THE INVESTIGATION OF THREE MIDWESTERN NATIONAL FORESTS FOR POSSIBLE HABITAT AND CURRENT MANAGEMENT STRATEGIES OF MOUNTAIN LION (FELIS CONCOLOR)

by

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A Thesis
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THESIS APPROVAL

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ANDREW M. BROOKMAN, for the Master of Science degree in Geography and Environmental Resources, presented on October 18, 2006, at Southern Illinois University Carbondale.

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The Nebraska, Nicolet (Wisconsin), and Ouachita (Arkansas) National Forests were investigated for suitability to incoming mountain lion from the West. Biologists defined the forests as suitable for mountain lion, and stated that mountain lions pose no threat to visitors. The GARP model predicted presence for the Nebraska N.F. in 19-20 (90-100%) model outputs, for the Nicolet N.F. in 9-14 (50-70%) model outputs, and for the Ouachita in 3-16 (20%-80%) model outputs. State classification is protecting mountain lions in Nebraska and Wisconsin. In Arkansas state classification is overridden by the United States Fish & Wildlife Service. Based on environmental needs and a prey base, all three national forests are suited to mountain lion existence. Presence of mountain lion in the national forests is documented, but data are inconsistent. Despite environmental suitability and proper forest management human activities in the forests do not allow significant mountain lion populations.

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CHAPTER 1

INTRODUCTION

This is an investigation of the environmental suitability of mountain lion in the Nebraska, Ouachita (Arkansas), and Nicolet (Wisconsin) National forests. Specifically the research questions that guided this investigation are as follows:

1. Are the environmental conditions of the national forests conducive to the existence of mountain lions? 2. How is the forest service managing the possibility of mountain lion occurrence? 3. What is the current state classification of mountain lions in Arkansas, Nebraska, and Wisconsin?

For this investigation topics relating to mountain lions were studied such as mountain lion populations, prey base, a transplantation study, policy & management, land use, and western influences. The study area chapter covers geomorphology, flora & fauna, and the climate that makes up the national forests. Methodology included the GARP model, surveying USFS wildlife biologists, and state classification of the species. The results of methodology and conclusions of said results sum up the investigation preformed.

Historically mountain lions have been successful at adapting and migrating to new and former habitats. *Felis concolor* inhabits the largest range of any terrestrial mammal. This species ranges across 110 degrees of latitude from the Yukon to the Straits of Magellan (Culver et al, 2000). The mountain lions that inhabit the U.S. today come from a small population of animals. The consistency of mtDNA indicates that North American pumas originate from a recent (late Pleistocene circa 10,000 years ago) recolonization by a small number of animals who originated from mountain lions in eastern South America 200,000 to 300,000 years ago (Culver et al, 2000). Historically, it is probable that no mountain lions

existed in the whole of the North American (Culver et al, 2000). The recolonization of North America by mountain lions was coincident with a late Pleistocene extinction that eliminated 80% of large vertebrates in North America, and may have removed pumas from the continent (Culver et al, 2000). In the case of mountain lions moving back to the Midwest it is not a matter of adapting to new habitat, but a matter of reclaiming former habitat.

For over a century mountain lions have been classified as extinct in the Midwest. In Illinois the last known mountain lion was killed in Cook County (the location of Chicago) in the 1850's (www.Naturealmanac.com, 2004). Wisconsin's official records state; that in the past mountain lions were found throughout Wisconsin, but have most likely been absent from the state since the early 1900's (Anderson et al, 2003). The foundation for the loss of mountain lions in the Midwest was not the loss of habitat, but rather eradication by humans. Both the mountain lion and the preferred prey of mountain lions (whitetail deer) were hunted to the point of extinction. Mountain lions were seen as a threat to humans and livestock. Both the Midwest and eastern states lost their resident mountain lions populations.

Since the 1940's, the public has recorded sightings of mountain lion in the Midwest. In the spring of 1953, Bryan P. Glass, an Oklahoma State University mammalogist, found and recorded tracks left by a mountain lion in an area to the southeast of Canton Reservoir, Canton, Oklahoma (Pike et al, 1997). The legitimacy of mountain lion sightings is questioned due to other species being misinterpreted as mountain lions. Most commonly, feral dogs, coyotes, bobcats, and even feral housecats have been mistaken for mountain lions. Despite the possibility of misinterpretation, in Nebraska for example, there is a possibility that mountain lions are occurring in the central and western areas of the state (Nebraska Dept. of Natural Resources, 2005). Captive mountain lions, either kept by private citizens or

businesses, have been known to escape or be released, but this number is few. Confirmed sightings from legitimate sources, such as wildlife agency personnel and law enforcement are possibly feral mountain lions. Another implication of feral mountain lions is the potential to breed, therefore creating a population of feral mountain lions. These feral mountain lions may possibly provide wild migrating cats with potential counterparts for breeding that otherwise would be nonexistent.

The national forests in this investigation are managed by the United States Department of Agriculture Forest Service. The Nebraska National Forest is in close proximity to established mountain lion populations residing in the states of Montana, Colorado, South Dakota and Wyoming (Nebraska Dept. of Natural Resources, 2005). The Nebraska National Forest represents the western portion of the Midwest.

In Nebraska, the majority of legitimate and confirmed mountain lion sightings are in the panhandle portion of the state (Nebraska Dept. of Natural Resources, 2005). The Nebraska National Forest (Fig.1.1) is located in the panhandle region of the state (Nebraska Dept. of Natural Resources, 2005). In Nebraska, mountain lions have been considered extinct since the end of the 19th century (Nebraska Dept. of Natural Resources, 2005).

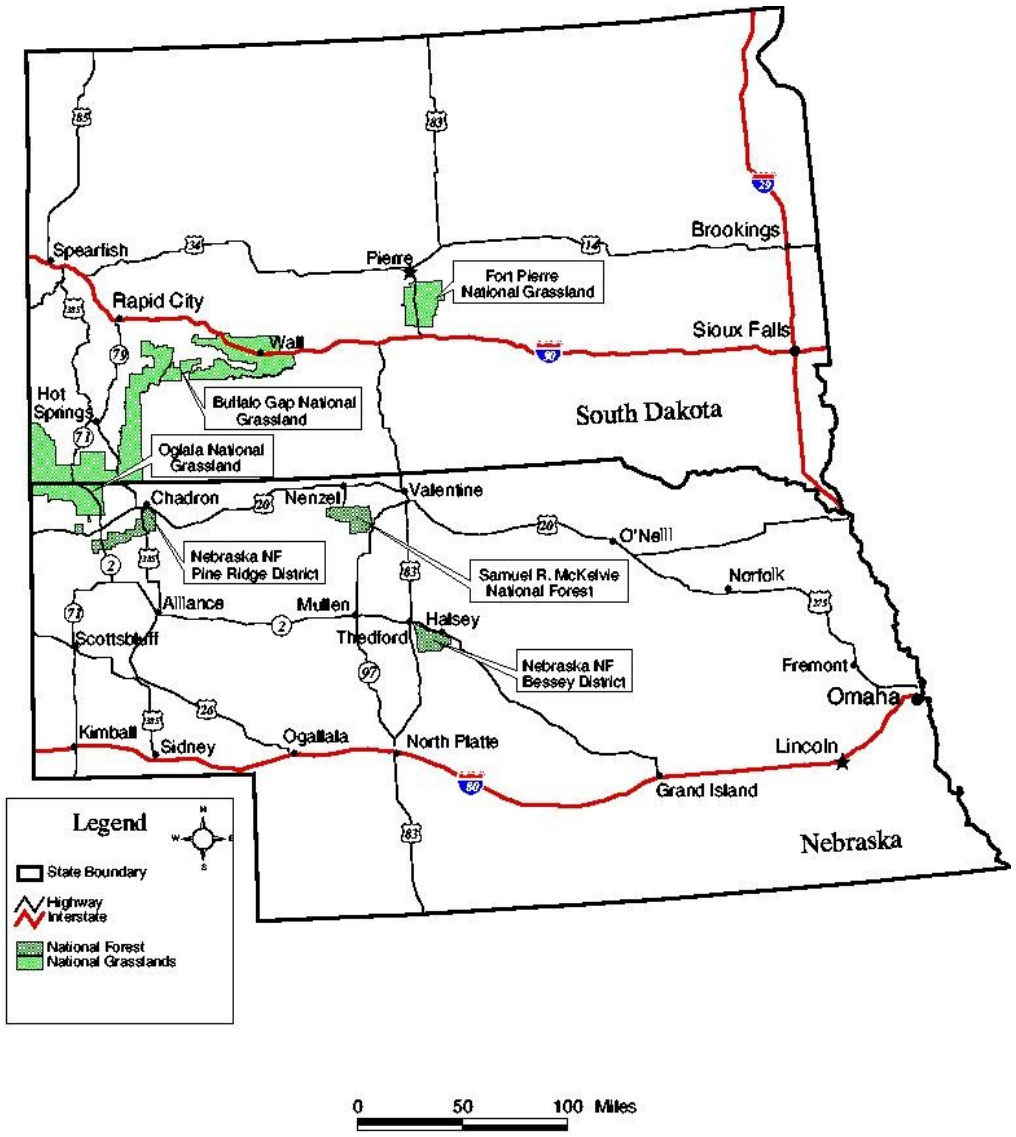

Figure 1.1 Nebraska National Forest located south/west of Chadron Nebraska. (www.fs.fed.us/r2/nebraska, 2005).

The Ouachita National Forest of Arkansas (Fig. 1.2) is within the outer dispersal range of mountain lions from Texas. The Ouachita National Forest represents the southern portion of the Midwest. There is a concentration of mountain lion sightings recorded within the national forest boundaries (Clark et al, 2000).

Figure 1.2. The Ouachita National Forest located in West Central Arkansas, (www.fs.fed.us/oonf/ouachita, 2002).

The Nicolet National Forest of North East Wisconsin (Fig.1.3) is representing the northern portion of the Midwest. The Nicolet National Forest in the northern region of Wisconsin could provide a refuge for mountains lions. National Forests offer areas of un-fragmented habitat and deer populations necessary for mountain lion existence. For Wisconsin the majority of recorded sightings are within the northern third of the state (Anderson et al, 2003). There are numerous recorded sightings that fall within the national forest boundaries (Anderson et al, 2003).

Figure 1.3. The Nicolet National Forest located in North Eastern Wisconsin, (www.fs.fed.us/r9/cnnf, 2004).

The Nebraska, Ouachita, and Nicolet National Forests represent three different environmental and geographical regions. All three areas have lost their resident populations of mountain lions. The variance in environmental conditions from North Western Nebraska, North Eastern Wisconsin, and West Central Arkansas adds diversity to the investigation. The national forests are likely candidates for natural reintroduction due to limited human populations.

In the Midwest, due to agriculture and human populations much of the area is uninhabitable to mountain lions. National forests may provide a sanctuary, for these areas have relatively low human populations. In Wisconsin, for example, agriculture along with a dense human population in the southern region of the state is not favorable for mountain lion existence. The Nicolet National Forest in the northern region could possibly provide a refuge from human interference that would be necessary for mountain lion's existence. A re-

colonization of mountain lions in the Midwest would be on a small scale due to the current land use and human populations of the area.

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Previous research concerning mountain lions relates to habitat requirements, habitat fragmentation, large carnivore management, and the politics of large carnivore management. For this literature review topics relating to mountain lions were investigated such as mountain lion populations, prey base, a transplantation study, policy & management, land use, and western influences. Mountain lions are an indicator species for habitat connectivity (Ernest et al, 2002). Mountain lions may be using riparian areas in proximity to streams and rivers to move to new areas (Nebraska Dept. of Natural Resources, 2005). Using these corridors there is a possibility for mountain lions to move great distances without encountering man, therefore their existence is unknown (Nebraska Dept. of Natural Resources, 2005). In one study, Mountain lions established home ranges that were in the area of, or included large river systems and smaller tributary systems (Riley & Malecki, 2001). In 2003, a juvenile mountain lion male was captured alive, and near Omaha; in 2004 a juvenile male was killed (Fig.2.1.1) by law enforcement (Nebraska Dept. of Natural Resources, 2005). Mountain lions have a preference for river systems, and these areas could be possible movement corridors (Nebraska Dept. of Natural Resources, 2005). These examples from Nebraska show instances of mountain lion migration through, or to areas that are populated with humans in the Midwest.

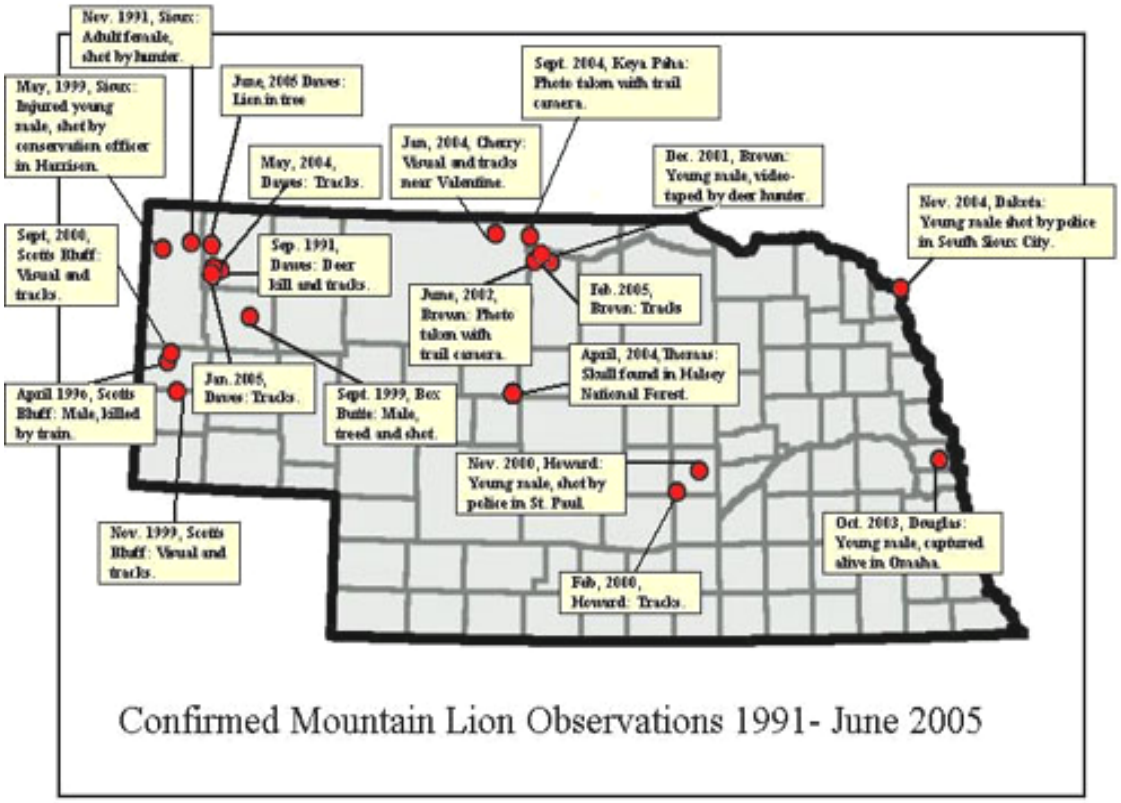

Figure 2.1.1. Mountain lion sightings and sign (Nebraska Game and Parks Commission, 2005)

2.2 MOUNTAIN LION POPULATIONS

Mountain lions require large areas of undisturbed habitat to exist (Beier, 1992). With a lack of animals migrating into a new area, a habitat area of 1000-2200 km^2 is required to support a mountain lion population with a 98% or more chance of survival (Beier, 1992). The 1000-2200 km^2 track of habitat is a basic land requirement, and would hold about 15-20 adult mountain lions (Beier, 1992). Home ranges for mountain lions can very from 120 to 2000 km^2 for males, and 32 to 1000 km^2 for females (Witmer et al, 1998). The size of a mountain

lions home range is related to seasonal movements of prey (Witmer et al, 1998). Seasonal ranges for mountain lions are often considerably smaller then annual ranges (Witmer et al, 1998). Minimum habitat requirements are a limiting factor for mountain lions migrating to the Midwest.

For mountain lions, it is difficult to get an accurate census of their populations. Although there is no definitive evidence of the mountain lion presence in Wisconsin, consistent sightings from credible sources make it possible that some mountain lions do exist in the state (Anderson et al, 2003). Exact census figures at a specific site level for mountain lions are not available (Ernest et al, 2002). When looking at localized mountain lion populations, their population configuration is not well known and inadequately documented (Ernest et al, 2002). Mountain lions are one of the most difficult land mammals to census (Riley & Malecki, 2001). Wisconsin is taking actions to get an accurate assessment of the probability of mountain lions in the state. Beginning in 1991, the Wisconsin Department of Natural Resources (WDNR) has been collecting and logging data on mountain lion sightings in the state as a component of their rare mammal observation program (Anderson et al, 2003).

This investigation fits a gap in research concerning mountain lions in the eastern portion of their known range and movement to the Midwest.

Figure 2.2.1. Current known Mountain lion home range. (www.dlia.org, 1999)

There has been a significant amount of research on mountain lions in the western portion of their home range; in contrast there have been few studies on the central and eastern portions of the mountain lions' home range (Pike et al, 1997). This lack of studies is an important gap in research, for mountain lions that occupy the eastern range are the mountain lions that would potentially migrate to the Midwest. There are deficiencies in the study of the current established eastern range habitat of mountain lions, and what habitat is available in the Midwest (Pike et al, 1997).

Studies concerning mountain lion populations in the western established range could not estimate population numbers. With the lack of accepted census techniques, an index of abundance (COUGARMORT) defined as the concentration of total mountain lion mortality (deaths/1000 km^2) was calculated from hunting districts dispersed across Montana (Riley & Malecki, 2001). In Arkansas, physical evidence was found consisting of scat and tracks that showed the possibility of at least one mountain lion in the state from 1996 to 2000 (Clark et al, 2000). In recent years physical evidence, such as tracks, from the counties Pulaski, Perry, Garland, and Hot Springs in Arkansas were concluded to be the tracks of mountain lion (Clark et al, 2000). These findings renewed an interest in the possibility of wild mountain

lions existing in Arkansas (Clark et al, 2000). In the years from 1961-1965 multiple sightings were recorded of mountain lion in northeastern Oklahoma (Pike et al, 1997). In 1968 the remains of a deceased young female mountain lion were discovered in McIntosh County in eastern Oklahoma (Pike et al, 1997). Researchers Bissonette and Maughan logged sightings of a mountain lion that had been seen on 2 different instances in the vicinity of Stringtown, Oklahoma (Pike et al, 1997). Also recorded was an adult, assumed female with multiple cubs in Sequoyah, Oklahoma, in 1974 (Pike et al, 1997). Sightings of mountain lion by the residents of Arkansas, along with sportsmen and biologists had risen to more then 30 reports in the time frame of a year in the middle of the 1980's (Arkansas Fish and Game records, 2000). A study in Arkansas from 1988-1991 was unable to find any mountain lions, or the sign of mountain lions such as remains, scat, or tracks in the state of Arkansas (Clark et al, 2000). This study came to the conclusion that there are, at this time, no naturally occurring and reproducing populations of mountain lions in Arkansas (Clark et al, 2000).

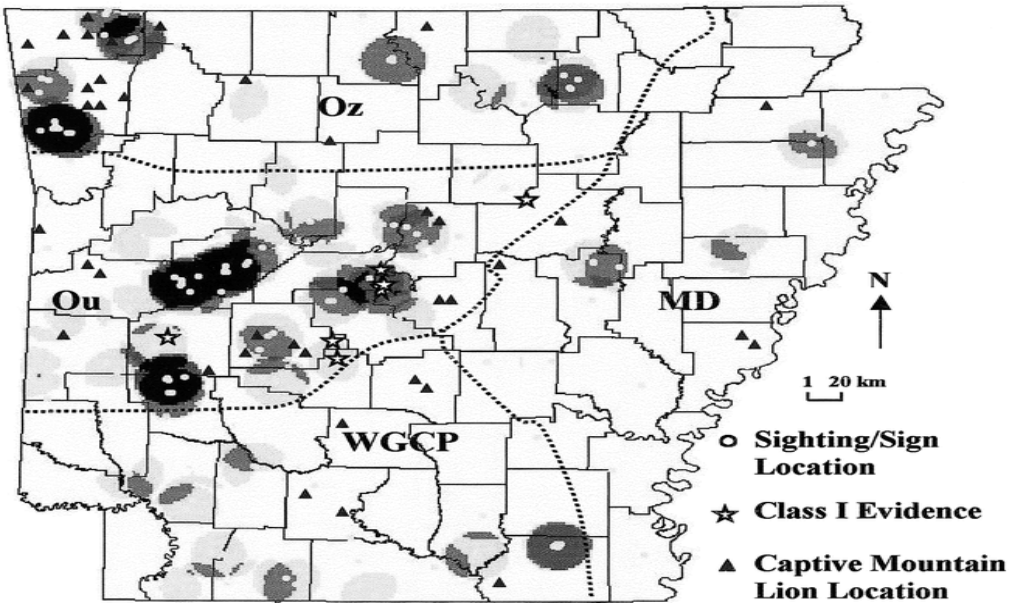

Figure 2.2.2. Reported sightings and sign from 1996-2000 In Arkansas. The darker the coloring of the ring, the higher the concentration of sightings. (Clark et al, 2000)

Within Minnesota, for example, in 2001 a nursing female with two young was killed outside of Duluth Minnesota (Clark et al, 2000). From that point, a small population has been recognized to reside in the northern part of Minnesota (Clark et al, 2000). Research concerning mountain lion habitat points towards the dispersal and existence of mountain lions is directly related to the quantity of topographic heterogeneity and the amount of forested area (Riley & Malecki, 2001). Habitat with greatly varying topological features, such as mountains and valleys that is heavily forested gives mountain lions the best habitat for the maximum population concentration (Riley & Malecki, 2001). Mountain lions can occupy a large range of habitats; however they favor open or mixed forest and shrubby cover types (Witmer et al, 1998). Mountain lions are documented to inhabit areas with highly varied topography with minimal forest cover (Riley & Malecki, 2001). In habitats with limited forest cover studies show that only a very small number of mountain lions can populate these regions (Riley & Malecki, 2001). The results from a study in Florida found mountain lions were located regularly (90%) in the hardwood swamps and pine flatwoods habitats (Belden & Hagedorn, 1992).

2.3 PREY BASE

The loss of a prey base contributed to the failure of mountain lion in the Midwest, for the eradication of whitetail deer coincided with the eradication of mountain lions. In the northern areas of the Rocky Mountains, species such as mule deer, whitetail deer, and elk are the most important pray for mountain lions (Riley & Malecki, 2001). These prey animals make up almost 100% of the mountain lions diet (Riley & Malecki, 2001). The Ouachita and Ozark mountains of Arkansas are remote habitats with little human inhabitation, and are

thought to produce the most reports of mountain lions (Clark et al, 2000). The Ouachita and Ozark mountain areas, along with the Gulf Coastal Plain have had increasing whitetail deer populations (Clark et al, 2000). In the Midwest whitetail deer populations are at a stable mark, for example Illinois has an estimated population ranging from 750,000 to 800,000 deer (www.Illinoisgameandfish.com, 2005). In 16 different analyses of mountain lion diet deer was the most common food source in 14 (Belden & Hagedorn, 1992). In areas that mountain lions occupy the availability and density of prey species is the sustaining factor of mountain lion population numbers (Riley & Malecki, 2001). Mountain lion concentration is based on metabolic requirements and prey availability (Riley & Malecki, 2001). There is a correlation linking mountain lion observations and deer harvests in Oklahoma and Wyoming (Clark et al, 2000). A similar correlation has also been found in Arkansas (Clark et al, 2000). Arkansas in recent years has been experiencing an increase in the number of whitetail deer (Clark et al, 2000).

The whitetail deer population is predicted to be approximately at 1 million for the state of Arkansas (Clark et al, 2000). Records kept from hunters show an increase in the deer population that coincides with the estimated increase in mountain lion sightings (Clark et al, 2000). Arkansas deer populations are speculated to be capable of supporting a mountain lion population (Clark et al, 2000). Observations of mountain lions had been logged in Marinette County, Wisconsin in the early 1900's, but the reports became fewer as whitetail deer numbers became new record lows (Anderson et al, 2003). The deer population in the state of Wisconsin rebounded in the 1930's and 1940's, and observations of mountain lions began again across the state (Anderson et al, 2003).

The whitetail deer population in Arkansas had been reduced to about 300 animals across the entire state by the early 1930's (Clark et al, 2000). During the 1930's time frame, coinciding with the deer loss, it was thought that the mountain lion also was lost from the state of Arkansas (Clark et al, 2000). With the deer population increasing in the state of Arkansas from the 1940's, and with a mountain lion in 1949 killed by a hunter in the western part of Arkansas there could be an association between the rise of the deer population and this mountain lion (Clark et al, 2000). From the 1950's and 1960's the amount of sighting occurrences and discovery of tracks and scat had been on the rise, and in 1969 a hunter killed a mountain lion in the southwestern portion of Arkansas (Clark et al, 2000). Southwest Arkansas is within dispersal range of mountain lions that reside in Texas, a state with known mountain lion populations (Clark et al, 2000). The records from Arkansas show 63 mountain lion recorded from 1945 to 1972, and that a small mountain lion population is or has existed within the state in the recent past (Clark et al, 2000). Arkansas state records show a positive correlation between the loss of whitetail deer populations in the Midwest and the loss of the mountain lion populations. Also a similar positive correlation can be shown from the increase in the deer populations, and the reported sightings of mountain lions.

2.4 TRANSPLANTATION STUDY

In 1988, the state of Florida preformed a study with the release of 7 mountain lions captured from Texas to examine the feasibility of mountain lions existing in Northern Florida (Belden & Hagedron, 1992). The social challenges of carnivore reintroduction are even more overwhelming then the biological ones (Miller et al, 1999). Because carnivores play indicator and keystone roles, reintroducing a group of extirpated carnivores is a step forward in

restoring the natural integrity to an area (Miller et al, 1999). This study is important to my investigation, for mountain lion actions were observed and documented in an area that they had not occupied for years. A group of 7 mountain lions were transplanted into a section northern Florida, and they were surveyed from June 15th 1988 to April 19th 1989 (Belden & Hagedron, 1992). The mountain lions had been recorded in 812 locations in the 306-day period (Belden & Hagedron, 1992). Although the mountain lions in this study established home ranges, the ranges overlapped (Belden & Hagedorn 1992). The 4 mountain lions that were in the wild 35 days or more (T-14, T-15, T-16, and T-18) established home ranges (range 96-930 km^2) that overlapped in a 2000 km^2 area, a density of 0.2 lions/100 km^2(Belden & Hagedorn, 1992). There is the possibility that mountain lions moving into the Midwest will be able to establish home ranges, and suggests animals released would establish home ranges if the right factors exist (Belden & Hagedron, 1992). A limiting factor to mountain lion movement is fragmentation of habitat by roadways and interstates (Belden & Hagedron, 1992). The mountain lions (7), studied in Florida crossed roads approximately 2,612 times within the study time frame (Belden & Hagedron, 1992). This averaged out to be 2.7 crossings per lion per day (Belden & Hagedorn, 1992). Of the 7 mountain lions, 5 dealt with crossing federal interstate highways, and only 2 of the 5 actually crossed the interstate 5 times before finding their home range (Belden & Hagedorn, 1992). This study concluded that road type plays a role in mountain lion movement (Belden & Hagedron, 1992). Interstates are a limiting factor, for mountain lions only crossed interstates in transition from the release point to establishing home ranges (Belden & Hagedorn, 1992). Mountain lions will cross interstates; however it is unlikely to be a part of their home range and a roadway that they are willing to cross regularly (Belden & Hagedorn, 1992).

Mountain lions reclaiming habitat in the Midwest may first inhabit large forest areas (Nebraska, Ouachita, and Nicolet National Forests), but could be pushed out due to humans entering the forest even if only seasonally. On March 25th, the first weekend of spring turkey hunting season, T-15 left her home range which she had established in September 1988 (Belden & Hagedorn, 1992). Subadult female T-14 established a home range without preliminary excursions (Belden & Hagedron, 1992). She was first to create and the first to leave a home range. On November 19th, the opening of the firearm season, she left her home range occupied for 5 months and began a 2-week excursion (Belden & Hagedorn, 1992). Once mountain lions are pushed out of the only habitat available they move, and in the Midwest, that movement likely leads to areas not favorable to mountain lion (Belden & Hagedron, 1992).

2.5 POLICY AND MANAGEMENT

In past years the problem concerning wildlife in North America was over-exploitation (Pletscher & Schwartz, 2000). Waterfowl, forest carnivores, and ungulates were over harvested for market purposes (Pletscher & Schwartz, 2000). Game species had little to no protection regulations to the point where most species were harvested to near extinction (Pletscher & Schwartz 2000). The debates concerning state wildlife management and policy are likely to become more common in the future as issues arise (Nie, 2004). The future trend in the direction of ecosystem management, conservation biology, and large mammal restoration will increasingly place wildlife agencies in the public eye (Nie, 2004).

Throughout the last two hundred years, human populations in the United States have steadily increased, and populations are projected to continue increasing (Alig et al, 2003).

With increasing human populations, large carnivores are among the most difficult taxonomic groups to conserve (Linnell et al, 2001).

In large carnivore management, the sociopolitical landscape is of as much importance as the biological landscape (Treves & Karanth, 2003). Public feeling and thoughts toward mountain lions have been undecided, never reaching the clarity of the position on wolves (Kellert et al, 1996). If the wolf is taken from the Endangered Species Act list, wolf management and conservation will seriously test the way that state wildlife management agencies are funded (Nie, 2004). How state wildlife management agencies make policy and management decisions will also be challenged (Nie, 2004). Large carnivore management, such as mountain lions, is a political challenge as much as a scientific one (Treves & Karanth, 2003). There are various reasons for the rise in political conflicts regarding our natural world, including population increase, land use and growth trends, urbanization, and shifting American ideals and beliefs towards wildlife (Nie, 2004). Through the history of agriculture and forestry in the Midwest, wildlife personnel have needed an understanding of existing wildlife habitat and population changes to identify what wildlife there possibly could be (Ribic et al, 1998).

Carnivores have a significant impact on biological communities by means of predation and interspecific competition (Treves & Karanth, 2003). Conserving apex carnivore species can have a beneficial effect on a complete ecosystem (Miller et al, 1999). Carnivores control or keep in balance the numbers of prey, therefore modifying the composition and function of the entire ecosystems (Treves & Karanth, 2003). Ecosystem impacts could be a concern for national forest wildlife biologists. There is possibly a shift in mountain populations within the national forests from zero to a small number. The amount of

sufficient habitat that incoming mountain lions have available outside the national forests in the Midwest is likely limited. Mountain lions have large range necessities and predatory needs, both wild prey and livestock, which is the main problems regarding mountain lion conservation (Linnell et al, 2001).

The possibility of human-mountain lion conflicts is a concern of Midwest residents. Under a number of circumstances carnivores have attacked humans (Treves & Karanth, 2003). 15 of 54 victims (28%) were attacked by mountain lions in close proximity to a home, cabin, or within a short distance of a motor home within a prepared recreational area (Beier, 1991). Guests make use of the national parks through the year for recreational purposes (Beier, 1991). From 1890-1990 Mountain lions attacked 8 people from December-February, 15 attacks from March-May, 21 attacks from June-August, 6 attacks from September-November, and 3 attacks with no month recorded (Beier, 1991). The changes in the number of attacks may coincide with greater human presence in the wilderness during the summer months (Beier, 1991). Mountain lion attacks have been on the rise in the last twenty years, even with undocumented nonfatal attacks during the beginning of record keeping (Beier, 1991). There were more fatal attacks within the last two decades (5) then in the preceding eighty years (4) (Beier, 1991). Mountain lions have attacked and kill humans with some regularity (Kellert et al, 1996). There are 9 recognized fatal attacks and 44 nonfatal attacks resulting in 10 human deaths and 48 nonfatal injuries from mountain lion attacks (Beier, 1991). The larger number of victims is due to there being 2 victims in 5 of the attacks (Beier, 1991). The majority of mountain lion attacks engaged children (Kellert et al, 1996). Of the mountain lion confrontations, 37of 58 victims (64%) were children up to 16 years old (Beier, 1991). Using 5-year age brackets the modal age of people attacked was 5-9 years old (19

Victims) (Beier, 1991). Of the 37 children attacked by mountain lions, 35% were by themselves, 43% were in groups of only children of two or more, and in 22% of attacks adults were in the company of the child attacked (Beier, 1991). These interactions with mountain lions may arise from human infringement on their habitat, mountain lion populations on the rise, or possibly both. Mountain lion documentation in the Midwest causes public anxiety, and the first concern of the public is being confronted by a mountain lion. Mountain lions pose a greater threat to humans than wolves, and they occupy a larger range in North America then grizzlies (Kellert et al, 1996). A concern associated with mountain lions is interactions that could take place when populations have a footing in the national forests and succeed to the point dispersion. Leaving the national forest setting, mountain lions will undoubtedly interact with residents in both rural and community settings. A rise in sightings and encounters with mountain lions in urban and suburban settings may be the result of dispersing juveniles for growing populations (Witmer et al, 1998). The 3 most forward cases of mountain lion attacks consisted of a mountain lion coming through a window of a remote cabin to assault a telephone lineman (Beier, 1991). One mountain lion came into a small town of 250 residents and attacked a 2 year-old boy in the garage of his home (Beier, 1991). In another instance a mountain lion attacked a 6 year-old boy in a residential setting (Beier, 1991). Humans have permitted the reoccupation of carnivores, which has lead to conflicts in a number of areas (Treves & Karanth, 2003). Carnivore management is of top significance to conservation biologists (Treves & Karanth, 2003). Human-carnivore conflicts (threats to human life, economic security, or recreation) pose a critical challenge because they position humans against carnivores (Treves & Karanth, 2003).

Carnivores require large quantities of protein and substantial home ranges which bring them into repeated competition with humans (Treves & Karanth, 2003). There has been a decrease in portions of the mountain lion range from altercations with livestock and native ungulate management (Witmer et al, 1998). Most large carnivore species (mountain lion) are specifically designed for ungulate (deer and elk) predation (Treves & Karanth, 2003). An investigation regarding predation of ungulates in the western portion of Glacier National Park, and adjacent areas of Flathead National Forest in Montana revealed that mountain lions were responsible for more deer and elk deaths then either wolfs or hunters (Kellert et al, 1996). The specialization of ungulate predation often brings carnivores to domestic ungulate populations when the scenario is present (Treves & Karanth, 2003). When mountain lions have the routine of killing livestock they generally repeat this behavior (Kellert et al, 1996). Dispersing young males and wounded mature mountain lions are most often responsible for predations (Witmer et al, 1998). Interaction between ranchers and mountain lions is particularly an area of concern (Kellert et al, 1996). Farmers and ranchers usually hold the most negative views toward large predators, a point of view based on the loss of revenue (Kellert et al, 1996). Losses from mountain lions are not great amounts of money across the entire domestic livestock industry, however losses from a single farm or ranch may be considerable (Witmer et al, 1998). The cost of conserving large carnivores is given to the individuals who reside within rural areas that have losses of livestock, and therefore lost revenue from carnivores (Naughton-Treves et al, 2003). Wildlife managers anticipate that direct payment for livestock losses will recover the farmer's acceptance towards carnivores and discourage killing the animals in fear of losses (Naughton-Treves et al, 2003). As large carnivore (mountain lion and wolf) populations grow or humans expand into their habitat,

carnivores more regularly come upon and kill domestic livestock (Naughton-Treves et al, 2003). Large carnivore conflicts with domestic livestock can be expensive and set back carnivore recovery programs (Naughton-Treves et al, 2003). Mountain lions have been credited with livestock losses into the hundreds of animals every year, and in some instances kill several animals in one encounter (Kellert et al, 1996). Mountain lions have great predatory instincts, and stockpile killing of livestock has been reported (Witmer et al, 1998).

From European scenarios, and a study of more recent North American data, Linnel et al (2001) put forth the theory that large carnivore success is more effectively explained by management policy, and the following of management policy. Management and policy configuration is a larger factor for large carnivore success then human population density (Linnell et al, 2001). An investigation was preformed using human densities correlated to loss of large carnivore populations (Linnell et al, 2001). For various species, Woodroffe (2000) discovered an association linking human density and extinction probability (Linnell et al, 2001). However, Woodroffe does not represent a true picture of the capacity for large carnivores to exist in the present world under positive management practices (Linnell et al, 2001). In Woodroffe's (2000) investigation, human density is an assessment of the actions that humans perform to eliminate large carnivores when removing carnivores is the human goal (Linnell et al, 2001). The North American extinction data used by Woodroffe (2000) is from the late 1800's and early 1900's (Linnell et al, 2001). During this period the general social plan, and politically authorized plan, was to eliminate large carnivores (Linnell et al, 2001). To the degree that actions are an indication of attitude, reaction to mountain lions, particularly the widespread elimination of the species reflects a similar perception toward other large carnivores (Kellert et al, 1996). Bounties have been approved multiple times by

county, state, and federal administrations (Linnell et al, 2001). In California, a state authorized bounty system eliminated 12,000 mountain lions from 1907 to 1963 (Kellert et al, 1996). The federal government has produced money to pay professional hunters who have used such methods as traps, poison, and hunting to eliminate carnivores (Linnell et al, 2001). Changing political views of nature have shifted the goals of carnivore management from those based on alarm and small economic interests to those based on a better understanding of ecosystem function and adaptive management (Treves & Karanth, 2003). The loss of bounties, the enactment of restrictions on mountain lion hunting, and growing deer herds have resulted in a rise in the range and in the numbers of mountain lions (Witmer et al, 1998). Many are in favor of carnivore protection be it for environmental, or esthetic reasons for restoring wolf and mountain lion populations (Naughton-Treves et al, 2003). Linnell et al (2001) suggest that the function of management is important enough that large carnivore populations would become stable or improve once the management policy objectives are in support of protection, even with human numbers consistent to growing. Public resistance can halt translocation, reintroduction, and deny the natural recovery of carnivores to former habitat (Treves & Karanth, 2003). Conservation of large carnivores depends on the tolerance and knowledge level of those who make up the current sociopolitical landscape and favorable ecological conditions (Treves & Karanth, 2003). Humans are the direct cause of most carnivore deaths around the world, and the majority of the current extirpations of carnivore populations (Treves & Karanth, 2003).

The passing of the Lace Act of 1900 by the federal government made illegal to transfer unlawfully killed wildlife across state borders (Pletscher & Schwartz, 2000). The passing of Lacey Act brought to an end the era of wildlife viewed as unprotected public

property (Pletscher & Schwartz, 2000). Formally policy concerning predators, including large carnivores, started shifting in the 1940's (Linnell et al, 2001). The most policy changes occurred in the first years of the 1970's (Linnell et al, 2001). The uncontrolled wide practice of using toxicants for carnivore management was outlawed in the United States in 1972 (Linnell et al, 2001). Research findings are leading policy on lethal control techniques, and are supporting the creation and improvement of non-lethal measures to carnivore management (Treves & Karanth, 2003). During the 1970's wolves, grizzly bears, and mountain lions had reached a level where all species were protected or managed as game species through Canada and the United States (Linnell et al, 2001). In the following 25 years since 1970's there has been no further loss of mountain lion in their established range state/provinces (Linnell et al, 2001). Wildlife managers in 15 states and provinces have reported that their mountain lion populations are stable to rising, as well as the remote populations of the Florida panther in Florida (Linnell et al, 2001). The stability of mountain lion populations to the point of expansion is happening even with human populations in North America almost quadrupling since 1900 (Woodroffe, 2000). The human population has risen 25 % from 1975 when the current era of conservation aimed at large carnivore management began (Linnell et al, 2001). New social views have come to encourage carnivore conservation as part of a broader social movement in favor of nature preservation (Treves & Karanth, 2003). The efforts to conserve mountain lions will depend on social tolerance by the local public (Kellert et al, 1996).

2.6 LAND USE

Land-use practices are compounded by forest expansion in many areas of the United States to give space for a possible recolonozation by past extirpated carnivores (Treves &

Karanth, 2003). Humans have altered the majority of the ecosystems that exist today (Miller et al, 1999). It has been projected that 83% of the earth's surface is directly or indirectly affected by human causes (Defries et al, 2004). The remaining percent of the earth's surface that has not been greatly altered is due to it being too cold (tundra) or too hot (desert) (Defries et al, 2004). During the 1800's to early 1900's there was a change of forest lands to crop fields or pastures, and the loss of the supporting foundation of ungulates (deer) on which carnivores subsist (Linnell et al, 2001). In Illinois, for example, the amount of habitat has declined and the quality of habitat has been degraded from 1920 to 1987 (Ribic et al, 1998). The changeover of forested lands to agricultural production throughout the last two centuries has caused the loss of forested land ranging from 20 to 50 % (Defries et al, 2004). Land-use choices must take into consideration the trade-offs between fulfilling human requirements and consequential ecosystem costs, based on social ideals (Defries et al, 2004). The loss and division of habitat from agricultural expansion and the change of agricultural areas into urban usage is known as the most significant risk to the management of biodiversity (Main et al, 1998). There is a rise across the entire country in the rate of urbanization compared to the 1982-92 period (Alig et al, 2003). Forest lands are the greatest amount of land being converted to urban uses (Alig et al, 2003). In Southern California parks may hold a small number of mountain lions, but adjacent lands fall under governmental and private jurisdictions, none of which consult prior to making decisions or consider mountain lion population viability (Berger, 2003). Large carnivores are thought to be vulnerable to local extinction in fragmented landscapes due to their need for relatively large home ranges, low numbers, and direct persecution from humans (Crooks, 2002).

In the modern global market economy, profitability is the deciding force involving landscape change (Main et al, 1998). Agriculture has been the major land use in the Midwest (Ribic et al, 1998). Through history, agricultural practices have been affecting wildlife (Ribic et al, 1998). Understanding ecological function and form is a necessity to comprehend the entire range of trade-offs related to land-use choices (Defries et al, 2004). The United States within a 40 year time period had 3.6 million acres of crop and pasture lands placed either into or out of production (Alig et al, 2003). In the United States, 1.5 million acres have come into or out of forestry production (Alig et al, 2003). There has been a trend in portions of the eastern United States to return agricultural land to forest (Defries et al, 2004). In the current time period, crop yields on average have been higher and more profitable then forestry product yields (Alig et al, 2003). With Crops yielding better then forestry products, there was a rise in land use for agriculture, but declining crop prices have allowed for a decline in the pressure to change forested lands to agricultural uses (Alig et al, 2003) From the taxation structure of the United States it is unfavorable for private land owners to keep land in non-profitable usage (Main et al, 1998). From this taxation structure there was a movement of shifting native habitats and low-intensity land uses to more productive uses (Main et al, 1998).With the change of agriculture practices in the Midwest from small family farms to a recent trend of large corporate farm systems has come the loss of habitat and wildlife (Ribic et al, 1998). Agricultural land-use in the United States has removed any connectivity in existing habitat, and this loss of connectivity has produced harmful effects on songbirds and wildlife (Ribic et al, 1998). With fragmentation of habitat still happening today in the Midwest, there is concern for the future survival of many current species (Ribic et al, 1998). Mountain lions living in areas that have been fragmented are vanishing without ways of

movement, such as corridors between fragments (Crooks, 2003). As habitat patch size decreases species disappear: with large, wide-ranging, and specialized species (mountain lion) disproportionately represented in the losses (Miller et al, 1999). Many areas in the Midwest are not suitable for mountain lions due to agriculture land-use and human populations dividing the landscape. The USDA's 1997 National Resource Inventory presents on a national scale 11 million acres of forest, cropland, and barren land had been converted to urban and other developed uses from 1992 to 1997 (Alig et al, 2003). Conflicts between humans and wildlife rise with the increase and growth of human populations, farming, and housing development (Treves & Karanth, 2003). Southwest Florida is one of the most quickly developing regions of the United States and is home to the only identified reproducing population of the endangered Florida panther (*Felis concolor coryi*) (Main et al, 1998). There is the possibility of mountain lion existence without large unfragmented areas of habitat with connections or corridors between the habitat islands. The mountain lion species is a very solitary animal and avoid human interactions as much as possible (Beier, 1992). The spatial preference of mountain lions makes the Midwest too fragmented and populated with humans for the species. For the Midwest, the sensitivity to habitat fragmentation would limit mountain lion retention in large portions of the Midwest.

2.7 WESTERN INFLUENCES

Although the western states are omitted from this investigation, it is important to recognize some possible factors affecting mountain lion populations in the West. Mountain lions were removed from almost all of North America by the 1930's to 1940's (Riley & Malecki, 2001). From the 1940's to present time mountain lions have been able to expand

their presence or range, and the number of mountain lions also has increased in the western states (Riley & Malecki, 2001). In Montana, mountain lions have tripled their range during the period of 1960-1995, and now inhabit 44 (78%) of the 56 counties. Similar trends are recorded in 8 of 11 other western states (Riley & Malecki, 2001). Mountain lions in the western portion of North America with ideal habitat and abundance of food sources, for example whitetail deer, mule deer, elk, moose, and pronghorn, is predicted to not be in any threat of extinction (Ernest et al, 2002). The expansion of mountain lion populations in the West could be a push factor contributing to eastward movement. Both mountain lion and human populations are expanding in the West. In certain areas human populations are encroaching on mountain lion habitat. California has a situation with human populations expanding and growing at a fast pace (Ernest et al, 2002). Human populations are reaching out into areas occupied by mountain lions, therefore increasing habitat loss and fragmentation (Ernest et al, 2002). It is speculated that rising mountain populations and rising intrusion by human populations into mountain lion habitat is creating a strong force to push mountain lions eastward.

CHAPTER 3

STUDY DESIGN

3.1 STUDY AREA INTRODUCTION

The Nebraska, Ouachita (Arkansas), and Nicolet (Wisconsin) Nation Forests were chosen to represent three different geographical areas of the Midwest. The Nebraska National Forest is located in the Northwest portion of Nebraska in the panhandle (USDA, 2006). The Ouachita National Forest is located in West Central Arkansas along the Oklahoma border (USDA, 2006). A portion of the Ouachita National Forest is located in Oklahoma. The Okalahoma portion of the forest is omitted from the investigation, for this study incorporates state classification of mountain lions (USDA, 2006). The Nicolet National forest is located in Northeast Wisconsin along the border of the Upper Peninsula of Michigan (USDA, 2006). The Nicolet National Forest, in 1993, was combined with the Chequamegon National Forest (USDA, 2006). Originally the Nicolet and the Chequamegon National Forests had been managed as two separate national forests (USDA, 2006). Although the Chequamegon and Nicolet National Forests have been combined for management purposes the forests have maintained individual identities, and are still posted with signs as individual forests (USDA, 2006). The Nicolet and Chequamegon National Forests have separate administrative districts, or ranger districts (USDA, 2006). For the purpose of this investigation only the Nicolet National Forest will be used. The other national forests chosen for this investigation only comprise one section of a National Forest system within the given states. The use of only the Nicolet National Forest is justified as a sample to maintain consistency with the other national forests chosen.

The classification system used for defining the national forests is the National Forest

Service Hierarchy of Ecological Units (USDA, 2005). The system of ecological units contains both biological information and the distribution of the given information (Bailey, 1983).

The hierarchy system allows for a stratified, consistent base to categorize ecological regions (Cleland et al, 1997). The hierarchy of ecological unit's first level of classification is domain on a global scale (Bailey, 1983). Division is second on a continental scale, and province is third on a regional scale (USDA, 1994). Domain, division, and province scales are used in a wide range of sampling and modeling procedures (Cleland et al, 1997). Section and subsection are used to describe multiple sub-regions of domain, division, and province (Bailey, 1983). Section is also used for forest area-wide planning and watershed analysis of large sections of a national forest (USDA, 1994). Land type association or "LTA" is used at the landscape level, and there are frequently several land type associations inside a section (Cleland et al, 1997). The attributes of a section will be the same as the LTA's, but LTA's split the already given attributes of the section to smaller units (USDA, 1994).The land type association level is used for breaking a forest into smaller units, entire forest, and area wide planning and evaluation (Cleland et al, 1997). Land type scale is used for specific project and designated management areas within a given forest for analysis and planning (Cleland et al, 1997). The purpose of creating ecological units is to classify land and water areas at different scales that have similar biological capabilities and have the potential to be managed together (Bailey, 1983). Ecological units are formed to consist of similar patterns in possible natural communities, soils, hydrologic function, landform, topography, lithology, and climate (Cleland et al, 1997). Other similarities that fall within ecological units consist of natural processes such as nutrient cycling, productivity, succession, and natural disturbance regimes

such as flooding, wind, and fire (USDA, 1994). Within the hierarchy of ecological units climate is the foremost boundary measure for ecological units at the larger scales, and climate altered by topography is the primary classification standard for larger scale unit classification (Cleland et al, 1997). Moving down the hierarchy to smaller scale divisions, the attributes such as geomorphic process, soils, and potential natural communities are as important as climate (Cleland et al, 1997). For the purpose of this investigation the section level of the hierarchy is used to represent the three different sub-regions in which the Nebraska, Ouachita, and Nicolet Nation Forests reside. The section level/scale was chosen because LTA is too specific showing the micro-level changes within a given area from thousands to hundreds of acres (USDA, 2005). The Nebraska, Ouachita, and Nicolet National Forests are comprised of millions of acres (USDA, 2005). The species that I have chosen to study, *Felis concolor*, would not be affected by small scale changes due to the large home range required. The section level attributes are representative of the attributes that make up the national forests. Future studies of a single forest, looking at LTA information would show niches within an area for small range or localized species. The purpose for choosing multiple forests is to show three different possible environments that mountain lions could once again inhabit. The purpose for choosing three study areas is not a comparison, but rather to add to the investigation a broader range of future places of mountain lion inhabitation. The classification of attributes for each section/subsection are categorized as geomorphology, lithology and stratigraphy, soil taxa, potential natural vegetation, fauna, climate, surface water characteristics, disturbance regimes, land use, and cultural ecology (USDA, 1994). The descriptions were compiled by the Eastern Region, Northern Region, and Southern Region offices. The Southeastern Forest Experiment Station also provided information. The

section attribute information was obtained from the publication: Ecological Sub regions of the United States, Section Descriptions. USDA, Forest Service, Admin. Publication WO-WSA-5, 1994.

3.1.1 NEBRASKA NATIONAL FOREST

The geomorphology for section 331F The Northwestern Great Plains, in which the Nebraska National Forest resides, consists of slightly sloping to rolling dissected shale plains. There are sheer level topped buttes in the section, and a number of eroded escarpments. Elevation ranges from 1,500 to 3,900 ft, or 458 to 1,200 meters. The lithology and stratigraphy is soft Cretaceous and Lower Tertiary non-marine sedimentary rock. The soil make-up consists of mesic and frigid Borolls and Ustolls particularly in the northern, southern, and eastern portions of the section. The soils are fairly deep to deep and have loamy to clayey textures (USDA, 1994).

The possible natural vegetation is prairie vegetation. Species consist of wheatgrass-needlegrass, such as western wheatgrass, green needlegrass, blue grama, needleleanthread, and buffalograss. Bluebunch wheatgrass, little bluestem, and sideoats grama exist in shallow soils. Widespread shrubs in the draws along streams consist of buffaloberry, chokecherry, snowberry, and sagebrush. The native ponderosa pine forest of the Pine Ridge Ranger District contributes to the ecosystem variety. The fauna consists of herbivores and carnivores such as white-tailed deer, mule deer, pronghorn, and bobcat. Smaller frequent herbivores comprise the white-tailed jackrabbit, white-tailed prairie dog, and black-tailed prairie dog. Uncommon, but present species associated with the section includes bighorn sheep and the black-tailed jackrabbit. Bison were at one time connected with the section (USDA, 1994).

The climate has an average annual precipitation ranging from 10 to 20 in (250 to 510 mm), with more then 50% occurring during the growing period. Winters are cold with desiccating winds and precipitation as snow. The climate for this section is cold continental. Temperature averages 3 to 9 Celsius, with a growing period that lasts 110 to 160 days. The surface water characteristics for section 331 is extensive, structurally controlled second and third order streams with little gradient, which are supported by high density, dendritic first order tributaries. Varying solid and pliable layers at low angles create a compound pattern of resistant layers, brief base levels, and headward and sideward erosion by undercutting. Ground water is limited over most of the area but does occur in the vicinity in sand and gravel deposits. The main rivers for the section 331F include the Missouri, Cheyenne, Little Missouri, and Niobrara. The disturbance regimes for the forest are fire and drought. The land use for this section is dry land farming and livestock grazing occurring within 85 % of the area. A few commercial timber harvests also take place (USDA, 1994).

3.1.2 OUACHITA NATIONAL FOREST

The section M231A Ouachita Mountains, in which the Ouachita National forest resides, was formed by tectonic faulting and uplift of resistant bedrock into a slim band of metamorphosed, parallel (east-west trending) mountain ranges. The prior events are followed by large scale wasting along with steep to moderate stream valley erosion with fluvial transport. 75 % of the area is made up of open high hills, with some open mountains. Elevation ranges from 100 to 800 meters. Local relief in large parts of the section range from 152 to 244 meters, but can range from 305 to 610 meters in areas of the low mountains. The lithology and stratigraphy is rock shaped during the Paleozoic (50%), Mesozoic (40%), and Cenozoic (10%) eras. The soil make-up is mostly udults. Hapludults are at greater elevations

on sharp slopes, mild slopes of ridge tops, and base slopes. Dystrochrepts and Ochraquults occur on the flood plains. These soils have a thermic temperature regime, udic moisture regime, and siliceous or mixed mineralogy. Soils are normally deep, often stony, and have sufficient moisture for use by vegetation throughout the growing time of year (USDA, 1994).

The possible natural vegetation is classified as oak-hickory-pine forest. Within section M231A forest types are mostly loblolly-shortleaf pine. The primary vegetation type is evergreen needle-leaved forest and a small region of cold deciduous, broad-leaved forest. Small areas of shortleaf oak type (southern red, scarlet, black, post, and blackjack oaks) and oak-hickory (black, scarlet, post, and white oaks and pignut and mockernut hickories) occur. The fauna consists of white-tailed deer, black bear, bobcat, gray fox, raccoon, gray squirrel, fox squirrel, eastern chipmunk, white-footed mouse, pine vole, short-tailed shrew, and cotton mouse. The turkey, ruffed grouse, bobwhite, and morning dove are game birds in diverse parts of the eastern section (USDA, 1994).

The climate has an average annual precipitation ranging from 1,220 to 1,420 mm. Mean annual temperature is 16 to 17 Celsius. The growing period ranges from 200 to 240 days. The surface water characteristics are high concentrations of small to medium size perennial streams and related rivers. Streams in intermountain basins have medium rates of flow, and some on mountain sides are characterized by high rates of flow and velocity. A trellis drainage pattern has been created, mostly with bedrock structural control. Key rivers for M231A include the Fourche and Dutch Creek, which run into the Arkansas River. The disturbance regimes are fire and climatic influences including irregular summer droughts, winter ice storms, and rare tornados. The land use for section M231A Ouachita Mountains is agricultural estimated on 25 % of the area (USDA, 1994).

3.1.3 NICOLET NATIONAL FOREST

The section 212J Southern Superior Uplands, in which the Nicolet National Forest resides, makes up the eastern two-thirds of the Superior Upland geomorphic province. 50% of the 212J is flat to lightly rolling lowlands (glacial ground moraines) and even laustrine plain. The remaining part of the section is hillier uplands with escarpments. The lowlands and plains are irregularly overlain by low, undulating ridges (glacial and moraines) and other mounded or hummocky glacial features, such as kames and eskers. Kettled glacial outwash plains are frequent in this section. Most prominent of the uplands are linear ranges trending southwest-northeast along the Superior shore. Drainage is dendritic with only minor entrenchment. Geomorphic processes operating in the section are lake shore and fluvial erosion, transport, and deposition. Elevation ranges from 183 to 600 m. Local relief is generally 30 to 183 meters. The lithology and stratigraphy is Pleistocene (Wisconsinan) till and stratified drift that is up to 152 meters deep, but more shallow on the uplands. Lacustrine deposits (stratified sand, silt, clay, marl, and peat) take place primarily along Lake Superior. Beneath the drift, bedrock is made up typically of Proterozoic igneous rocks, both felsic and mafic volcanics and plutonics. Volcanics lie beneath the major highlands or ranges. Archean metavolcanics and granite form bedrock in the northeast corner, and bedrock outcrops are frequent in the upland areas. The soil make-up consists of Spodosols, Enisols, Inceptisols, and Histosols. These soils have a frigid temperature regime, and xeric, udic, an aquic moisture regimes. Parent materials are mostly acidic, except for calcareous materials linked with the Lake Superior clay plain and the Green Bay lobe (USDA, 1994).

The possible natural vegetation is maple-beech-birch, spruce-fir forests. Acer-Tsuga and Acer-Series occur on mesic landforms. Tsuga Series occur on dry-mesic landforms,

Pinus series occur on xeric landforms, and Tsuga-Thuja Series occur on wetland landforms. The fauna is predators consisting of Great Plains wolf, lynx, and fisher. Herbivores include moose, white-tailed deer, snowshoe hare, and porcupine. Additional mammals include artic shrew, least chipmunk, and northern flying squirrel. Lost species that have been reintroduced are the marten, fisher, peregrine falcon, moose, and wolf. The wolverine, mountain lion, woodland caribou, and bison are still species listed as extinct (USDA, 1994).

The climate has an average annual precipitation ranging from 660 to 910 mm taking place mostly during the summer period. Considerable lake-effect snowfall occurs throughout the section 212J, ranging from 1,530 to 1,016 mm from Lake Superior. Temperature ranges from 3 to 6 Celsius. Section 212J has a humid-continental climatic regime, with an average annual temperature range from about 4 to 7 Celsius. Climate alongside Lake Superior is modified maritime continental, with an average annual temperature range of 3 to 6 Celsius. Large portions of the section 212J have 80 to 145 days of a freeze-free phase. Next to Lake Superior there are 100 to 140 freeze-free days. The surface water characteristics are frequent lakes, streams, springs, spring ponds, and wetlands have been created in the glacial landscape. The drainage network is immature, and stream frequency is fairly low. Inside the section two major watersheds begin; the St.Lawrence (Lake Superior and Lake Michigan) and the Mississippi River watershed. Low gradient streams and rivers characterize the majority of the section. High water during the spring and fall and low-flow during summer periods characterize most streams and rivers that run into Lake Superior. Streams are underlain by deep till, outwash, lacustrine, sandstone, and a mixture of igneous and metamorphic bedrock types. Lakes are primarily associated with collapsed till of moraines and outwash plains. The disturbance regime in pine and mixed-pine cover types on xeric and

dry mesic landforms is fire occurring at about 50 to 250 year intervals. The land use for section is related to forest vegetation. The most widespread land uses are outdoor recreation, wildlife habitat, and production of wood fiber (USDA, 1994).

3.2 THE GARP MODEL

The Genetic Algorithm for Rule-Set Predictions model (GARP) was used to determine if the national forests meet the environmental requirements to support mountain lions. It is feasible to construct ecological models based on known occurrences of species that predict their geographic distributions with high accuracy (Godow & Peterson, 2000). The GARP models ecological niches and potential geographic distributions of species. GARP has been used broadly with diverse regions and taxa (Feria & Peterson, 2002). Widespread efforts have focused recently on predicting species' geographical distributions based on known points of occurrence (Feria & Peterson, 2002). The Genetic Algorithm for Rule-Set Prediction (GARP) uses a sequence of if, and, and then statements to establish the ecological niche of organisms (Feria & Peterson, 2002). The program works by creating a series of presence and absence models, with the parameters decided by the user (Desktop GARP). Within the model a number of iterations is run up to 2560 or decided by the user (Feria & Peterson, 2002). Lastly, the model results are output into a format selected by the user (Desktop GARP). The three formats available are bitmaps, ASCII Grids, and ARC/INFO Grids (Desktop GARP). GARP encompasses more modeling techniques than others by using a multiple regression analysis to produce the probability of presence (Peterson & Vieglais, 2001). GARP uses various independent algorithms, for example, BIOCLIM and logistical regression, to create component rules to produce the possible niche of a species (Peterson, 2001). GARP is considered superior to other methods, for it is a

collection of other techniques, and has a better predictive ability then any one by itself (Godown & Peterson, 2000).

The GARP modeling system uses a genetic algorithm to produce a series of maps showing presence and absence of the species being studied (Desktop GARP). This genetic algorithm is a machine learning technique that simultaneously generates and tests a range of models (Stockwell & Peters, 1999). GARP creates an algorithm, which uses a set of environmental variables, then projects this algorithm onto a map of either a continent or the entire earth (Peterson & Vieglais, 2001). The GARP model also incorporates an internal statistical accuracy assessment, via the Chi-squared method. While the user can define this accuracy, the default level for the program is 95 percent (Stockwell & Peters, 1999). The individual analysis system is comprised of eight programs.

These programs are outlined and listed in Table 1.

Table 3.2.1 Programs contained within GARP. (Stockwell & Peters 1999).

Program	Operation
RASTERIZ	Converts spatial data files to raster layers
PRESAMPL	Produces training and test sets by random sampling
INITIAL	Develops an initial approximate model
EXPLAIN	Refines model using a genetic algorithm
VERIFY	Provides predictive verification information on the output rule set
PREDICT	Takes the model and predicts probability for each value
IMAGE	Takes the predicted probabilities and produces a number results in the required image format
TRANSLATE	Takes the model and forms natural language explanation rules

The first step in the GARP modeling process is the collection of points. Data points from the known historical established range for mountain lions was used in the model as test and training data points (GARP Desktop). The departments of fish and game from Arizona,

New Mexico, Colorado, Wyoming, and Idaho were contacted to confirm the range of mountain lions within the given state. For Montana and Texas maps were found from fish, wildlife, and parks (Montana) and Texas Tech. University (Texas) confirming known ranges of mountain lions within the states. The GARP model runs the data in decimal degree format (DD) (GARP Desktop). The data points collected are decimal degree coordinates at the county level. Data points used were collected from Lat.-Long.com. There were 20 points collected from every state except for Arizona, for Arizona only has 15 counties, for a total of 135 points. In testing the GARP model was able to produce 90% accuracy with as little as 10 data points (Stockwell & Peterson, 2002). Given the lack of knowledge regarding the distribution and natural history of most species, interpolation techniques must even work with small numbers of known occurrence points (Feria & Peterson, 2002).

There were multiple reasons for choosing the county level data. First, the states of Arizona, Colorado, Idaho, and New Mexico listed the species as statewide. Taking random county points is an unbiased method without uncertainty of choosing a location that mountain lions do not inhabit. Choosing county points allowed for a uniform method to take points across the entire eastern and southern range of mountain lions; which all fall within the known current range of mountain lions. Each county point is a slice of the environment of that area. Examples of the point locations include a tall grass prairie, forest, agricultural field, mountain, and desert. In Montana and Texas, mountain lions are not state wide, therefore random counties were selected until the desired number of counties (20) were chosen that held mountain lion populations. Secondly, mountain lions are a mobile species with large home ranges (2000km^2). All points are within the known species range, and at any given time could be inhabited by a mountain lion. The points were then entered into a spreadsheet

format using Microsoft Excel (Microsoft Corporation; Redmond, WA). The species (*Felis concolor*) was entered first, followed by the degrees west, then the degrees north.

The first step in the application of the GARP model is to select the environmental data layers to overlay. There are six continental overlays and one world overlay. Overlays provide continental boundaries for the outputs, for example North America. For this investigation, the North American dataset was selected, as well as the geographic projection. Next, the desired environmental layers to use in the model were selected. All 14 environmental layers available in the native range set were used. Environmental datasets were downloaded from the Desktop GARP website. These datasets come in the GARP native format (GARP desktop). The data set contains 14 environmental layers in two general categories terrain and climate. The terrain related layers include Digital Elevation Model Source: USGS 1:250,000 DEM, processed onto a 1km grid, and used to calculate all the terrain related layers (Lifemapper.org, 2002). Aspect is maximum rate of change in elevation between each cell and the eight neighboring cells (Lifemapper.org, 2002). Flow direction is direction of flow from each cell in the DEM to its steepest down-slope neighbor (Lifemapper.org, 2002). Flow accumulation is upstream catchment area draining into a cell (Lifemapper.org, 2002). Slope is maximum change in the elevations between each cell and the eight neighboring cells (Lifemapper.org, 2002). Compound Topographic Index is a wetness index that is a function of the upstream contributing area and the slope of the landscape (Lifemapper.org, 2002). Climatic layers include ground frost frequency, precipitation, solar radiation, minimum temperature, mean temperature, maximum temperature, vapor pressure, and wet day frequency (Lifemapper.org, 2002). The third step is to upload the reference data points by selecting the spreadsheet created (GARP Desktop).

Lastly, other options are selected (projection, runs, iterations, best subset, and output (GARP Desktop). For this investigation, a continental-scale model was created using default options; 20 runs, 1,000 iterations, and North American projection.

In order to optimize overall model performance, 20 individual ecological niche outputs were developed. The 20 model outputs were compressed into a single model output. The summing of the individual predictions into a single composite prediction is to better define the areas of highest likelihood of mountain lion presence. The GARP program produces a given number of outputs based on the complexity of the data (Anderson et al, 2003). The summing of outputs together produces a generalized assessment based on the number of overlapping models (Stockwell et al, 2005).The prediction value of this output compression is considerably higher then individual models. The higher the value of each pixel within the composite output shows the greater number of predictions predicting mountain lion presence. The 20 predictions were summed into a single composite model using Arcmap 9 (ESRI; Redlands, CA 2004) and the Grid Stack command, resulting in a single output that was projected onto maps of the national forests. This composite was then used as a generalized assessment of mountain lion based on the number of overlapping replicate predictions. A graduated color ramp is used to represent the number of outputs predicting present. The breaks for the compressed output are in 10% increments.

Accuracy assessment is a critical part to any ecological niche modeling (Fielding & Bell, 1997). GARP employs the use of an internal accuracy assessment (χ^2) for each of the models created (Peterson & Vieglas, 2001). The χ^2 statistic is used to evaluate the statistical significance of the predictions with expected numbers based on the points for the predicted individuals that would fall within the area predicted present if distributed randomly (Peterson

et al, 1999). Additionally, *p* values are calculated for the models internally by GARP (Peterson, 2001).

3.3 SURVEY OF USFS WILDLIFE BIOLOGISTS

An e-mail survey was sent to wildlife biologists of the Nebraska, Ouachita, and Nicolet National Forests concerning mountain lions as both an ecological factor, and as a potential threat to visitors. This survey was tailored to the professional knowledge of wildlife biologists. Wildlife biologists have a vast knowledge of flora and fauna within the national forests. Wildlife biologists actively survey the forests for both plant and animal occurrence. The biologists create and implement forest plans, or management statements. Wildlife biologists understand the implications associated with a species reintroduction. This e-mail survey consisted of 7 questions. The questions are listed below in the order as given in the survey.

1. Are there any ecosystem management shifts that have occurred from mountain lion presence in your National Forest, or the possibility of presence in your national forest?
2. What would you suggest for possible mountain lion management in an area such as your national forest?
3. How do you perceive mountain lion impacting the ecosystem of your national forest?
4. Are mountain lions currently part of your national forest ecosystem?
5. Are there policy or management plans in your national forest for mountain lion attacks or confrontational situations? If no, what would you suggest as a policy or management plan?
6. Do you believe there is a possible threat now or in the near future to visitors of your national forest from mountain lion attacks/confrontations?

7. How does your national forest treat reports of mountain lion sightings within the national forest?

3.4 STATE CLASSIFCATION OF MOUNTAIN LIONS

The last method used for this investigation was the research of state classification of mountain lions within Nebraska, Arkansas, and Wisconsin. State classification is a guide to base individual national forest plans of management, or any management plan regarding mountain lions in the given state. Classification can range from current native fauna to extinct. If a species is classified extinct there usually comes no protection from hunting or trapping. A state will not designate resources to protect a species that officially does not exist within the state. Large carnivores are a highly controversial topic in states that are in the process of a natural repopulation. Without protection mountain lions could be killed anytime. State classification as a protected species gives mountain lions the necessary protection to repopulate former eastern portions of their range.

CHAPTER 4

RESULTS

4.1 MODEL PREDICTIONS

The GARP model predicted mountain lions presence in the Nebraska, Ouachita (Arkansas), and Nicolet (Wisconsin) National Forests. Within the national forest boundaries there was variation in the number of outputs predicting presence, except for the Nebraska National Forest, which was completely in the 19-20 (90%-100%) range of outputs predicting present. The Nebraska National Forest has the highest number of outputs predicting presence of mountain lion.

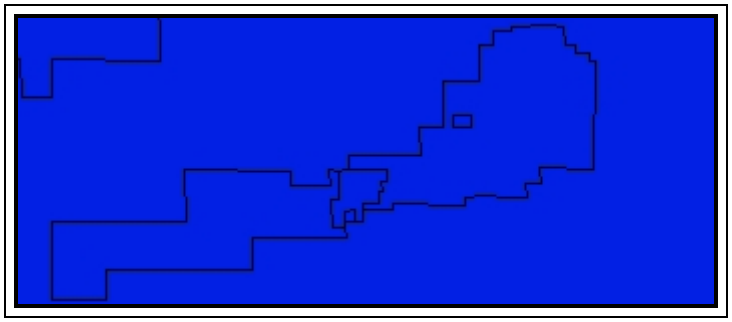

Figure 4.1.1 Nebraska National Forest mountain lion prediction From the GARP Model.

The Nebraska National Forest is in close proximity to established mountain lion populations of the western states. The environmental factors of the Nebraska National Forest are similar to the neighboring western states.

The Ouachita National Forest had the greatest variation in outputs predicting presence, with a range of 3-16 (20%-80%).

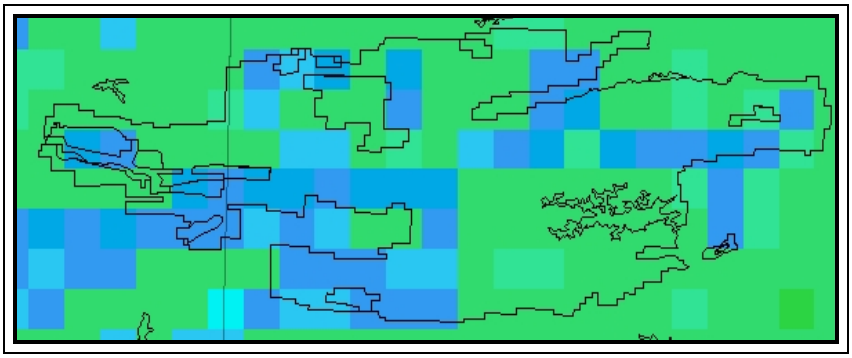

Figure 4.1.2. The Ouachita National Forest mountain lion prediction map from the GARP model.

The greater number of model outputs showing present are clustered. These clustered results illustrate areas of altering elevations with shifting terrain that is more suitable to mountain lions. Low-level areas within the forest boundaries are used for agriculture and human settlement. These low areas were predicted absent in 17 out of 20 outputs. The entire Ouachita National Forest is predicted to be possible habitat for mountain lions. The Ouachita National Forest has the greatest range of models predicting presence of all 3 National Forests.

For the Nicolet National Forest mountain lions were predicted present in 9-14 (50%-70%) of outputs.

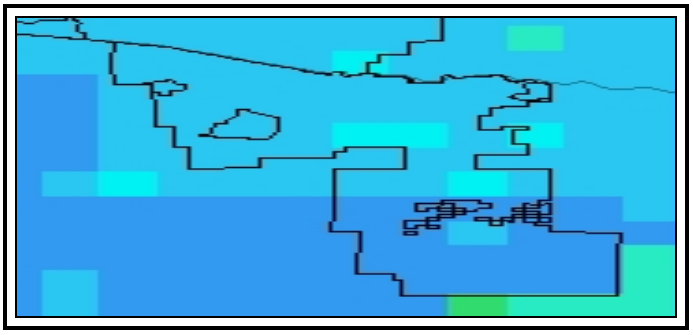

Figure 4.1.3. The Nicolet National Forest mountain lion prediction map From the GARP model.

The Nicolet National Forest in Wisconsin had a varying number of outputs predicting presence. There was a limiting factor to the number of outputs predicting presence for the Nicolet National Forest. The exclusive use of data points from the historical established range included the use of environmental conditions with distinct variance from this forest. The data points from the south and southwest, for example, Texas, Arizona, and New Mexico have few environmental conditions that match the Nicolet National Forest. Mountain lions from the northern range could be successful in the Nicolet National Forest, and this is reflected in the models predicting presence. For the Nicolet National Forest mountain lions were predicted present in 9-14 (50%-70%) of outputs varying across the National Forest. The outputs show that Mountain lions could survive in the Nicolet National Forest, but there is some variability from portions of the incoming native range.

4.2 SURVEY RESULTS

The survey sent to wildlife biologists of the Nebraska, Ouachita, and Nicolet National Forests focused on mountain lion management, and confrontations related to visitors. The identity of the individuals is omitted from the answers. The questions were

answered as representatives of the United States Department of Agriculture and United States National Forest Service.

Question 1: Are there any ecosystem management shifts that have occurred from mountain lion presence in your National Forest, or the possibility of presence in your National Forest?

-**Nebraska National Forest**: "No. Our mission and policy is to manage habitat conditions for designated species, of which the mountain lion is not identified".

-**Ouachita National Forest**: "There are no native mountain lions on the Ouachita National Forest or in Arkansas. The lions that were here were extirpated currently in the state, there are western mountain lions that have been under permit and people released when they got to be too much of a pain to feed and deal with. We are restoring the native forest ecosystem such as Shortleaf Pine/Bluestem grass ecosystem because fire suppression, this system has changed. This management however is not tied to a non existent mountain lion, but rather species that use this system, such as the red-cockaded woodpecker (endangered), brownheaded nuthatch, prairie warbler, and the Diana fritillary butterfly. Any system that supports deer will support mountain lions. Deer are a generalist and mountain lions will go where the food is".

-**Nicolet National Forest**: "No. Species not confirmed present at this time".

Question 2: What would you suggest for possible mountain lion management in an ecosystem such as your National Forest?

-**Nebraska National Forest**: “The Forest Service does not manage wildlife”.

-**Ouachita National Forest**: “Manage the habitat types for its prey base that supports deer and this will take care of the mountain lion”.

-**Nicolet National Forest**: “First, verify presence of the species. Then educate the public and give it some space”.

Question 3: How do you perceive mountain lion impacting the ecosystem of your National Forest?

-**Nebraska National Forest**: “Minor if any”.

-**Ouachita National Forest**: “The mountain lion would not impact an ecosystem on the national forest, but it could impact the social structure with predation of livestock. Studies in areas with mountain lions and livestock show that lions prey 60% on deer and 40% on domestic livestock when livestock is available. We would like to have mountain lion in the system and studies have shown that the Oucahita National Forest is one of the few national forests in the Eastern United States that has remote areas to support lion, but social acceptability and support for reintroduction by the state is not there”.

-**Nicolet National Forest**: “None presently. If found and verified, I would anticipate some minor changes to the ungulate biomass on the national forest because of an additional

predator. Public access could change as people attempt to locate and view the cat or worry about it creating problems".

Question 4: Are mountain lions currently part of your National Forest ecosystem?

-**Nebraska National Forest**: "No population data exists for the forest or state wide".

-**Ouachita National Forest**: "No they are not".

-**Nicolet National Forest**: "Unknown. No confirmed presence documented. Multiple sightings annually. A couple of suspicious deer kills investigated with no final conclusions as to the predator (lion, wolf, bear)".

Question 5: Are there policy or management plans in your National Forest for mountain lion attacks or confrontational situations? If no, what would you suggest as a policy or management plan?

-**Nebraska National Forest**: no answer.

-**Ouachita National Forest**: Since the forest does not have a legitimate population of resident mountain lions; there is not a need for such management or policy. The states manage the populations of wildlife and the federal land managers manage the habitat. The state would have to be in on the deal with the reintroduction of mountain lion and manage the conflicts and populations. If there were livestock depredation, the state would have to deal

with that. If there were a mountain lion attack, which are rare, and happens in places like California where mountain lions and their food base have been displaced with people and houses, it would be the state that would deal with it as they do with bears".

-**Nicolet National Forest**: "Species/population management is a state responsibility per the Sikes Act. They, not the forest determine population management objectives. As for habitat and people management, our policy would be to provide habitat for mountain lions if deemed a desirable native species or non-native species by the state in consultation with the forest. I also believe it is necessary to adopt educating the public posture about the safety and the value of large predators in the ecosystem".

Question 6: Do you believe there is a possible threat now or in the near future to visitors of your National Forest from mountain lion attacks/confrontations?

-**Nebraska National Forest**: no answer.

-**Ouachita National Forest**: "There is no threat now or in the future".

-**Nicolet National Forest**: "No. While there maybe a lion on the national Forest, hound pursuit of bear, coyote, fox, and bobcat are likely to impress upon a lion the dangers of humans as a result of being pursued and treed. Also, white-tailed deer are so abundant that lions have a limited reason to appear in residential or visitor rich areas. Visitors have a better chance of being charged by a black bear than a lion and that has rarely happened".

Question 7: How does your national forest treat reports of mountain lion sightings within the National Forest?

-**Nebraska National Forest**: No answer.

-**Ouachita National Forest**: "We have a folder entitled mountain lion and if made aware of valid sightings, notations are filed there. The Arkansas Game and Fish Commission have the responsibility to try and verify such sightings since they have jurisdiction over wildlife. The Arkansas Game and Fish Commission have not yet confirmed any mountain lion sightings. There may be a rare case where a western mountain lion has come east. There are also people with lions under permit that release their lions into the wild, or at night for them to run about as a feral house cat. There are no reproducing populations of mountain lions in Arkansas. Most sightings reported are from people that report seeing a black mountain lion which probably derived from their seeing a Walt Disney movie. Neither the forest nor the state has the personal or funding to try and verify sightings of black mountain lions".

-**Nicolet National Forest**: "We provide all reports to the Wisconsin DNR rare mammal observation system for follow-up by the state and at times attempt to verify if a lion was present by back tracking and collection of scat or hair for DNA analysis".

4.3 STATE DESIGNATION

The way Nebraska, Arkansas, and Wisconsin state governments currently classify *Felis concolor* plays a role in the success of mountain lions as they return, and their ability to

build a stable population throughout the state. The classification status for mountain lions is either protected or extinct. States classification of mountain lion is the basis for a successful natural reintroduction to the Midwest.

The state of Nebraska classifies mountain lion as a wild game animal without a season, and therefore given protection from human interference (Nebraska Game and Parks Commission, 2006). The species *Felis concolor* has full protection 365 days a year, unless seen threatening livestock, humans, or found within city limits (Nebraska Game and Parks Commission, 2006). If a mountain lion is found in any of the above mentioned circumstances the animal may be removed or killed (Nebraska Game and Parks Commission, 2006).

In the state of Arkansas, *Felis concolor* is considered extinct, and therefore receives no protection from the state of Arkansas (Arkansas Game and Fish Commission, 2006). In Arkansas, the federal government has given protection to mountain lions, and listed the animal under federal endangered protection (Arkansas Game and Fish Commission, 2006). The species that the federal protection was created for is *Felis concolor coryi*, or commonly known as the Florida Panther. The Florida panther (Coryi) is a sub-species Concolor, and not the same as the mountain lion migrating from the West. Any mountain lion found within the state of Arkansas is protected by the United States Fish & Wildlife service.

In Wisconsin, currently the mountain lion has been classified as a special concern species by the Wisconsin Department of Natural Resources. Under Wisconsin law mountain lions are fully protected from shooting, trapping, or poisoning. *Felis concolor* has been placed in the Wisconsin Natural Heritage Inventory as a species of historical occurrence.

CHAPTER 5

CONCLUSIONS & DISCUSSION

5.1 GARP MODEL OUTPUTS

Based on the GARP model outputs the Nebraska, Ouachita (Arkansas), and Nicolet (Wisconsin) National Forests have the necessary environmental conditions to sustain mountain lion populations.

The Nebraska National Forest is in close proximity to current mountain lion populations in the western U.S. This is reflected in the model outputs, 20 of which predicted mountain lions presence. The Nebraska National Forest provides environmentally a straightforward transition for mountain lions migrating from the West. There have been multiple confirmed sightings of mountain lion within the Nebraska National Forest.

The Ouachita National Forest (Arkansas) has the greatest environmental variation from the western mountain lion range. Heavily forested areas within the national forest of pronounced elevation and terrain changes are clustered, with more outputs predicting presence for these areas. There are areas of the national forest with mountain lion presence predicted in only 3 outputs. Within the forest boundaries there are large areas of agricultural land use and human settlements, and these conditions make up the low presence prediction areas. The Ouachita National Forest has a source for incoming wild mountain lions. The forest is within the possible dispersal range of mountain lions from Texas. In a similar scenario as the Nicolet National Forest, there was variation in the model outputs predicting presence due to the range of data points used.

The Nicolet National Forest (Wisconsin) is shown to have environmental variation from the western mountain lion range; however the entire national forest is found to be

favorable to mountain lion. The variation derives from the environmental conditions of the data points used from the southwestern states. The environmental conditions of the southwestern states are not similar enough to the conditions of the Nicolet National Forest to support mountain lions from that region. Despite variation in the model outputs, the Nicolet National Forest could support mountain lions coming from the northern portion of their established range. The Nicolet National Forest contains both bear and wolf populations. Bears and wolfs share habitat with mountain lions in the western states, and have similar requirements. This indicates that in the Nicolet National Forest mountain lions would also be successful. The Nicolet National Forest has a long reintroduction phase given the distance from current mountain lion populations South Dakota.

5.2 FOREST SERVICE MANAGEMENT

The National Forest Service's role is to manage habitat for species of flora and fauna deemed important or native. The NFS does not select the species to manage, rather state fish and game commissions are responsible for selection and classification. State wildlife biologists and NFS biologists work in conjunction to develop forest plans and management of the forest. The NFS has no ability to protect mountain lions on NFS property outside what the state has decided for statewide classification. If the state government must classify the species as "of importance", then the NFS modifies current strategies to include the new species. Currently none of the chosen national forests have mountain lion included in the management scheme. The NFS has managed the forests to restore or maintain a native state, and unintentionally managed the habitat for mountain lions success. Mountain lions at one time occurred in all three areas that make up the national forests. The management objectives

of the NFS have restored a prey base, and provided the proper cover for mountain lions. The NFS has managed the habitat for mountain lion success without any intention. Wildlife biologists confirmed the need for no change in forest management for mountain lions to survive in the national forests.

National Forest wildlife biologists concluded there is no foreseeable threat to visitors of the national forests at this time. Mountain lions attacks have been historically documented, but they generally try to avoid humans whenever possible. There number of mountain lions that are currently in the national forest is estimated to be very low. The minimal population numbers compounded with the preference to avoid humans' makes mountain lion confrontations very unlikely.

If this investigation was to be repeated with expanded resources there would be changes made to depth of the investigation. Even with the census difficulties of mountain lion, I would set trail cameras and conduct observations within the national forests for animals and sign of the animals. Highly probable corridor areas would be investigated in conjunction with the national forests using the same methods mentioned above. During the winter months when foliage cover is minimum I would incorporate grid based aerial photography for the spotting of mountain lions. Individuals that have physically been confronted or witnessed mountain lions in the Midwest and national forests would be contacted to retrieve their accounts of sightings.

5.3 STATE ROLE IN MANAGEMENT

The Nebraska and Wisconsin state governments have taken protection measures for mountain lions residing within state boundaries. In both states mountain lions are protected

from being hunted or killed. In the case of Arkansas the United States Fish & Wildlife Service has handed down protection overriding the state classification. Although intended for the subspecies (*Felis concolor coryi*), the protection includes mountain lion that exist in the western states. The United States Fish & Wildlife Service designated protection is limited to unlawfully killing the species, and does not require any land management for the species.

State governments need to confirm the species as present before management can take place. Protection is a "blanket" that can be applied without knowing the extent of the species within the state. Protection hints at the possibility of the species in the state, but needs no conformation. Confirming requires wild mountain lions being observed and documented. For conformation to be achieved multiple mountain lions would need to be sighted consistently for an extended period of time. Given the nature of the species confirming would be very difficult. In the current western range the species is very dispersed, cautious of man, and generally reclusive. To obtain an accurate census of mountain lion populations within the national forests would be difficult.

Livestock depredation is a concern for ranchers and farmers. The wildlife biologist of the Ouachita National Forest stated that up to 40% of a mountain lions diet comes from livestock when available. Anyone within the home range of mountain lions that establish themselves within the national forests is at threat of losing livestock to mountain lions. Given the minimal repopulation of mountain lions in the national forests, bordering ranch livestock losses would be very low. In the rare instances that livestock would be taken as prey state government should follow a compensation guideline after sufficiently proving the animal/s were killed by a mountain lion. In Wisconsin possibly a wolf or bear could be responsible, therefore only proving a large carnivore was the cause of death would be sufficient for

compensation. This compensation plan should be implemented after sufficiently proving there are resident mountain lions in the region.

5.4 THREE STAGES OF MOUNTAIN LION RETURN

From this investigation, I conclude the scenario of a large carnivore returning to new or former habitat occurs in three stages. The first stage is reintroduction, and this is the current statues of mountain lions in the Midwest. In this stage incoming mountain lions are dispersing from metapopulations and larger populations. The reintroduction animals are classified as transient, and have not established home ranges in the new areas. There is an indefinite lag time before reintroduction animals reach the numbers to the point of reproducing, particularly with mountain lions existing in dispersed low numbers in their current range. It is very plausible that with a consistent flow of reintroduction mountain lions that repopulation can occur. The area requirements and the nature of mountain lions makes the time between reintroduction and repopulations even more substantial. There have been recorded sightings of mountain lion in the Midwest since the 1940's, and attempts to confirm mountain lions since that time. Sixty six years later we are in the same state of confirming the presence of the species in the Midwest. This time frame is an indicator of the timeline for the future repopulation and conformation.

The repopulation of this species is an extensive process that could take over a century. The transition from reintroduction to repopulation is expected to occur in small island populations never attaining a state wide distribution due to the land use and human populations in the Midwest. Land use and human populations places the national forests as a primary location for repopulation events. After repopulation there is a lag time before

breeding mountain lions can be documented due the difficulty of locating this mobile species that covers large areas as a regular action. In western states where mountain lions are known to exist there are no accurate census methods.

The third and last stage of the returning species scenario is recognition of mountain lion as part of the ecosystem. In this stage there is a shift from focusing on the geographic landscape to the political landscape. Large carnivores have a history of intolerance from humans. The unknown factor is the public reaction to the documentation of mountain in the given states. National Forests biologists confirmed the public's uneasiness with the repopulation of large carnivores. The success of mountain lions during this last stage will hinge on the political views of the time toward natural balance, and the realization of the species as a key part of the ecosystem. Educating the public on the importance of having mountain lions in the Midwest is fundamental. A focal point of educating the public would be focusing on the species as returning native fauna, and not as an invasive species to the Midwest.

5.5 DISCUSSION

Locations where mountain lions have been sighted in Wisconsin and Arkansas could have been included as data points, therefore increasing the number of models predicting presence for the Nicolet and Ouachita National Forests. These points were omitted from the model for 2 reasons. First, captive mountain lions have been released by residents of the states either permanently or temporarily. Although sightings may be legitimate, it is not possible to confirm if the animal is wild or a released domestic animal. Second, many species have often been mistaken for mountain lion. Species that are commonly mistaken for

mountain lion includes foxes, coyotes, dogs, housecats, and bobcats. The possible misrepresentation of mountain lion in the Midwest by domestic cougars, or a mistaken species was too great to include these points into the model. The questionable points would have skewed the models to show more presence in the Midwest then the current outputs.

State government classification is the foundation for the long term success of mountain lions in the national forests and the Midwest. The protected status is a "hands off" way to conserve what mountains lions may be migrating in. The next step is recognition of the species as part of the state fauna. The transition from protection to recognition is when public reaction will be the greatest. Protection implies the occasional transient animal moving through, to the rare case of a resident animal. Recognition of the species as part of the state fauna establishes the possibility of the animal residing in portions of the state. Educating the public would be a central part of managing mountain lions. Giving the public detailed accounts of occurrence areas, and actions to be taken if found in a confrontational situation would be basic steps in educating the public on mountain lion occurrence.

The species (*Felis concolor*) is a very adaptable animal, and it is probable that the species could environmentally succeed in the chosen national forests. All three national forests at one time had resident populations of mountain lions. Given the versatility of the species to occupy such an expansive current range, it is logical to conclude that they would be able to survive in this former habitat. The greatest limiting factor to mountain lion residency in the Midwest is interference from human populations. Mountain lions have a low tolerance for human intrusion in their established home range. Mountain lions will abandon home ranges if human presence is too great. Even if seasonal, such as hunting seasons, this temporary human presence is strong enough to push mountain lions from their home range.

The Midwest can offer prey densities higher than that of western states, therefore allowing mountain lions to create smaller home ranges. For mountain lions to achieve residency in the Midwest, there would have to be an adaptation to both increased human presence and smaller home ranges. The positive aspect of this adaptation is it would require the modification of a behavior or spatial preference. The modification of a behavior can occur much faster then, for example, a genetic adaptation to a new environment such as coat color or pattern. If mountain lions were to become more tolerant of humans, there would be no limitations to the repopulation of the Nebraska, Nicolet (Wisconsin), and Ouachita (Arkansas) National Forests. States that offer no protection to incoming mountain lion would still pose a danger, for mountain lions would have no protection from being hunted and killed.

Throughout history the species has been persecuted by humans, and was driven to the brink of extinction. From that time mountain lions have been able to rebound in record numbers across the West. When the natural repopulation of the Midwest by mountain lions takes places it will be the greatest feat by any species of our time. We today are privileged to witness the beginning stages of this development. The distance from current mountain lion populations too the majority of the Midwest makes this an astonishing event.

We are fortunate today that previous generations had the forethought to preserve portions of land to retain the native landscape of the Midwest. These natural areas, such as national forests, are likely candidates for mountain lion repopulation. Without these protected natural areas it is probable that the species would never be able to take a footing in the Midwest. Future generations of wildlife and land managers hopefully will carry on the ideals of past generations to keep what is established, and continue to form the wildlife habitats of

tomorrow. This will create the platform for mountain lions to again become part of the native fauna of the Midwest.

BIBLIOGRAPHY

Adrian Treves & K. Ullas Karanth. 2003. Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. *Conservation Biology.* 2003. p. 1491-1499. Volume 17, No.6

Anderson, R.P., D. Lew, and A.T. Peterson. 2003. Evaluating predictive models of species' distributions: Criteria for selecting optimal models. *Ecological Modeling* 162: 211 – 232.

Anderson, R.P., M. Gomez-Laverde, and A.T. Peterson. 2002. Geographic distributions of Spiny Pocket Mice in South America: Insights from predictive models. *Global Ecology and Biogeography* 11(2): 131 - 141.

Bailey R.G. 1983. Delineation of Ecosystem Regions. Environmental Management **7:** 365-373**.**

Bailey R.G. 1994. United States Department of Agriculture, Forest Service Inventory and Monitoring Institute. Map of North American Ecoregions. http://www.fs.fed.us/institute/ecoregions/na_map.html. Accessed May 25, 2006

Beier, Paul.1992. Determining Minimum Habitat Areas and Habitat Corridors for Cougars. *Conservation Biology.* 1993. Volume 7, No.1 p. 94-108.

Beier, Paul. 1991. Cougar Attacks on Humans in the United States and Canada. *Wildlife Society Bulletin.* 1991. 19:403-412.

Belden, Robert and Bruce W. Hagedorn.1992. Feasibility of Translocating Panthers into Northern Florida. *Journal of Wildlife Management* 2003.

Brian Miller, Katherine Ralls, Richard P. Reading, J. Michael Scott, and James Esta. 1998. Biological and Technical Considerations of Carnivore Translocation: A Review. *Animal Conservation.* 1999. 2, 59-68.

Christine A. Ribic, Richard E. Warner, and Philip C. Mankin. 1998. Changes in Upland Wildlife Habitat on Farmland in Illinois 1920-1987. *Environmental Management* Vol. 22 No.2, pp.303-313.

Crooks, R. Kevin. 2002. Relative Sensitivities of Mammalian Carnivores to Habitat Fragmentation. *Conservation Biology.* 2002. Vol. 16 Issue 2 page 488. 2002.

David Clark, Steffany White, Annalea Bowers, Leah Lucio, and Gary Heidt. 2000. A Survey of Recent Accounts of the Mountain Lion (*Felis concolor*) in Arkansas. *Southern Naturalist* Vol. 1 No.3, pp. 269-278.

David T. Cleland, Peter E. Avers, W. Henry McNab, Mark E. Jensen, Robert G. Bailey, Thomas King, and Walter E. Russell. 1997. National Hierarchical Framework of Ecological Units. *Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources,* Mark S. Boyce and Alan Haney, editors. Yale University Press, New Haven & London. 1997. pp 181-200.

Daniel H. Pletscher & Michael K. Schwartz. 2000. The Tyranny of Population Growth. *Conservation Biology.* 2000.1918-1919 Volume 14, No.6

David R.B. Stockwell. Date Unknown. Genetic Algorithms for Species Distribution Modeling. San Diego Supercomputer Center.
http://biodi.sdsc.edu/~davids/*Project*/SGER/GAS/outline.html
Accessed April 1, 2006.

David R.B. Stockwell, James H. Beach, Aimee Stewart, Gregory Vorontsov, David Vieglais, and Ricardo Scachetti Pereira. 2006. The Use of the GARP Genetic Algorithm and Internet Grid Computing in the Lifemapper World Atlas of Species Biodiversity. *Ecological Modeling.* 2006. Volume 195, Issues 1-2 139-145.

Desktop GARP. 2002. Desktop GARP Home. http://www.lifemapper.org/desktopgarp. Accessed May 1st 2006.

Eric, Anderson Adrian Wydeven, and Robert Holsman. Distribution of Cougar Sightings in Wisconsin 1994-2003. Presentation at the eastern cougar conference, date Unknown.

Fielding, A.H. and J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence / absence models. *Environmental Conservation* 24(1): 38 – 49.

Feria, T.P. and A.T Peterson. 2002. Prediction of bird community composition based on point-occurrence data and inferential algorithms: A valuable tool in biodiversity assessments. *Diversity and Distributions* 8: 49 – 56.

Gary W. Witmer, Sandra K. Martin, and Rodney D. Sayler. 1998. Forest Carnivore Conservation and Management in the Interior Columbian Basin: Issues and Environmental Correlates. United States Department of Agriculture, Forestry Service. General Technical Report, Pnw-GTR-420, July 1998.

Godown, M.E. and A.T. Peterson. 2000. Preliminary distributional analysis of U.S. endangered bird species. *Biodiversity and Conservation* 9: 1313 – 1322.

Holly Ernest, Walter Boyce, Vernon Bleich, Bernie May, San Stiver, and Steven Torres. 2002. Genetic Structure of Mountain Lion (*Felis concolor*) Populations in California. *Conservation Genetics* 4: 353-366, 2003.

Jason Pike, James H. Shaw, and David M Leslie. 1997. Mountain Lion in Oklahoma and Surrounding States. Oklahoma Academy of Science. 77: 39-42 (1997).

Jeanie Hilten. Discover Life in America & The Great Smokey Mountains National Park All Taxa Biodiversity Inventory. www.dlia.org. Accessed November 8th ,2005. Mountain lion home range map. The Smithsonian Book of North American Mammals, edited by Don E. Wilson and Sue Ruff. Copyright 1999.

John D. Linnel, Jon E. Swenson, and Reidar Anderson. 2001. Preditors and People: Conservation of Large Carnivores is Possible at High Human Densities if Management Policy is Favorable. *Animal Conservation.* 2001. 4: p. 345-349.

Jim Jung.2004. Big Cat Comeback? www.Naturealmanac.com Accessed October 26th, 2005.

Joel Berger.2003. Is it Acceptable to Let a Species Go Extinct in a National Park. *Conservation Biology.* 2003. p.1451-1454 Volume 17 No.5.

Karen Payne and D.R.B. Stockwell. Date Unknown. GARP Modeling System User's Guide and Technical Reference. http://biodi.sdsc.edu/Doc/GARP/Manual/manual.html Accessed April 3, 2006.

Lat-Long.com. Author Unknown. County Coordinates. Date Unknown. http://www.lat-long.com. Accessed June, 12 2006.

Lisa Naughton-Treves, Rebecca Grossberg, and Adrian Treves. 2003. Paying for Tolerance: Rural Citizen's Attitudes Towards Wolf Depredation and Compensation. *Conservation Biology.* 2003. p. 1500-1511 Volume 17, No.6.

Lifemapper.org.2002. http://www.lifemapper.org/lm-HowLifemapperWorks/EnvironmentalData.html. Accessed June 8th, 2006.

John D.C. Linnell, Jon E. Swenson, and Reidar Anderson 2001. Predators and People: Conservation of Large Carnivores at High Human Densities if Management Policy is Favorable. *Animal Conservation.* 2001. 4, 345-349.

Martin B. Main, Fritz M. Roka, Reed F. Noss. 1998. Evaluating Costs of Conservation. *Conservation Biology.* 1999. p. 1262-1272. Volume 13 No.6.

Martin Nie.2004. State Wildlife Management and Policy: The Scope and Bias of Political Conflict. *Public Administration Review*. 2004. March/April Volume 64. No.2 p.221-233.

M. Culver, W.E. Johnson, J. Pecon-Slattery, and S.J. O'Brien. 2000. Genomic Ancestry of the American Puma (*Felis concolor*). *The Journal of Heredity.* 91:(3) 2000.

McNab, W.H., and Avers, P.E. (*Compilers*). 1994. Ecological Subregions Of the United States: section descriptions. USDA Forest Service, Admin. Publication WO-WSA-5.

Montana Fish, Wildlife, and Parks. Mountain lion range map for the state of Montana. Data Unknown and Author Unknown. http://fwp.mt.gov/fieldguide/detail_AMAJH04010.aspx. Date accessed, June 1, 2006.

Nebraska Game and parks Commission, 2005. www.ngpc.state.ne.us Observation reports and figure 1. Accessed October 26th, 2005.

P.J. Perea. Part 2: Our Best Hunting Areas. 2005 Can Hunters Top Last Seasons Record-Breaking Deer Harvest? Here is the Scoop. www.Illinoisgameandfish.com Accessed Nov 1st, 2005.

Peterson, A.T. and D.A. Vieglas. 2001. Predicting species invasions using ecological niche modeling: New approaches from bioinformatics attack a pressing problem. *BioScience* 51(5): 363 – 371.

Peterson, A.T. 2001. Predicting species geographic distributions based on ecological niche modeling. *The Condor* 103: 599 – 605.

Peterson, A.T., J. Soberon, V. Sacnchez-Cordero. 1999. Conservatism of ecological niches in evolutionary time. *Science* 285(5431): 1265 – 1267.

Ralph J. Alig, Andrew J. Plantinga, SoEun Ahn, and Jeffery D.Kline. 2003 Land Use Changes in the United States: 1952 to 1997, With Projections to 2050. United States Department of Agriculture, Forestry Service. General Technical Report, PNW-GTR-587, September 2003.

Riley, Shawn and Richard A. Malecki.2001. A Landscape Analysis of Cougar Distribution and Abundance in Montana, USA. *Environmental Management* Volume 28, No.3, pp. 317-323. 2001.

Robert P. Anderson, Daniel Lew, and A Townsend Peterson.2001. Evaluating Predictive Models of Species' Distributions: Criteria for Selecting Optimal Models. *Ecological Modeling.* 162 (2003) 211-232.

Ruth S. Defries, Jonathan A. Foley, and Gregory P. Anser. 2004. Land-use Choices: Balancing Human Needs and Ecosystem function. *Ecol Environ*. 2004. 2(5): p.249-257.

Stockwell, D. and D. Peters. 1999. The GARP modelling system: Problems and solutions to automated spatial prediction. *International Journal of Geographical Information Science* 13(2): 143 – 158.

Stockwell, D.R.B. and Peterson A.T., 2002. Effects of sample size on accuracy of species distribution models. Ecological Modelling 148:1-13.

Stephen R. Kellert, Matthew Black, Colleen Reed Rush, and Alistair J. Bath. 1995. Human Culture and Large Carnivore Conservation in North America. *Conservation Biology.* 1996. p. 977-990 Volume 10. No. 4.

Texas Tech University.1997 The mammals of Texas online edition. http://www.nsrl.ttu.edu/tmot1/feliconc.htm. Author Unkown. 1997. Accessed June 1, 2006.

United States Department of Agriculture, Forestry Service.2002. Map of Ouachita National Forest. Author Unknown www.fs.fed.us/oonf/ouachita, 2002. Accessed April 30, 2006.

United States Department of Agriculture, Forestry Service.2004. Map of Nicolet National Forest. Author Unknown www.fs.fed.us/r9/cnnf, 2004. Accessed April 30, 2006.

United States Department of Agriculture, Forestry Service.2005. Map of the Nebraska National Forest. Author Unknown www.fs.fed.us/r2/nebraska, 2005 Accessed April 30, 2006.

Woodroffe, R. 1999. Predators and People: Using Human Densities to Interpret Declines of Large Predators. *Animal Conservation.* 2000. 3: 165-173. 2000.

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