | Keith | 41.2392 | -101.6831 |
| NA | YES | 03/01/92 | 1992 | Hall | 40.8422 | -98.5522 |
| NA | YES | 02/02/92 | 1992 | Madison | 42.0408 | -97.6811 |
| 2 | NO | 07/28/93 | 1993 | Hall | 40.7911 | -98.4450 |
| 2 | NO | 04/04/93 | 1993 | Wheeler | 41.7581 | -98.5311 |
| NA | YES | 12/03/93 | 1993 | Antelope | 42.1386 | -98.0586 |
| NA | YES | 11/27/93 | 1993 | Butler | 41.3800 | -97.2219 |
| NA | YES | 11/30/93 | 1993 | Holt | 42.2681 | -98.3447 |
| NA | YES | 04/12/93 | 1993 | Madison | 42.0694 | -97.6003 |
| NA | YES | 04/01/93 | 1993 | Morrill | 41.6878 | -103.1611 |
| 1 | NO | 10/06/94 | 1994 | Garden | 41.3139 | -102.1250 |
| 1 | NO | 05/12/94 | 1994 | Garfield | 41.8297 | -99.2142 |
| 2 | NO | 03/15/94 | 1994 | Hall | 40.7917 | -98.4842 |
| 1 | NO | 11/17/94 | 1994 | Loup | 41.9203 | -99.3283 |
| 5 | NO | 05/21/94 | 1994 | Morrill | 41.5422 | -102.8250 |
| NA | YES | 01/04/95 | 1995 | Holt | 42.8319 | -98.8217 |
| NA | YES | 11/09/95 | 1995 | Merrick | 40.8778 | -98.2822 |
| NA | YES | 12/01/95 | 1995 | Otoe | 40.6150 | -96.0183 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 2 | NO | 07/08/96 | 1996 | Buffalo | 40.6575 | -98.9511 |
| NA | YES | 03/19/96 | 1996 | Buffalo | 40.6764 | -99.3083 |
| NA | YES | 12/01/96 | 1996 | Hall | 40.7172 | -98.7167 |
| NA | YES | 12/01/96 | 1996 | Hall | 40.7892 | -98.4094 |
| NA | YES | 12/19/96 | 1996 | Hall | 40.7492 | -98.5869 |
| NA | YES | 03/18/96 | 1996 | Hamilton | 41.0764 | -98.0006 |
| NA | YES | 02/20/96 | 1996 | Keith | 41.2697 | -101.9500 |
| NA | YES | 03/18/96 | 1996 | Merrick | 41.0761 | -98.0044 |
| NA | YES | 11/20/96 | 1996 | Sheridan | 42.6375 | -102.2061 |
| 1 | NO | 04/13/97 | 1997 | Cherry | 42.7900 | -100.9931 |
| 1 | NO | 03/31/97 | 1997 | Hall | 40.8497 | -98.4644 |
| NA | YES | 03/30/97 | 1997 | Antelope | 42.1789 | -98.1678 |
| NA | YES | 03/01/97 | 1997 | Buffalo | 40.7000 | -98.7939 |
| NA | YES | 12/12/97 | 1997 | Cherry | 42.8111 | -101.6950 |
| NA | YES | 01/08/97 | 1997 | Hall | 40.7894 | -98.4042 |
| NA | YES | 01/09/97 | 1997 | Hall | 40.7886 | -98.4142 |
| NA | YES | 01/09/97 | 1997 | Hall | 40.7889 | -98.4047 |
| NA | YES | 01/09/97 | 1997 | Hall | 40.7889 | -98.4117 |
| NA | YES | 11/25/97 | 1997 | Hall | 40.7811 | -98.4597 |
| NA | YES | 12/31/97 | 1997 | Lincoln | 41.0981 | -100.6900 |
| NA | YES | 12/01/97 | 1997 | Morrill | 41.5803 | -102.8550 |
| NA | YES | 05/07/97 | 1997 | Nance | 41.3442 | -97.9753 |
| NA | YES | 07/01/97 | 1997 | Nance | 41.3414 | -97.8586 |
| NA | YES | 12/29/97 | 1997 | Nance | 41.3731 | -97.9267 |
| NA | YES | 08/01/97 | 1997 | Otoe | 40.6678 | -95.9731 |
| NA | YES | 11/16/97 | 1997 | Otoe | 40.6239 | -96.0167 |
| NA | YES | 02/05/97 | 1997 | Platte | 41.3667 | -97.4922 |
| 1 | NO | 01/11/98 | 1998 | Morrill | 41.6936 | -103.2039 |
| 1 | NO | 12/01/98 | 1998 | Otoe | 40.6344 | -96.0214 |
| NA | YES | 02/01/98 | 1998 | Buffalo | 40.6647 | -98.9250 |
| NA | YES | 02/01/98 | 1998 | Buffalo | 40.6667 | -98.9094 |
| NA | YES | 02/01/98 | 1998 | Cherry | 42.8042 | -101.6781 |
| NA | YES | 02/01/98 | 1998 | Hall | 40.7806 | -98.4703 |
| NA | YES | 02/09/98 | 1998 | Merrick | 41.0828 | -97.9914 |
| NA | YES | 03/01/98 | 1998 | Wheeler | 41.7847 | -98.6989 |
| 8 | NO | 12/24/99 | 1999 | Garden | 41.3161 | -102.1269 |
| NA | YES | 04/03/99 | 1999 | Buffalo | 40.7194 | -99.3756 |
| NA | YES | 12/01/99 | 1999 | Otoe | 40.6336 | -96.0153 |
| NA | YES | 12/01/99 | 1999 | Otoe | 40.6347 | -96.0214 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | NO | 12/27/00 | 2000 | Buffalo | 40.6664 | -99.2550 |
| 1 | NO | 12/28/00 | 2000 | Buffalo | 40.6597 | -98.9500 |
| 1 | NO | 12/29/00 | 2000 | Buffalo | 40.7158 | -98.7406 |
| 1 | NO | 12/26/00 | 2000 | Dawson | 40.6806 | -99.5411 |
| 1 | NO | 12/30/00 | 2000 | Hall | 40.7536 | -98.5881 |
| 1 | NO | 12/31/00 | 2000 | Hall | 40.7489 | -98.5858 |
| 1 | NO | 06/01/00 | 2000 | Keith | 41.2961 | -102.0331 |
| 4 | NO | 11/01/00 | 2000 | Morrill | 41.6317 | -103.0039 |
| NA | YES | 11/04/00 | 2000 | Hall | 40.8403 | -98.3117 |
| 1 | NO | 03/01/01 | 2001 | Dawson | 40.6850 | -99.6144 |
| 1 | NO | 02/15/01 | 2001 | Garden | 41.3175 | -102.1400 |
| 1 | NO | 02/16/01 | 2001 | Garden | 41.3178 | -102.1261 |
| 1 | NO | 02/28/01 | 2001 | Garfield | 41.8092 | -99.1822 |
| 1 | NO | 01/19/01 | 2001 | Holt | 42.2653 | -98.3392 |
| 1 | NO | 01/19/01 | 2001 | Holt | 42.3358 | -98.4186 |
| 1 | NO | 01/19/01 | 2001 | Holt | 42.4333 | -98.5981 |
| 5 | NO | 01/01/01 | 2001 | Morrill | 41.6808 | -103.1281 |
| 1 | NO | 02/16/01 | 2001 | Nance | 41.3944 | -98.0039 |
| NA | YES | 11/28/01 | 2001 | Antelope | 42.1792 | -98.1656 |
| NA | YES | 12/16/01 | 2001 | Buffalo | 40.6597 | -99.0850 |
| NA | YES | 02/05/01 | 2001 | Custer | 41.2639 | -99.8267 |
| NA | YES | 01/14/01 | 2001 | Greeley | 41.7350 | -98.5464 |
| NA | YES | 02/28/01 | 2001 | Hall | 40.7522 | -98.5589 |
| NA | YES | 12/10/01 | 2001 | Hall | 40.7506 | -98.5789 |
| NA | YES | 12/11/01 | 2001 | Hall | 40.8294 | -98.3261 |
| NA | YES | 02/26/01 | 2001 | Hamilton | 41.0792 | -97.9958 |
| NA | YES | 01/01/01 | 2001 | Holt | 42.2314 | -98.3039 |
| NA | YES | 01/01/01 | 2001 | Holt | 42.2956 | -98.3825 |
| NA | YES | 03/13/01 | 2001 | Holt | 42.2950 | -98.3831 |
| NA | YES | 01/24/01 | 2001 | Kearney | 40.6517 | -99.0375 |
| NA | YES | 11/08/01 | 2001 | NA | 40.6689 | -99.0753 |
| NA | YES | 01/01/02 | 2002 | Blaine | 41.7506 | -99.7672 |
| NA | YES | 11/04/02 | 2002 | Buffalo | 40.6867 | -98.9347 |
| NA | YES | 08/07/02 | 2002 | Scottsbluff | 41.8186 | -103.5389 |
| 6 | NO | 10/30/03 | 2003 | Garden | 41.4619 | -102.5911 |
| NA | YES | 03/28/03 | 2003 | Buffalo | 40.7003 | -99.0922 |
| NA | YES | 01/02/03 | 2003 | Cherry | 42.8097 | -101.6881 |
| NA | YES | 02/18/03 | 2003 | Garden | 41.5422 | -102.2650 |
| NA | YES | 01/11/03 | 2003 | Madison | 42.0239 | -97.5683 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| NA | YES | 11/28/03 | 2003 | Nance | 41.2766 | -98.2525 |
| 2 | NO | 02/13/04 | 2004 | Garden | 41.3031 | -102.0561 |
| NA | NO | 02/07/04 | 2004 | Morrill | 41.7028 | -103.2481 |
| NA | NO | 02/01/04 | 2004 | Otoe | 40.6333 | -96.0203 |
| NA | NO | 02/05/04 | 2004 | Otoe | 40.6825 | -96.2364 |
| NA | YES | 05/05/04 | 2004 | Buffalo | 40.6814 | -99.3919 |
| 1 | YES | 12/17/04 | 2004 | Holt | 42.4513 | -98.6891 |
| NA | YES | 12/23/04 | 2004 | Holt | 42.4511 | -98.6907 |
| NA | YES | 03/27/04 | 2004 | Lincoln | 40.9736 | -100.4581 |
| NA | YES | 02/18/04 | 2004 | Madison | 42.0171 | -97.5347 |
| NA | YES | 01/01/04 | 2004 | Morrill | 41.5869 | -102.8661 |
| NA | YES | 03/22/04 | 2004 | Otoe | 40.5736 | -96.0361 |
| NA | YES | 03/26/04 | 2004 | Otoe | 40.5576 | -95.9860 |
| NA | YES | 10/04/04 | 2004 | Sarpy | 41.1472 | -96.0650 |
| NA | YES | 12/12/05 | 2005 | Dawson | 40.7203 | -99.7214 |
| NA | YES | 06/23/05 | 2005 | Garden | 41.3157 | -102.1274 |
| NA | YES | 02/02/05 | 2005 | Keith | 41.3006 | -101.9269 |
| NA | YES | 02/25/05 | 2005 | Keith | 41.3006 | -101.9269 |
| NA | YES | 07/03/05 | 2005 | Keith | 41.1669 | -101.4067 |
| NA | YES | 01/29/05 | 2005 | Scottsbluff | 41.9652 | -104.0079 |
| NA | YES | 06/23/05 | 2005 | Wheeler | 41.6772 | -98.3645 |
| 1 | YES | 03/03/05 | 2005 | NA | 42.0872 | -97.9705 |
| NA | YES | 11/05/05 | 2005 | NA | 42.9087 | -98.7332 |
| NA | NO | 03/24/06 | 2006 | Buffalo | 40.6652 | -99.2562 |
| NA | NO | 03/22/06 | 2006 | Garden | 41.3165 | -102.0378 |
| NA | YES | 03/11/06 | 2006 | Brown | 42.2028 | -99.9038 |
| NA | YES | 03/04/06 | 2006 | Buffalo | 40.6775 | -98.9975 |
| NA | YES | 11/02/06 | 2006 | Buffalo | 40.6855 | -98.9443 |
| NA | YES | 11/18/06 | 2006 | Buffalo | 40.6831 | -99.3805 |
| NA | YES | 11/28/06 | 2006 | Buffalo | 40.6668 | -99.1277 |
| NA | YES | 01/30/06 | 2006 | Dawson | 40.7868 | -99.8998 |
| NA | YES | 10/21/06 | 2006 | Hall | 40.7398 | -98.5779 |
| NA | YES | 01/23/06 | 2006 | Holt | 42.3312 | -98.4258 |
| NA | YES | 02/15/06 | 2006 | Holt | 42.4495 | -98.7080 |
| NA | YES | 01/01/06 | 2006 | Morrill | 41.5295 | -102.8169 |
| NA | YES | 01/14/06 | 2006 | Otoe | 40.5230 | -96.2725 |
| NA | NO | 08/11/07 | 2007 | Boone | 41.6068 | -98.2270 |
| NA | NO | 12/22/07 | 2007 | Buffalo | 40.6618 | -99.2373 |
| NA | NO | 12/10/07 | 2007 | Butler | 41.3830 | -97.2742 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| NA | NO | 01/01/07 | 2007 | Garden | 41.3241 | -102.1843 |
| NA | NO | 01/01/07 | 2007 | Howard | 41.2675 | -98.4264 |
| NA | NO | 10/01/07 | 2007 | Howard | 41.2650 | -98.4305 |
| NA | NO | 11/01/07 | 2007 | Howard | 41.2650 | -98.4305 |
| NA | NO | 06/20/07 | 2007 | Keith | 41.1823 | -101.4963 |
| NA | NO | 11/01/07 | 2007 | Rock | 42.3176 | -99.4849 |
| NA | YES | 11/24/07 | 2007 | Antelope | 42.1819 | -98.1934 |
| NA | YES | 11/07/07 | 2007 | Boyd | 42.8298 | -98.8112 |
| NA | YES | 12/04/07 | 2007 | Cherry | 42.8455 | -100.5209 |
| NA | YES | 12/04/07 | 2007 | Garden | 41.4223 | -102.1685 |
| NA | YES | 02/28/07 | 2007 | Hall | 40.7722 | -98.6002 |
| 1 | YES | 07/23/07 | 2007 | Hall | 40.7752 | -98.5973 |
| NA | YES | 11/02/07 | 2007 | holt | 42.4954 | -98.9208 |
| NA | YES | 12/07/07 | 2007 | Holt | 42.4536 | -98.7248 |
| NA | YES | 02/03/07 | 2007 | Madison | 42.0061 | -97.5596 |
| NA | YES | 05/09/07 | 2007 | Scottsbluff | 41.7613 | -103.4175 |
| 1 | YES | 12/14/07 | 2007 | NA | 41.4196 | -102.1699 |
| NA | NO | 01/24/08 | 2008 | Antelope | 42.1604 | -98.1270 |
| NA | NO | 05/28/08 | 2008 | Antelope | 42.1627 | -98.1609 |
| NA | NO | 03/01/08 | 2008 | Garden | 41.3238 | -102.1411 |
| NA | NO | 02/10/08 | 2008 | Greeley | 41.6395 | -98.2969 |
| NA | NO | 01/11/08 | 2008 | Hall | 40.7713 | -98.4925 |
| NA | NO | 01/09/08 | 2008 | Holt | 42.5168 | -98.9704 |
| 3 | NO | 11/10/08 | 2008 | Holt | 42.2112 | -98.5884 |
| NA | NO | 05/20/08 | 2008 | Howard | 41.2673 | -98.4272 |
| NA | NO | 08/24/08 | 2008 | Howard | 41.1836 | -98.5019 |
| NA | NO | 01/11/08 | 2008 | Madison | 42.0677 | -97.8343 |
| NA | NO | 08/15/08 | 2008 | Nance | 41.4087 | -97.7344 |
| 1 | YES | 11/30/08 | 2008 | Dawson | 40.7077 | -99.6753 |
| 1 | YES | 11/22/08 | 2008 | Garden | 41.4196 | -102.1699 |
| 1 | YES | 11/22/08 | 2008 | Garden | 41.4196 | -102.1699 |
| NA | YES | 03/17/08 | 2008 | Garfield | 41.7708 | -99.2215 |
| 1 | YES | 12/08/08 | 2008 | Holt | 42.1082 | -98.3493 |
| 1 | YES | 12/23/08 | 2008 | Lincoln | 41.1826 | -101.1655 |
| 1 | YES | 12/19/08 | 2008 | Scottsbluff | 41.8711 | -103.6312 |
| NA | YES | 02/18/08 | 2008 | Scottsbluff | 41.9070 | -103.7436 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| NA | YES | 03/06/08 | 2008 | Scottsbluff | 41.9372 | -103.9430 |
| 5 | NO | 09/11/09 | 2009 | Cherry | 42.9073 | -100.4586 |
| NA | NO | 01/10/09 | 2009 | Dawson | 42.6931 | -98.1292 |
| NA | NO | 01/30/09 | 2009 | Holt | 42.3357 | -98.4375 |
| 4 | NO | 12/01/09 | 2009 | Holt | 42.2112 | -98.5884 |
| 1 | NO | 04/13/09 | 2009 | Keith | 41.2127 | -101.6718 |
| 1 | NO | 05/20/09 | 2009 | Keith | 41.1724 | -101.3074 |
| NA | NO | 01/28/09 | 2009 | Madison | 42.0478 | -97.7374 |
| NA | NO | 01/28/09 | 2009 | Madison | 42.0676 | -97.8344 |
| 5 | NO | 12/25/09 | 2009 | Merrick | 41.2446 | -97.7559 |
| 3 | NO | 11/14/09 | 2009 | Nance | 41.4389 | -97.6753 |
| 1 | NO | 07/29/09 | 2009 | Nemaha | 40.3381 | -95.6500 |
| 2 | NO | 10/01/09 | 2009 | Saunders | 41.3647 | -96.4280 |
| NA | NO | 01/11/09 | 2009 | NA | 42.6946 | -98.1278 |
| 1 | YES | 01/23/09 | 2009 | Garden | 41.4161 | -102.1725 |
| 1 | YES | 11/14/09 | 2009 | NA | 41.8690 | -103.7180 |
| 1 | YES | 11/29/09 | 2009 | NA | 42.0276 | -97.6939 |
| 1 | NO | 03/20/10 | 2010 | Brown | 42.5786 | -99.6935 |
| 1 | NO | 09/28/10 | 2010 | Cherry | 42.8667 | -100.2506 |
| NA | NO | 03/18/10 | 2010 | Harlan | 40.0275 | -99.3095 |
| NA | NO | 03/26/10 | 2010 | Harlan | 40.0365 | -99.2598 |
| NA | NO | 04/20/10 | 2010 | Harlan | 40.0703 | -99.2042 |
| 5 | NO | 08/31/10 | 2010 | Holt | 42.2191 | -98.5829 |
| NA | NO | 02/25/10 | 2010 | Nance | 41.3452 | -97.9757 |
| NA | NO | 02/25/10 | 2010 | Nance | 41.4180 | -97.7233 |
| 3 | NO | 05/14/10 | 2010 | Nance | 41.3128 | -98.0521 |
| NA | NO | 10/14/10 | 2010 | Nance | 41.4389 | -98.0763 |
| NA | NO | 10/14/10 | 2010 | Nance | 41.4484 | -98.0712 |
| NA | NO | 10/14/10 | 2010 | Nance | 41.4556 | -98.0673 |
| 1 | NO | 02/01/10 | 2010 | Otoe | 40.5373 | -95.7833 |
| NA | NO | 10/24/10 | 2010 | NA | 42.6919 | -98.0618 |
| 1 | YES | 01/26/10 | 2010 | Buffalo | 40.6856 | -99.0138 |
| 1 | YES | 05/11/10 | 2010 | Dawson | 40.8343 | -99.9932 |
| 1 | YES | 05/12/10 | 2010 | Dawson | 40.8343 | -99.9932 |
| NA | YES | 03/18/10 | 2010 | Harlan | 40.0957 | -99.3712 |
| 1 | YES | 11/20/10 | 2010 | Jefferson | 40.1322 | -97.2050 |
| 2 | YES | 05/01/10 | 2010 | Phelps | 40.5356 | -99.2683 |
| 1 | YES | 12/22/10 | 2010 | Polk | 41.2026 | -97.7855 |
| 1 | YES | 03/01/10 | 2010 | NA | 40.8738 | -98.3780 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | YES | 03/17/10 | 2010 | NA | 40.8128 | -98.4386 |
| 2 | NO | 08/04/11 | 2011 | Cherry | 42.8667 | -100.2506 |
| 1 | NO | 01/27/11 | 2011 | Knox | 42.7483 | -98.0470 |
| 4 | NO | 09/25/11 | 2011 | Knox | 42.7074 | -98.1491 |
| 4 | NO | 12/31/11 | 2011 | Knox | 42.8526 | -97.8768 |
| 4 | NO | 04/05/11 | 2011 | Nance | 41.3129 | -98.0533 |
| 1 | YES | 02/27/11 | 2011 | Knox | 42.7631 | -97.9851 |
| 1 | YES | 03/02/11 | 2011 | Nemaha | 40.4580 | -95.8967 |
| 1 | YES | 11/22/11 | 2011 | Rock | 42.4044 | -99.2875 |
| 1 | YES | 02/05/11 | 2011 | Saunders | 41.3246 | -96.4154 |
| 1 | YES | 09/11/11 | 2011 | NA | 42.0876 | -97.9704 |
| 1 | YES | 11/19/11 | 2011 | NA | 42.0876 | -97.9704 |
| 1 | YES | 12/29/11 | 2011 | NA | 41.3471 | -97.9850 |
| 1 | NO | 06/19/12 | 2012 | Burt | 42.0000 | -96.2167 |
| 1 | NO | 07/15/12 | 2012 | Burt | 42.0000 | -96.2167 |
| 1 | NO | 07/23/12 | 2012 | Cumming | 41.9983 | -97.0046 |
| 1 | NO | 07/13/12 | 2012 | Dodge | 41.7133 | -96.6969 |
| 4 | NO | 11/26/12 | 2012 | Holt | 42.1104 | -98.5634 |
| NA | NO | 01/25/12 | 2012 | Knox | 42.7484 | -98.0440 |
| 1 | YES | 02/05/12 | 2012 | Boone | 41.5613 | -98.1413 |
| 1 | YES | 03/20/12 | 2012 | Burt | 42.0330 | -96.2485 |
| 1 | YES | 12/14/12 | 2012 | Burt | 41.7633 | -96.0830 |
| 1 | YES | 04/27/12 | 2012 | Douglas | 41.2087 | -96.0927 |
| 1 | YES | 04/04/12 | 2012 | Holt | 42.2867 | -99.2240 |
| 1 | YES | 03/10/12 | 2012 | Howard | 41.2767 | -98.3619 |
| 1 | YES | 03/18/12 | 2012 | Howard | 41.2786 | -98.3668 |
| 1 | YES | 12/02/12 | 2012 | Howard | 41.1836 | -98.4605 |
| 1 | YES | 02/23/12 | 2012 | Lincoln | 41.1559 | -100.7583 |
| 1 | YES | 03/18/12 | 2012 | Lincoln | 41.0258 | -100.3781 |
| 1 | YES | 03/26/12 | 2012 | Lincoln | 41.0424 | -100.4895 |
| 1 | YES | 01/01/12 | 2012 | Madison | 41.9521 | -97.6270 |
| 1 | YES | 01/16/12 | 2012 | NA | 41.0905 | -100.6398 |
| 1 | YES | 03/01/12 | 2012 | NA | 40.6836 | -99.3805 |
| 1 | YES | 03/05/12 | 2012 | NA | 40.6826 | -99.5382 |
| 1 | YES | 03/05/12 | 2012 | NA | 40.6835 | -99.5395 |
| 1 | YES | 12/01/12 | 2012 | NA | 41.3325 | -102.1736 |
| 1 | YES | 12/01/12 | 2012 | NA | 41.3325 | -102.1736 |
| 1 | YES | 12/01/12 | 2012 | NA | 41.3325 | -102.1736 |
| 2 | NO | 08/11/13 | 2013 | Dakota | 42.2917 | -96.3686 |

**Appendix C. Continued.**

| Observed | Carcass | Date | Year | County | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | NO | 11/09/13 | 2013 | Knox | 42.8457 | -97.8413 |
| 1 | NO | 12/11/13 | 2013 | Nemaha | 40.5035 | -95.7017 |
| 1 | NO | 07/15/13 | 2013 | Otoe | 40.6508 | -96.1957 |
| 1 | NO | 01/02/13 | 2013 | NA | 42.2682 | -98.3395 |
| 1 | YES | 01/13/13 | 2013 | Adams | 40.7493 | -98.5918 |
| 1 | YES | 01/13/13 | 2013 | Adams | 40.7493 | -98.5918 |
| 1 | YES | 04/15/13 | 2013 | Antelope | 42.1144 | -98.0207 |
| 1 | YES | 01/30/13 | 2013 | Cherry | 42.8286 | -100.5301 |
| 1 | YES | 12/30/13 | 2013 | Cherry | 42.8131 | -100.5971 |
| 2 | YES | 03/11/13 | 2013 | Gage | 40.0451 | -96.5403 |
| 1 | YES | 01/04/13 | 2013 | Howard | 41.2220 | -98.4381 |
| 1 | YES | 02/14/13 | 2013 | Howard | 41.1836 | -98.4605 |
| 1 | YES | 02/13/13 | 2013 | Knox | 42.7572 | -98.0221 |
| 1 | YES | 02/27/13 | 2013 | Madison | 41.9974 | -97.3652 |
| 1 | YES | 02/04/13 | 2013 | Merrick | 41.0803 | -98.0048 |
| 1 | YES | 03/11/13 | 2013 | NA | 40.6697 | -99.3693 |
| 1 | YES | 03/15/13 | 2013 | NA | 40.6829 | -99.3712 |
| 1 | YES | 09/26/13 | 2013 | NA | 41.7128 | -96.0863 |
| 1 | YES | 12/01/13 | 2013 | NA | 41.4046 | -97.3568 |
| 1 | YES | 12/12/13 | 2013 | NA | 41.9954 | -104.0430 |
| 1 | YES | 12/14/13 | 2013 | NA | 41.1796 | -98.4654 |
| 1 | YES | 12/22/13 | 2013 | NA | 40.6779 | -99.3742 |
| 2 | NO | 02/18/14 | 2014 | Cherry | 42.8984 | -100.4847 |
| 3 | NO | 02/24/14 | 2014 | Cherry | 42.7859 | -100.9254 |
| NA | NO | 02/27/14 | 2014 | Cherry | 42.7917 | -101.0000 |
| 1 | NO | 04/23/14 | 2014 | Knox | 42.8369 | -97.5108 |
| 1 | YES | 01/05/14 | 2014 | NA | 40.6913 | -99.5343 |
| 1 | YES | 01/19/14 | 2014 | NA | 40.6779 | -99.3742 |
| 2 | YES | NA | | NA | 40.6551 | -98.9919 |
| 1 | YES | NA | | NA | 41.0024 | -96.1688 |
| 1 | YES | NA | | NA | 42.1977 | -98.2061 |