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Assessing the current and projected future distribution of a recently re-establishing fisher (*Martes pennanti*) population in eastern North Dakota

A Thesis in

Wildlife/Fisheries Biology

By

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Submitted in Partial Fulfillment

Of the Requirements for the Degree of

Master of Science

May 2010

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SYNOPSIS

Fishers (*Martes pennanti*) were extirpated from North Dakota during the late 19th century; however, there has been an increase in verified fisher sightings over the past 10 years, which likely includes individuals from an expanding Minnesota population. I evaluated fishers' current and projected future distribution in the eastern half of North Dakota through verified reports, presence-absence field data, and simulation modeling. Additionally, the Red River of the North (North Dakota and Minnesota border) experienced an extreme flood event, which inundated all riparian forests within the study area from about 23 March–22 May 2009 and I also examined the effects of this extreme flood event on detection rates between 2008 and 2009 on a portion of the Red River.

Verified reports (2002–2007) were obtained from the North Dakota Game and Fish Department and field data was obtained from population surveys conducted during the summers of 2008 and 2009 using enclosed track-plates and remote cameras. Detection devices were placed within the minimal and fragmented forests of eastern North Dakota including the Forest, Goose, Park, Pembina, Red, Sheyenne, Tongue, and Turtle Rivers and the Pembina Hills. Fishers' potential distribution and occupancy were simulated using the model, HexSim, based on population parameters and habitat preferences determined from prior studies in Minnesota and other states and provinces. Multiple scenarios were conducted, which differed in dispersal distance (10 km, 30 km, and 75 km) and habitat categories (forest vs. non-forest and 11 habitat categories). I also compared detection rates observed during the summers of 2008 (16 Jun–1 Aug) and 2009 (1 Jun–18 Aug) along the Red River from Grand Forks, North Dakota to Pembina, North Dakota where extreme flooding occurred.

My research established that fishers are no longer extirpated from North Dakota. Verified reports were mostly concentrated in the northeast portion of the state (12 of 16 reports; 75%) and few reports occurred farther south (Sheyenne National Grasslands; 2 of 16 reports; 12.5%) and west (Devil's Lake and the Turtle Mountains; 2 of 16 reports; 12.5%). I obtained fisher detections at all rivers and regions surveyed in 8 of 12 counties; however detection rates were higher in the northeast and lower in the southeastern part of the state. Based on verified reports and survey data the current distribution of fishers in eastern North Dakota was found to be primarily within the northeast corner of the state with few detections and reports occurring south of the Goose River or west of the Pembina Hills.

Simulation modeling indicated the landscape of eastern North Dakota contained 5% and 10% of preferred fisher habitat depending on the base map, but fishers were predicted to occupy less than was available varying by dispersal distance (20-50% at 10-km dispersal distance, 55-79% at 30-km dispersal distance, and 79% at 75-km dispersal distance) over 250 years. Habitat potential estimates ranged from 97.3 (±7.9 SE) females at 10 km dispersal distance to 591.0 (±7.5 SE) females at 75-km dispersal distance. The model scenarios were better at predicting occupancy of large patches than small fragmented patches and identified regions where populations were most likely to persist in the future. Overall the results and predictability of the model would be greatly improved through additional behavioral studies in the region.

Although, fishers were detected throughout the study area during both years of sampling along the Red River, unexpectedly, detection rates were much higher in 2009 than 2008 (28 out of 35 sites [80%] and 25 out of 57 sites [44%], respectively). The outcome of the study demonstrates that fishers were able to persist in the region following a severe, multi-month flood that inundated most of the forest habitat.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Thomass Serfass, for being instrumental in my education at Frostburg. Steve Loughry was invaluable to me in the field and back at FSU. The other FSU graduate students were helpful in their discussions and advice. My family and friends offered encouragement and support. Nathan Schumaker provided me with advice and model assistance, and my project greatly benefited from our interactions. My committee members Dr. Dorothy Fecske and Dr. Daniel Fiscus provided helpful critiques and guidance on my thesis. The North Dakota landowners permitted land access, and also provided hours of conversation and enjoyment. The people of eastern North Dakota will always have my respect and gratitude. Finally, thank you to the Biology Department at FSU and the North Dakota Game and Fish Department for giving me the opportunity to complete my Masters and conduct research in North Dakota.

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CHAPTER 1

The Fisher: Introduction

Description

The fisher (*Martes pennanti*) is a mesocarnivore of the Family Mustelidae (Powell 1981, 1993, Douglas and Strickland 1987). Fishers have dark brown, almost black, fur and may have a few white patches of fur near the neck and throat (Powell 1981, Hazard 1982, Nowak and Paradiso 1983, Forsyth 1985, Powell et al. 2003). They have stout legs, long, dense bodies, slightly rounded ears, and long, bushy tails (Godin 1977, Hamilton and Whitaker 1979, Strickland et al. 1982, Forsyth 1985, Douglas and Strickland 1987). Fishers have unsheathed, semi-retractable claws that assist them in climbing (Powell 1981, Forsyth 1985, Powell et al. 2003).

Fishers are sexually dimorphic (Godin 1977). Adult males range from 90 to 120 cm in length and typically are much larger than females, which range 75 to 95 cm in length (Godin 1977, Hamilton and Whitaker 1979, Moors 1980, Strickland et al. 1982, Forsyth 1985). In both sexes, the tail comprises approximately 30 percent of the total body length (Powell 1981, Nowak and Paradiso 1983, Powell et al. 2003). The weight of a fisher generally is between 3.5 to 5.5 kg for males and 2.0 to 2.5 kg for females (Powell 1981, Powell et al. 2003).

Male and female fishers are capable of breeding at 1 year of age (Eadie and Hamilton 1958, Wright and Coulter 1967, Mead 1994); however, males >2 years have greater reproductive success (Wright and Coulter 1967, Mead 1994). Fishers exhibit delayed implantation, which results in a 10-11 month gestation period (LaBeree 1941, Hall 1942, Mead 1989) followed by the birth of a typical litter of 2-3 altricial kits (Hall

1942, Hazard 1982, Mead 1994). Breeding occurs in the spring (March – April) approximately 3-8 days after the female gives birth (LaBeree 1941, Hall 1942, Douglas and Strickland 1987).

Distribution and Range

Fishers occur only in North America (De Vos 1952, Powell 1981, 1993, Hazard 1982, Powell et al. 2003). Their historical range extended across Canada, southward into portions of California, Montana, Idaho, Wyoming, New Mexico, North Dakota, Minnesota, Illinois, Iowa, Tennessee, and the northeastern United States (Hagmeier 1956, Powell 1993). Within these regions, their range was restricted to landscapes with adequate canopy cover or forested areas (Brander and Books 1973).

The original widespread distribution of fishers declined during the late 19th century (Hagmeier 1956, Balser and Longley 1966, Powell 1993). At that time, remaining populations in the United States occupied forests in Maine, California, Minnesota, New York, and New Hampshire (Brander and Books 1973). The species decline was linked to forest fragmentation (logging, urbanization, and fires), trapping (Brander and Books 1973, Strickland et al. 1982, Douglas and Strickland 1987, Powell 1993), and predator control (Douglas and Strickland 1987). Fisher populations re-established in many areas during the mid 20th century (Hagmeier 1956), following a reduction in the price of pelts (Balser 1960, Irvine et al. 1964, Balser and Longley 1966), restrictions on trapping, government protection of forested areas, and the initiation of reintroduction projects (Irvine et al. 1964, Douglas and Strickland 1987). For example, fishers were translocated from various locations to 6 Canadian provinces and 13 states between 1947 and 2002 (Ombalski 2006). Although the distribution of fishers has expanded considerably since the 1950's, portions of the historic range remain unoccupied (Hagmeier 1956, Gibilsco 1994).

In North Dakota, fishers historically occurred in the northeast region of the state including the Park, Pembina, Turtle, and Salt (Forest) Rivers, Grand Forks, and the Hair Hills (Pembina Hills), with unverified sightings occurring within the forests of the Turtle Mountains and the Souris and Mouse Rivers (Bailey 1926). Records from 1801-1808 show that fisher pelts were the fourth most abundant type of fur sold from the Red River Valley region, preceded by beaver (*Castor canadensis*), gray wolf or coyote (*Canis lupis*, *Canis latrans*), and red fox (*Vulpes vulpes*) pelts (Bailey 1926). However, high fisher fur sales did not persist in the region, and the species was likely extirpated by 1900 (Bailey 1926, Adams 1961). Recently (post 2002), there has been an increase in verified fisher sightings in the form of trail camera photographs and carcasses of roadkilled, trapped, snared, legally, and illegally shot animals (D. Fecske, North Dakota Game and Fish Department, unpublished data). However, the current status and distribution of the fishers in North Dakota was unknown at the time of our research. Animals were believed to have originated from Minnesota based on sightings and trapping records indicating western movement trends within Minnesota (Berg and Kuehn 1994, Erb 2005, 2008, Sovada and Seabloom 2005).

Habitat

Fishers' ability to live in various habitats is influenced by weather, availability of food, and den sites (tree cavities), beyond the basic requirements of canopy cover and species composition and structure (Strickland et al. 1982, Douglas and Strickland 1987, Allen 1993). Fishers typically are associated with coniferous (De Vos 1951, Allen 1983, Buskirk and Powell 1994) and mixed (deciduous and coniferous) landscapes (Godin 1977, Forsyth 1985, Arthur et al. 1989*a*), they also occupy second growth stands and recently treated/burned areas (Godin 1977, Hazard 1982, Allen 1983). Proulx et al. (1994) determined that in Alberta, translocated fishers occurred in mixed forest (deciduous and coniferous), scrub, marsh, wetland, and grassland habitats, but most frequently occupied contiguous deciduous forest. Fishers in Maine were detected in coniferous and mixed forests more than in deciduous stands (Arthur et al. 1989*a*).

One habitat feature fishers avoid is open areas (Coulter 1966, Kelly 1977, Powell 1980, Forsyth 1985, Arthur et al. 1989*a*, Buskirk and Powell 1994); however, travel through open areas to reach forest patches has been documented (Arthur et al. 1989*b*). Open areas are prevalent in fragmented landscapes and may occur between areas of suitable habitat patches. If suitable patches are fragmented, they are more likely to be reached when connected by non-preferred forest than by open areas (Buskirk and Powell 1994). In fact, fragmented forest patches may not be used if they are separated substantially by open areas (Buskirk and Powell 1994). Fishers in north-central Idaho avoided open areas, but did use corridors with minimal cover (Jones and Garton 1994). Fishers in California used forested areas with large amounts of cover (>60%) >50 percent of the time and rarely used open areas with minimal cover ($\leq$39%; Zielinski et al. 2004).

Another landscape feature fishers may avoid is open water, even when frozen (Coulter 1966, Kelly 1977). Although fishers will swim to reach forested patches, they do not commonly cross open water (De Vos 1952). Their avoidance of water may not be an aversion to water, but to the lack of cover (Coulter 1966, Kelly 1977). Fisher home ranges and travel routes typically include wetlands or streams (Ingram 1973, Kelly 1977), but waterways >10 m in width can become barriers for movement (Kelly 1977).

Foraging

Fishers generally consume prey based on abundance or accessibility, with small mammals such as hares and rabbits (Leporidae), squirrels (Sciuridae), shrews (Soricidae), and mice (Muridae) comprising much of the diet (De Vos 1952, Balser 1960, Coulter 1966, Powell 1980, Douglas and Strickland 1987, Arthur et al. 1989*a*, Powell and Zielinski 1994). Porcupines (*Erethizon dorsatum*) also are an important food source for fishers (Coulter 1966, Powell and Brander 1977, Powell 1980, Powell and Zielinski 1994). Also, fishers consume berries, nuts, birds, and carrion when present (Balser 1960, Coulter 1966, Kelly 1977, Douglas and Strickland 1987, Arthur et al 1989*a*).

Fishers use different travel patterns depending on the type of prey they are pursuing; movement can be fairly straight, include directional changes such as side to side and back and forth movements, or follow circular formations (De Vos 1952, Coulter 1966, Powell and Brander 1977, Powell 1980, Allen 1983, Arthur et al. 1989*a*). Although fishers have arboreal capabilities, prey typically is pursued on the ground (Brander and Books 1973). Because different prey species occur in different habitats, a fisher's foraging strategy is influenced by both the landscape and available prey (Powell 1980).

Activity Patterns

Fishers typically are solitary animals, except during the breeding season, when males and females associate, and post parturition, when females and their kits den and travel together (Coulter 1966, Wright and Coulter 1967, Ingram 1973). Fishers once were thought to be nocturnal (De Vos 1952, Coulter 1966), but recently have been observed to display crepuscular (Kelly 1977, Arthur and Krohn 1991) and diurnal activity patterns (Weir and Corbould 2007). Activity patterns may be affected by temperature, prey abundance, sex, breeding period, habitat (Weir and Corbould 2007), or age (Arthur and Krohn 1991).

Fishers undergo daily rhythms of activity and inactivity, with the number of active periods ranging from 1-3 and lasting between 1-5 hours each (Powell 1979, 1993). Straight-line movements of 2.5-5.0 km between resting sites were observed in Michigan (Powell 1979), New Hampshire (Arthur and Krohn 1991), and Maine (Kelly 1977) for males. Females typically moved shorter distances between resting sites, ranging from 1.5-3.0 km, in these regions (Kelly 1977, Arthur and Krohn 1991). Both sexes show variation in the distance moved depending on season and location (Kelly 1977, Arthur and Krohn 1991). One example of this is that males display greater movements in spring when they are searching for females (Leonard 1986).

Adult fisher activity currently is not greatly affected by predators (Hamilton and Whitaker 1979), but their association with cover suggests that they historically were predated. Kills of the young by other carnivores has been documented (Webster et al. 1985) and humans may pose the greatest threat to fishers through trapping, hunting, and increased urbanization (Hamilton and Whitaker 1979, Powell 1993).

Communication

Because fishers generally travel alone, their primary mode of intraspecific communication is scent marking (Leonard 1986). Territory boundaries are delineated using combinations of excretions from scent glands, (Strickland et al. 1982, Forsyth

1985, Leonard 1986, Douglas and Strickland 1987, Powell 1993) urine, and feces (Coulter 1966, Leonard 1986, Powell 1993). Scent marking is of particular importance during the breeding season (Coulter 1966, Wright and Coulter 1967, Leonard 1986, Frost et al. 1997) when scent glands located on the hind feet expand (Frost et al. 1997). The escalation in scent marking during the breeding season likely is influenced by the abundance of transient males seeking females (Leonard 1986).

Home Range

Fishers have extensive home ranges, with males covering larger areas than females (Powell 1994, Zielinski and Schmidt 2004). Home range size varies by region (Douglas and Strickland 1987), but the average size across multiple studies has been identified as 40 km^2 for males and 15 km^2 for females (Powell 1993). The difference in home range area between males and females may be related to body size energy requirements (Powell 1994). Patchiness may affect home range size because multiple patches may be required to obtain the necessary resources (Powell 1994), making the home range larger than if it were a continuous patch. Fishers display intrasexual territoriality, in which males and females may overlap in range but animals of the same sex will not (Arthur et al. 1993, Powell 1994). Distinct territories and home ranges force male and female juvenile fishers to disperse into unoccupied areas (Arthur et al. 1993).

Dispersal

Dispersal is a process that promotes expansion of populations. Among mammals, dispersal has 2 main results: to improve genetic fitness through increased gene flow and to reduce competition over resources (Feldhamer et al. 2007). Range expansion occurs when populations reach carrying capacity or individuals with high dispersal rates begin to inhabit areas near the periphery of their range (Holt 2003). New areas are reached using corridors that previously fell outside the animal's range, and small habitat patches are used to facilitate travel to larger patches (Keitt et al. 1997). The importance of these small patches depends on the species' dispersal distance and other barriers that may inhibit expansion (Keitt et al. 1997). Movement between new patches may allow species to re-establish areas from which they have been extirpated. However, the ability of populations to be successful is limited by the slow process of expansion and multiple other factors influencing dispersal (Arthur et al. 1993), energy loss, resource abundance, and distance between patches (Zollner and Lima 1999).

Fishers exhibit natal dispersal, which has been observed at varying times of the year. Studies show that kits typically leave their mother at around 5 months of age (Coulter 1966, Douglas and Strickland 1987, Arthur and Krohn 1991, Arthur et al. 1993); however, family units have been observed to remain intact for up to 1 year (De Vos 1952). Dispersal to new areas does not occur until a few months after the kits leave their mother (Coulter 1966, Douglas and Strickland 1987, Arthur and Krohn 1991, Arthur et al. 1993), and establishment of home ranges may not occur until 1 year after birth (Arthur et al. 1993). Although natal dispersal is known to occur, it is difficult to monitor in species with low population densities, such as the fisher (Gardner and Gustafson 2004), and simulation modeling may guide and assist project designs, data analyses, and overall conclusions.

Survey Techniques

Distribution and analysis of fisher and other rare carnivore populations historically depended on data provided by trapping records and other verified sightings

(Zielinski and Kucera 1995), primarily because of the high cost of radio telemetry and mark/recapture studies (Douglas and Strickland 1987). New non-invasive methods such as enclosed track plates and camera stations currently are used to assess populations (Zielinski and Kucera 1995). Track plates are aluminum plates positioned on the bottom of a small enclosure with an open end (Zielinski and Kucera 1995). The plates are covered with some type of imprinting medium, as well as contact paper if the tracks are to be kept (Zielinski 1995, Ray and Zielinski 2008). Bait is placed at the end of the track plate near the side of the enclosure that is blocked or closed, to draw the animal into the device (Ray and Zielinski 2008). Remote cameras are secured to trees or other stationary units and positioned with the bait in the frame to obtain photographs of the target species (Kays and Slauson 2008). These assessments provide reliable presence-absence data on species (Zielinski and Kucera 1995); moreover, cameras provide additional information such as time of day, behavior, and age (Kays and Slauson 2008).

Modeling Techniques

Landscape level analysis is used for covering large regions and the patterns and processes they contain (Turner 2005). Due to fishers' extensive home ranges and the large study area (in my study, all suitable habitat in eastern North Dakota), a landscape approach is required to assess the species population. Landscapes were analyzed based on heterogeneity and the resulting effects on the fisher population. Heterogeneity in landscapes is influenced by abiotic and biotic processes (such as climate, soils, competition, and predation), disturbances, and human uses (Turner et al. 2001, Turner 2005). Landscape heterogeneity is important to organisms because it affects their behavioral patterns (Gehring and Swihart 2004, Turner 2005) by influencing their movements, due to habitat preference, food availability, and mortality rates.

To study a population's movement at the landscape level, models are used to simulate the population. Spatially explicit population models (SEPMs) involve replicating a particular species population within a real (mapped) landscape containing heterogeneous components (Dunning, Jr. et al. 1995). SEPMs are important because they allow scientists to assess animal behavior and their responses to landscapes at large extents (Dunning, Jr. et al. 1995).

Objectives

The intent of my project was to assess the current and potential future distribution of fishers in the eastern half North Dakota. Specifically, I used field surveys to determine the distribution and habitat associations of the population. I subsequently used a spatially explicit population model to assess and derive various scenarios for predicting movement corridors, habitat potential estimates over 250 years, and distribution (current and potential future) of the population. Finally, I assessed the predictive qualities of the model by comparing the current distribution of the population (based on survey results and verified reports) to that predicted by the model.

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CHAPTER 2

VERIFIED REPORTS, FIELD SURVEYS, AND SIMULATION MODELING

Abstract

Fishers (*Martes pennanti*) were extirpated from North Dakota during the late 19th century; however, there has been an increase in verified fisher sightings over the past 10 years, which likely includes individuals from an expanding Minnesota population. I evaluated fishers' current and projected future distribution in the eastern half of North Dakota through verified reports, presence-absence field data, and simulation modeling. Verified reports were obtained from the North Dakota Game and Fish Department and field data was obtained from population surveys conducted during the summers of 2008 and 2009 using enclosed track-plates and remote cameras. Detection devices were placed within the minimal and fragmented forests of eastern North Dakota including the Forest, Goose, Park, Pembina, Red, Sheyenne, Tongue, and Turtle Rivers and the Pembina Hills. Fishers' potential distribution and occupancy were simulated using the model, HexSim, based on population parameters and habitat preferences determined from previous studies. Multiple scenarios were conducted, which differed in dispersal distance (10 km, 30 km, and 75 km) and habitat categories (forest vs. non-forest and 11 habitat categories). Verified reports were concentrated in the northeast portion of the state (12 of 16 reports; 75%) and were less frequent farther south (Sheyenne National Grasslands; 2 of 16 reports; 12.5%) and west (Devil's Lake, and the Turtle Mountains; 2 of 16 reports; 12.5%). I obtained fisher detections at all rivers and regions surveyed and in 8 of 12 counties surveyed, however detection rates were highest in the northeast and lowest in the southeast. Based on verified reports and survey techniques the current distribution of

fishers in eastern North Dakota was found to be primarily within the northeast corner of the state with few detections and reports occurring south of the Goose River. The model predicted that the landscape of eastern North Dakota contained 5% and 10% of preferred fisher habitat depending on the base map, but fishers were predicted to occupy less than was available varying by dispersal distance (20-50% at 10-km dispersal distance, 55-79% at 30-km dispersal distance, and 79% at 75-km dispersal distance) over 250 years. Habitat potential estimates ranged from 97.3 (±7.9 SE) females at 10 km dispersal distance to 591.0 (±7.5 SE) females at 75-km dispersal distance. The model scenarios were better at predicting occupancy of large patches than small fragmented patches and identified regions where populations were most likely to persist in the future. Overall, the results and predictability of the model would be greatly improved from additional behavioral studies in the region.

Introduction

The fisher (*Martes pennanti*) is a forest-dependent mesocarnivore (Powell 1981, Douglas and Strickland 1987, Powell 1993). The original distribution of fishers in North Dakota was limited because of the paucity of forested areas in the landscape. Nonetheless, fishers historically were reported to occupy riparian forests along the Red River of the North (hereafter, Red River) drainage, but were extirpated by the early 1900s, presumably from overtrapping (Bailey 1926, Adams 1961). Recently (post-2002), there has been an accumulation of evidence indicating that fishers may be occupying portions of the Red River drainage in North Dakota, including individuals that were road-killed or inadvertently caught in traps set for other furbearers (North Dakota Game and Fish Department, unpublished data) however, these reports are scattered and may not represent the extent of the population. Fisher presence in North Dakota appears to be derived from the expansion of a well-established fisher population in Minnesota (Berg and Kuehn 1994, Erb 2005, 2008, Sovada and Seabloom 2005).

Fishers were never extirpated from Minnesota; a population remained in the extreme northeast region (Lake and Cook Counties) and in 1968 fifteen fishers were translocated from the northeast to Itasca State Park (Hubbard County) in the northcentral part of the state (Berg 1982). Although a trapping season was initiated in Minnesota in 1977–1978 (Berg 1982), the population has been steadily increasing since the 1990s and fishers have been verified in the limited forests of western Minnesota (Erb 2005, 2008). Historic records of fishers in North Dakota are less detailed than Minnesota, but indicate that fishers mainly were limited to the northeast region including the Park, Pembina, Turtle, and Salt (Forest) Rivers, Grand Forks, and the Hair Hills (Pembina Hills), with unverified sightings occurring within the forests of the Turtle Mountains and the Souris and Mouse Rivers (Bailey 1926).

The current and potential distribution of fishers in North Dakota is unknown. Verified reports collected by the North Dakota Game and Fish Department (NDGF) and presence-absence sampling can be used to estimate fishers' current range, but cannot in itself be used to predict the potential future status and distribution of the population. However, computationally intensive simulation modeling techniques, such as spatially explicit population models (SEPMs), can predict areas of occupancy and expansion based on population parameters and landscape conditions over designated time periods (Dunning, Jr. et al. 1995, Kenward et al. 2001, South et al. 2001). SEPMs have been used to simulate species expansion (Lurz et al. 2001), movement and dispersal (South et al. 2001, Gardner and Gustafson 2004), occupancy (Rushton et al. 1997), and habitat use (Rhodes et al. 2005) for a suite of terrestrial vertebrate species.

I assessed current distribution of fishers in North Dakota based on verified reports and field data, and projected the potential future status and distribution of the population with simulation modeling. Verified reports and field data (presence-absence sampling) provided a representation of the current distribution of fishers in North Dakota and known distribution and demographic data for fishers in Minnesota was used to design and calibrate the simulation model scenarios to represent the projected future distribution. I predicted that the population reached the Red River by following forested riparian corridors. Following the same assumption, I anticipated that the dispersion of fishers in North Dakota ultimately would include the Pembina Hills and the Turtle Mountains. I also predicted that the size of the fisher population would be limited by the amount of suitable habitat.

Methods

Study Area

My study area included the deciduous forests of eastern North Dakota, which occur predominantly as fragmented patches along riparian areas (Fig. 2.1). Within this region I focused primarily on forested sections of the Red River drainage and its tributaries (Forest, Goose, Park, Pembina, Red, Sheyenne, Tongue, and Turtle Rivers), and also the upland forested areas of the Pembina Hills (Table 2.1). The Red River flows northward approximately 635 km (almost double the straight line distance) from its start at the confluence of the Bois de Souix and Ottertail Rivers at Whapeton, North Dakota and Breckenridge, Minnesota to the Canadian line and creates the Minnesota and North

Dakota border (Renard et al. 1986, Hagen et al. 2005). The Pembina Hills encompass 1,140 km^2 in the northeast region of the state (Bryce et al. 1998). This area is characterized by steep slopes and woodlands, and contains the origins of 3 tributaries of the Red River (Pembina, Tongue, and Park Rivers [Bryce et al. 1998]).

Historically, the portions of eastern North Dakota and western Minnesota encompassing the Red River drainage consisted of mainly tallgrass prairie, much of which has now been replaced with agricultural fields and other development (Renard et al. 1986, Albert 1995, Hagen et al. 2005). The forested portions of the region historically were distributed as semi-contiguous, fragmented patches, mostly limited to riparian areas (with the exception of the Pembina Hills in North Dakota), a condition that persists today (Renard et al. 1986, Albert 1995, Hagen et al. 2005). Common tree species occurring in the bottomland riparian forests of North Dakota are green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoids*), and willow (*Salix* spp. [Bailey 1926, Renard et al. 1986, Hagen et al. 2005, Sovada and Seabloom 2005]) with understories of hawthorn (*Crateagus* spp.) and gray dogwood (*Cornus foemina* [Renard et al. 1986]). The upland forests in North Dakota contain aspen (*Populus tremuloides*), bur oak (*Quercus macrocarpa*), balsam poplar (*Populus balsamifer*), box elder (*Acer negundo*), and paper birch (*Betula papyrifera*) and have understories of juneberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), gooseberry (*Ribes missouriense*), and raspberry (*Rubus* spp. [Renard et al. 1986, Hagen et al. 2005, Sovada and Seabloom 2005]). In Minnesota the floodplain extends approximately 18 km from the Red River border after which the landscape contains deciduous forests and eventually continuous mixed forest in the north and northeastern regions of the state (Albert 1995).

Model

I used the simulation model HexSim 1.5.10 (Environmental Protection Agency, Corvallis, Oregon, http://www.epa.gov/hexsim), formerly PATCH, to predict fisher movement and occupancy into and within North Dakota. HexSim is a SEPM for animal dispersal, which is particularly applicable for terrestrial populations (Schumaker 1998). HexSim has been used to model movement and distribution patterns of a variety of vertebrate species, including wolves (*Canis lupus*; Carroll 2003, 2006, Stronen 2009), kangaroo rats (*Dipodomys* Spp.; N. H. Schumaker, Environmental Protection Agency, personal communication), and northern spotted owls (*Strix occidentalis caurina*; U.S. Fish and Wildlife Service 2008). HexSim uses input maps and demographic parameters of species to simulate life cycles (Fig. 2.2). Each variation of the model is called a scenario, which results in an output of a population's success in a given landscape over a set number of years. Scenarios require spatial data (HexMap), time series (number of years and replicates), population definitions (e.g., initial number of individuals, initial placement, home range size, habitat requirements, traits and accumulators, and affinities), and life cycle events (e.g., age structure, survival rates, reproduction rates, movement criteria, interactions, and introductions). Movement, occupancy, and overall success are simulated throughout the landscape and can be displayed and analyzed using a simulation viewer, population census data, and report and tally generators. Simulations can be viewed in HexSim or exported as shapefiles and tally data for use in ArcMap.

Procedure

I used 3 techniques to assess the current and projected future fisher distribution in North Dakota: 1) NDGF verified reports from 2002–2007, 2) presence-absence field data collected during the summers of 2008 and 2009, and 3) simulated occupancy and habitat potential estimates obtained from HexSim. Verified reports and field data were used to establish the current distribution of fishers and to evaluate the efficacy of HexSim scenarios in predicting the distribution of fishers over a 250-year period.

Verified Reports

Twenty-five reports of fisher occurrences were documented by NDGF from 1976 to 2007. I only used verified reports with known global positioning system (GPS) coordinates and carcasses (16 of the 25 reports; all occurring from 2002-2007). Carcasses were of shot, snared, trapped, and road-killed fishers. Date, gender, and location were recorded for all individuals.

Field Data

I used 2 types of detection devices—remote cameras (Cuddeback ® NoFlash, Expert, and Excite; Non Typical, Inc., Greenbay, WI and DLC ® Covert II Assassin; DLC Trading Co, Llc., Lewisburg, KY) and enclosed track-plates (Zielinski and Kucera 1995)—to survey for fishers in the riparian and upland forests of the study area. I monitored 144 unique sites from 16 June–1 August 2008 and 163 unique sites from 1 June–21 August 2009, with 307 unique sites over the combined 2 years (Fig. 2.3). I used both detection devices in 2008, either individually or in combination (3 sites with a remote camera only, 35 sites with a track-plate only, and 106 sites with both detection devices), but only cameras were used during 2009. At stations with both a camera and an enclosed track-plate, the camera was positioned so that the area photographed included the entrance of the enclosed track-plate. At each station I used beaver meat, and lures comprised of beaver castor and skunk essence as attractants. The beaver castor was mixed with glycerol and placed next to the bait in the center of the coverage area of a camera or inside a track-plate. A cotton swab was dipped in the skunk essence, placed in a perforated film canister, and hung from a nearby tree with fishing line. Except for the Pembina Hills, survey sites were located along rivers and within the riparian forest. The Pembina Hills do not contain a single forested riparian corridor, but rather more continuous forest extending beyond waterways; therefore a least cost path (LCP) line (based on fisher habitat preferences) was created in ArcMap 9.3 to determine the placement of survey sites (see Appendix A).

In the summer of 2008 a pilot phase (15 sites) and 4 cycles (roughly 40 sites each) of sampling was conducted. A cycle consisted of placement of sampling devices (typically 40 per cycle) for a 6-10 day period, with re-baiting occurring approximately midway through a cycle—about 3 to 5 days. The initial focus of the study was the Pembina, Red (north of Grand Forks), Tongue, and Turtle Rivers. I also surveyed portions of the Forest, Park, Red (south of Grand Forks), and Sheyenne rivers, but less intensively. Stations were set-up in a semi-systematic matter to ensure representation of forested patches throughout the length of the river corridors included in the survey areas.

In summer 2009, 4 cycles were conducted; each cycle consisted of roughly 50 sites being surveyed for 14 days with a re-baiting event on day 7. Areas were surveyed alternating between the north (Forest, Park, Pembina, Red [north of Grand Forks] Tongue, and the Pembina Hills) and south (Goose, Red [south of Grand Forks], Sheyenne, and Turtle Rivers) regions of the study area. Stations were systematically placed along the riparian forests or LCP line of the Forest, Park, Red (south of Fargo) and Sheyenne Rivers and the Pembina Hills. However stations along the Goose, Pembina, Red (north of Fargo), Tongue, and Turtle Rivers were sampled based on patch size. Patches were divided into 4 categories: small (0-50 ha), medium (50-250 ha), large (250-500 ha), and x-large (500+ ha). Patches included in the study were selected through stratified random sampling using Hawths Tools in ArcMap 9.3 to ensure that patch size categories along each river were representatively sampled.

Detection rates were defined as the number of detection sites divided by the total number of sites. Detection locations were compared to the occupancy predicted by the model to assess model input parameters and efficacy.

HexSim Scenarios

I started the modeling process by simulating the dispersal of fishers from extreme northeast Minnesota (where the population was limited to in the early 1900s; Balser 1966, Berg and Kuehn 1994) to the Red River (Minnesota–North Dakota border). To parameterize the model I used Minnesota trapping data (Erb 2005, 2008), population estimates (e.g., approximately 6,000 females; J. Erb, Minnesota Department of Natural Resources, unpublished data), and Minnesota habitat data (Gap Analysis Program [GAP] data) reclassified into 11 habitat categories (cropland, prairie, planted perennials or grasses, wetland, lacustrine, riverine, shrubland, woodland, barren, developed-high, and developed-low) and ranked according to their suitability to fishers. The first scenario included only Minnesota and simulated the expansion of fishers westward. The model was calibrated by completing multiple HexSim scenarios until the results matched expansion rates (arrival from eastern Minnesota to North Dakota-Minnesota border over

100 year time period) from trapping data (Erb 2008). The population parameters (e.g., age specific birth rates and survival rates; see Appendix B) from outcomes of the Minnesota-only simulations were then applied to the eastern half of North Dakota to determine potential dispersal routes and overall potential distribution of fishers in North Dakota.

The habitat maps (eastern half of North Dakota and the north half of Minnesota) were created using GAP data in ArcMap 9.3 and were reclassified into the same 11 land cover categories as the Minnesota input map. I exported the habitat maps as bitmaps and imported them into HexSim to produce HexMaps via the HexMap generator function. I created 2 landscape HexMaps and 1 source HexMap for each habitat map of eastern North Dakota and northern Minnesota. The landscape maps contained values for all cells and the source maps were the location from which the population originated (northeast Minnesota for the northern Minnesota simulations and western Minnesota for the eastern North Dakota simulations). The North Dakota and Minnesota landscape HexMaps were comprised of forest and non-forest regions and 11 habitat categories (Fig. 2.4, 2.5). The original data set had 30 m^2 resolution (0.09 ha). Prior to creating HexMaps, I ranked habitat types in each 0.09 ha cell from 0-10 (0 = NoData and least preferred to 10 = most preferred) based on fisher habitat preferences (Arthur et al. 1989, Buskirk and Powell 1994, Jones and Garton 1994, Proulx et al. 1994; Table 2.2). Databases of ranked habitats were then reconstructed to hexagon maps with 3000 m width (779 ha). Each hexagon was assigned the average value of all ranked 0.09 ha cells that comprised it. Resulting HexMaps used for landscape simulation modeling also contained values ranging from 0 to 10, in which hexagons containing a value of 10 represented most preferred fisher habitat.

Female-only models, which assumed male presence within the landscape, were completed on the study area under various scenarios. I completed multiple scenarios on North Dakota Map-1 (forest vs. non-forest; Fig. 2.4) and Map-2 (11 habitat categories; Fig. 2.5) and used the same source map of western Minnesota to initiate simulations for both habitat maps. Map-1 and Map-2 were combined with population definitions, life cycle events, and a specific time series. Population dynamics included age structure, reproduction rates (Table B1, Appendix B), survival rates (Table B2, Appendix B), movement criteria (dispersal distance), and introduction (continuous dispersal); these values were consistent for all simulations, except for the dispersal distance in the movement criteria event. Constant population definitions and cycle event inputs were calculated from the initial Minnesota scenarios (see Appendix B). Dispersal distances were assessed at 10-km, 30-km, and 75-km maximums, which were determined based on juvenile dispersal distances (Leonard 1980, Raine 1982, 9.5-60.0 km, females and males; Arthur et al. 1993, range 5.0-18.9 km, females). Straight-line distances were used to define the distance traveled and the model calculated total distance traveled (can be side to side, not always straight line) thus dispersal maximums were set to slightly larger values than the observed study values. The initial population inputs defined were the number of individuals, initial placement, home range size, resource values required (habitat quality), and specific traits (age class, group member [individual with a home range] or floater [individual without a home range]). All scenarios started with 250 individuals expanding from western Minnesota and allowed fishers to have home range sizes from 7.9–23.3 km^2; average female home range size is 15 km^2 (Powell 1993). Habitat quality remained consistent throughout all simulations for the habitat maps used—in Map-1 available habitat included hexagons containing forest (hexagon value >1) and in Map-2 available habitat included hexagons containing forest and categories located near or between forest (hexagon value >4.2). I conducted 100 simulations of each fisher population scenario for 250 years in eastern North Dakota with fishers initially and continually expanding from western Minnesota. After final simulations occupancy was compared to verified detections and expansion to assess the models' ability to predict the movement and success of fishers in North Dakota. Using the simulation viewer and tallies in ArcMap, I observed the routes taken by fishers and documented the order of occupancy at Devil's Lake, the Pembina Hills, the Sheyenne National Grasslands, and the Turtle Mountains, which represent the largest patches of forest in central and eastern North Dakota (Fig. 2.6). Mean patch size of HexMaps was calculated by generating 100 random points within the forest using Hawths Tools in ArcMap. The percent of forest occupied at year 10 (approximate time fishers have been in North Dakota), habitat potential estimates, mean home range size, and the model's prediction capability of an area with multiple fisher detections (all tributaries from the Goose river north) were determined for 3 dispersal distance scenarios on Map-1 and Map-2. Maximum occupancy was defined as the peak occupancy of each specific scenario and did not mean that all available habitat was occupied. Habitat potential estimates were generated by HexSim outputs and also calculated based on the available habitat and the mean home range size used by females.

Results

Verified Reports and Field Data

Verified fisher reports were documented in 8 counties (Barnes, Benson, Cavalier, Grand Forks, Pembina, Ransom, Rolette, and Walsh) in eastern North Dakota with the majority of reports (12 of 16 reports; 75%) occurring in the northeastern region and fewer occurring in the southeastern (2 of 16 reports; 12.5%) and east central regions (2 of 16 reports; 12.5%). The number of individuals reported per year ranged from 0–5 over the 6-year period (Fig. 2.7 and Table 2.3, 2.4). Sex determination revealed that of the 16 carcasses examined there were 11 males and 5 females (Table 2.3).

Overall fisher detections were obtained at 115 of 307 (37%) sites surveyed in 2008 and 2009 (Fig. 2.3, 2.8). Most detections (109 of 252 sites; 43%) occurred from the Goose River north. One or more detections were obtained at all rivers and regions surveyed (Table 2.5). Fishers were detected in 8 of 12 counties (Cass, Cavalier, Grand Forks, Griggs, Pembina, Steele, Traill, and Walsh counties; Table 2.6) surveyed with the majority of detections being located in the northeastern portion of the state. The number of detections ranged from 67% of sites in Cavalier county (6 of 9 sites) to 0% of sites in Barnes (0 of 5 sites), Nelson (0 of 3 sites), Ransom (0 of 15 sites), and Richland (0 of 8 sites) counties (Fig. 2.9). Based on verified reports and field data the current distribution of fishers in North Dakota encompassed the northeastern region of the state with limited presence further west and south.

Model

Area occupied

Maximum occupancy at the 10-km dispersal distance was reached after 75 years for Map-1 and at year 10 for Map-2. Maximum occupancy at the 30-km dispersal distance was reached at year 150 for Map-1 and year 75 for Map-2, however after year 100 the population decreased. The 75-km dispersal distance reached maximum occupancy at year 10 for both Map-1 and Map-2 (Fig. 2.10, 2.11). Occupancy at dispersal distance 10-km did not vary from year 75 for Map-1 and from year 10 for Map-2 through the end of the 250 year simulations and fishers did not expand beyond the northeast corner of the state (i.e., Pembina Hills and surrounding patches south to the Sheyenne River [Fig. 2.12, 2.13]). However, at the dispersal distance of 30 km females were predicted to occupy the Pembina Hills and the Sheyenne National Grasslands for Map-1 and these areas plus Devil's Lake for Map-2 (Fig. 2.14, 2.15). The populations were predicted to further expand to Devil's Lake and the Turtle Mountains after 50 years for Map-1 and to the Turtle Mountains after 75 years for Map-2, but after 100 years the populations in Map-2 were predicted to no longer occupy areas south such as the Sheyenne National Grasslands. At the 75-km dispersal distance fishers occupied approximately 80% of the forested patches in eastern North Dakota after 10 years and did not expand further during the 250 year simulations (Fig. 2.16, 2.17).

The areas occupied differed by map type and dispersal distance among the various simulations performed within the model at maximum occupancy. For Map-1, 5% (482,422 ha) of the study area was represented as forest and the model predicted 51% (246,035 ha) of the forest to be occupied at 10-km dispersal distances, 79% (382,489 ha) of the forest at 30-km dispersal distances, and 79% (382,489 ha) of the forest available at 75-km dispersal distances (Fig. 2.10). For Map-2, 10% (920,778 ha) of the study area represented available habitat and the model predicted 17% (163,590 ha) of the available habitat at 10-km dispersal distances, 79% (727,586 ha) of the available habitat at 30-km dispersal distances, and 79% (727,586 ha) of the available habitat at75-km dispersal distances (Fig. 2.11).

The mean available patch size for Map-1 was 509.7 (± 41.8 SE) km^2 and the occupied patches had a mean size of 432.6 (±45.0 SE) km^2 and for Map-2 mean available patch size was 503.7 (± 55.0 SE) km^2 and the occupied patches had a mean size of 523.7 (± 50.7 SE) km^2. In contrast, the mean patch size for detection locations was 209.5 (±36.5 SE) km^2.

Habitat Potential Estimate

The habitat potential estimates after 250 years for Map-1 at all dispersal distances were under 250 females, ranging from 97.3 (±7.9 SE) females at the 10-km dispersal distance to 211.2 (±5.4 SE) females at the 75-km dispersal distance (Fig. 2.18 and Table 2.7). At 10-km dispersal distance the habitat potential estimate slowly increased to around 100 females, but never stabilized and gradually continued to increase over the 250 year simulation period. Population success varied considerably at this dispersal distance, with 28% of the simulations resulting in extirpation. At the 30-km dispersal distance the habitat potential estimate reached an asymptote at around 100 females in about 50 years and then slowly increased to about 150 females at around 100 years, remaining near that level throughout the remainder of the simulation. Extirpation occurred in about 18% of the simulations for this dispersal distance. At the 75-km dispersal distance the habitat potential estimate reached a maximum of about 200 females at approximately year 50 and remained relatively constant thereafter. The mean home range sizes ranged from 18.06 (±0.02 SE) km^2 for the 10-km dispersal distance to 18.63 (±0.01 SE) km^2 for the 75-km dispersal distance (Table 2.8). Based on the mean home range used in the model and available habitat, the estimate of habitat potential after 250 years ranged from 258.9 females at 75-km dispersal distance to 263.6 females at 30-km dispersal distance (Table 2.9).

Habitat potential estimates for Map-2 increased over 250 years as dispersal distances increased, ranging from 120.2 (±4.6 SE) females at 10 km dispersal distance to 591.0 (±7.5 SE) females at 75-km dispersal distance (Fig. 2.19 and Table 2.7). At the 10-km dispersal distance the habitat potential estimate reached an asymptote at around 25 years of 100 females and remained consistent throughout the remainder of the 250 year simulations. At the 30-km distance the habitat potential estimate leveled off at about 450 females at year 150 and remained constant thereafter. At the 75-km distance the population increased rapidly and reached the population maximum of roughly 600 females near year 30. Mean home range sizes ranged from 19.59 (±0.03 SE) km^2 for 10-km dispersal distance to 21.08 (±0.01 SE) $km^2$for 30-km dispersal distance (Table 2.8). Based on home range size predicted by the model and available habitat the predicted habitat potential estimate of the area modeled ranged from 436.8 females at 30-km dispersal distance to 470.0 females at 10 km dispersal distance (Table 2.9).

Prediction capability

The predictive qualities of the simulations differed both by map and dispersal distance (Table 2.10, 2.11). The percent of locations where fishers were predicted to occur and were detected ranged from 9% (Map-1, 10 km) to 16% (Map-1, 30 and 75 km). Generally, model scenarios performed best in heavily forested areas such as the Pembina Hills and least effectively in heavily fragmented riparian forests comprised of small isolated patches. For example, the model performed poorly on the upper Red River where fishers were detected at high rates, but few of the detection sites were predicted as suitable for fishers in the model. Overall models performed better at 30-km and 75-km dispersal distances than at 10 km. At higher dispersal distances fishers were able to reach large forested patches (Devil's Lake, Turtle Mountains, Sheyenne National Grasslands) that were suitable, but isolated, whereas these areas were not predicted at shorter dispersal distances. At shorter dispersal distances fishers were predicted to reach the Pembina Hills, but did not establish lasting populations outside of this region. Also, the Sheyenne National Grasslands were identified as occupied at 30-km and 75-km dispersal distances, but at the 30-km dispersal distance the population did not always persist in that area. The model preformed more effectively in displaying regions where fisher populations are likely to persist in North Dakota over multiple years.

Overall, for Map-1 and Map-2 the 10-km scenario predicted the most detections correctly in the Pembina Hills (4 of 8; 50%) and the least detections correctly in the Goose River (0 of 3; 0%), Forest River (0 of 4; 0% [Map-2 only]), Turtle River (0 of 13; 0%), and the 30-km and 75-km scenarios predicted the most detections correctly in the Pembina Hills (6 of 8; 75%) and the least detections correctly in forests along the Red River (4 of 89; 4% [Table 2.9, 2.10]). Verified reports and field data resembled the occupancy predictions at 30-km and 75-km (Map-1 and Map-2) as predicted occupancy showed individuals occurring in the Pembina Hills, Sheyenne National Grasslands, and

Devil’s Lake (and the Turtle Mountains only at 75-km dispersal distance) and all these predicted areas contained verified reports or field detections (Fig. 2.16, 2.17, 2.20, 2.21, 2.22, 2.23)

Discussion

Based on field surveys and verified reports my research established that fishers are no longer extirpated from North Dakota. The current distribution of fishers occurred in the northeast portion of the state, extending from the North Dakota-Minnesota border west to the Pembina Hills and covered the forested portions of the rivers in the region (Forest, Pembina, Red [north of Fargo], Tongue, and Turtle). Detections occurred less frequently in the southeast within riparian forests of the Goose, Red [south of Fargo], and Sheyenne Rivers. Forest composition was similar throughout the study areas and did not appear to have contributed to the lower occurrence of fishers in the southeast (see Table 2.1). I suspect the difference was related to fishers only recently populating the state and not having yet had an opportunity to pioneer the southern portions of the study area.

HexSim 10-km scenarios predicted that for Map-1 and Map-2 fishers would not expand much beyond the Pembina Hills and Devil’s Lake. Available habitats existed beyond these regions, but a maximum dispersal distance of 10-km did not allow females to reach other forested areas to create home ranges. More variation between Map-1 and Map-2 existed at the 30-km dispersal distance. In Map-1 all major forested areas were occupied by year 50 and in Map-2 they were occupied by year 75. However, in Map-2 the population in the south (Sheyenne National Grasslands) was extirpated after 100 years and the population only remained viable in the northern portion of the state. Populations that expand to new areas, with favorable conditions and abundant resources, may initially experience exponential growth before their numbers level off to carrying capacity (Klein 1968, Bolen and Robinson 2003), which could be what this scenario is displaying. The 75-km dispersal distance scenarios were able to occupy all major forested areas at year 10 in Map-1 and Map-2, showing that fishers would currently (expansion began approximately 10 years ago) be established in throughout eastern North Dakota, which is not the case as the Sheyenne River (including the Sheyenne National Grasslands) and the Turtle Mountains had variable occupancy. The Sheyenne National Grasslands contained verified reports (including carcasses [2] and photos [1]), but I did not detect fishers there during my sampling effort and the Turtle Mountains were surveyed during the summer of 2007 with track-plates and remote cameras and no fisher detections were obtained (Bagherian 2008). Based on the area occupied the 30-km dispersal distance best represented verified report and detection locations in Map-1 and Map-2. At this dispersal rate under current conditions of the model the fisher population is expected to be occupying the Pembina Hills and the Sheyenne National Grasslands for Map-1 and these areas plus Devil's Lake for Map-2 (Fig. 2.14, 2.15). The populations were predicted to further expand to Devil's Lake and the Turtle Mountains after 50 years for Map-1 and to the Turtle Mountains after 75 years for Map-2, but after 100 years the populations in Map-2 were predicted to no longer occupy areas south such as the Sheyenne National Grasslands suggesting it may not contain optimal habitat.

Habitat potential estimates over 250 years were found to be variable in their predictions depending on scenario and dependent on continuous dispersal from Minnesota. If continuous dispersal did not occur populations were not likely to remain within the state at any dispersal distance or either habitat map. The largest concentration of females with home ranges existed in the four main forested areas (Devil's Lake, Pembina Hills, Sheyenne National Grasslands, and the Turtle Mountains), but females in between these areas may be important to the population's overall success over time as the distance between these regions is likely too far for an individual fisher to travel during one dispersal event. The habitat potential estimates indicated the number of females that could inhabit the area if specific forested regions are reached, which is dependent on the behavior of the fishers and the specific dispersal distance in the region.

Overall, the model predicted that fishers will be able to expand into forested regions of North Dakota, but their success will be limited by the minimal amount of forest present (as the model predicted mainly large patches as occupied). It is important to note that the model did not predict occupancy (requires a designated home range) along the small fragmented patches of many rivers, but floaters (individuals without home ranges) were present in those areas. However, if the model is correct fragmented forests where in which fishers were detected (e.g., Red River) will not sustain populations overtime and the area occupied will decrease, but if the model is incorrect fishers will continue to occupy fragmented forests along the rivers and the area occupied will increase.

If the model is correct and fishers are inhabiting areas they may not in the future increased mortality (e.g., disease outbreak, population crashes of prey, incidental or regulated trapping, etc.) could isolate the population and cause its extirpation overtime. The fisher population is also highly dependent on the forested area of the Pembina Hills. The Pembina Hills exhibits high occupancy levels and represents the main source of dispersal within the state. If the population decreases in the Pembina Hills re-population of other regions in the state (specifically the Turtle Mountains) is unlikely.

Modeling a species life cycle without specific behavioral data to base the model on causes limitations on its predictability. HexSim inputs were calibrated from scenarios conducted for the fisher population in Minnesota. However, this approach was confounded because habitat conditions in Minnesota differed substantially from those in North Dakota. East of the Red River Valley in Minnesota the state contains contiguous mixed forests (Albert 1995) in contrast to the fragmented forests in eastern North Dakota (Renard et al. 1986, Hagen et al. 2005). Verified reports of fishers and outcomes of my survey efforts demonstrated that fishers were unexpectedly occupying what would be considered unsuitable habitats based on documented fisher habitat use (Allen 1983, Arthur et al. 1989, Buskirk and Powell 1994, Zielinski et al. 2004). In fact, there are no documented studies fishers persisting in small forests, which made parameterizing the model a challenge. Other behavioral limitations were present due to a lack of information on dispersal distance of juveniles, home range size, and diet and resources used. Having specific data on all or any of these factors on fishers in North Dakota would greatly improve the ability of the model and could be obtained through further studies involving marked or radio- or GPS-collared individuals.

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Table 2.1. The proportion of forest in 10-km segments (extending 500 m in each direction) along the rivers surveyed in 2008 and 2009 in eastern North Dakota for fishers. The proportion of forest ranged from 12% on the Forest River to 43% on the Pembina River.

River	**Length (km)**	**Segments**	**Proportion**	**SE**	**Min**	**Max**
Forest	260	27	0.1172	0.0221	0.0025	0.4102
Goose	163	17	0.2252	0.0555	0.0118	0.9966
Park	378	38	0.2487	0.0500	0.0036	0.9906
Pembina	172	18	0.4336	0.0584	0.1951	0.9262
Red N	247	25	0.2043	0.0131	0.0955	0.3334
Red S	410	41	0.2756	0.0203	0.1158	0.9023
Sheyenne	642	65	0.2649	0.0198	0.0343	0.9613
Tongue	122	13	0.2487	0.0551	0.0069	0.7571
Turtle	171	17	0.2264	0.0367	0.0042	0.6289

Table 2.2. HexSim habitat inputs (used to calculate hexagon values) based on known fisher preference (Arthur et al. 1989, Buskirk and Powell 1994, Jones and Garton 1994, Proulx et al. 1994) and habitat present in the eastern half of North Dakota.

Habitat type	**Rank**	**Comments**
Cropland	3	cover at times; used between forest patches
Grass - Planted Perennials	3	cover at times; used between forest patches
Prairie	3	cover at times; used between forest patches
Wetland	5	cover at times; associated with forest
Shrubland	5	cover at times; associated with forest
Lacustrine	1	avoided; may have forest at edges
Riverine	3	cover at times; forest at edges
Woodland	10	preferred habitat
Developed - High	1	avoided; may have trees along roads
Developed - Low	2	cover at times; eg., parks
NoData	0	-

Table 2.3. Sixteen verified fisher reports (carcasses) were obtained in eastern North Dakota from 2002–2007 by the North Dakota Game and Fish Department. The number of reports ranged from 0 to 5 over the 6-year period, with males being more commonly observed (11 males, 5 females).

Year	**Number of Reports**	**Male**	**Female**
2002	1	1	0
2003	0	0	0
2004	4	3	1
2005	5	4	1
2006	4	1	3
2007	2	2	0

Table 2.4. The number of verified fisher reports obtained in eastern North Dakota from 2002–2007 by the North Dakota Game and Fish Department in by county. The number of reports ranged from 1 in Benson, Barnes, Ransom and Rollete counties to 4 in Walsh county.

County	**Number of Reports**
Cavalier	2
Pembina	3
Walsh	4
Grand Forks	3
Benson	1
Barnes	1
Ransom	1
Rolette	1

Table 2.5. The number of fisher survey and detection sites by river from presence-absence sampling conducted during the summers of 2008 and 2009 in eastern North Dakota. Detection rates ranged from 21% on the Goose River to 63% in the Pembina Hills.

River/Region	**Sites**	**Detections**	**Rates**
Goose	14	3	0.21
Forest	12	5	0.42
Park	23	6	0.26
Pembina	26	13	0.50
Pembina Hills	8	5	0.63
Red	89	53	0.60
Tongue	21	11	0.52
Turtle	59	13	0.22

Table 2.6. The number of fisher survey and detections sites in eastern North Dakota during the summers of 2008 and 2009 by county. Detection rates ranged from 0% in Barnes, Nelson, Ransom, and Richland counties to 67% in Cavalier county.

County	**Sites**	**Detections**	**Rates**
Barnes	5	0	0.00
Cass	14	2	0.14
Cavalier	9	6	0.67
Grand Forks	87	34	0.39
Griggs	4	1	0.25
Nelson	3	0	0.00
Pembina	75	37	0.49
Ransom	15	0	0.00
Richland	8	0	0.00
Steele	4	2	0.50
Traill	22	8	0.36
Walsh	61	25	0.41

Table 2.7. Habitat potential estimates of female fishers in eastern North Dakota based on simulations conducted in HexSim over 250 years. The number of females increased with dispersal distance and time in Map-1 and Map-2.

		Year 10	**Year 25**	**Year 50**	**Year 100**	**Year 150**	**Year 250**
		Mean (SE)	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**
Map-1	10-km	14.0 (1.4)	20.1 (3.4)	33.2 (5.5)	50.9 (6.2)	64.6 (7.3)	97.3 (7.9)
	30-km	28.3 (2.2)	54.4 (5.5)	84.0 (7.5)	96.4 (8.2)	108.9 (7.7)	127.7 (8.1)
	75-km	48.7 (2.8)	105.1 (6.67)	175.7 (7.9)	194.7 (7.9)	205.2 (7.3)	211.2 (5.4)
Map-2	10-km	66.0 (4.4)	121.8 (8.6)	132.1 (6.9)	129.4 (5.5)	136.4 (5.9)	120.2 (4.6)
	30-km	69.5 (3.1)	188.8 (10.1)	295.8 (10.2)	411.5 (10.6)	440.3 (7.7)	458.0 (7.7)
	75-km	198.7 (7.9)	493.5 (10.4)	493.5 (10.4)	591.9 (6.1)	598.2 (7.2)	591.0 (7.5)

Table 2.8. Predicted home ranges sizes of female fishers in eastern North Dakota based on simulations conducted in HexSim. Home ranges had set min-max values of 7.9–23.3 km^2 in the model. Predicted home range size ranged from 18.06 km^2 (10-km dispersal distance in Map-1) to 21.98 km^2 (30-km dispersal distance in Map-2).

	Dispersal Distance	**Home Range (km^2)**	**SE (km^2)**
Map-1	10-km	18.06	0.02
	30-km	18.3	0.02
	75-km	18.63	0.01
Map-2	10-km	19.59	0.03
	30-km	21.08	0.01
	75-km	20.73	0.01

Table 2.9. Habitat potential estimates of female fishers in eastern North Dakota derived from the total amount of available habitat and the mean home range estimates of the model. Census estimates were generated from HexSim and represent the predicted population size of simulation replicates.

	Dispersal Distance	**Area Available (km^2)**	**Mean Home Range (km^2)**	**Habitat Potential Estimates**	
				Home Range	**Census**
Map-1	10-km	4824.2	18.1	267.1	97.3
	30-km	4824.2	18.3	263.6	127.7
	75-km	4824.2	18.6	258.9	211.2
Map-2	10-km	9207.8	19.6	470.0	120.2
	30-km	9207.8	21.1	436.8	458.0
	75-km	9207.8	20.7	444.2	591.0

Table 2.10. Survey sites (non-detection and detection) compared to model predictions at 10-km, 30-km, and 75-km dispersal for Map-1. The areas surveyed had the same predicted occupancy at 30-km and 75-km dispersal distances.

		+-[a]		-+[a]		++[a]		--[a]	
River/Region	**Dispersal Distance**	**Sites**	**Percent**	**Sites**	**Percent**	**Sites**	**Percent**	**Sites**	**Percent**
Goose	10 km	-	-	3	21	-	-	11	79
	30 & 75 km	4	29	-	-	3	21	7	50
Forest	10 km	-	-	4	33	-	-	8	67
	30 & 75 km	2	25	1	8	3	25	6	42
Park	10 km	1	4	5	22	1	4	16	70
	30 & 75 km	9	39	3	13	3	13	8	35
Pembina	10 km	6	23	5	19	8	31	7	27
	30 & 75 km	8	31	2	8	11	42	5	19
Pembina Hills	10 km	2	25	1	0	4	50	1	25
	30 & 75 km	3	25	-	-	5	75	-	-
Red	10 km	-	-	57	64	4	4	28	31
	30 & 75 km	-	-	57	64	4	4	28	31
Tongue	10 km	4	19	4	19	5	24	8	38
	30 & 75 km	6	29	2	10	7	33	6	29
Turtle	10 km	-	-	13	22	-	-	46	78
	30 & 75km	7	12	10	16	3	5	39	66
Overall	10 km	13	5	92	37	22	9	125	50
	30 & 75 km	39	15	75	30	39	16	99	39

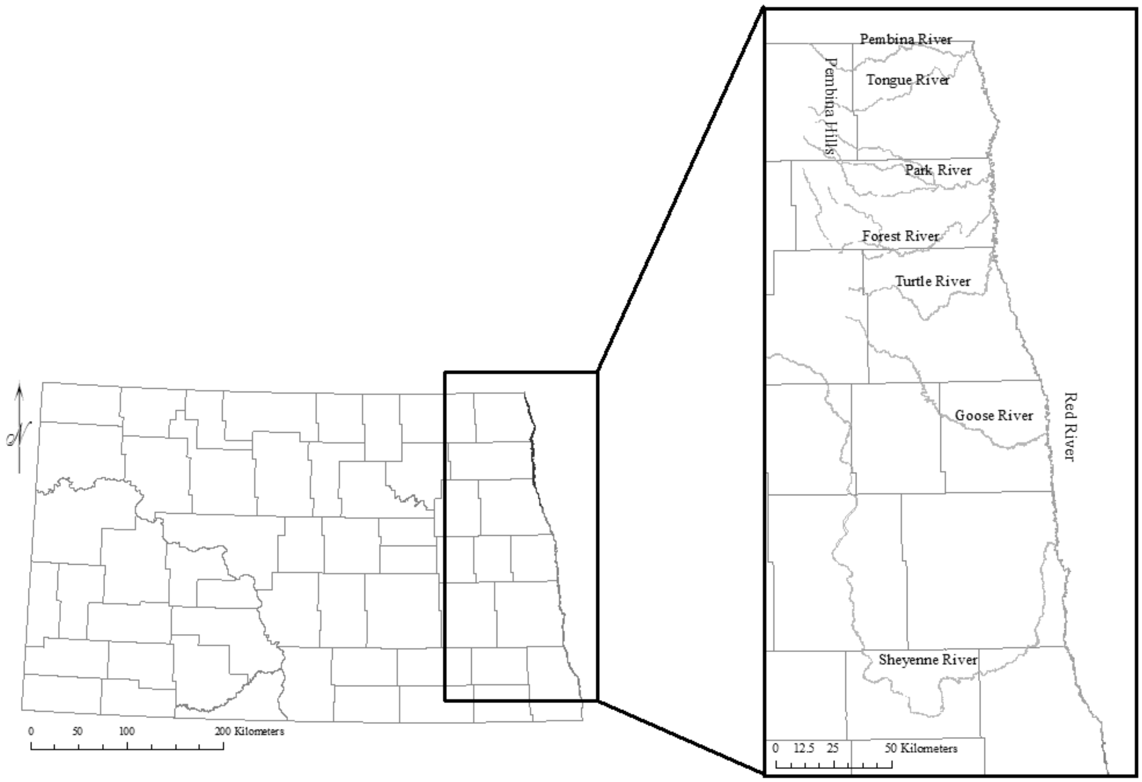
[a] +- = predicted not detected, -+ = detected not predicted, ++ = predicted and detected, -- = neither predicted or detected predicted, but not detected

Table 2.11. Survey sites compared to model predictions at 10-km, 30-km, and 75-km dispersal for Map-2. The areas surveyed areas had the same predicted occupancy at 30-km and 75-km dispersal distances.

		+-[a]		-+[a]		++[a]		--[a]	
River/Region	**Dispersal Distance**	**Sites**	**Percent**	**Sites**	**Percent**	**Sites**	**Percent**	**Sites**	**Percent**
Goose	10 km	-	-	3	21	-	-	11	79
	30 & 75 km	6	43	-	-	3	21	5	36
Forest	10 km	2	17	3	25	1	8	6	50
	30 & 75 km	3	25	2	17	2	17	5	42
Park	10 km	8	35	3	13	3	13	9	39
	30 & 75 km	9	39	3	13	3	13	8	35
Pembina	10 km	5	19	9	35	4	15	8	31
	30 & 75 km	5	19	9	35	4	15	8	31
Pembina Hills	10 km	3	25	-	-	5	50	0	25
	30 & 75 km	3	25	-	-	5	75	-	-
Red	10 km	-	-	57	64	4	4	28	31
	30 & 75 km	-	-	57	64	4	4	28	31
Tongue	10 km	6	29	2	10	7	33	6	29
	30 & 75 km	6	29	2	10	7	33	6	29
Turtle	10 km	-	-	13	22	-	-	46	78
	30 & 75 km	6	10	10	17	3	5	40	68
Overall	10 km	24	10	90	36	24	10	114	45
	30 & 75 km	38	15	83	33	31	12	100	40

[a] +- = predicted not detected, -+ = detected not predicted, ++ = predicted and detected, -- = neither predicted or detected predicted, but not detected

Figure 2.1. The study area in eastern North Dakota surveyed for fishers during the summers of 2008 and 2009.



N
0 50 100 200 Kilometers
Pembina River
Tongue River
Pembina Hills
Park River
Forest River
Turtle River
Goose River
Red River
Sheyenne River
0 12.5 25 50 Kilometers

Figure 2.2. Flow chart of the model HexSim (adapted from Schumaker 1998). HexSim was used to simulate the expansion of fishers into eastern North Dakota from western Minnesota.

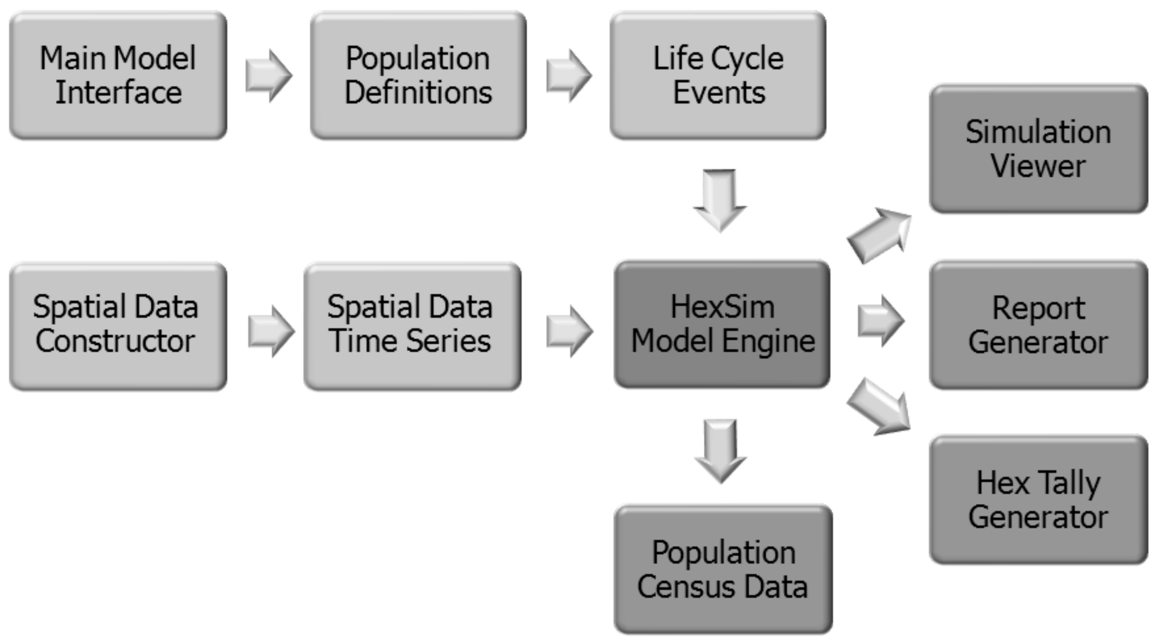

Main Model Interface
Population Definitions
Life Cycle Events
Simulation Viewer
Spatial Data Constructor
Spatial Data Time Series
HexSim Model Engine
Report Generator
Hex Tally Generator
Population Census Data

Figure 2.3. Location of survey sites obtained during presence-absence sampling for fishers in eastern North Dakota during the summers of 2008 and 2009.

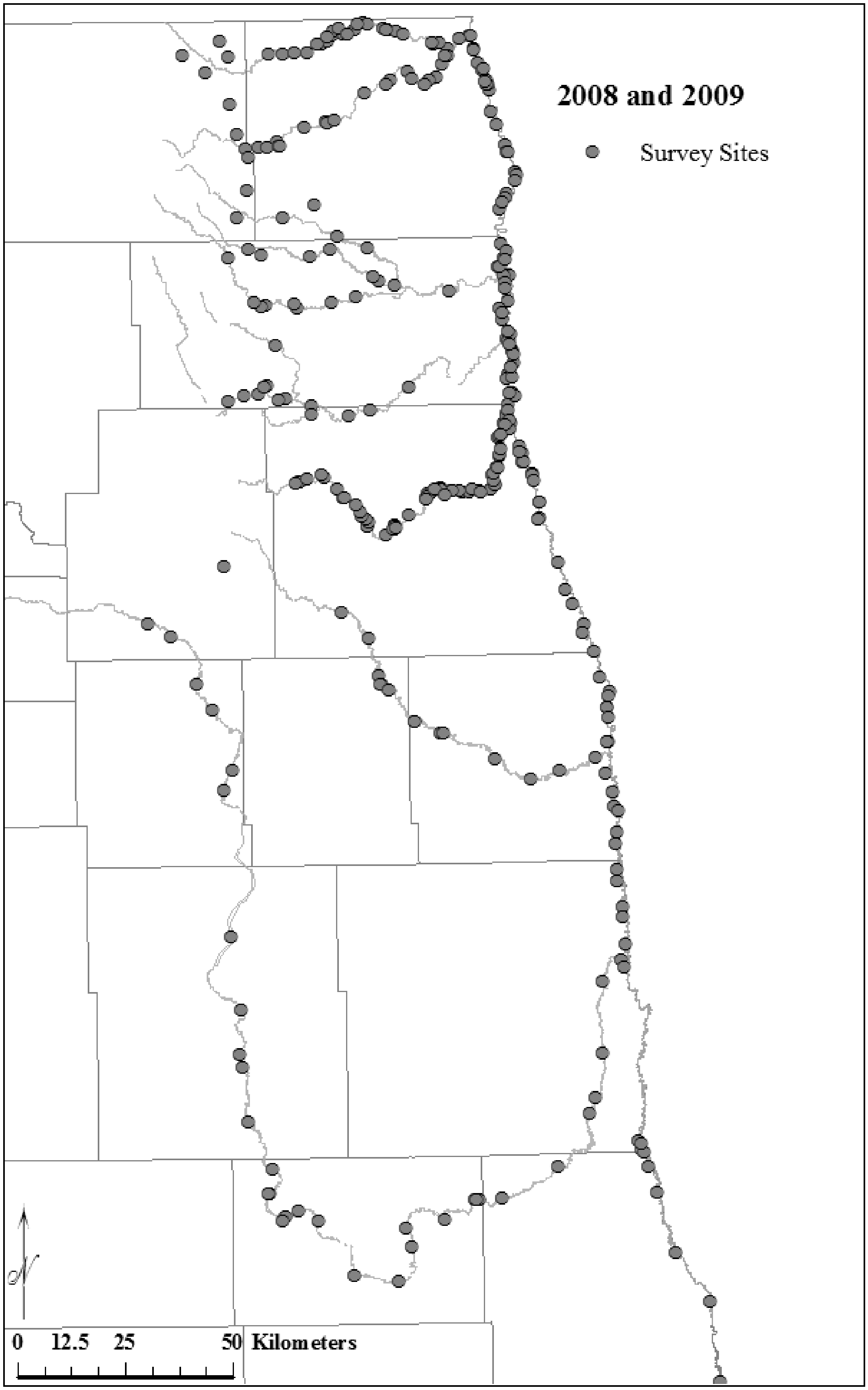

2008 and 2009
Survey Sites
N
0 12.5 25 50 Kilometers

Figure 2.4. HexMap (forest vs. non-forest; Map-1) of eastern North Dakota on which fisher distribution was simulated. All forest was given a value of 10 and all non-forest a value of 0 to construct hexagons.

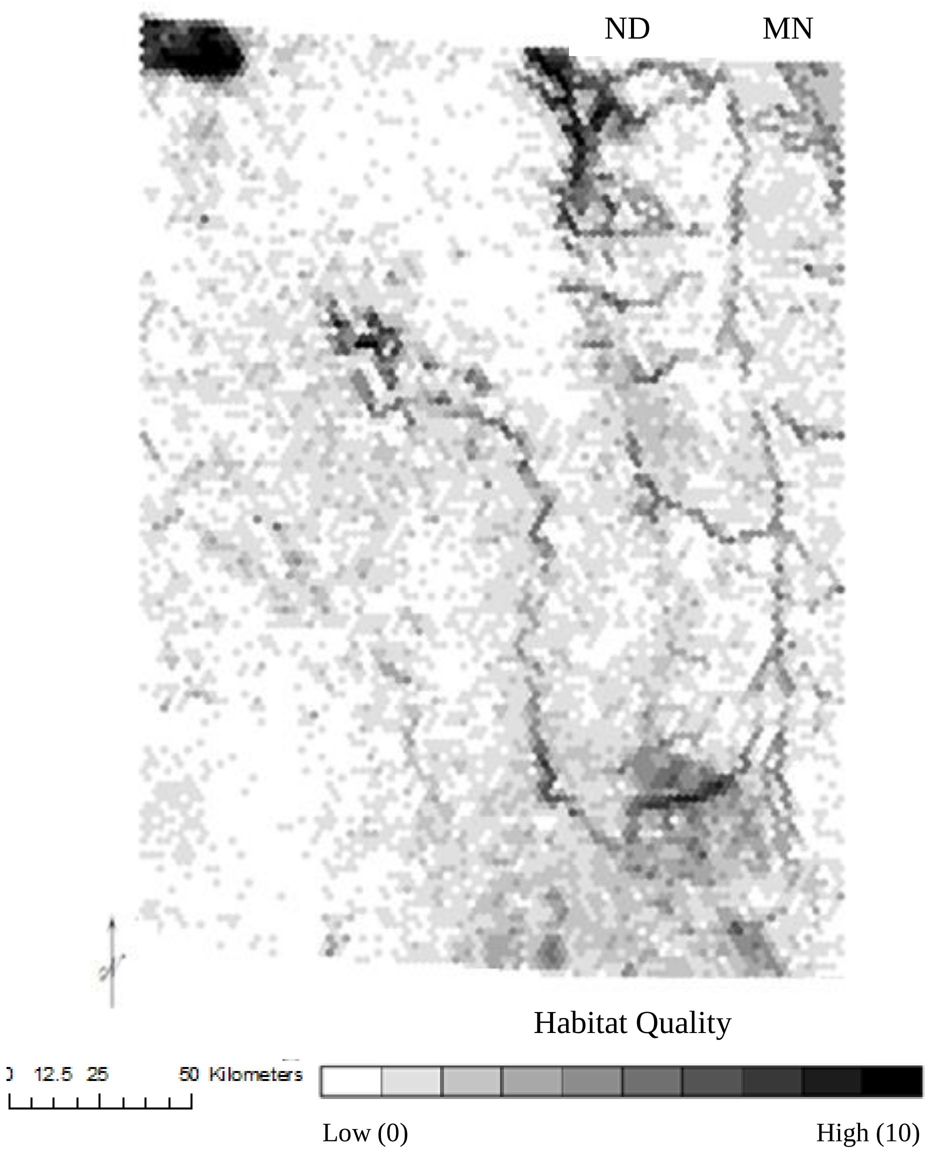

ND
MN
Habitat Quality
12.5 25 50 Kilometers
Low (0)
High (10)

Figure 2.5. HexMap (11 habitat categories; Map-2) of eastern North Dakota on which fisher distribution was simulated. For habitat rankings see Table 2.2.

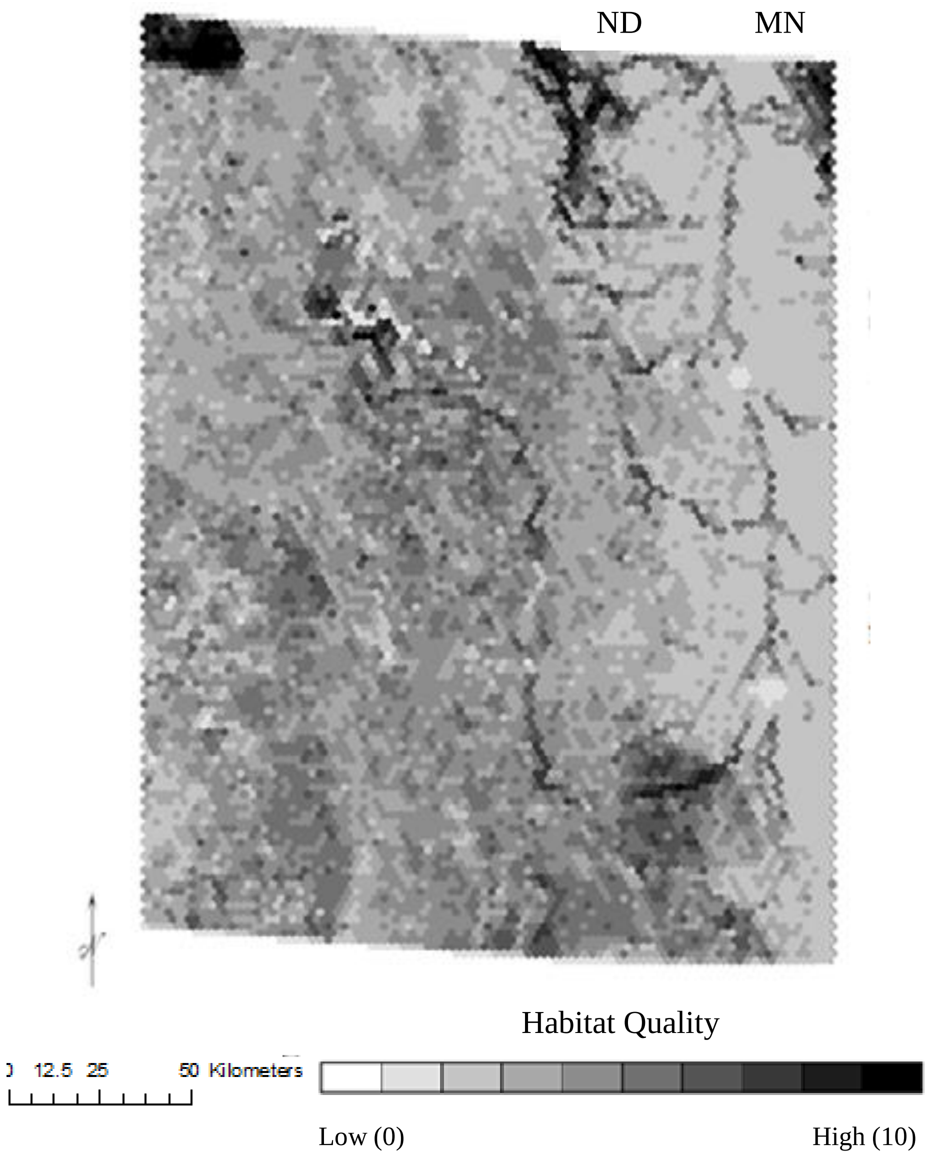

ND
MN
Habitat Quality
0 12.5 25 50 Kilometers
Low (0)
High (10)

Figure 2.6. Area used for the simulation of fishers in eastern North Dakota, with the largest forest regions indicated (Devil’s Lake, Pembina Hills, Turtle Mountains, and Sheyenne National Grasslands).

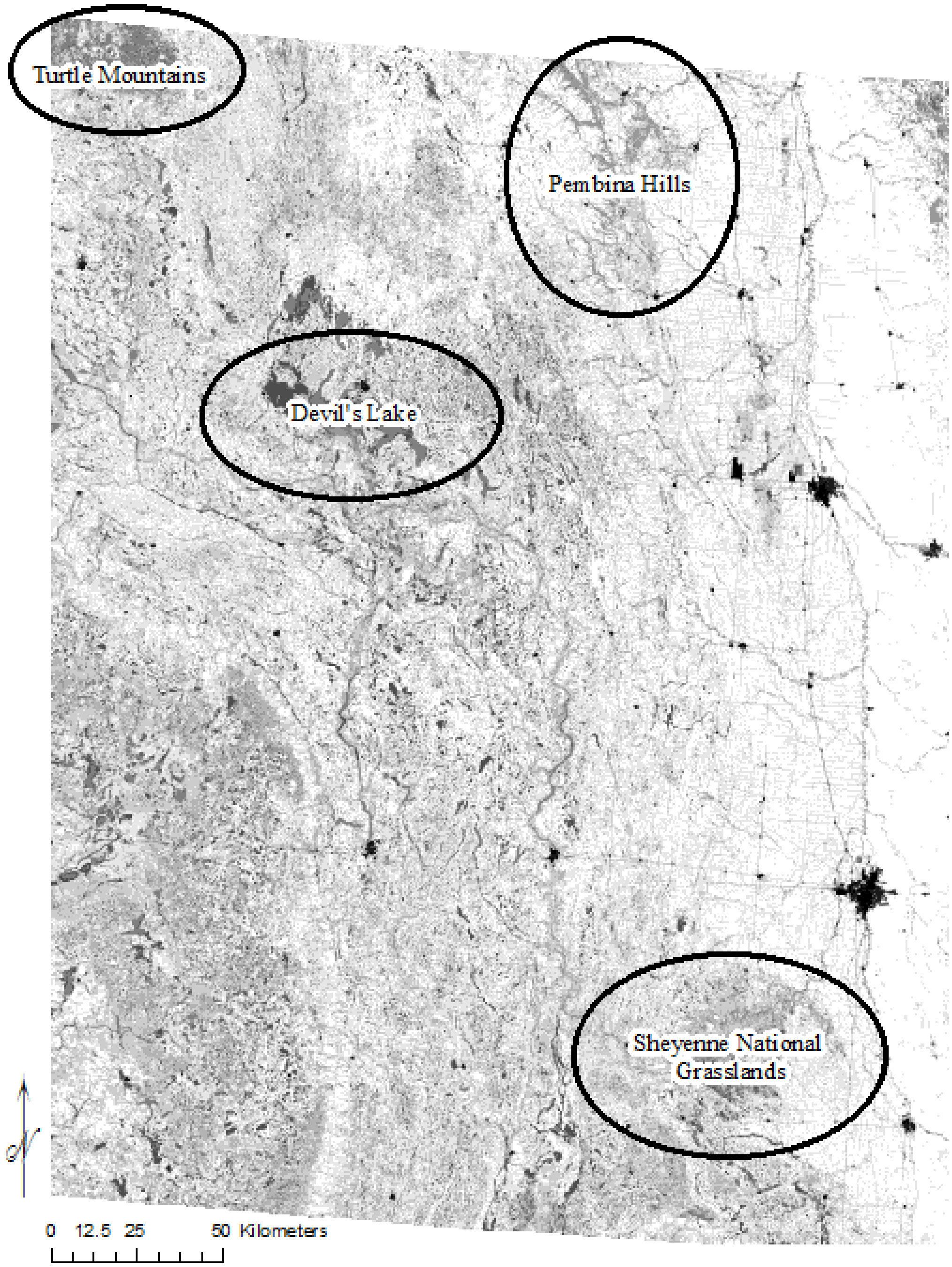
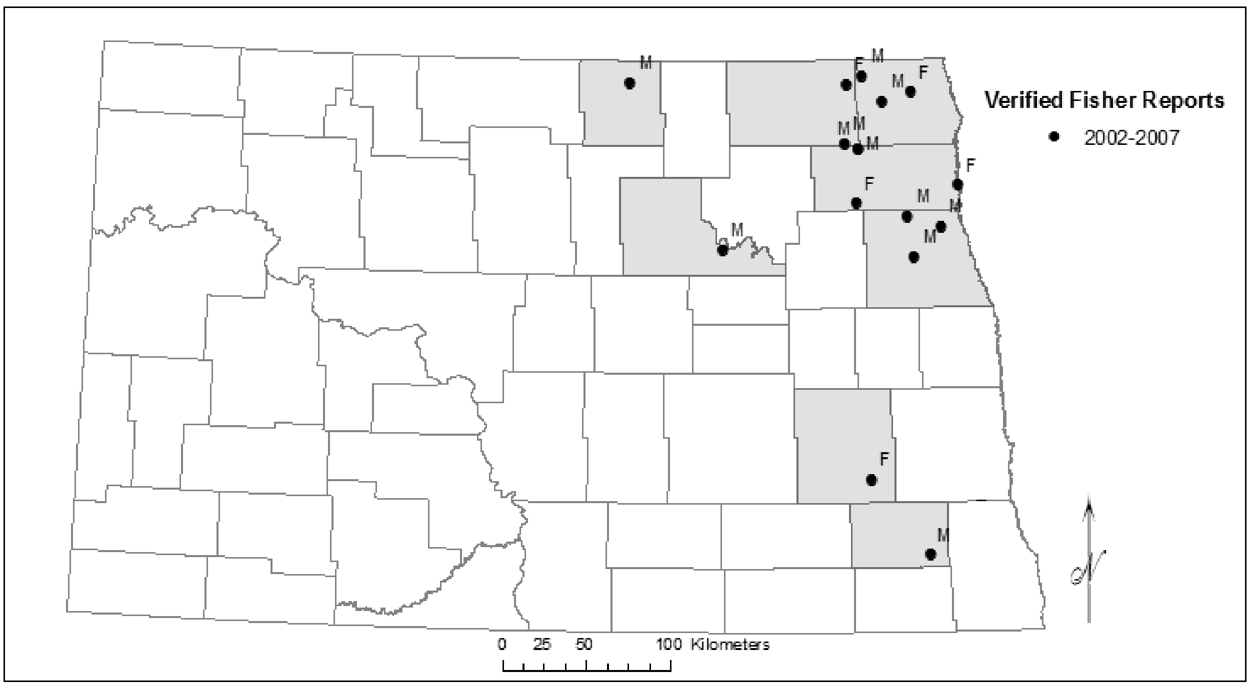

Turtle Mountains
Pembina Hills
Devil's Lake
Sheyenne National
Grasslands
0 12.5 25 50 Kilometers

Figure 2.7. Verified fisher reports in North Dakota from 2002–2007 (labeled by gender when available). The majority of reports were male and occurred in northeastern North Dakota.



Verified Fisher Reports
2002-2007
0 25 50 100 Kilometers

Figure 2.3. Location of detection sites obtained during presence-absence sampling for fishers in eastern North Dakota during the summers of 2008 and 2009. Detections occurred north of the Goose River in the northeast region of the state.

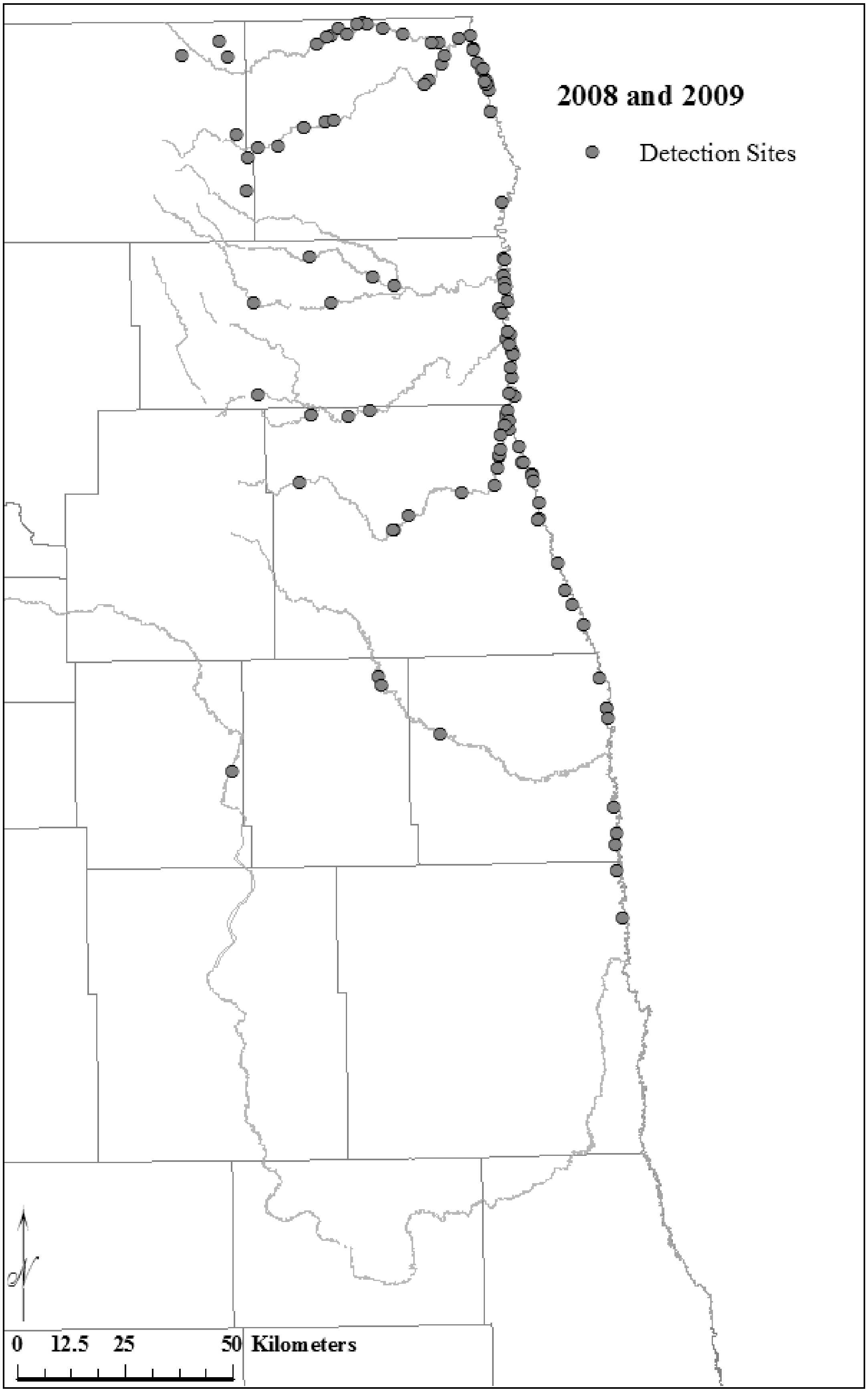

2008 and 2009
Detection Sites
N
0 12.5 25 50 Kilometers

Figure 2.9. Detection rates by county from fisher presence-absence surveys in eastern North Dakota conducted during the summers of 2008 and 2009. Detection rates were highest in the northeast and lowest in the southeast.

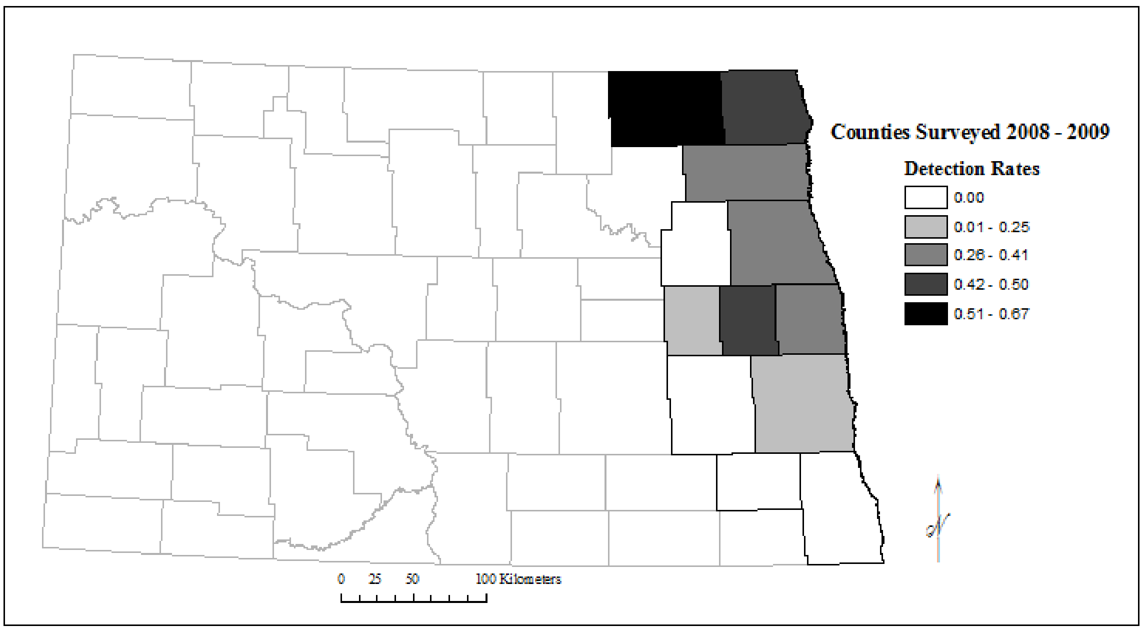
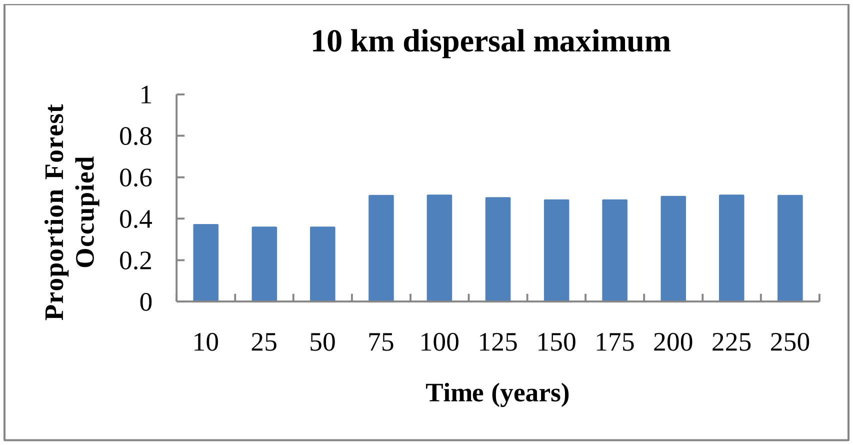
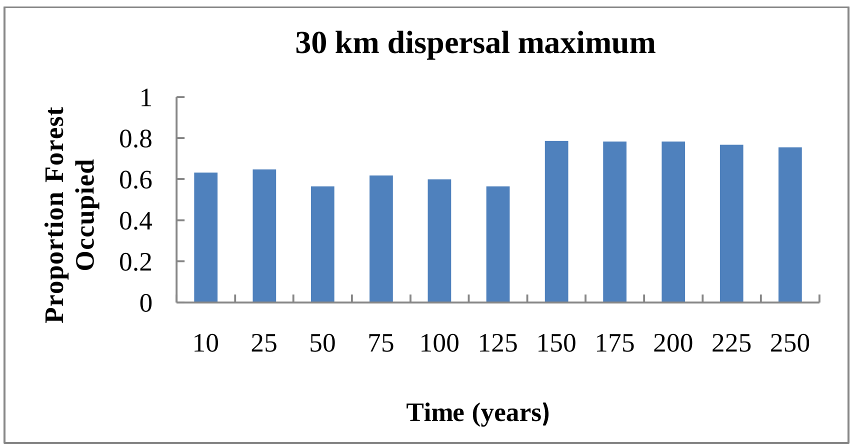

Counties Surveyed 2008 - 2009
Detection Rates
0.00
0.01 - 0.25
0.26 - 0.41
0.42 - 0.50
0.51 - 0.67
0
25
50
100 Kilometers
N

Figure 2.10. The proportion of forest occupied in Map-1 by fishers in eastern North Dakota by dispersal distance (10, 30, and 75 km). The amount of time it took to reach maximum occupancy varied by dispersal distance and ranged from 10 years at the 75-km dispersal distance to 150 years at the 30-km dispersal distance. The amount of available habitat occupied ranged from 51% at the 10-km dispersal distance to 79% at the 30- and 75-km dispersal distances.


10 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)


30 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)

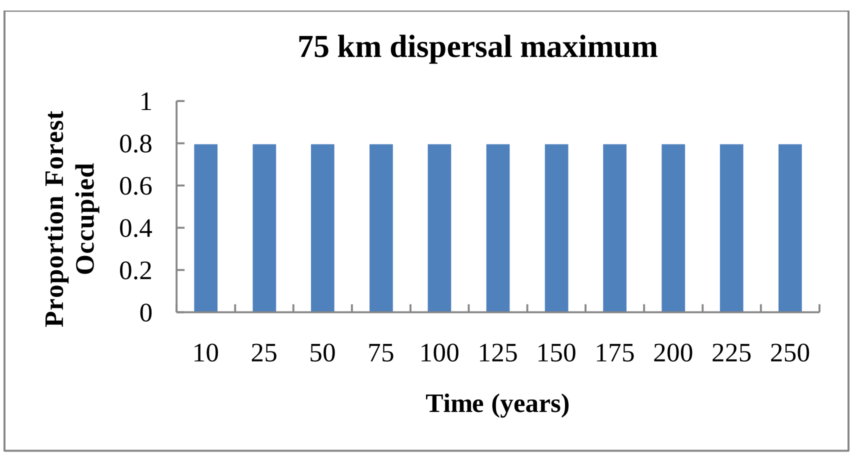
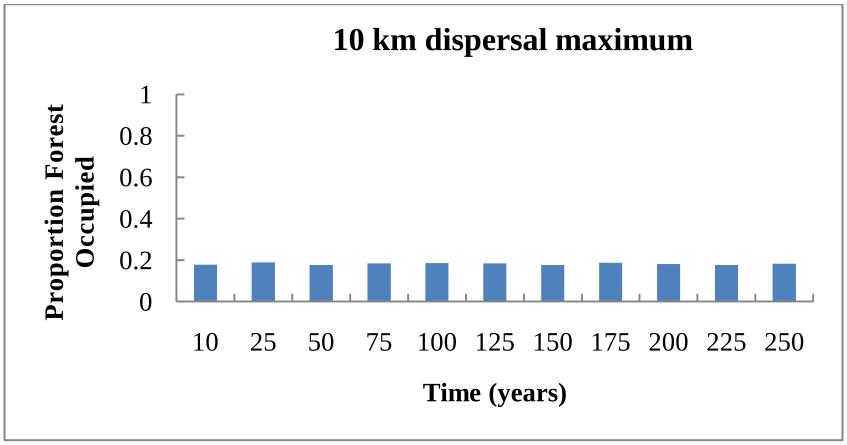
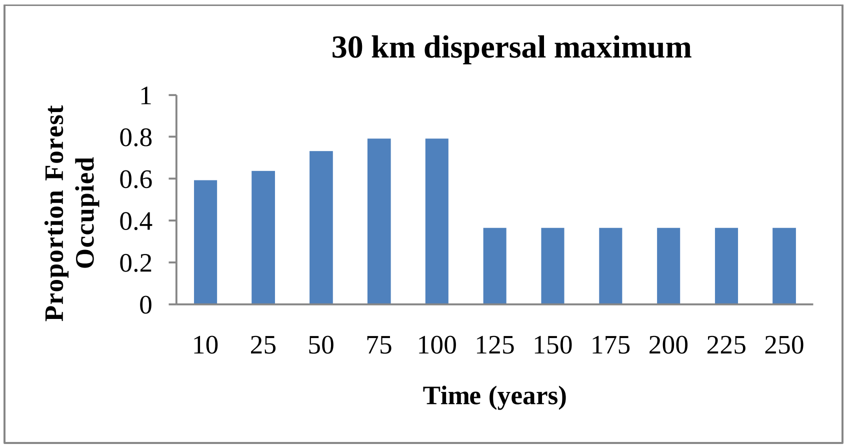

75 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)

Figure 2.11. The proportion of forest occupied in Map-2 by fishers in eastern North Dakota by dispersal distance (10, 30, and 75 km). The amount of time it took to reach maximum occupancy varied by dispersal distance and ranged from 10 years at the 10- and 75-km dispersal distances to 75 years at the 30-km dispersal distance. The amount of available habitat occupied ranged from 17% at the 10-km dispersal distance to 79% at the 30- and 75-km dispersal distances. After year 100 the area occupied decreased in the 30-km dispersal distance scenarios.


10 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)


30 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)

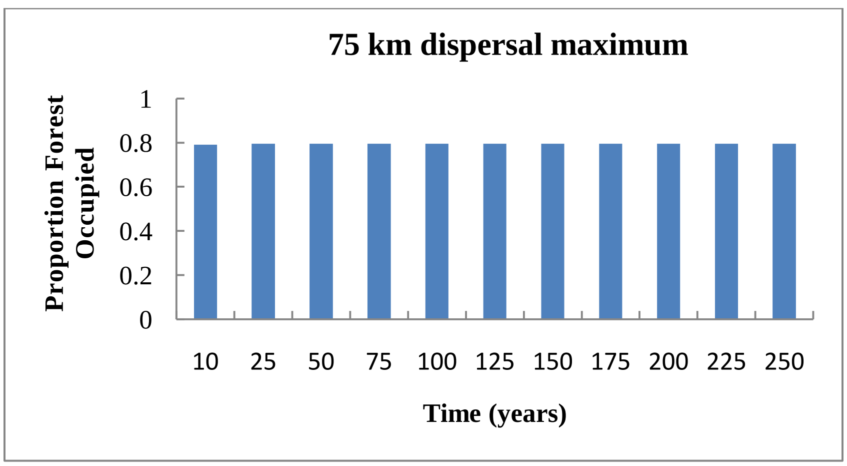
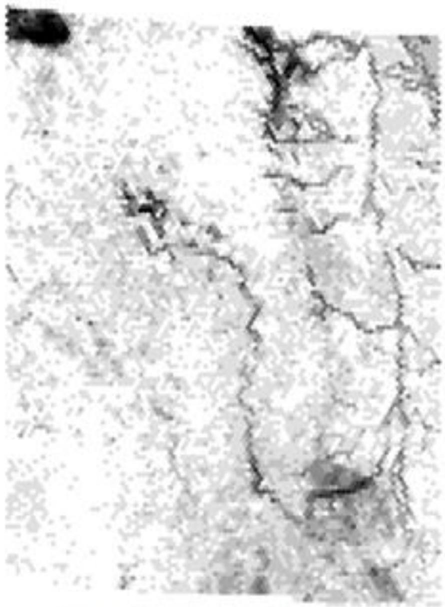

75 km dispersal maximum
Proportion Forest Occupied
1
0.8
0.6
0.4
0.2
0
10
25
50
75
100
125
150
175
200
225
250
Time (years)

Figure 2.12. The study area of eastern North Dakota showing a) HexMap of forest vs. non-forest (Map-1) and predicted occupancy by fishers with 10-km maximum dispersal (100 replicates) at: b) 10 years, c) 50 years, and d) 250 years.



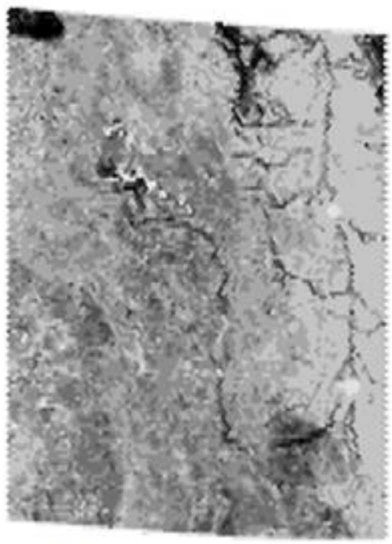
a) HexMap: forest vs. non-forest

b) Occupancy (10 years; 100 replicates)

c) Occupancy (50 years; 100 replicates)

d) Occupancy (250 years; 100 replicates)

Figure 2.13. The study area of eastern North Dakota showing a) HexMap of 11 habitat categories (Map-2) and predicted occupancy by fishers with 10-km maximum dispersal (100 replicates) at: b) 10 years, c) 50 years, and d) 250 years.



a) HexMap: categories

b) Occupancy (10 years; 100 replicates)

c) Occupancy (50 years; 100 replicates)

d) Occupancy (250 years; 100 replicates)

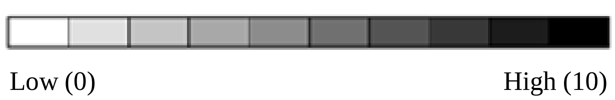


Figure 2.14. The study area of eastern North Dakota showing a) HexMap of forest vs. non-forest (Map-1) and predicted occupancy by fishers with 30-km maximum dispersal (100 replicates) at: b) 10 years, c) 50 years, and d) 250 years.

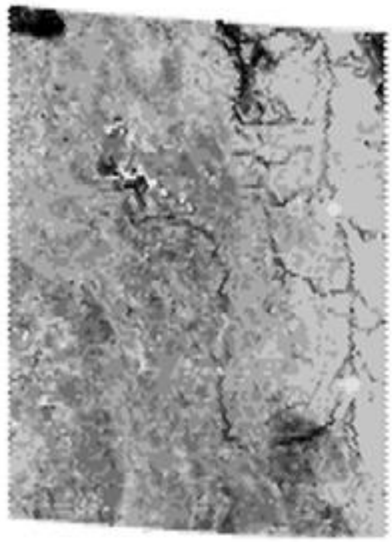
a) HexMap: forest vs. non-forest

b) Occupancy (10 years; 100 replicates)

c) Occupancy (50 years: 100 replicates)

d) Occupancy (250 years: 100 replicates)

Figure 2.15. The study area of eastern North Dakota showing a) HexMap of 11 habitat categories (Map-2) and predicted occupancy by fishers with 30-km maximum dispersal (100 replicates) at: b) 10 years, c) 50 years, and d) 250 years.



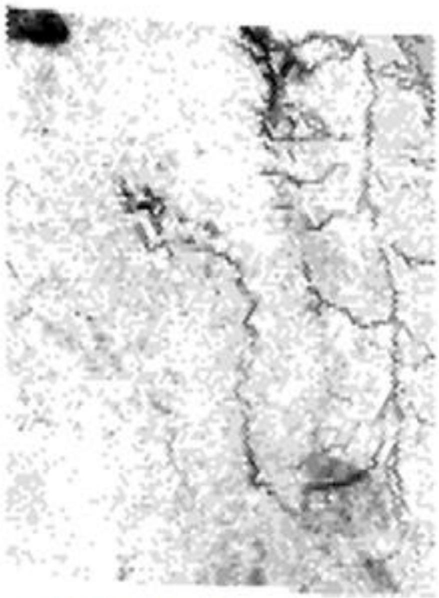
a) HexMap: categories

b) Occupancy (10 years; 100 replicates)

c) Occupancy (50 years; 100 replicates)

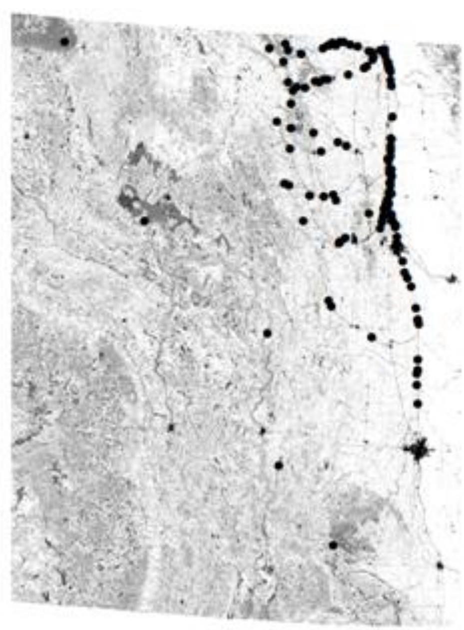
d) Occupancy (250 years; 100 replicates)

Figure 2.16. The study area of eastern North Dakota showing a) HexMap of forest vs. non-forest, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 75-km (100 simulations), and c) location of verified fisher reports and detections.



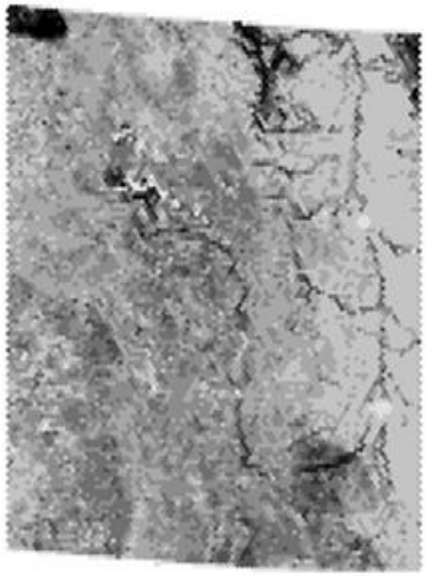
a) HexMap: forest vs. non-forest

b) Occupancy (10 years; 100 replicates)



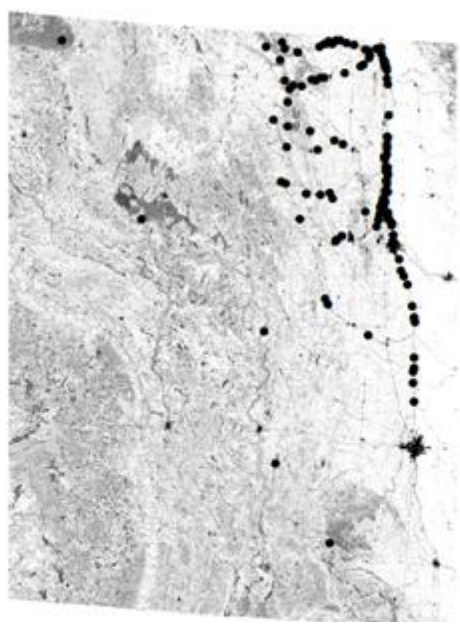
c) Report and detection locations

Figure 2.17. The study area of eastern North Dakota showing a) HexMap of 11 habitat categories, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 75-km (100 simulations), and c) location of verified fisher reports and detections.



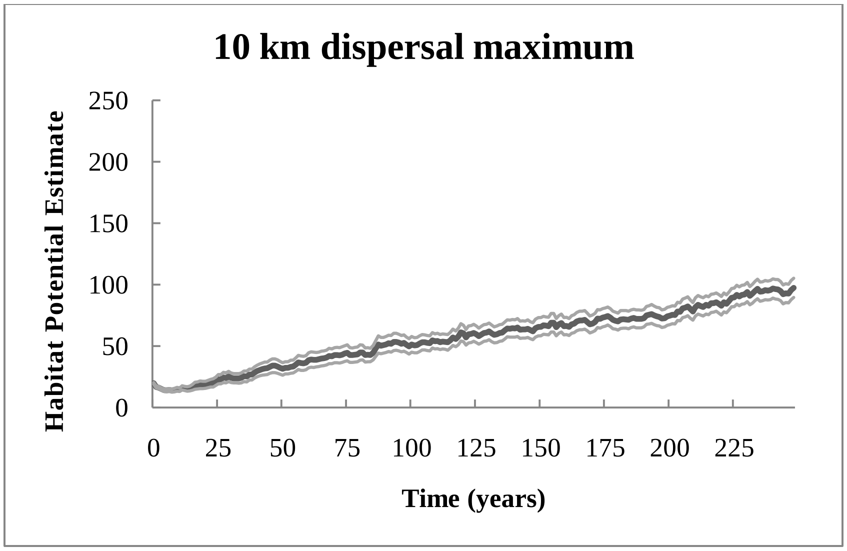
a) HexMap: categories

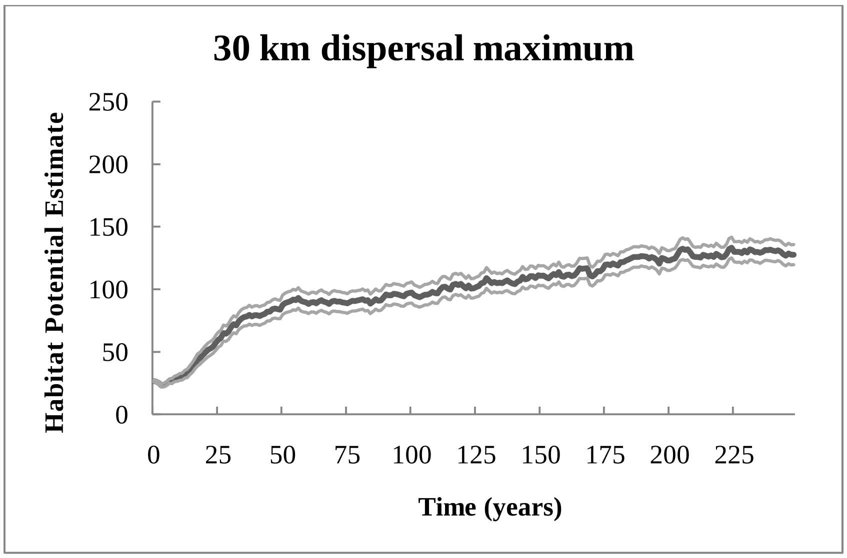
b) Occupancy (10 years; 100 replicates)



c) Report and detection locations

Figure 2.18. Habitat potential estimates of female fishers in eastern North Dakota based on scenarios of with varying dispersal distance for Map-1 (forest vs. non-forest). Overall as dispersal distances increased the population size increased and ranged from 97.3 (±7.9 SE) females at the 10-km dispersal distance to 211.2 (±5.4 SE) females at the 75-km dispersal distance.


10 km dispersal maximum
Habitat Potential Estimate
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
Time (years)


30 km dispersal maximum
Habitat Potential Estimate
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
Time (years)

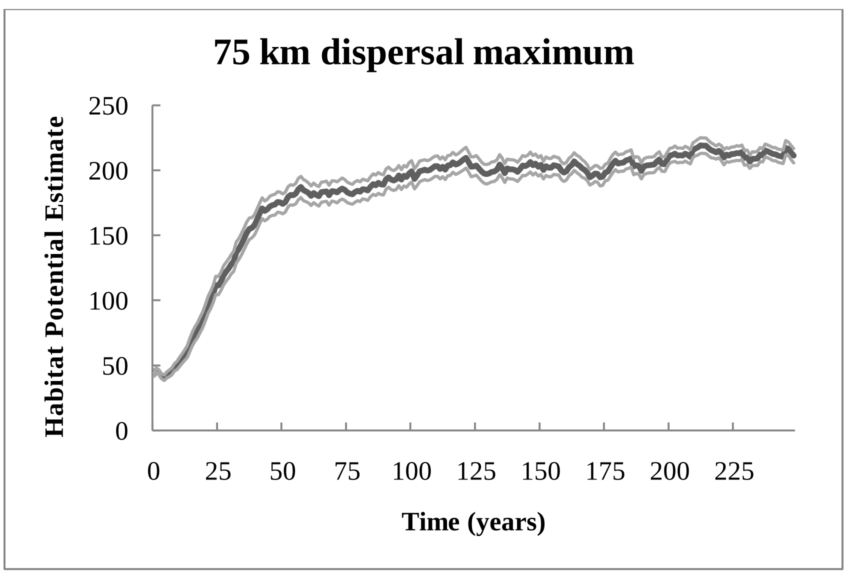
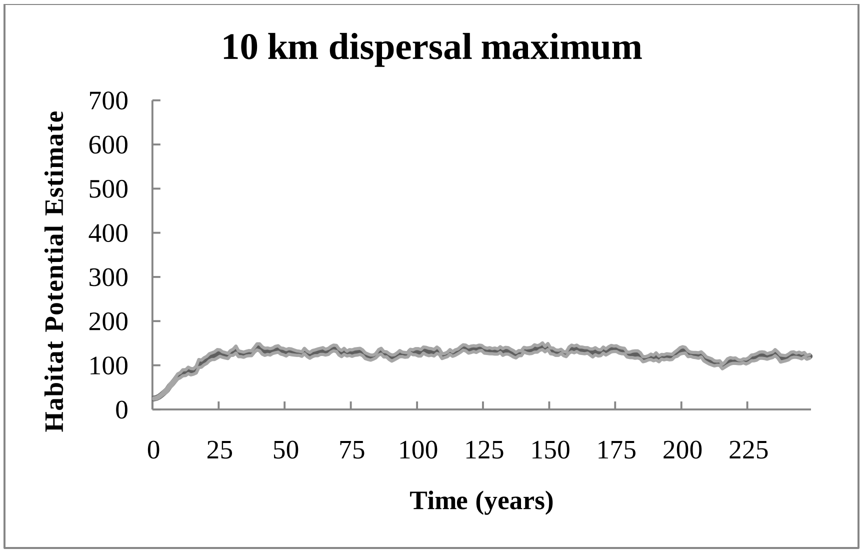
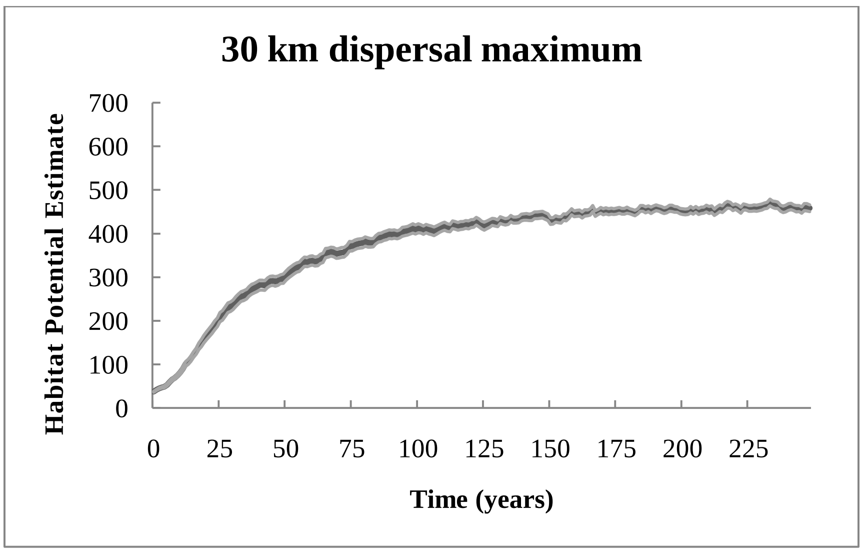

75 km dispersal maximum
Habitat Potential Estimate
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
225
Time (years)

Figure 2.19. Habitat potential estimates of female fishers in eastern North Dakota based on scenarios of with varying dispersal distance for Map-2 (11 habitat categories). Overall as dispersal distances increased the population size increased and ranged from 120.2 (±4.6 SE) females at 10 km dispersal distance to 591.0 (±7.5 SE) females at 75-km dispersal distance.


10 km dispersal maximum
Habitat Potential Estimate
700
600
500
400
300
200
100
0
0
25
50
75
100
125
150
175
200
225
Time (years)


30 km dispersal maximum
Habitat Potential Estimate
700
600
500
400
300
200
100
0
0
25
50
75
100
125
150
175
200
225
Time (years)

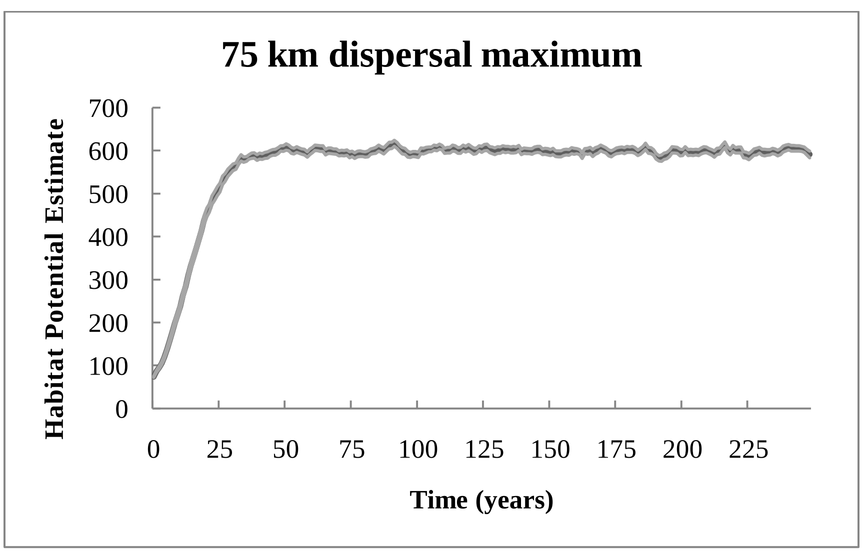
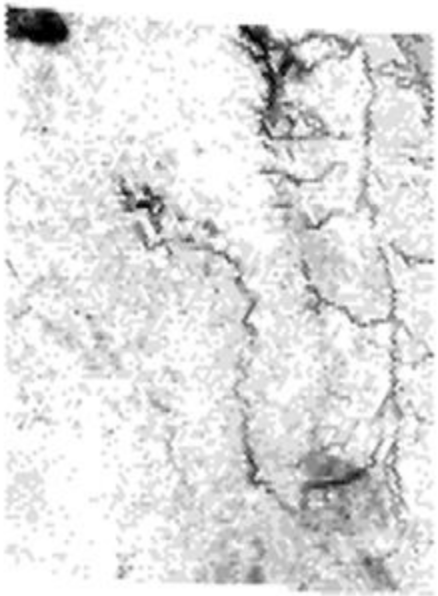
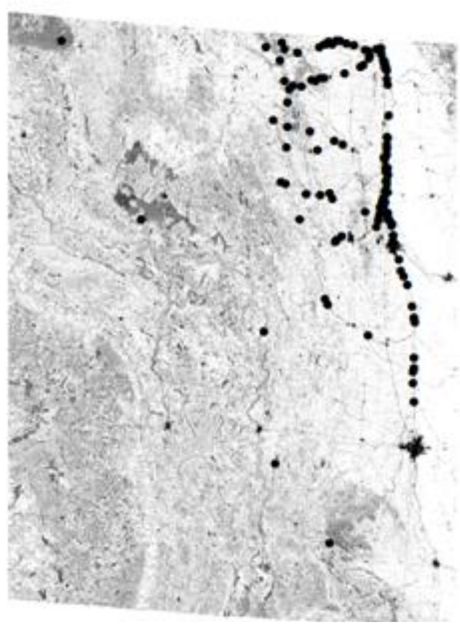

75 km dispersal maximum
Habitat Potential Estimate
700
600
500
400
300
200
100
0
0
25
50
75
100
125
150
175
200
225
Time (years)

Figure 2.20. The study area of eastern North Dakota showing a) HexMap of forest vs. non-forest, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 10-km (100 simulations), and c) location of verified fisher reports and detections.



a) HexMap: forest vs. non-forest

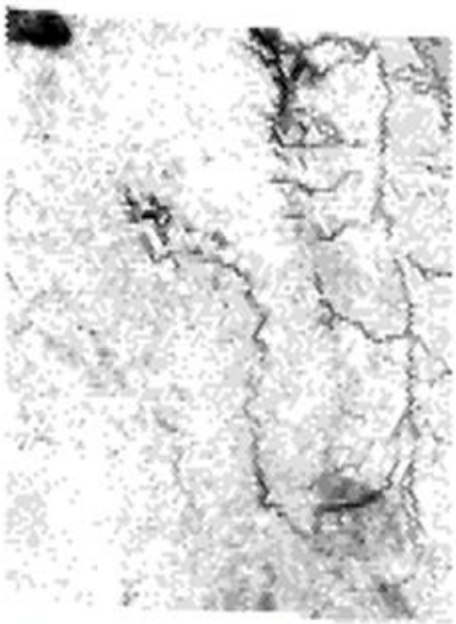
b) Occupancy (10 years; 100 replicates)



c) Report and detection locations

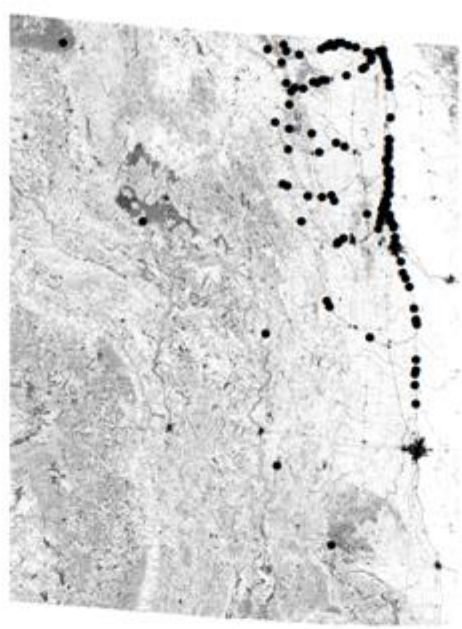
Low (0) High (10)

Figure 2.21. The study area of eastern North Dakota showing a) HexMap of forest vs. non-forest, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 30-km (100 simulations), and c) location of verified fisher reports and detections.



a) HexMap: forest vs. non-forest

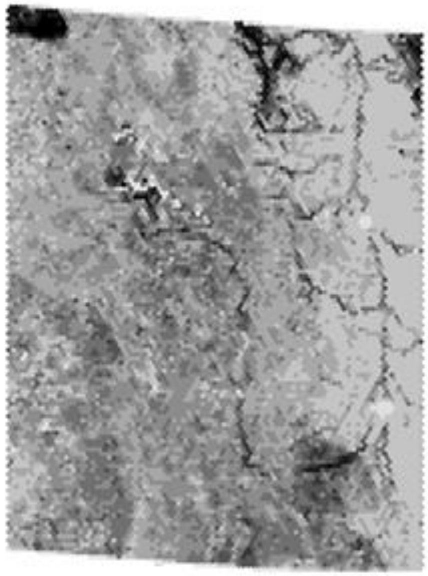
b) Occupancy (10 years; 100 replicates)



c) Report and detection locations

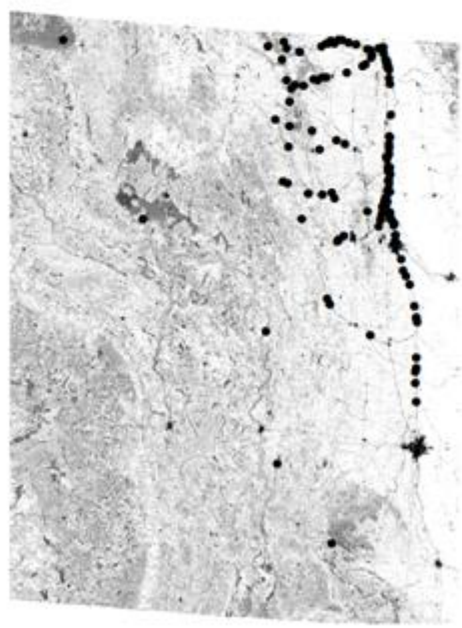
Low (0) High (10)

Figure 2.22. The study area of eastern North Dakota showing a) HexMap of 11 habitat categories, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 10-km (100 simulations), and c) location of verified fisher reports and detections.



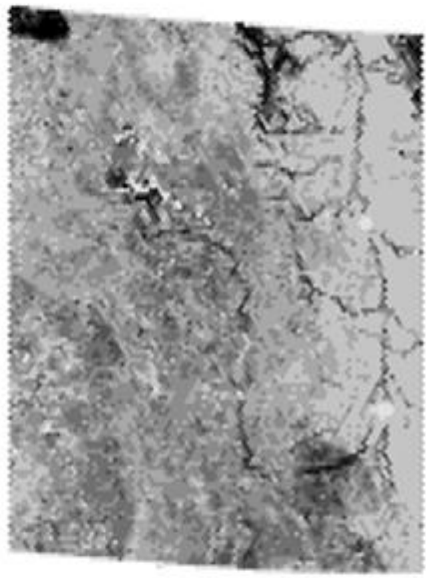
a) HexMap: categories

b) Occupancy (10 years; 100 replicates)



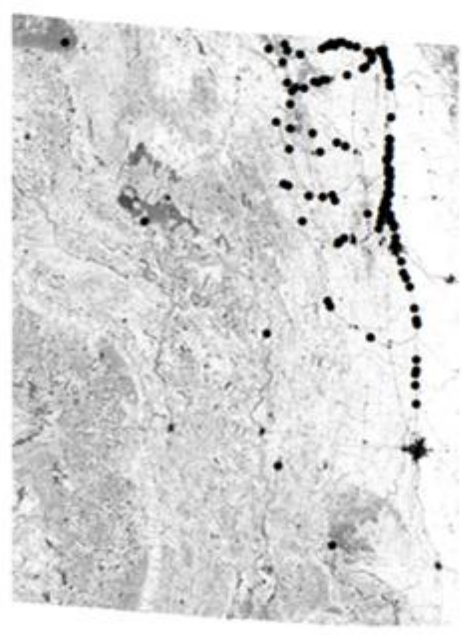
c) Report and detection locations

Figure 2.23. The study area of eastern North Dakota showing a) HexMap of 11 habitat categories, b) predicted occupancy by fishers after 10 years with a maximum dispersal of 30-km (100 simulations), and c) location of verified fisher reports and detections.



a) HexMap: categories

b) Occupancy (10 years; 100 replicates)



c) Report and detection locations

Low (0)

High (10)

CHAPTER 3

PERSISTENCE OF FISHERS AFTER AN EXTREME FLOOD EVENT

Abstract

Historically, the continent-wide distribution of fishers (*Martes pennanti*) is reported to include portions of eastern and northcentral North Dakota, but not elsewhere in the state. This population was reported to have become extirpated from overtrapping by the early 1900s. Verified reports indicate that fishers have been re-establishing riparian forests (the only areas with substantive forest cover in the region) in the last 10 years. During the summers of 2008 (16 Jun–1 Aug) and 2009 (1 Jun–18 Aug) I conducted presence-absence sampling using enclosed track-plates and remote cameras to determine the distribution of fishers along 237 km of the Red River of the North in North Dakota, between the cities of Grand Forks and Pembina. Between sampling events the Red River experienced an extreme flood, which inundated all riparian forests within the study area from about 23 March–22 May. Because of the severity of the flood, I anticipated that fishers could have perished or at least displaced from much of the study area, resulting in lower detection rates in 2009 than 2008. Fishers were detected throughout the study area during both years of sampling and, unexpectedly, detection rates were much higher in 2009 than 2008 (28 out of 35 sites [80%] and 25 out of 57 sites [44%], respectively). The outcome of the study demonstrates that fishers were able to persist in the region following a severe, multi-month flood that inundated most of the forest habitat.

Introduction

The fisher (*Martes pennanti*) is considered a forest-dependent carnivore (De Vos 1951, Allen 1983, Arthur et al. 1989, Buskirk and Powell 1994). The original distribution of fishers in North Dakota was limited because of the paucity of forested areas in the landscape (Bailey 1926, Adams 1961). Nonetheless, fishers historically were reported to occupy riparian forests along the Red River of the North (hereafter, Red River) drainage, but were extirpated by the early 1900s likely from overtrapping (Bailey 1926, Adams 1961). Recently (post 1999), there has been an accumulation of evidence indicating that fishers are once again occupying portions of the Red River and its tributaries in North Dakota, including individuals that were roadkilled or inadvertently caught in traps set for other furbearers (D. Fecske, North Dakota Game and Fish Department, personal communication). This re-establishing population appears to be derived from the expansion of a well-established fisher population in Minnesota (Berg and Kuehn 1994, Sovada and Seabloom 2005, Erb 2008).

The Red River is prone to flooding and anecdotal reports of major flooding date back to the 1700s (Bluemle 1997, USGS 2007). Formal documentation of flooding on the river began in the 1880s and, since that time, significant flooding has occurred during 18 different years (Bluemle 1997, USGS 2007). There have been no studies assessing the impact of severe flood events on mammals inhabiting riparian forests along the Red River. In fact, I located few published studies anywhere that assessed the response of mammals to periodic and extreme flooding. The few studies and reports on the topic have indicated responses to flooding varies among species and individuals within a species, with some more likely to remain within the flooded area rather than moving to surrounding areas not impacted by the flood (Gehrt et al. 1993, Williams et al. 2001). The likelihood of survival is species-dependent, varying by behavioral patterns, various life-history requisites, and flood duration and severity.

Species that are partially arboreal often are able to survive by taking refuge in trees within the floodplain during flood events (e.g., fox squirrels [*Sciurus niger*; Yeager and Anderson 1944], opossums [*Didelphis virginiana*; Yeager and Anderson 1944], *Peromyscus* spp. [Stickel 1948, McCarley 1959, Batzli 1977, Williams et al. 2001], and raccoons [*Procyon lotor*; Yeager and Anderson 1944, Gehrt et al. 1993]). The severity and duration of the flood also may influence survival rates, but these factors appear to be dependent on species and habitat conditions. There was no mortality reported among raccoons exposed to 2 long-lasting (69 and 78 days, respectively) floods that occurred in the falls of 1985 and 1986 in eastern Kansas (Gehrt et al. 1993), whereas studies in several states have documented various responses in the survival and recruitment (declines or no effect) of *Peromyscus* spp. following flood events persisting >1 week (e.g., Illinois [Batzli 1977], Missouri [Williams et al. 2001], Oklahoma [Blair 1939], and Texas [McCarley 1959]). In contrast, non-arboreal species (e.g., cottontail rabbits [*Lepus sylvaticus*; Yeager and Anderson 1944], groundhogs [*Marmota monax*; Yeager and Anderson 1944], Ord's kangaroo rats [*Dipodomys ordii*; Anderson et al. 2000], shrews [*Soricidae* spp.; Williams et al. 2001, Wijnhoven et al. 2006], voles [*Cricetidae* spp.; Anderson 2000, Williams et al. 2001, Wijnhoven et al. 2006], and white-tailed deer [*Odocoileus virginianus*; Samuel and Glazener 1971]) are more likely to disperse. Small mammal species that leave the floodplain also are slow to recolonize the area after the water recedes (Wijnhoven et al. 2006).

The initial focus of my study was to document the distribution of fishers in North Dakota through the use of enclosed track-plates and remote cameras. However, many of my study sites occurred along the riparian forests of the Red River, which was flooded from 23 March–22 May 2009, between my sampling periods: 16 June–1 August 2008, and 1 June–18 August 2009. I used this opportunity to determine if fishers occupied the study area after the flood and to compare detection rates between non-flood (2008) and flood (2009) years. Based on the severity of the flood, I anticipated that fishers would be absent or detected at lower rates during 2009.

Methods

Study Area

My study includes 237 km of deciduous riparian forest along the North Dakota side of the Red River, from the towns of Grand Forks to Pembina (Fig. 3.1). The Red River originates at the confluence of the Bois de Sioux and Ottertail Rivers at Wahpeton, North Dakota and Breckenridge, Minnesota (Koel and Peterka 1998). From its origin, it flows northward, forming a winding border of about 635 km (almost double the straight-line distance) between North Dakota and Minnesota, before entering Manitoba, Canada (Renard et al. 1986, Koel and Peterka 1998, Deschamps et al. 2002, Hagen et al. 2005). Prior to reaching Manitoba, 8 tributaries originating in North Dakota and 8 originating in Minnesota enter the Red River (Koel and Peterka 1998, Hagen et al. 2005).

Previous to habitation by European settlers, portions of North Dakota drained by the Red River consisted of mainly tallgrass prairie, much of which now has been replaced with agricultural fields and other development (Renard et al. 1986, Hagen et al. 2005). The forested portions of the drainage were distributed as semi-contiguous, fragmented patches mostly limited to riparian areas, a condition that persists today (Renard et al. 1986, Hagen et al. 2005). I used ArcGIS 9.2 to analyze data derived from the North Dakota Gap Analysis Program (GAP) (USGS; http://gapanalysis.nbii.gov) to determine the mean width of riparian forests along the Red River in North Dakota to be 132.02 (±9.57 SE) m (based on 200 random points [using only forested points; 57%]—I took perpendicular measurements from the river to the outward extent of the forest). Common tree species in my study area were green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana),* eastern cottonwood (*Populus deltoids)* and willow (*Salix* spp.; Bailey 1926, Renard et al. 1986, Hagen et al. 2005, Sovada and Seabloom 2005) with understories containing hawthorne (*Crageagus* spp.) and gray dogwood (*Cornus foemina*) (Renard et al. 1986).

The topography in the Red River drainage generally is of low relief and, hence is subject to flooding, especially when rainfall combines with snow melt during spring. The frequency of severe flooding on the Red River at Grand Forks has increased from approximately every 6 years to every 3 years, in part because of increased precipitation levels in the last century (Bluemle 1997, USGS 2007). The floodplain of the Red River is not well defined, but covers the lakebed of former Lake Agassiz (Deschamps et al. 2002). Thus, if the banks of the Red River are breached only limited areas of higher elevation and development (e.g., dikes around cities and farmsteads and elevated roads and rail networks) impede the flow, which results in the river width expanding kilometers outward (Bluemle 1997, Deschamps et al. 2002). Flooding is exacerbated by drainage ditches created to convert wetland into agricultural areas (Bluemle 1997). The northward flow of the Red River also contributes to flooding because the spring thaw typically initiates in southern portions of the drainage (Bluemle 1997). The flowing water from the south accumulates behind unfrozen portions of the river further north, resulting in ice jams and subsequent flooding (Bluemle 1997). Overall, the likelihood of flooding is influenced by interactions among factors such as the level of soil saturation in the fall, winter snow accumulation, spring precipitation, thaw rates, and the river gradient (Bluemle 1997). I estimated from aerial photographs and gauge station data that virtually all (>95%) of the forested portions of my study area was underwater (from 7–8 weeks) during the spring 2009 flood.

Flood Delineation

I obtained Landsat 5 pathway 31 row 26 imagery from the U.S. Geological Survey (USGS) website (http://glovis.usgs.gov) for the Red River drainage at time of flooding (10 Apr 2009) and gauge station data from the USGS website (http://nwis.waterdata.usgs.gov) for the 4 gauge stations along the Red River in my study area. I analyzed the flood imagery using ENVI 4.7 to determine the flood extent and width as close to the peak of the flood event at the gauge stations of Grand Forks, North Dakota (1 Apr 2009); Oslo, Minnesota (1 Apr 2009); Drayton, North Dakota (6 Apr 2009); and Pembina, North Dakota (15 Apr 2009) as possible. I extracted a subset of the study region from the Landsat imagery and calibrated it for reflectance and with the Quick Atmospheric Correction Algorithm (QUAC) to remove atmospheric interference. To better identify the flood, I set the spectral analysis to specific spectrum using the Normalized Difference Water Index (NDWI; McFeeters 1996). This method was determined to be the most accurate when delineating flooded regions (Jain et al. 2005). I used band math to complete the NDWI calculation and the result was a spectrum ranging from −1 to 1, with −1 to 0 representing vegetation features and 0 to 1 representing water features. This technique visually separated water and vegetation features, and I used the created image to manually digitize the flood extent into a vector. I exported the digitized vector as a shapefile for use in ArcMap 9.2 to determine the area and width (mean [±SE] and range based on perpendicular measurements taken at 200 random points from the outward edges of the flood) of the flooded region.

Presence-absence Sampling

I used 2 types of detection devices—remote cameras (Cuddeback ® NoFlash, Expert, and Excite models; Non Typical Inc., Greenbay, WI) and enclosed track-plates (Zielinski and Kucera 1995)—to survey for fishers in the forested regions of the study area. I monitored 57 sites from 16 June–1 August 2008 (non-flood year) and 35 sites from 1 June–18 August 2009 ([approximately 68.5 days after initially flooding] flood year; Fig. 3.2). I used both detection devices in 2008, either individually or in combination (2 sites with a remote camera only, 23 sites with an enclosed track-plate only, and 32 sites with both detection devices), but only cameras were used during 2009. At stations with both a camera and an enclosed track-plate, the camera was positioned so that the area photographed included the entrance of the enclosed track-plate. At each station I used beaver meat, and lures comprised of beaver castor and skunk essence as attractants. The beaver castor was mixed with glycerol and placed next to the bait, in center of the coverage areas of a camera or inside a track-plate. A cotton swab was dipped in the skunk essence, placed in a perforated film canister, and hung from a nearby tree with fishing line.

Because the purpose of this project was not to assess the effects of a flood event on fisher presence, different methods were used to choose site location between years. My initial goal was to determine if fishers were present in the study area and, if so, gain insight about their distribution. Consequently, in 2008 I sampled in a semi-systematic matter to ensure representation of forested patches throughout the length of the river corridor included in the study area. In 2009 camera locations were randomly selected among forested patches using Hawths Tools in ArcMap 9.2. Four survey cycles (a survey cycle comprised placement and removal of a suite of detection devices over roughly the same 10-day sampling period) were completed during each of the sampling years. Detection devices were re-baited once, mid-way through a cycle.

Although exact locations were not surveyed both years, 100% of the sites were within 3.5 km of a site surveyed during the opposite year. The mean patch size surveyed during 2008 was 60.50 (±11.00 SE) ha and 67.80 (±13.80 SE) ha in 2009. Twenty-eight (49%) of the sites sampled in 2008 occurred in patches surveyed in 2009 and 21 (60%) of sites sampled in 2009 sites occurred in patches sampled in 2008. Maximum upstream and downstream placement of sites near the margins (upstream and downstream limits) of the study area occurred in both years. The mean distance (south to north) between sites was 2.85 km (±0.26 SE) km in 2008 and 3.66 (±0.45 SE) km in 2009.

I compared detection rates between years in 2 ways: 1) using all sites, and 2) paired sites. I defined paired sites as an area where a detection device had been placed in both 2008 and 2009. Specifically, I considered an area to comprise a paired site if the location of detection device in 2008 was in the same patch or within 500 m of the location of a detection device in 2009 (n = 23). Paired sites had a mean patch size of 91.4 (±13.40 SE) ha and a mean distance of 5.27 (±0.46 SE) km between their locations. Detection rates for each year were calculated by dividing the total number of detections by the total number of sites and chi-squared tests calculated in MINITAB (Minitab Inc., State College, Pennsylvania) were used to determine if detection rates were independent between 2008 and 2009.

Results

Flood Delineation

The flooded area comprised approximately 120,000 ha and had a mean width of 10.98 (±0.18 SE, range = 3.12–15.00) km spanning Minnesota and North Dakota (Fig. 3.3). Most forested patches along the Red River in North Dakota have a width of <150 m and all were inundated during the flood (Fig. 3.3). The flood event was extreme in the study area and all 4 USGS gauge stations on the Red River recorded water levels in the top 3 ever recorded (Fig. 3.4). The gauge stations were above USGS flood stage for an average of 55.25 (± SE 1.65) days (Grand Forks, North Dakota [n = 52 days; 23 Mar–14 May 2009]; Oslo, Minnesota [n = 57 days; 23 Mar–19 May 2009]; Drayton, North Dakota [n = 59 days; 25 Mar–22 May 2009]; and Pembina, North Dakota [n = 53 days; 29 Mar–20 May 2009]).

Presence-absence Sampling

I detected fishers less frequently in 2008 than 2009 at all sites (25 of 57 [44%] vs. 28 of 35 [80%] sites, respectively; $\chi_1^2 = 11.598$, $P = 0.001$) and at paired sites (11 of 23 [48%] vs. 19 of 23 [83%] sites, respectively; $\chi_1^2 = 6.133$, $P = 0.013$). The locations of detections were distributed throughout large portions of the study area during both years of the study (Fig. 3.2). Fishers were detected during each survey cycle for both 2008 and 2009 and the frequency of detections did not differ among cycles within either year (see Table 3.1). The first fisher detection in 2009 occurred during the first survey cycle of the year at a site adjacent to the town of Pembina, 15 days after the river level receded below flood stage (20 May 2009) and 75 days after initial flooding (see Fig. 3.5). I detected fishers at 11 of 14 (79%) sites during the first survey cycle of 2009, which was similar to detection rates of the ensuing 3 survey cycles.

Discussion

Historical records suggest that flooding has been a common event along the Red River, especially during spring months (Bluemle 1997). Because of the low topography along the Red River flood waters often extend kilometers beyond the river channel (Bluemle 1997, Deschamps et al. 2002). Forested portions of the Red River drainage occur almost entirely as narrow, riparian patches and, hence are entirely covered in water during severe flood events. During the flood, in spring 2009, the 4 gauge stations along the Red River recorded water levels in the top 3 ever reported, which resulted in the inundation of the riparian forests throughout my study area (and most other forested areas in the drainage) for 7–8 weeks.

Very little is known about the impacts of flooding on mammal populations inhabiting riparian areas. Because of the difficulty in predicting when and where a flood will occur, the majority of information gathered on the topic was not acquired as part of a designed project, but instead the result of studies that were in progress when flooding occurred—as was the case with my investigation. Most published information on the topic is based on studies and observations of small mammals (Yeager and Anderson 1944, Stickel 1948, McCarley 1959, Batzli 1977, Anderson et al. 2000, Williams et al. 2001, Wijnhoven et al. 2006) with the exception of opossums (Yeager and Anderson 1944), raccoons (Yeager and Anderson 1944, Gehrt et al. 1993), and white-tailed deer (Samuel and Glazener 1970).

Species with arboreal capabilities (e.g., *Peromyscus* spp., fox squirrels, opossums, and raccoons) initially are known or presumed to take refuge in trees located within the floodplain (Yeager and Anderson 1944, Stickel 1948, McCarley 1959, Batzli 1977, Gehrt et al. 1993, Anderson et al. 2000, Williams et al. 2001), but may perish or move beyond flooded areas if the flood persists for a long duration (Blair 1939, Anderson et al. 2000). Whereas, non-arboreal species tend to disperse or perish during initial flooding (Yeager and Anderson 1944, Samuel and Glazener 1971, Williams et al. 2001, Wijnhoven et al. 2006). Little is known about survival or recolonization rates of individuals that disperse beyond flooded areas, except for a few studies of small mammals (Stickel 1948, Batzli 1977, Anderson et al. 2000, Wijnhoven et al. 2006). Survival likely is species-dependent and based on a variety of interactive factors behavioral patterns, social interactions, life-history requisites, and flood duration and severity (Blair 1939, McCarley 1959, Batzli 1977, Gehrt et al. 1993, Williams et al. 2001).

I located no documentation describing the effects of flooding on forest dependent mammalian species occupying areas where forests occur almost exclusively in riparian habitats. Fishers are considered to be forest dependent and habitats where I detected them in North Dakota (i.e., narrow bands, discontinuous bands of riparian comprised entirely of deciduous trees) generally would have been regarded as sub-optimal habitat for the species, and the surrounding landscape (mostly agricultural fields and otherwise non-forest) regarded as non-habitat.

My initial sampling in 2008 demonstrated that fishers were relatively widespread within the study area. However, the spring 2009 flood inundated all riparian forests in my study area for 7–8 weeks, and I anticipated that fisher detection rates would be low during the post-flood sampling period, especially during the first sampling cycle which was initiated less than two weeks after the Red River had subsided below flood levels. Instead, fishers were detected at 11 of 14 sample sites during the first post-flood sampling cycle and detection rates remained high throughout the summer (Table 3.1).

I can only speculate on how the flood influenced the movements, distribution, and survival of fishers existing in the study area. Fishers could have taken refuge in trees during the early stages of the flood, but it would seem unlikely that they could have effectively foraged in the flooded landscape throughout the duration of the flood. Occupying patches of high ground in otherwise flooded areas could have sustained some fishers. However, the number of individuals sustained in these areas presumably would have been limited by the territorial nature of the species (Arthur et al. 1993, Powell 1993). The landscape beyond the reaches of flood waters traditionally would have been considered largely non-habitat for fishers—in my study area trees planted for shelterbelts and in residential areas may have provided habitat that sustained some individuals. Fishers also could have occupied margins of the non-forest–forest interface during periods when flood water contracted, but I doubt that the majority of fishers inhabiting the pre-flood riparian forest remained within the flooded area, especially during peak levels of flooding. Anecdotal reports (photographs) received from local residents at the time of flooding indicate that fishers were using habitats including shelterbelts, active and abandoned farmsteads, and city limits during the flood event.

Regardless of where fishers resided during the flood event, my sampling indicated that riparian forests were occupied by fishers soon after the flood ended, and overall detection rates following the flood in 2009 were higher than detections during surveys conducted during relatively the same time period in 2008. I have no substantive information from which to explain the increased rate of detections that occurred during 2009. Primary prey items may have been depleted and slow to recover (Wijnhoven et al. 2006), causing fishers to more actively search for food (e.g., carrion, such as carcasses of fish stranded inland after the flood receded and those of other animals killed during the flood) and, thus, more frequently encounter and be attracted to detection sites.

Overall fisher detection rates were not negatively affected by the flood event; fishers were detected more often in all sites and paired sites in 2009 than in 2008. The cause of the increased rate of detections is unclear. Regardless, fishers in the fragmented riparian forests of the Red River drainage appear capable of persisting through extreme flood events that would appear to at least temporarily displace them from preferred habitats.

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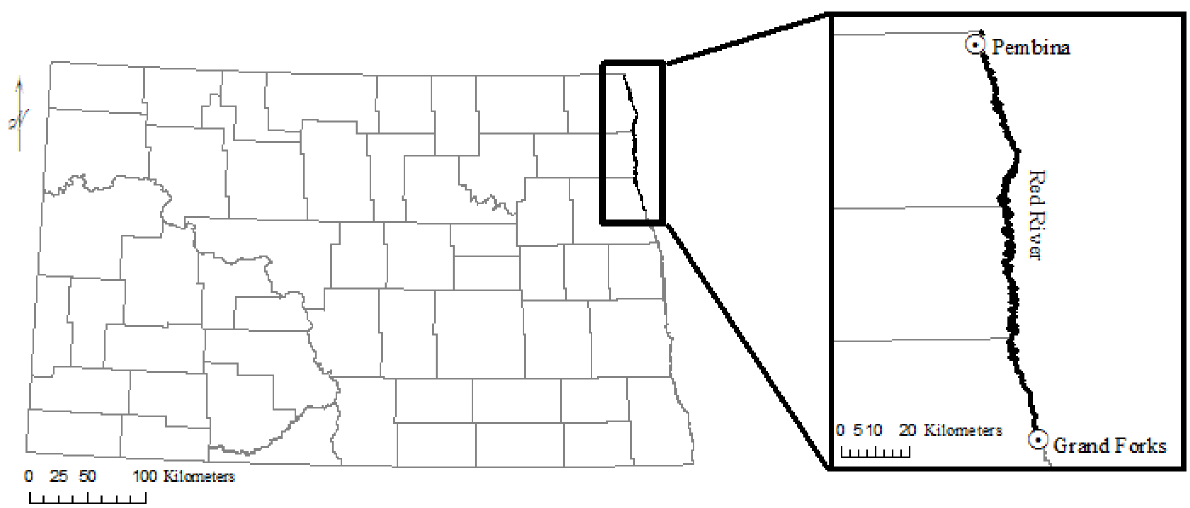
Table 3.1. Summary of fisher detections during surveys conducted in the summers of 2008 and 2009 along the Red River of the North in northeastern North Dakota.

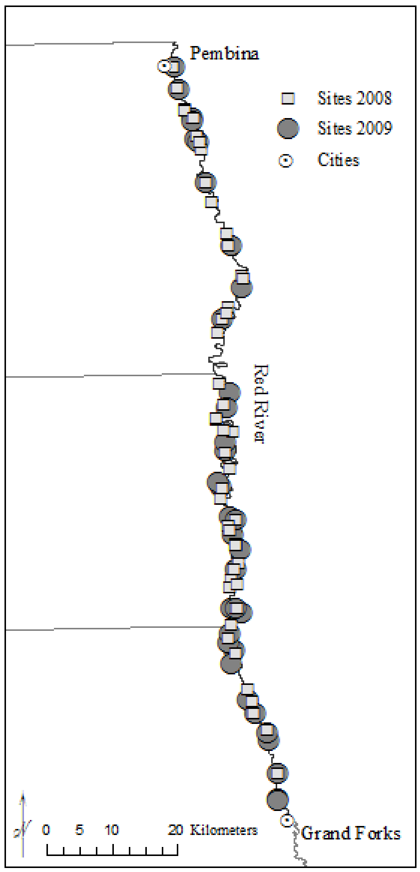
	2008		2009	
	Survey Period	No. Detections:No. Sites (%)	Survey Period	No. Detections:No. Sites (%)
Cycle 1	16 Jun-23 Jun	3:8 (38)	1 Jun-17 Jun	11:14 (79)
Cycle 2	22 Jun-1 Jul	11:24 (46)	23 Jun-8 Jul	2:3 (67)
Cycle 3	9 Jul-19 Jul	7:18 (39)	13 Jul-28 Jul	12:15 (80)
Cycle 4	24 Jul-1 Aug	4:7 (57)	3 Aug-20 Aug	3:3 (100)

Figure 3.1. Study area along the Red River of the North in northeastern North Dakota where surveys were conducted in riparian forests to assess the presence and distribution of fishers, summers of 2008 and 2009.

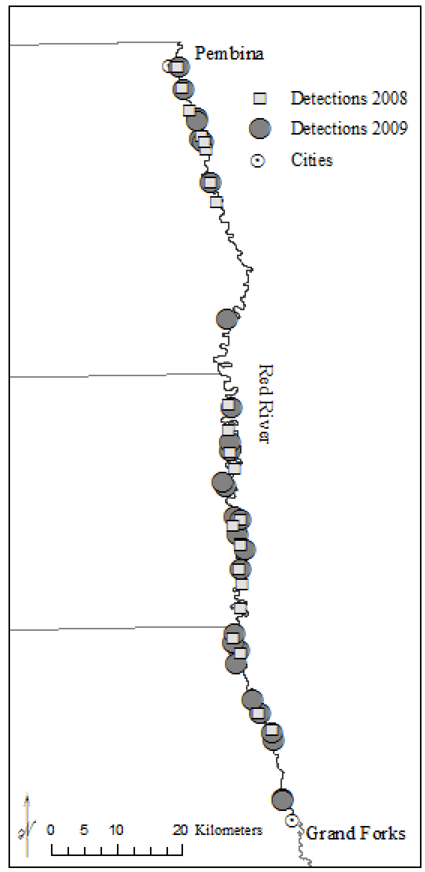


N
0 25 50 100 Kilometers
Pembina
Red River
0 5 10 20 Kilometers
Grand Forks

Figure 3.2. The distribution of sample sites (a) placed along the Red River of the North in northeaster North Dakota to detect fishers during summers 2008 (*n* = 57) and 2009 (*n* = 35). Fishers were detected (b) at 25 (44%) of the sample sites during 2008 and 28 (80%) of the sample sites during 2009.



a) Site locations



b) Detection locations

Figure 3.3. The extent of flooding along the Red River of the North (delineated from Landsat 5 imagery on 10 Apr 2009) and the distribution of forest patches in the study area along the Red River of the North in northeastern North Dakota.

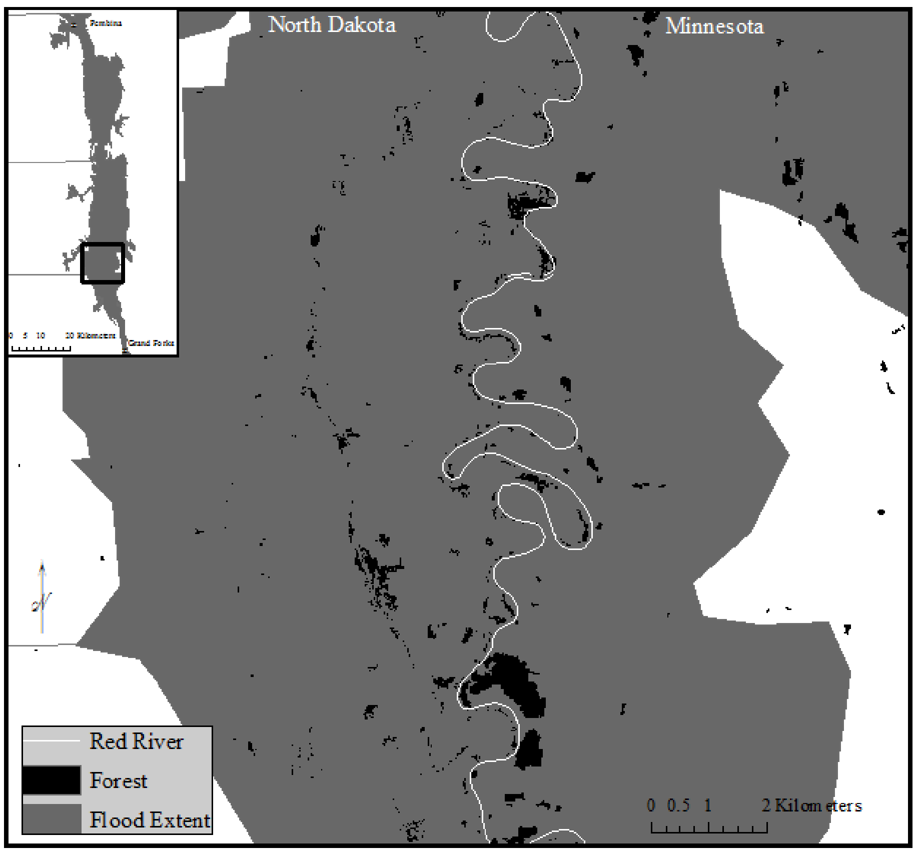
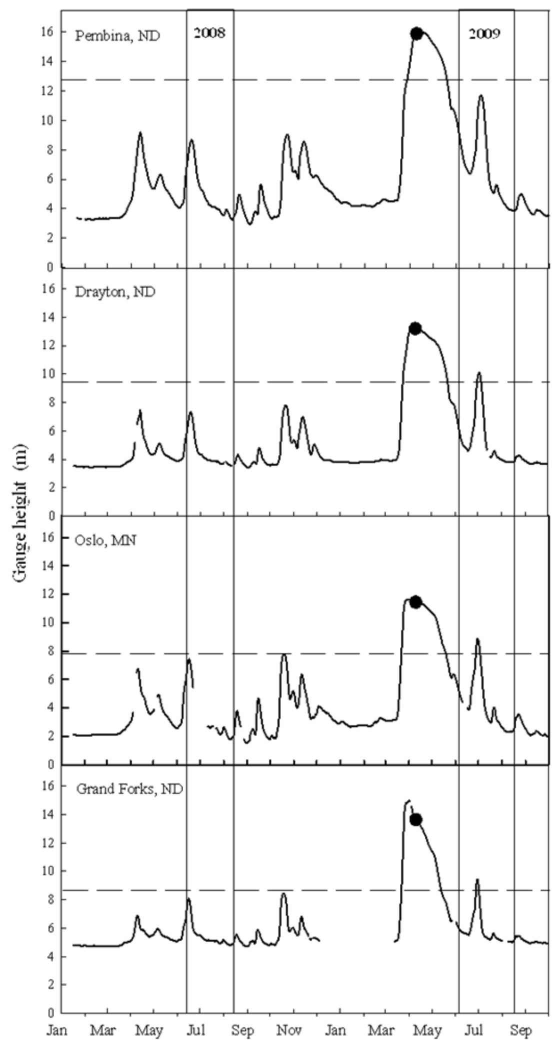

North Dakota
Minnesota
Red River
Forest
Flood Extent
0 0.5 1 2 Kilometers
N

Figure 3.4. Gauge levels from USGS stations (Grand Forks, North Dakota; Oslo, Minnesota; Drayton, North Dakota; and Pembina, North Dakota) from January 2008–September 2009 along the Red River of the North in northeastern North Dakota. Periods when surveys were conducted to detect fishers, 2008 and 2009, are indicated with vertical rectangles and are labeled by year. The dashed, horizontal line through each graph represents flood stage for the specific gauge station and black dots signify the date (10 Apr 2009) of the Landsat 5 imagery used to delineate the flood extent.



Pembina, ND
2008
2009
Drayton, ND
Oslo, MN
Grand Forks, ND
Gauge height (m)
0
2
4
6
8
10
12
14
16
Jan
Mar
May
Jul
Sep
Nov
Jan
Mar
May
Jul
Sep

Figure 3.5. Flooding along the Red River of the North in Pembina, North Dakota on 10 April 2009. A fisher was detected at a site (indicated by the dot) on 4 June 2009, 15 days after the river receded below flood stage and 75 days after the first day of the flood).

APPENDIX A

Least Cost Path Analysis

Least cost path analysis was used to predict pathways fishers may be using within the Pembina Escarpment. Least cost path is completed by first categorizing the desired features, in this case patch size and habitat type, and then creating a cost raster by weighting the two parameters into one raster (ex. 50:50, 75:25). The cost raster then has a value for each individual cell and provided with a source can be used to create a cost distance and cost back link raster. The cost distance raster takes into account the distance from the source and the cost back link raster calculates a route back cell by cell that has the least cost. These two rasters are then combined with a destination and a least cost path is determined from the source to the destination raster.

Analysis was completed in ArcMap 9.3 using 30m Gap Analysis Program (GAP) data for landcover of North Dakota (NAD 1983 UTM Zone 14N). North Dakota GAP data was obtained from the North Dakota Game and Fish, the raster was reclassified to contain 11 habitat categories (agriculture, planted perennials, prairie, shrubland, woodland, riverine, lacustrine, wetlands, barren, developed-high, and developed-low). The study area was extracted from the states by selecting the counties of interest along the Pembina Hills (Fig. A.1) and a model was made to conduct the analysis (Fig. A.2). To complete this task a raster containing forest patches was made and used to calculate the area of the patches. The landcover and forest patch maps were weighted (60:40), based on sensitivity analysis, to create a cost raster for use in the model. The cost raster was then used along with a source raster (Pembina Hills) to produce the distance and back link rasters. The cost distance and back link rasters were combined with the destination raster (Sheyenne River) to create the least cost path line (Fig. A.3).

Figure A.1. Map of North Dakota with the study area of least cost path (LCP) analysis of fisher movement based on habitat preferences surrounded in a black rectangle.

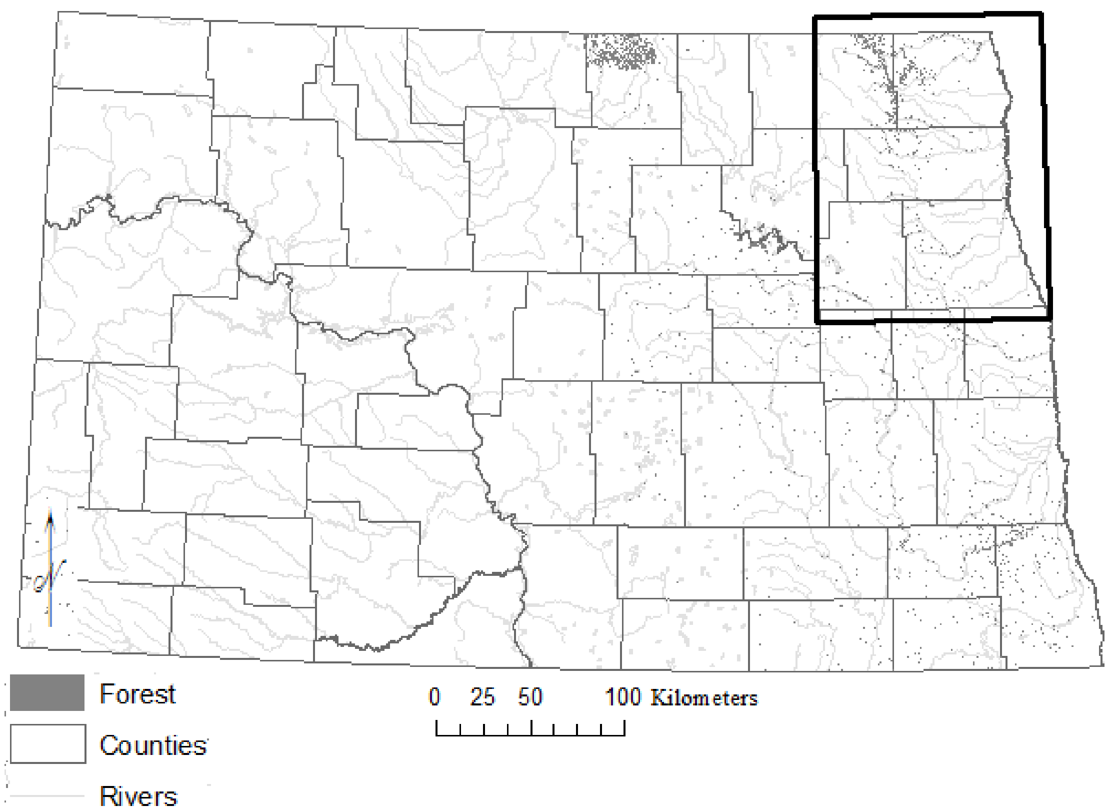

Forest
Counties
Rivers
0 25 50 100 Kilometers

Figure A.2. Model used to create a least cost path (LCP) line of fisher movement based on habitat preferences in eastern North Dakota from the Pembina Hills to the Sheyenne River.

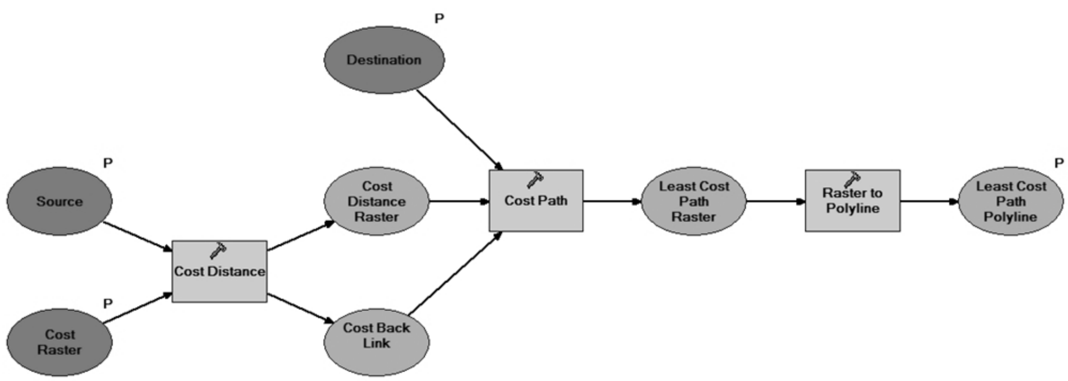
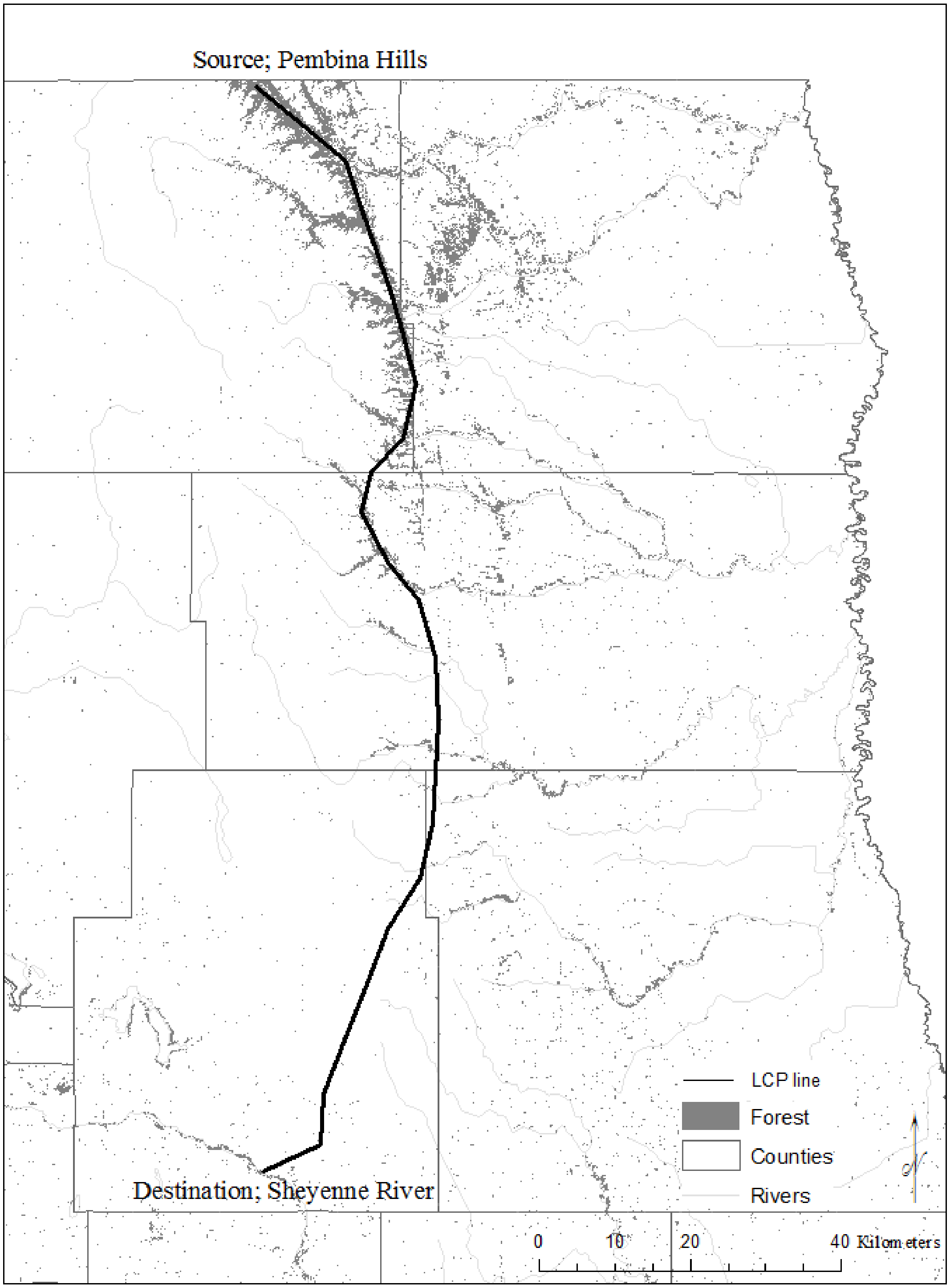

P
Destination
P
Source
Cost
Distance
Raster
Cost Path
Least Cost
Path
Raster
Raster to
Polyline
P
Least Cost
Path
Polyline
Cost Distance
P
Cost
Raster
Cost Back
Link

Figure A.3. Map of eastern North Dakota and the least cost path (LCP) line created based on fisher habitat preferences.


Source; Pembina Hills
Destination; Sheyenne River
LCP line
Forest
Counties
Rivers
0
10
20
40 Kilometers

APPENDIX B

Minnesota HexSim Inputs

Table B.1. Reproduction matrix input for HexSim used to simulate the fisher life cycle in Minnesota.

	Birth Rate				
Age Class	**0**	**1**	**2**	**3**	**4**
0	1	0	0	0	0
1	0.1	0.2	0.3	0.3	0.1
2	0.1	0.2	0.3	0.3	0.1
3	0.1	0.2	0.3	0.3	0.1
4	0.1	0.2	0.3	0.3	0.1
5	0.1	0.2	0.3	0.3	0.1
6	0.1	0.2	0.3	0.3	0.1
7	0.1	0.2	0.3	0.3	0.1
8	0.1	0.2	0.3	0.3	0.1
9	0.1	0.2	0.3	0.3	0.1
10	0.1	0.2	0.3	0.3	0.1

Table B.2. Survival rates by age class used for simulating fisher life cycle in Minnesota.

Age Class	**Survival Rates**
0	0.3
1	0.3
2	0.6
3	0.75
4	0.75
5	0.75
6	0.6
7	0.3
8	0.25
9	0.1
10	0.1

Figure B.1. Northern Minnesota HexMap containing forest vs. non-forest habitat categories. Outputs from scenarios completed on the Minnesota forest only HexMap were applied to the eastern North Dakota forest only HexMap to simulate fisher distribution.

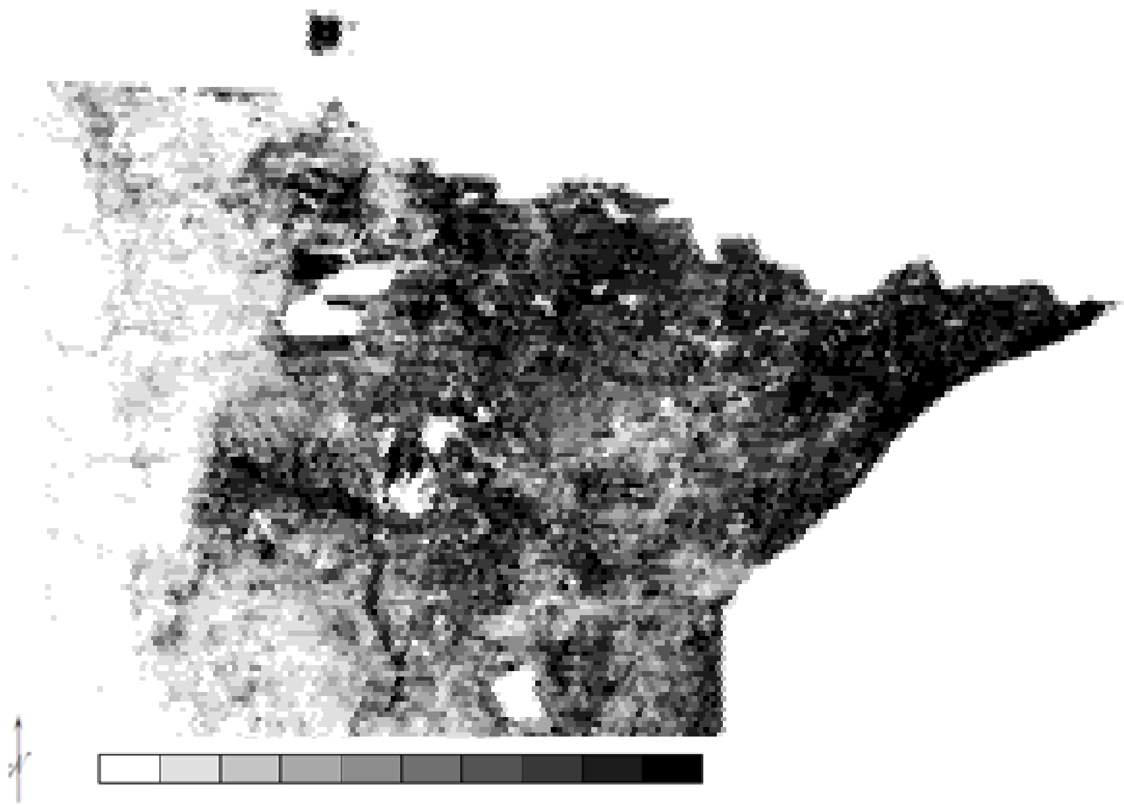
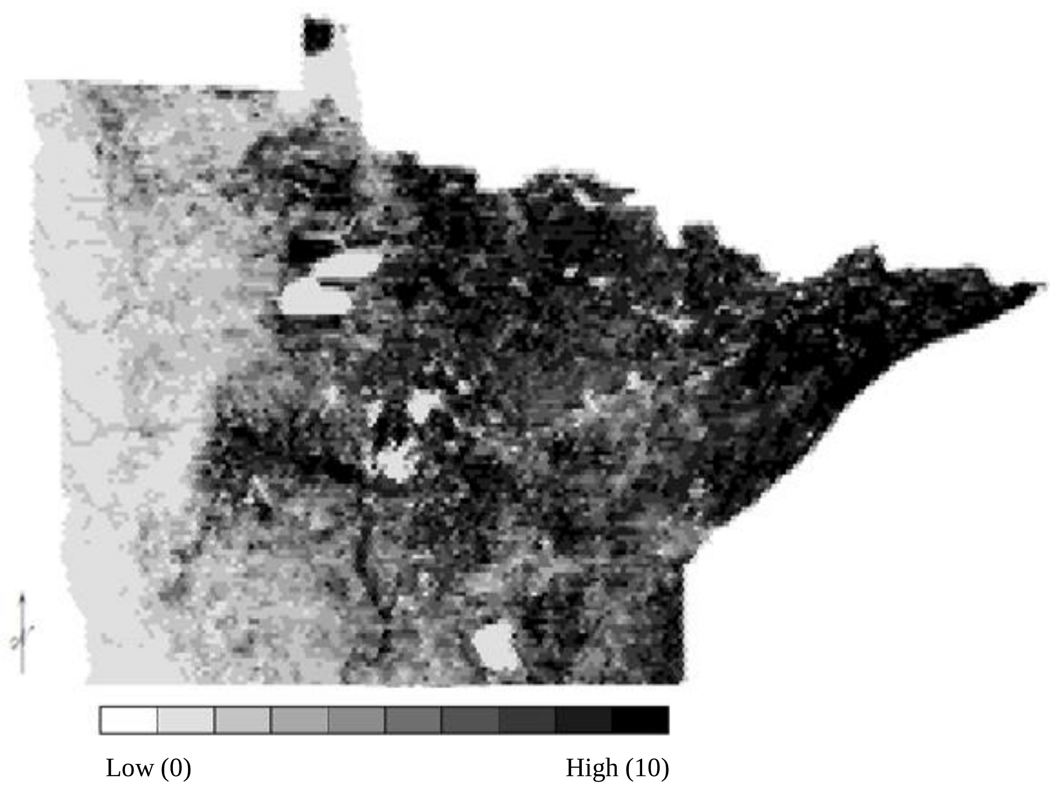

Low (0)
High (10)

Figure B.2. Northern Minnesota HexMap containing all 11 habitat categories. Outputs from scenarios completed on the northern Minnesota category HexMap were applied to the eastern North Dakota category HexMap to simulate fisher distribution.


Low (0)
High (10)

Appendix C

Coordinates of Survey and Detection Sites

Table C.1. The latitude and longitude (WGS 1984) coordinates of detection devices for fisher presence-absence set-up in eastern North Dakota during the summers of 2008 and 2009.

Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
48.2783	-97.1228	48.01046	-97.4017	48.95662	-97.6876
48.27065	-97.1331	48.00214	-97.4024	48.96852	-97.6725
48.25605	-97.1407	47.96742	-97.4574	48.96966	-97.6359
48.21773	-97.1307	47.92508	-97.5316	48.93031	-97.8723
48.15478	-97.1357	47.94567	-97.587	48.94995	-97.7208
48.01348	-97.2935	47.94583	-97.5902	48.9784	-97.6709
48.01358	-97.2683	47.95435	-97.5848	48.97873	-97.6008
48.02617	-97.1886	47.96041	-97.5905	48.99281	-97.571
48.06215	-97.184	47.96641	-97.6037	48.98062	-97.5085
48.08502	-97.1751	47.9751	-97.6105	48.97894	-97.4964
48.08803	-97.1737	47.98972	-97.6211	48.97509	-97.4694
48.12427	-97.1766	48.00448	-97.6624	48.94682	-97.3534
48.15323	-97.159	48.04674	-97.7212	48.93743	-97.306
48.75009	-97.8509	48.04027	-97.8002	48.73634	-97.8839
48.739	-97.911	48.0413	-97.7944	48.86568	-97.5056
48.73476	-97.9493	48.014	-97.384	48.87743	-97.3467
48.788	-97.697	48.02214	-97.361	48.92202	-97.3089
48.78756	-97.6926	48.01702	-97.3268	48.96385	-97.2365
48.79041	-97.6712	48.01673	-97.3226	48.90504	-97.213
48.87367	-97.4895	48.02454	-97.1906	48.71738	-97.1294
48.88985	-97.4344	48.10458	-97.1104	48.86092	-97.1821
48.87533	-97.4228	48.089	-97.104	48.77689	-97.1604
48.93454	-97.2267	48.071	-97.1025	48.21397	-97.8358
48.86865	-97.1883	48.24671	-97.1448	48.21066	-97.8582
48.84922	-97.1791	48.25034	-97.1275	48.2243	-97.9217
48.73382	-97.1325	48.30339	-97.1274	48.21949	-97.9643
48.63266	-97.132	48.36901	-97.1565	48.20801	-98.0171
48.59818	-97.1541	48.38307	-97.1537	48.40098	-97.7976
48.49828	-97.1478	48.40874	-97.1378	48.40905	-97.8925
48.47885	-97.1636	48.48019	-97.1623	47.45364	-96.8994
48.46094	-97.1302	48.52828	-97.156	47.41849	-96.8722
48.46222	-97.1481	48.62323	-97.135	47.38177	-96.8506
48.331	-97.1431	48.6748	-97.1017	47.3502	-96.8476
48.32421	-97.1398	48.671	-97.101	47.34019	-96.8333
48.30501	-97.1279	48.04903	-97.0743	47.29541	-96.843
48.21723	-97.1282	47.98768	-97.0543	47.27353	-96.8458

Cont.

Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
46.59961	-96.7725	48.52668	-97.9455	48.3439	-97.1404
46.53908	-97.2891	48.52284	-97.6886	48.38387	-97.1556
46.53909	-97.2989	48.46524	-97.5585	48.43371	-97.1452
46.50874	-97.8719	48.54903	-97.6686	47.95431	-97.0541
46.4997	-97.8806	48.447	-97.4885	48.61557	-97.1451
46.55915	-97.9209	48.43245	-97.3193	48.71797	-97.1244
47.938	-97.504	48.42244	-97.6122	48.86554	-97.192
47.946	-97.505	48.41171	-97.8068	48.89301	-97.1963
46.14668	-96.5781	48.41345	-97.9284	48.93319	-97.2249
47.76765	-97.6752	48.32576	-97.8657	48.09195	-97.11
47.63382	-97.5606	48.1785	-97.7564	47.95081	-97.0568
47.61647	-97.5539	48.18661	-97.5713	48.03419	-97.0712
47.53717	-97.4554	48.94805	-97.3332	47.86029	-97.0001
47.51013	-97.3774	48.96864	-97.4454	47.67292	-96.8953
47.42905	-97.0121	48.99178	-97.5614	47.62112	-96.88
47.7119	-97.5912	48.98437	-97.6503	47.55838	-96.8625
47.61687	-97.5565	48.94878	-97.3581	47.55561	-96.8602
47.60307	-97.5331	48.97787	-97.5003	47.53671	-96.8567
47.53659	-97.4554	48.99133	-97.5908	47.48452	-96.8638
47.51183	-97.3678	48.96474	-97.6854	46.31294	-96.5988
47.45551	-97.2089	48.96996	-97.6228	46.41718	-96.7011
47.41085	-97.1003	48.14044	-97.1429	46.54353	-96.7502
48.9596	-98.0262	48.1702	-97.1486	46.64637	-96.795
48.92727	-97.9994	48.18179	-97.1452	47.01532	-96.8328
48.82685	-97.9987	48.33844	-97.1278	46.98793	-96.8971
48.71754	-97.9425	48.39186	-97.1644	47.86708	-98.0334
48.59025	-97.9814	48.51372	-97.135	47.72052	-98.2013
48.51184	-97.9056	48.49437	-97.1418	46.52246	-97.8356
48.50822	-97.755	48.44599	-97.1454	46.55832	-97.9249
48.61558	-97.737	48.65855	-97.1031	46.70932	-97.9836
48.525	-97.573	48.80414	-97.1735	46.82321	-97.9958
48.4558	-97.5368	48.86	-97.1865	46.94161	-97.9986
48.50898	-98.0115	48.889	-97.199	47.09566	-98.0277
48.41232	-97.6882	48.96355	-97.2322	47.43971	-98.0173
48.40639	-97.9064	48.07094	-97.0981	46.83841	-96.9039
48.23982	-97.8928	48.04533	-97.072	47.5664	-98.0766

Cont.

Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
46.4425	-97.4921	47.77456	-96.9572	46.71364	-96.9486
46.50078	-97.7726	47.71505	-96.932	47.9891	-97.054
46.60938	-97.9079	48.15897	-97.1383	48.237	-97.904
46.85046	-98.0045	48.21133	-97.1196	47.94	-97.494
47.3985	-98.0433	48.21624	-97.1403	47.21777	-96.8454
47.6201	-98.1229	48.27039	-97.13	47.19334	-96.8454
47.74876	-98.2741	48.29718	-97.1206	47.80354	-96.9795
48.73947	-97.8454	48.31739	-97.1355	47.73025	-96.9274
48.87043	-97.3679	48.15696	-97.1497		
48.90497	-97.3262	48.13215	-97.162		
48.95617	-97.2709	48.12739	-97.1718		
48.73941	-97.8415	48.04713	-97.1958		
48.77757	-97.7657	48.01461	-97.2377		
48.84788	-97.5726	48.01799	-97.2025		
48.86177	-97.3832	48.0147	-97.3028		
48.921	-97.3145	47.58846	-96.8519		
48.0365	-97.8073	47.58205	-96.8542		
47.943	-97.502	47.48488	-96.8606		
48.02321	-97.682	46.60209	-97.0461		
48.00475	-97.6589	46.54049	-97.217		
48.0047	-97.3992	46.49951	-97.3906		
48.02012	-97.3608	46.48043	-97.5116		
48.01921	-97.2626	46.37042	-97.5337		
48.034	-97.1937	46.38633	-97.6683		
48.04888	-97.193	46.74487	-96.9277		
48.14982	-97.154	46.538	-97.2968		
48.04462	-97.7744	47.14139	-96.8316		
48.05445	-97.7302	47.1204	-96.8303		
47.99856	-97.4062	47.06261	-96.8265		
48.02003	-97.3771	47.02968	-96.8391		
48.00799	-97.3471	46.65389	-96.8023		
48.01276	-97.234	46.63574	-96.7937		
48.06271	-97.1808	46.62939	-96.7871		
48.1013	-97.1707	48.198	-97.756		
48.12902	-97.168	48.194	-97.143		
47.937	-97.507	48.17569	-97.1497		

Table C.2. The latitude and longitude (WGS 1984) coordinates of detection devices which received fisher detections in eastern North Dakota during the summers of 2008 and 2009.

Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
48.1785	-97.75642	47.61647	-97.55386	48.21624	-97.14033
48.2243	-97.9217	47.51013	-97.37735	48.27039	-97.13
48.96852	-97.67247	48.77757	-97.76567	48.29718	-97.12057
48.94995	-97.72082	48.9596	-98.0262	48.31739	-97.13545
48.99281	-97.57103	48.92727	-97.99941	48.3439	-97.1404
48.98062	-97.50846	48.71754	-97.94248	48.38387	-97.1556
48.10458	-97.11038	48.50822	-97.75502	48.43371	-97.14518
48.93454	-97.2267	48.41232	-97.68815	47.95431	-97.05412
48.90504	-97.21301	48.177	-97.642	48.61557	-97.14511
48.071	-97.10254	48.93218	-98.14659	48.86554	-97.192
47.3502	-96.84761	48.7643	-97.97711	48.89301	-97.19629
48.86865	-97.18831	48.64925	-97.9497	48.93319	-97.22492
48.25034	-97.12751	48.46524	-97.55848	47.95081	-97.05675
47.29541	-96.84302	48.447	-97.48852	48.03419	-97.07115
48.86092	-97.18208	48.41345	-97.92843	47.86029	-97.00011
48.30339	-97.12743	48.1785	-97.75642	47.62112	-96.87995
47.27353	-96.84575	48.18661	-97.57126	47.55838	-96.86253
48.84922	-97.17912	48.94805	-97.33317	47.55561	-96.86019
47.21777	-96.84539	48.96864	-97.44537	47.53671	-96.85674
48.40874	-97.13777	48.99178	-97.56144	47.43971	-98.01725
47.1204	-96.83031	48.98437	-97.65034	48.73947	-97.84538
48.49828	-97.14783	48.94878	-97.3581	48.87043	-97.3679
48.04903	-97.07434	48.99133	-97.59082	48.90497	-97.32622
48.46222	-97.14813	48.96474	-97.68536	48.95617	-97.27091
48.331	-97.14307	48.96996	-97.62281	48.86177	-97.38319
47.80354	-96.97945	48.14044	-97.1429	48.921	-97.31447
47.73025	-96.92744	48.1702	-97.14861	48.14982	-97.15401
48.30501	-97.12785	48.18179	-97.14516	48.06271	-97.18082
47.938	-97.504	48.33844	-97.12775	48.1013	-97.17069
48.01348	-97.29347	48.39186	-97.16437	48.12902	-97.16802
48.08502	-97.17513	48.49437	-97.14184	47.937	-97.507
48.08803	-97.1737	48.44599	-97.14542	47.96742	-97.45742
48.739	-97.911	48.80414	-97.17352	48.02454	-97.19061
48.788	-97.697	48.86	-97.18645	47.63382	-97.56056
48.79041	-97.67123	48.889	-97.199	47.77456	-96.95724

Cont.

Latitude	Longitude
48.1785	-97.75642
48.77757	-97.76567
48.17569	-97.14971
48.96355	-97.23223
48.07094	-97.09806
48.04533	-97.072
48.15897	-97.13832
48.21133	-97.11959
48.0413	-97.79441
47.9891	-97.05395