UnderGoldenWings
North Dakota Golden Eagle Project

December 2, 2011

Mr. Dennis Rankin
Environmental Protection Specialist
USDA, Rural Utilities Service
1400 Independence Avenue SW
Stop 1571
Washington, DC 20250-1571

RE: Notice of Intent for Preparation of an Environmental Impact Statement for Basin Electric Power Cooperative's proposed Antelope Valley Station to Neset Transmission Project in North Dakota

Dear Mr. Rankin:

I will start by introducing myself professionally. My name is Dr. Anne Marguerite Coyle (Margi), I am currently an assistant professor of biology at Jamestown College. My past employment as an ecologist/wildlife/ landscape biologist includes working for the UFWS, USFS, and the USGS. For the past 9 years I have served as the principle investigator of the North Dakota golden eagle project. I have studied the population in North Dakota extensively since 2002. I compiled all known nests, conducted nest site checks, new nest surveys, monitored reproduction, survival, mortality, juvenile dispersal and movements, created potential habitat models, and investigated the potential impacts of disturbance. I work closely with the USFWS federal agent, the Dakota Zoo, and the Minnesota Raptor Rehabilitation Center with the recovery of injured raptors. I not only created and managed the North Dakota golden eagle database, I also serve on the North America Conservation of the Golden Eagle Working Group with the other experts in North America.

I grew up in northeastern Indiana. My family was in the oil business for years. I understand perspectives of both business and biology. I was raised to believe that people in positions of power have an obligation to be leaders in the community. I also believe politicians, heads of industry, and other leaders have an obligation to lead with responsible citizenship. That means always placing human, community, and subsequently environmental health for-front in the decision-making process. As any successful business understands, on the job safety must be a top priority. This proactive preventative strategy reduces risk and saves the industry money in the long run. Similarly, being preventative on environmental, community, and human health issues will also lead to long-term success.

Anne Marguerite Coyle, PhD
Jamestown ND,
701-260-3753
flyfreege@aim.cm / http://undergoldenwings.org/

The Little Missouri National Grassland in western North Dakota provides some of the largest expanses of grasslands in North America. Grasslands are the second most heavily used and disturbed habitats worldwide. Approximately 47% of the temperate grasslands worldwide have been converted to agriculture or urban development. The remaining grasslands are under pressure from over-grazing and multi-use activities that compromise habitat integrity and species diversity. One of the largest threats to the remaining grasslands is habitat fragmentation. Once disturbed, the land can never recover completely. Most of the vegetative regeneration must come from root propagation, and in some cases this is prohibited by constructed and disturbed locations. Disturbed areas such as roads, oil pads, and industry infrastructure, hinder species movements, increase habitat fragmentation, and decreasing available habitat. Habitat is compromised in two ways, first by reduction of habitat area and second by providing corridors for invasive species. These non-native invasive species thrive in disturbed areas, out-compete native species, spread, and cause a cascading degradation to the integrity of neighboring in-tack grasslands habitats and consequently decrease species diversity and richness. Minimizing disturbance and maintaining large continuous sections of habitat provide core areas essential for maintaining ecological integrity and biodiversity.

Disturbances and invasive species can penetrate the exposed edges of a habitat. This is termed “edge effect”. Large road-less and undisturbed areas have a larger “core” area compared to their perimeter. Therefore, larger core habitats are less influenced by activities and disturbances along the perimeter. Consequently, sections of habitat that have larger core areas contain greater biodiversity. These "core" areas if protected can be sources for populations of species. The species in the core area can flourish and help to maintain surrounding areas with dispersing individuals.

The core areas that have habitat surrounding them with minimal use have greater ecological integrity and greater biodiversity. This is because the surrounding areas can "buffer" the “edge effect” created by disturbances and invasive species. Theodore Roosevelt National Park and the surrounding National Grassland is an ideal example of such a system. The TRNP together with LMNG managed by the USFS then acts as a source for the overall ecological health and integrity of the entire grasslands ecosystem of western North Dakota.

Additionally, these grasslands provide the vital habitat for nesting golden eagles in North Dakota.

Therefore, I present to you two recommendations and supporting evidence to minimize potential impacts of the proposed placement of a major power line (Basin Electric Power Cooperative) on: 1) core habitat areas in the grasslands ecosystem and 2) the golden eagle population in Western North Dakota.

Anne Marguerite Coyle, PhD
Jamestown ND,
701-260-3753
flyfreege@aim.cm / http://undergoldenwings.org/

Recommendations:

1) Macro-Corridor D & E should be dropped from consideration for this project
2) All Power lines, all junctions, and related structures be constructed with the most effective raptor friendly equipment.

1) Figure 1 - There are over 200+ known potential territories and an uncertain number of undiscovered territories centered along the Little Missouri River and throughout the Little Missouri National Grassland extending west into Montana, as far east as Flasher, ND, and south into South Dakota. In some cases these birds can endure disturbance; however, each pair reacts differently and many have illustrated intolerance to disturbance. My research along with research in North America illustrates that electrocutions are a significant cause of mortality; and therefore, still present a direct threat to the population. Ensuring major power lines are directed away from known nesting territories is my strong recommendation. This will minimize fragmentation and disturbance in areas of critical habitat, and reduce the chance for electrocutions of golden eagles in high nest density areas. Therefore, I recommend Macro-Corridor D & E be dropped from consideration for this project.

2) Figure 2 - The LMNG serves as the primary nesting ground for golden eagles in North Dakota, and also provides vital habitat for dispersing juveniles. During my research I tagged 18 juvenile golden eagles and monitored their movements from 2002 - 2011. The data show that the entire Little Missouri National Grassland is extensively used by juvenile golden eagles. Data from birds collected during this study and data from other collections by the USFWS and the Minnesota Raptor Rehabilitation Center show numerous incidents of mortality resulting from electrocutions. The territory location and movement data, coupled with the mortality data. This will illustrate the imperative need to use raptor friendly equipment on any and all power lines in western North Dakota to ensure compliance with the US Migratory Bird Act and the Bald and Golden Eagle Act. Therefore, I strongly recommend that all power lines, junctions, and related infrastructure be constructed with the most effective raptor friendly equipment.

This study was funded by UND, NDGF, USFS, USFWS, DSU, and UGW.

Thank you for your time and consideration,

Dr. Anne Marguerite Coyle (Margi)
Jamestown ND,
701-260-3753; flyfreege@aim.cm / http://undergoldenwings.org/

Anne Marguerite Coyle, PhD
Jamestown ND,
701-260-3753
flyfreege@aim.cm / http://undergoldenwings.org/

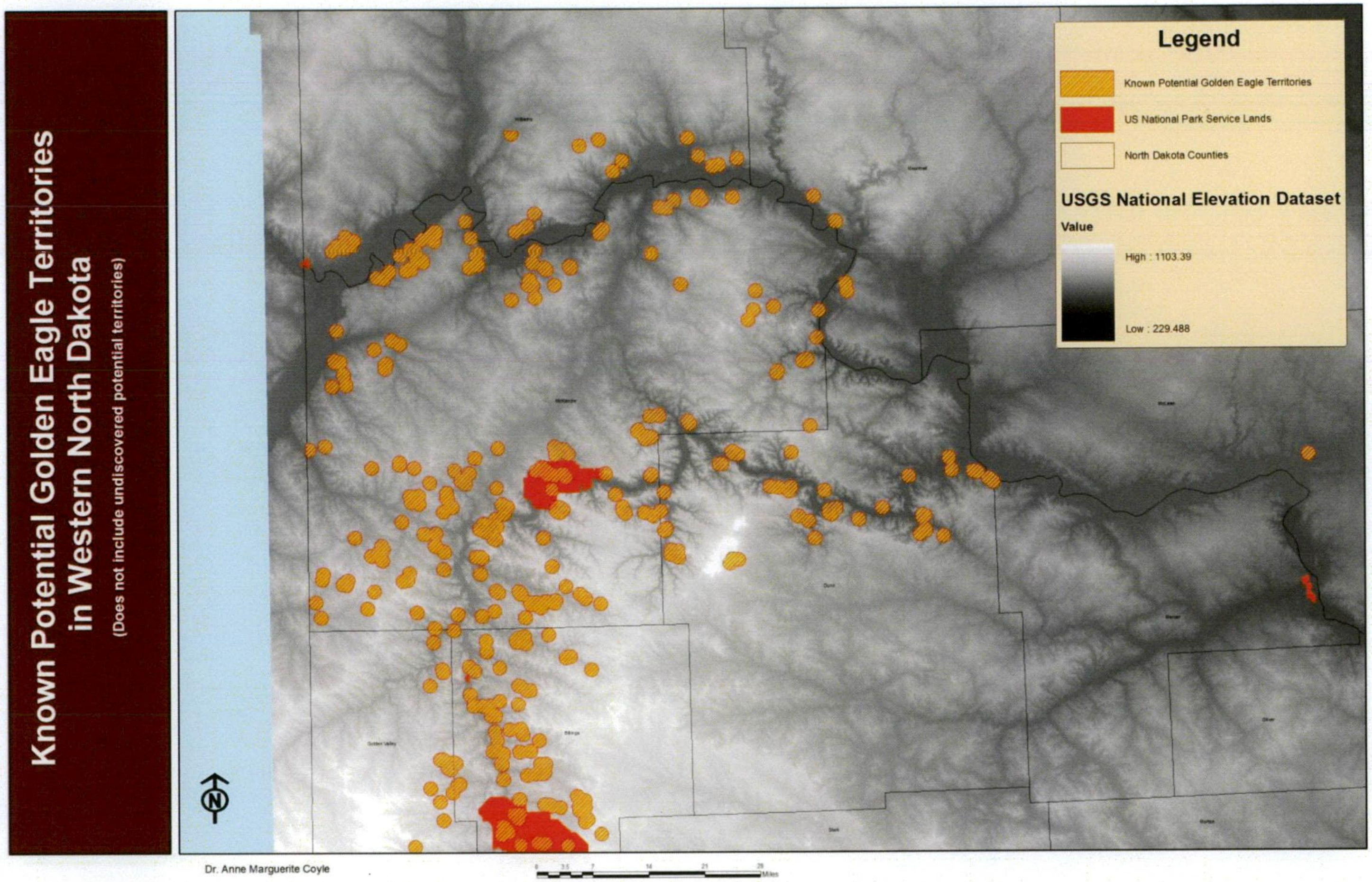


Figure 1. Known potential golden eagle nesting territories in western North Dakota. These were developed from known nesting site locations. Other undiscovered or new nest sites may exist therefore continued monitoring in areas prior to construction is necessary.

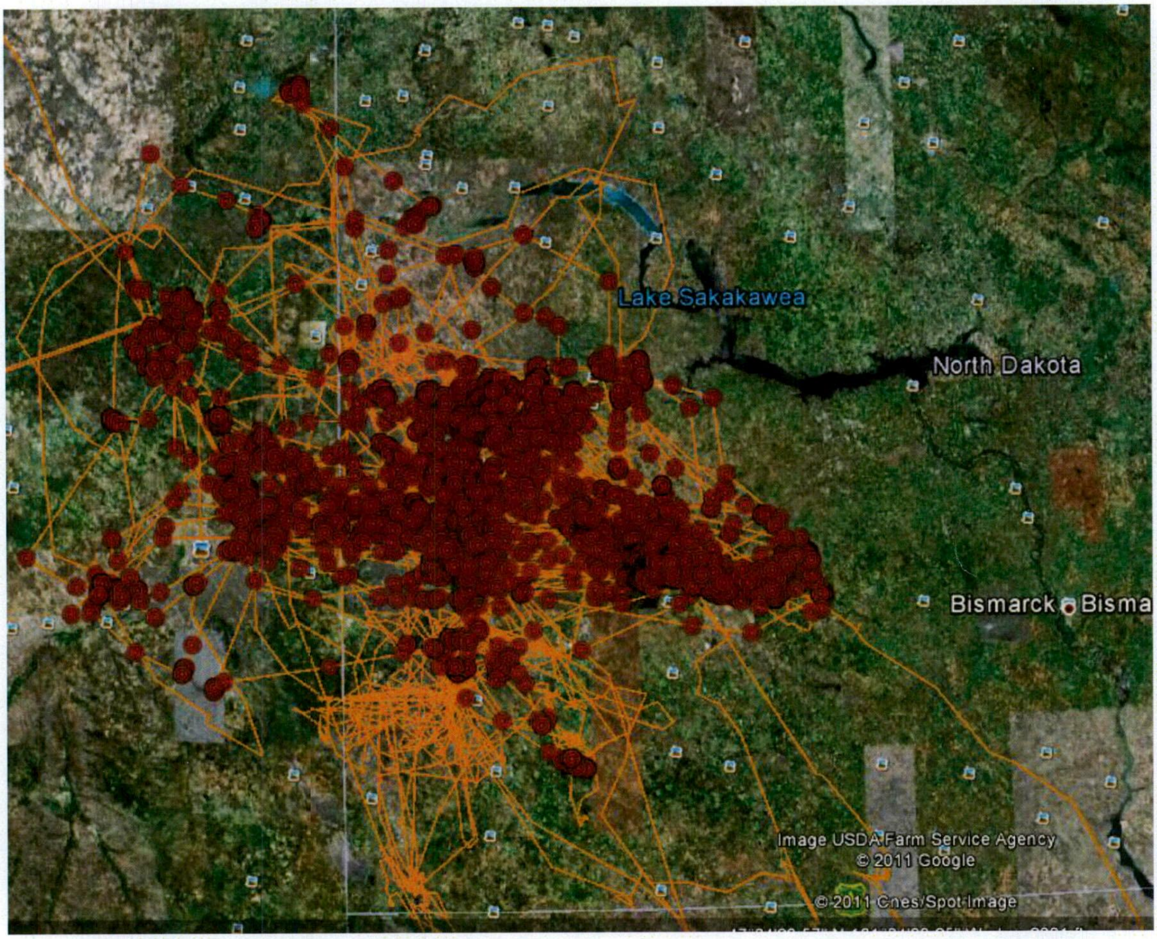
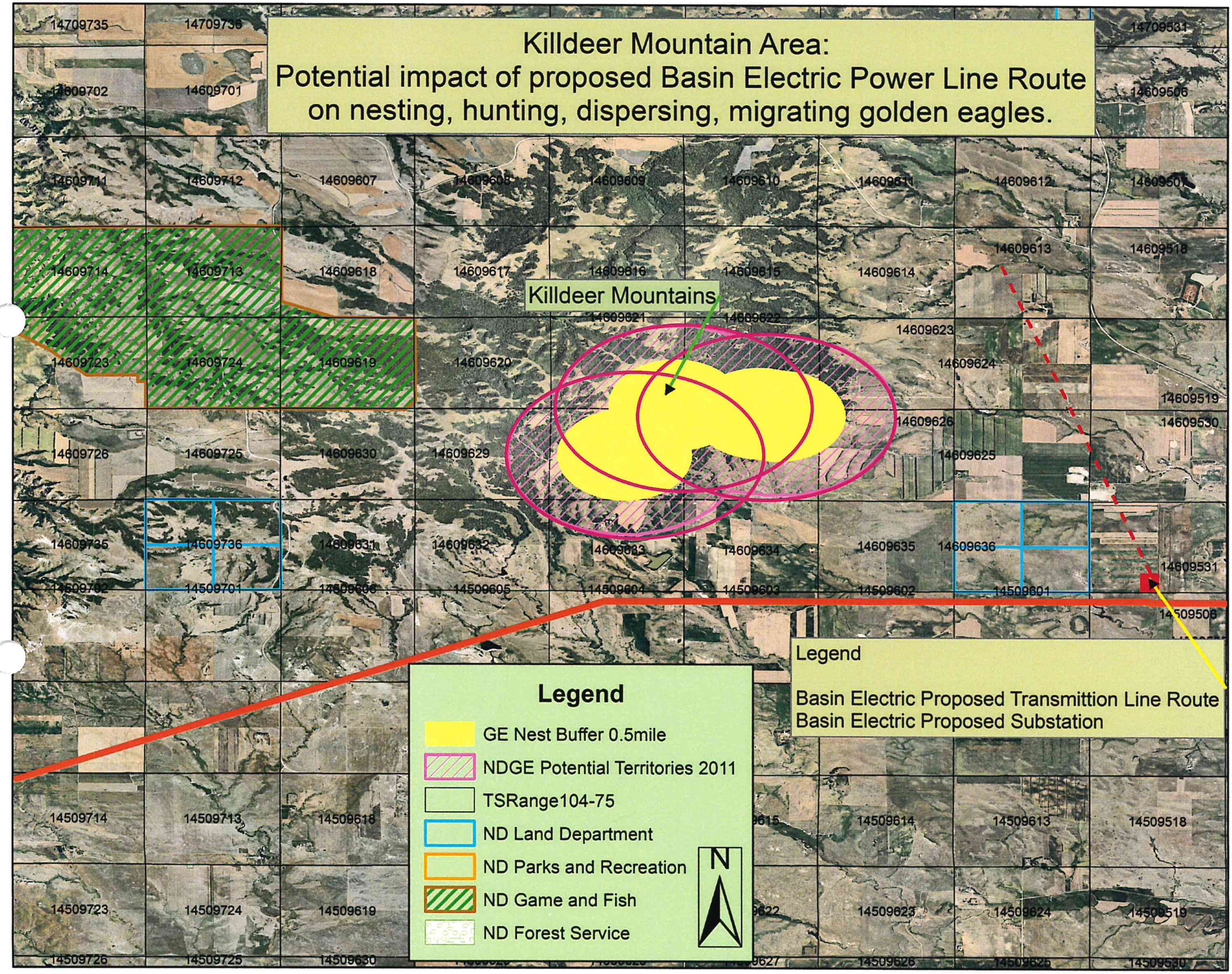


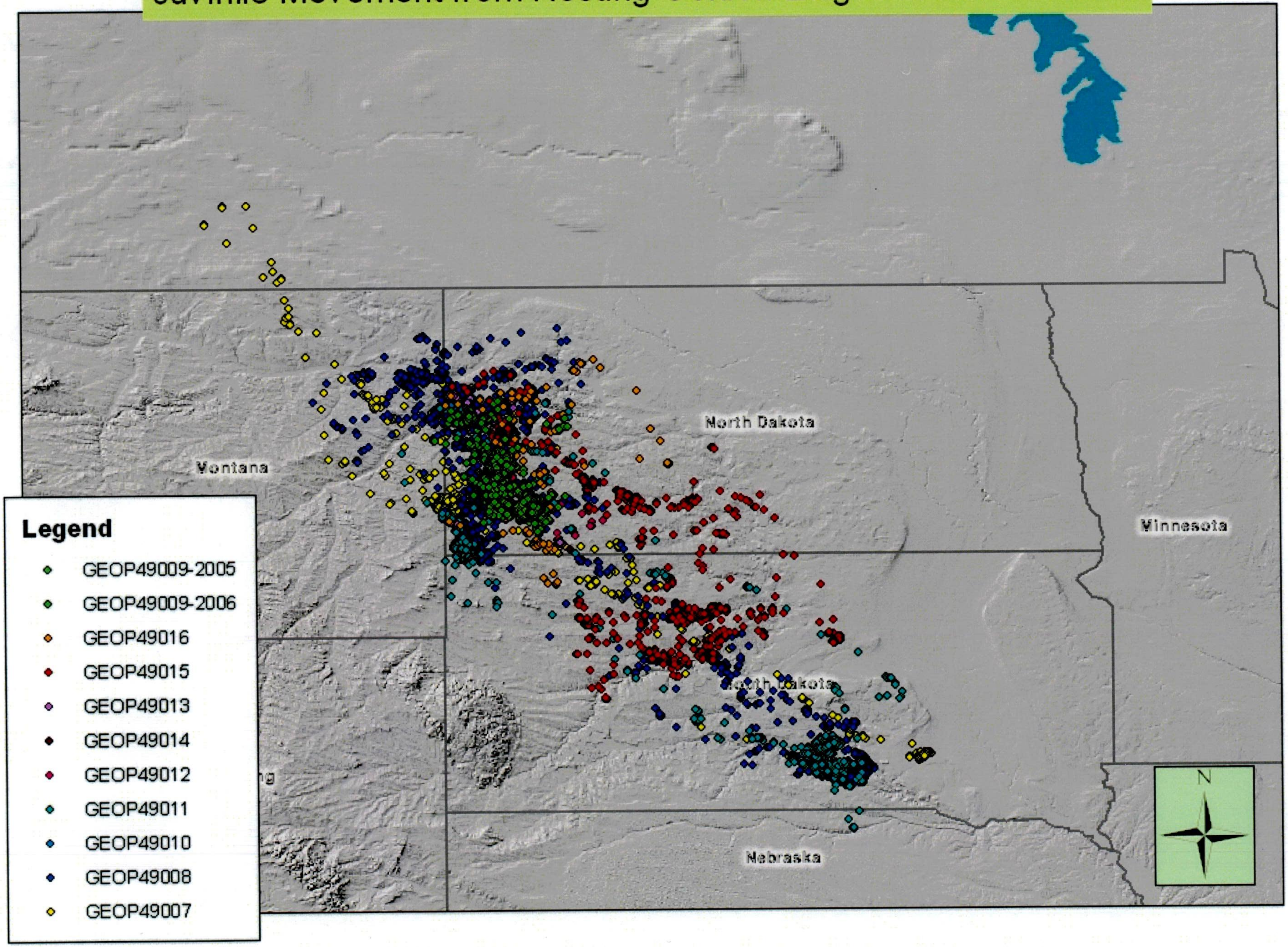
Figure 2. Evidence supporting the need to ensure all power lines and associated structures are constructed with raptor friendly equipment. Locations of 18 juvenile golden eagles tagged over 8 years with PPT Solar Paneled GPS units (2004-2011). The yellow lines depict the shortest distance between recorded GPS locations to indicate the sequence of movements. The lines do not represent the actual path taken by the bird between recorded points. Each bend in the line is a single GPS location. There may also be additional locations along the line used extensively by juvenile golden eagles. Not all locations are depicted on this map.

Anne Marguerite Coyle, PhD
Jamestown ND,
701-260-3753
flyfreege@aim.cm / http://undergoldenwings.org/



Killdeer Mountain Area:
Potential impact of proposed Basin Electric Power Line Route
on nesting, hunting, dispersing, migrating golden eagles.
Killdeer Mountains
Legend
GE Nest Buffer 0.5mile
NDGE Potential Territories 2011
TSRange104-75
ND Land Department
ND Parks and Recreation
ND Game and Fish
ND Forest Service
N
Legend
Basin Electric Proposed Transmittion Line Route
Basin Electric Proposed Substation

Juvinile Movement from Nesting Golden Ealges of North Dakota



1. *<u>Mortality – Post fledgling</u>. This study illustrates that the majority of mortalities that occur to birds from occupied nests that were monitored, occurred just prior to or at the time of fledgling No siblicide was observed. Few nestling mortalities were recorded. Early nest failure was difficult to determine do to large survey area and limited time. If surveys for estimating nest success are from the air many post fledging mortalities may go undetected. We found many under the nest. Telemetry has been very helpful to determine mortality of post fledglings that were away from the natal nest site.*

2. *<u>Shooting, Poisoning, poaching</u>. The federal agent and many of us are very concerned about pheasant hunters shooting raptors and golden eagles. There have been numerous incidences. I even spoke with a biologist from pheasants forever who approached me very concerned saying everyone he talks to brags about shooting raptors and eagles. Poaching for feathers is still a problem. I am currently working with a student on raptor education. She has developed a program that can be used by teachers and agencies. DSU is funding supplies and for her and other students to go to schools to present. This meets the curriculum requirements for K – 12. I am working with tribal elders presenting to kids on the cultural and biological importance of GE's.*

3. *<u>Oil and gas development</u> is a serous issue in North Dakota. The USFWS is fighting now on a number of violations of rigs and disturbance too close to nest sites and likely causing abandonment. They have provided funding to supplement the USFS efforts to monitor known nest sites and to expand the project to conduct new nest/population surveys through to 2013.*

4. *<u>Electrocutions:</u> I had a student tabulate mortality data and prepare a presentation on electrocution issues in North Dakota. Again the USFWS is continually working with companies to update their lines/pole to be raptor friendly.*

5. *<u>On foot disturbance</u>. Mortality due to humans includes causes such as shooting to on foot disturbances. On foot disturbances include, but are not limited to, climbers, surveyors, researchers, and tourists. When people approach a nest adult eagles will flush and, subsequently, young chicks or eggs can die from exposure to cold/ hot temperatures, or if the disturbance persists long enough adults my abandon a nest. Finally, on foot disturbances can flush young that can not yet fly from the nest and they die from impacting the ground. Need for change in protocol for survey of Oil well sites. See dissertation appendix.*

6. *USFWS and University of Minnesota Mortality Reports* : Various causes of mortality, both natural and anthropologic, have been documented in North Dakota. Paper records from the USFWS and the University of Minnesota list 13 types of causes for mortality to golden eagles in North Dakota. These only report incidental findings of dead eagles (Table 20 & 21). Although numbers are reported they are not representative of the population.

Table 20. Number of reported causes of mortality for each age class; U.S. Fish and Wildlife Service, 1992-2005. Only three deaths were confirmed with necropsies, one shot, 2 electrocutions.

Causes of Mortality	#Adults	#Juveniles	#Unknown Age
Electrocution	11	4	11
Lead shot ingestion	1	-	1
Collision – Contacted oil equipment when being chased by smaller bird	-	-	1
Shot	3	2	5
Power line	1	-	-
West Nile	2	-	-
Unknown	21	12	3

Table 21. Number of reported causes of mortality; University of Minnesota Raptor Rehabilitation Center Records, 1990-2005.

Causes of Mortality	#Unknown Age
Collision w/ Vehicle	3
Projectile	2
Toxicity	2
Disease	1
Undiagnosed Disease	2
Unknown Trauma	6

Causes of Mortality in ND	Source
Collision w/ Vehicle	University of Minnesota Raptor Center
Projectile	University of Minnesota Raptor Center
Toxicity	University of Minnesota Raptor Center
Disease	University of Minnesota Raptor Center
Undiagnosed Disease	University of Minnesota Raptor Center (Coyle 2006)
Unknown Trauma	University of Minnesota Raptor Center
Electrocution	USFWS (Coyle 2006)
Lead shot ingestion	USFWS (Coyle 2006)
Collision – Contacted oil equipment when being chased by smaller bird	USFWS
Shot (recreation, by pheasant advocates)	USFWS
Compound fracture – wings – possible collision – euthanized.	USFWS
Unknown – broken leg	USFWS
Road kill or power line	USFWS
West Nile	USFWS / Dakota Zoo / (Coyle 2003) (Coyle 2005)
Wind storm – broken neck below nest	(Coyle 2003) (Coyle 2005)

Wind storm – stuck in mud	(Coyle 2003) (Coyle 2005)
Wind storm – under fallen nest	(Coyle 2003) (Coyle 2005)
Exposure – chick during surveying activity and on foot disturbance	USFS / Volunteer (Coyle 2005)
Incidental trapping and poisoning	USFWS / Landowners
Shot	USFWS / Dakota Zoo / Via Phone Conversation Dr. Mc Ewen, CO, / Landowners
Power line Strike	USFWS / Power company
Unknown	USFWS / (Coyle 2006)

Potential Impacts of Oil and Gas Development On Select North Dakota Natural Resources

A Report to the Director

May 2011

http://gf.nd.gov/sites/default/files/publications/specialty-publications/directors-report-oil-gas-may-2011.pdf

GROUPING AND COOPERATIVE HUNTING AMONG NESTING ADULT GOLDEN EAGLES IN THE BADLANDS OF WESTERN NORTH DAKOTA

ANNE MARGUERITE COYLE[1]

Department of Biology, Box 9019, University of North Dakota, Grand Forks, ND 58202-9019 U.S.A.

[1] *Biology Department, 6062 College Lane, Jamestown College, Jamestown, ND 58405 U.S.A.*

acoyle@jc.edu, 701-260-3753

The grouping behavior of cooperative breeding and hunting is documented in raptors. Cooperative hunting in birds of prey is well documented for species such as Aplomado Falcon (*Falco femoralis*; Hector 1985, Brown et al. 2004) Harris's Hawks (*Parabuteo unicinctus*; Dawson and Mannan 1991, Coulson and Coulson 1995), American Kestrels (*Falco sparverius*; Varland and Loughin 1992), and the Lanner Falcon (*Flaco biarmicus*; Leonardi 1999). Cooperative hunting involves two or more individuals coordinating and cooperating their efforts while pursuit of the same prey (Hector 1986), however not necessarily cooperating following prey capture (Packer and Rutten 1988). Group size, prey size and type, success of the hunt, and mechanisms influencing grouping and cooperative hunting can very between species (Hector 1985, Packer and Ruttan1988, Dawson and Mannan 1991, Varland and Loughin 1992, Coulson and Coulson 1995, Leonardi 1999, Brown et al. 2004).

Cooperative breeding has been observed in raptors such as Galapagos Hawk (*Buteo galapagoensis*; Faaborg et al. 1980), Harris's Hawks (Mader 1975, Bednarz 1988, Dawson and Mannan 1991), Bald Eagles on the Santa Catalina Island (Garcelon et al. 1995), Madagascar Fish-Eagle (*Haliaeetus vociferoides*; Tingay et al. 2002), Eurasian Hobbies (*Falco subbuteo;* Zuberogoitia et al. 2003), and Booted Eagles (Martínez et al. 2005). This involves the cooperation of three of more birds to raise young at a particular nest (Kimball et al. 2003).

Although grouping behavior is documented in raptors little is known about cooperative hunting and breeding among nesting Golden Eagles (*Aquila chrysaetos*; Kochert et al. 2002, Kimball et al. 2003). In winter months Golden Eagles are known to group while feeding on carcasses (Deblinger and Alldredge 1996, Kochert et al. 2002).

Also, Golden Eagles will group during migration and have been observed hunting in groups of two or three birds attacking Wild Turkeys (*Meleagris gallopavo*; Thomas et al. 1964), Sandhill Cranes (*Grus canadensis*), and Whooping Cranes (*Grus americana*) in fight (Ellis et al. 1999). Golden Eagles are described as territorial in the nesting season (Marzluff et al. 1997), yet it is well documented that they cooperatively hunt as nesting pairs (Carnie 1954, Collopy 1983). In these paired hunts the male and female both hunt in "tandem" scanning the landscape for prey (Carnie 1954, Collopy 1983). Martinez et al. (2005) offers potential supporting evidence for cooperative hunting in eagles. They report an account of two cooperatively breeding Booted Eagles (*Hieraaetus pennatus*) attacking the same raven (Martínez et al. 2005). They did not distinguish the behavior as cooperative or competitive.

Interestingly, I was unable to find documentation for cooperative hunting or breeding among nesting Golden Eagles either in the literature or speaking with other raptor biologists (Brian Latta, Dan Svingen, Dr. Mark Fuller pers. comm.).

The purpose of this paper is to document group cooperative hunting by multiple pairs of nesting Golden Eagle adults over six years of Golden Eagle nest surveys in North Dakota. This unique group behavior challenges the current understanding of Golden Eagle territorial nesting behavior. I will present possible explanations for these observations.

METHODS

The geographic range for nesting Golden Eagles in North Dakota (Fig. 1) extends throughout the Great Plains Region (Bluemle 2000) (Escano 1981, Ward et al. 1983, Allen 1987, Coyle 2008). This includes the area around the Missouri River and Lake

Sakakawea, extends west to Montana and south to South Dakota, with the majority of know nesting sites concentrated in and around the Badlands surrounding the Little Missouri River (Escano 1981, Ward et al. 1983, Allen 1987, Coyle 2008). The region is dominated by short grass prairie, intermixed with sagebrush along the river bottoms, cottonwood and green ash in the riparian habitats, and juniper on the badlands hill slopes (Bryce et al. 1986).

As part of a long-term project to survey and monitor Golden Eagle nests in North Dakota, aerial and ground nest checks (2002 - 2008, 2010, and 2011) and aerial nest surveys (2005 and 2011) were conducted. Cooperative hunting behavior was first observed and documented in 2003. Therefore, these observations were included as an objective in subsequent years. The observers include the pilots Jeff Faught (North Dakota Game and Fish Department) and Boyde Trester (private contract pilot from Beach, ND), technicians (Allison Poff, Sara Milne, Lori Lundin, Brittany Hasbargen, and Rochell Reddig) and the lead researcher (A. Marguerite Coyle).

RESULTS

We observed paired hunting behavior within the breeding season in North Dakota multiple times and consistently throughout the project. Outside of the breeding season we watched multiple birds feeding on carcasses or hunting in close proximity. Most significantly we witnessed eleven groups of adults (three to six) with two or more cooperatively hunting within nine occupied territories, one historical territory, and one defended area (Fig 1) between 2003-2005.

Occupied territories are based on the presence of two or more cooperating eagles defending an area with either an occupied nest found that field season or a known previously occupied nest site. Historical territories are have an occupied nest record in the master database however the nest has not been relocated in this study and may no longer exist. A defended area is an area that has two or more defending eagles however a nest site has not been located. Cooperative hunting was observed in habitats consisting of woody patches of green ash, birch, and aspen interspersed with open grassy areas at the lower elevations bordered by a cliff or rocky out crops at higher elevations. The territories were distributed throughout the western core range from north along Lake Sakakawea to south along the Little Missouri River corridor. The nest site type with in the territories varied: rock ledge, cliff, tree, and ground. In all cases of cooperative hunting eagles were either soaring at higher elevations over ridges or hunted together by flying wing tip to wing tip back and forth at tree top level or lower within 0.5 km or less of the nest site.

In 2003 we observed two separate groups of three adult Golden Eagles and four groups of four eagles hunting in tandem. At one of the nest sites, three adults were observed hunting in tandem directly below an occupied nest with a fourth adult incubating. In 2004 we observed three groups of three adult eagles hunting in tandem.

Additionally, on three separate occasions (2003, 2004, and 2005) we observed five to six Golden Eagles, three pairs from the three neighboring occupied territories, grouped in the nesting seasons. In 2003 and 2004 they appear to be cooperatively living and in 2005 they were observed cooperatively hunting. We would expect both behaviors to be precluded by territoriality. The bird's territories are spaced each approximately 2 km apart. They line one major ridge consisting of two flat topped buttes. Three pairs were observed above each of the three known or historic nest site locations in courtship behavior every year of the study (2002-2007). In 2003, five adult eagles were located perched in a row along the ridge above the the occupied nest site (one adult and two downy chicks). The birds flew off the ridge and would come back down. The pilot retreated from the area when one of the perched birds what appeared to be a male (smaller in height and size then the one next to it) raised its head feathers and charged the plane. In (2004) five or six eagles were seen soaring with one perched along the same ridge near the occupied nest. Perching and soaring together above an occupied nest would suggest they are cooperatively living. From a distance during a ground check in 2005 five eagles were observed flying above the ridge to the west of the occupied nest site. During the observation in 2005 it appears that they were cooperatively hunting.

While preparing this document I searched the North Dakota Golden Eagle Master Database (Coyle 2008) for other possible records of grouping. I discovered two historical accounts of grouping. In 1992 Koenig and Anderson and in 1997 Lincoln observed three adults at a single occupied nest location within Theodore Roosevelt Park. Lincoln had been intensively observing this site since 1995 and noted the observation of a third adult in the area as "weird".

We did not observe a successful cooperative hunt so it is unknown how the birds respond to one another after capturing prey. However, no aggression was ever observed between the adults despite aggressive territorial defensive behavior toward our plane. We did not notice aggression between siblings. Siblings were observed together with parents learning to soar and hunt, flying, feeding, and perched post fledgling. Although we did observe a few instances of sub-adults nesting, all of the cooperative hunting groups consisted entirely of adult eagles.

DISCUSSION

Cooperative hunting was not the focus of our research. Additionally, we minimized time around the nest site to avoid disturbing nesting birds. So although rare, the fact that we observed cooperative hunting in Golden Eagles multiple years and at multiple sites, in addition to two historical accounts, suggests that this is truly occurring and not just a fluke occurrence.

According to the optimal foraging theory (McArthur and Pianka 1966) hunting should occur if the benefits outweigh the costs (McArthur and Pianka 1966, Packer and Rutten 1988). Variables such as energy value of prey, prey density, time spent hunting, handling time, movement, environmental resistance to movement, are considered in the theory. Packer and Rutten's (1988) game-theoretical models using data from many studies and species predict that when no other factors force individuals to group, cooperative hunting for a single prey will occur only when hunting solo is not efficient. They predict that group hunting is dependent on prey abundance and size. Results also indicate group hunting will be cooperative when prey size is small and will occur when prey size is large only if hunting solo is less successful (Packer and Rutten 1988).

We propose four possible advantages to cooperative hunting for Golden Eagles in North Dakota: improving success when hunting large prey, increasing the chance of prey capture, supporting large clutch sizes, and supporting cooperative breeding.

Collopy (1983) reports observing only two successful captures of prey from tandem hunts. The male usually leads from a greater altitude while the female follows and more prey capture attempts are initiated by males. Both successful captures were from second attempts, one from each sex (Collopy1983). He concluded that solo hunts were more successful. This would appear to contradict results presented by Packer and Rutten (1988) and the optimal foraging theory unless another explanation exists. Females do increase their time hunting when rearing chicks (Carnie 1954 and Collopy 1984). Carnie (1954) reports increased paired hunts when rearing chicks in response to the increased demands of the young. Despite a potential low success rate of tandem hunts (Collopy 1983), this would suggest some benefit exists and group hunting increases success of feeding the offspring. Hector (1985) and Leonardi (1999) indicate that cooperative hunting in falcons is prey specific and limited to species that predate on birds. It is possible that type, size, energy value of prey, or other factors may be driving paired hunting in eagles, however, neither Carnie (1954) nor Collopy (1983) were able to make this determination.

All of our observations of paired or group cooperative hunting occurred within the nesting season and many were confirmed to be rearing young. Therefore, it is possible to assume this behavior may increase efficiency in hunting and could aid in rearing multiple young through fledging by increasing the quantity or quality of food (Bortolotti 1986). Collapy (1984) reported a greater amount of food per individual is brought to nests with multiple chicks compared to single chick nests. However the % consumed is lower per individual in multi-chick nests throughout later weeks resulting from sibling competition. A study in Scotland (Watson et al. 1992) found nest density increases with food availability and breeding success increases with increased live prey. Nests had one to four chicks, few observations of sibling competition, no documented cases of siblicide, and high rates of nestling survival to fledging (Coyle 2008). In these circumstances food demands will be high. Cooperative hunting may provide a solution to ensure survival of all chicks. Furthermore, successfully rearing larger broods might increase the chance of cooperative behavior in those juveniles when they mature. We observed young eagles together frequently including in play as also documented by, O'Toole (1999) in North Dakota. We observed young eagles learning to fly and hunt together with a parent. Numerous locals have described accounts of Golden Eagles tossing Black-tailed Prairie Dogs (*Cynomys ludovicianus*) in the air to teach the young to hunt and catch prey. We observed parents tossing sticks to, feeding, and leading the fledged siblings in different flight patterns. Both fledged siblings were observed participating together with their parents. Perhaps this cooperative behavior between siblings leads to cooperative behavior as adults via innate or learned behavior. The lack of aggressive behavior among juveniles and fledglings may likely be due to the increased provisioning due to group hunting.

Prey type, size, and availability also may influence hunting behavior in adults (Packer 1988). Cooperative hunting is advantageous for Lions (*Panthera leo*) capturing and killing large fast prey (Stander 1992) and may also benefit Golden Eagles in the same way. This has been observed in two species of predatory birds: Florida Scrub-Jays (*Aphelocoma coerulescens*; Bowman 2003) and Loggerhead Shrikes (*Lanius ludovicianus*; Frye and Gerhardt 2001). In both observations breeding pairs attacked and killed a snake. Although not an abundant food source, fawns are a well-documented prey used by Golden Eagles (Carnie 1954, McGahan 1968, Beecham 1970, Bowmen 2001, Coyle 2008). Fawns are born in the spring and summer coinciding with the increased food demands of growing Golden Eagle chicks. Therefore, it is possible cooperative hunting ensures the capture of a specific type of prey and helps to meet the demands of the growing chicks. We observed an adult Golden Eagle bring the hind quarter of a freshly killed Pronghorn (*Antilocapra Americana*) fawn to a nest site (2008). In the Italian Alps Roe Deer (*Capreolus capreolus*) is one of the main prey for Golden Eagles in number and weight (Pedrini and Sergio 2001). Golden Eagles are known to take large Pronghorn fawns (Goodwin 1976, Deblinger and Alldredge 1996), adult (male and female) Pronghorns (Deblinger and Alldredge 1996), and adult (male) White-tailed Deer (*Odocoileus verginianus*) over the winter months (Willard 1916). Taking a Pronghorn is difficult for Golden Eagles and requires multiple attacks, preferably from behind to overcome Pronghorn's defensive behavior, and separating the best target from the heard (Deblinger and Alldredge 1996). A pair or group of eagles would likely increase the success of attacks on larger young or adult Pronghorns. This would support Packer and Rutten's (1988) model and prediction that cooperative hunting is favored for large prey when solo hunting is less effective.

Cooperative hunting may also help capture smaller prey, particularly if they need to be flushed or driven from heavy cover as is common in our study area. Coulson and Coulson (1995) observed a group of six adult Harris's Hawks cooperatively hunt, kill and feed on a cotton-tail rabbit. Jones (1999) documented ground walking Mountain Caracaras (*Phalcoboenus megalopterus*) in Peru cooperate to move large rocks to obtain prey. Cooperative behavior would increase the ability to chase out smaller prey from shrubby habitats, (Coulson and Coulson 1995). Golden Eagles diet in North Dakota includes many small prey species such as snakes, birds, prairie dogs, rabbits, waterfowl, and others (Coyle 2008). A single Golden Eagle in North Dakota was observed dropping rocks on a brush pile to drive out a rabbit into the open (D. Klemic pers. comm). Such hunting could be more efficient in a group. Packer and Rutten (1988) predict cooperative hunting will occur if a second hunter increases the probability of catching a prey.

Bednarz (1988) suggests cooperative hunting is one possible reason Harris's Hawks select relatively larger prey compared to the solitary hunting Swainson's Hawk (*Buteo swainsoni*). Prey behavior may encourage cooperative hunting. However, Golden Eagles in North Dakota have a varied source of prey available and if prey type and behavior is driving cooperative behavior than we would argue other populations which are more dependent on rabbits for prey would also exhibit cooperative hunting. Therefore, although we present this as one possible factor we do not believe it has a major influence on cooperative hunting of Golden Eagles in North Dakota.

Packer and Rutten (1988) suggest other mechanisms may force grouping and therefore cooperative hunting, such as cooperative breeding. It is uncertain if the eagle pairs we observed were cooperatively breeding. However, cooperative breeding has been observed in other raptors such as Galapagos Hawk (*Buteo galapagoensis*; Faaborg et al. 1980), Harris's Hawks (Mader 1975, Bednarz 1988, Dawson and Mannan 1991), Bald Eagles on the Santa Catalina Island (Garcelon et al. 1995), Madagascar Fish-Eagle (*Haliaeetus vociferoides*; Tingay et al. 2002), Eurasian Hobbies (*Falco subbuteo;* Zuberogoitia et al. 2003), and Booted Eagles (Martínez et al. 2005). We were unable to intensively observe these nest sites for cooperative breeding due to time constraints (group behavior was outside the scope of the research proposal) and the inaccessibility of nests. Still cooperative breeding may be occurring as evident by the observation of three adult eagles hunting in tandem below an incubating female. Furthermore, the group of six eagles found together in 2003, 2004, and 2005 may have bred cooperatively in those years based on their strong associations around an occupied nest, our inability to find surrounding nests for two of the three pairs, and territorial defense toward our plane but not each other (occurred at multiple sites). This group territoriality (Brown 1969) was documented in cooperatively breeding Harris's Hawks (Dawson and Mannan 1991), further supporting this possible explanation.

The data were not acquired from a systematic survey designed to capture cooperative behavior, therefore we cannot make conjectures about spatial or temporal variations in the behavior. We can only confirm that it occurs in this population over multiple years in multiple territories.

Cooperative behavior has been a curiosity to evolutionary biologists for many years. For all the mechanisms mentioned above, cooperative hunting is more likely to be advantageous if neighboring nesting pairs are genetically related to some extent (Hamilton 1964). Our telemetry data illustrate strong natal nest site fidelity of post fledging young. They return to the natal nest territory following their first winter migration and return to that site in multiple years A. Coyle (unpubl. data). Therefore, it is possible they would select an available nesting territory adjacent to their natal territory preferring familiar habitat and so nest close to a relative (either a parent or sibling). In this case any cooperation with their neighbor nesting pairs would have an evolutionary advantage because they would be increasing their fitness by ensuring the survival of their relatives' offspring. If this propensity to nest close to the natal nest site exists it would not be surprising that some cooperative hunting would occur in golden eagles.

Golden Eagles in North Dakota use cooperative hunting at some locations in some years. It is unclear exactly why they use such foraging tactics but further behavioral studies focused on foraging, hunting, and genetic testing of cooperative individuals within groups to assess levels of relatedness would provide insight into what drives this behavior in nesting golden eagles of North Dakota. Furthermore, management of this protected bird will need to take this behavior into account. Management plans will need to consider the impact of management decisions on territory location and size and the ability of birds to breed and hunt cooperatively.

Energy development dramatically increased after 2007. Oil pads were placed on the south facing slope of the ridge where the groups of six birds were observed. It is not conclusive however probable that this disturbance may have caused the birds to leave the area. More research is needed to determine the impact energy development is having on nesting Golden Eagles in North Dakota

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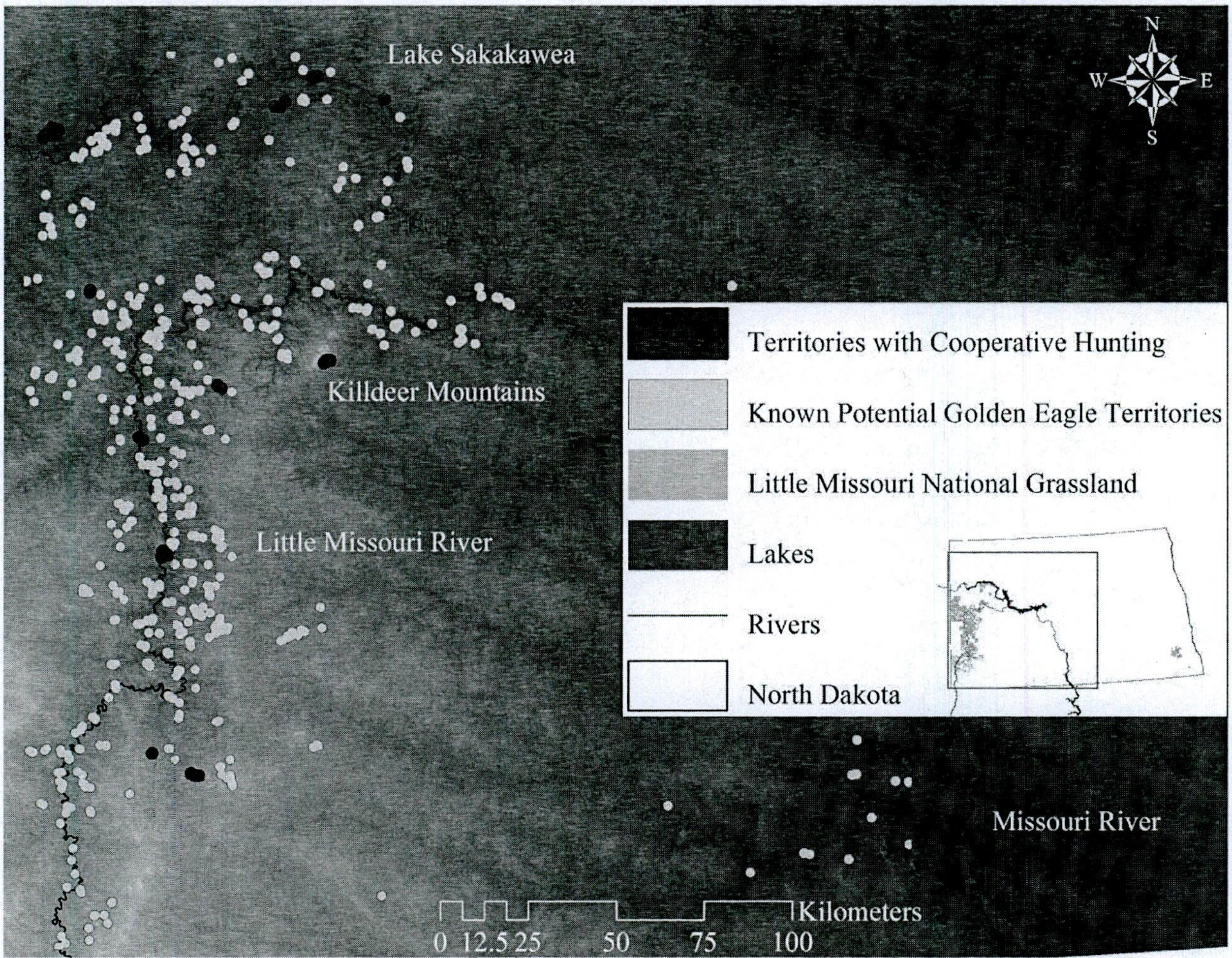
Figure 1. Study Area. The legend map illustrates the range for nesting Golden Eagles in North Dakota. Our research was conducted throughout their range in the western Great Plains (Bluemle 2000) portion of western North Dakota and we focused our efforts in and around the Little Missouri National Grassland. The grey scale map was created from the US Geological Survey National Elevation Data and illustrates the elevation or topography. The darker color represents lower elevations or depressions in the topography such as the body of water in the top of the map; Lake Sakakawea, and the lighter areas represent higher relief such as buttes; Killdeer Mountains. The known potential territories (lighter dots) are areas with known current or historical nest sites as determined by Coyle (2008), and the territories where we observed cooperative hunting are depicted in black.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WILDLIFE:

An unusual eagle behavior is documented, and threatened, in N.D.'s oil patch

Gayathri Vaidyanathan, E&E reporter

Published: Wednesday, March 13, 2013

Scientists studying golden eagles in North Dakota's oil fields have documented a novel cooperative hunting behavior that should be of interest to evolutionary biologists studying the benefits of altruism and cooperation in species including humans.

Golden eagles in the Killdeer Mountains Wildlife Management Area of North Dakota often grouped together near nesting sites to hunt prey, soaring about treetops wingtip to wingtip. In another case, about five adults grouped together right above the nest of an incubating female.

The behavior is unusual because the birds are usually fiercely territorial and do not tolerate rivals near their nesting sites. A nesting pair occupies a territory and safeguards it fiercely.

The new observations were made by biologist Anne Marguerite Coyle, a professor at Jamestown College who has been studying golden eagles in the state since 2002. They are as yet unpublished, and a draft was obtained by *EnergyWire*.

Opportunities to study the behavior could be lost as the state has decided to proceed with oil drilling in the Killdeer Mountains (*EnergyWire*, Jan. 28). The birds, which are protected under the Bald and Golden Eagle Protection Act, do not tolerate disturbance and usually abandon their nests and newborn birds, called fledglings, if humans come within half a mile of their territory.

Such invasions have happened in North Dakota as wellpads have sprouted in the Bakken Shale, even in state parks such as Killdeer. On federal lands, the Forest Service restricts oil drilling activities between February and July, when the birds roost. And wellpads are supposed to be built at least a half-mile away from nests, but there have been cases where the industry does not follow, Coyle said.

Whether the energy activity has caused a decline in raptor numbers is difficult to say because no one has done systematic surveys of golden eagles over multiple years. There is no base line. Less rigorous nest counts suggested that there were fewer nests in 2011 than in previous years.

In 2008, Coyle tagged 18 fledglings with tiny GPS telemetry units. At the end of the season, most of them did not survive as they were shot at by hunters, electrocuted by power lines (many of which power wellpads), killed by windstorms or poisoned by lead from bullets in carcasses.

The high rate of fatalities among fledglings makes her believe that the future of the golden eagle may be threatened in North Dakota. Mark Fuller, a research wildlife biologist for the U.S. Geological Survey, said this is possible, given the birds occupy about 60 square miles of territory.

"Being the big birds they are, the individuals use large areas. So it would be difficult to avoid doing things in any comparatively large area and not having the potential to affect the eagles," Fuller said.

Concerns about the raptors have been raised in other parts of the United States, especially with the birds often flying into wind turbines.

USGS is working out a survey method to map out the areas that are highly populated by the birds locally. These areas could be preserved from energy development, Fuller said

UNDER GOLDEN WINGS
Golden Eagle Project

THE LITTLE MISSOURI NATIONAL GRASSLANDS

ESTIMATING THE STATUS OF THE NESTING GOLDEN EAGLE POPULATION IN NORTH DAKOTA

INTRODUCTION

This report presents the findings from a 5 year study (2002-2006) of golden eagle (*Aquila chrysaetos*) nest sites in southwestern North Dakota. Historical records of golden eagle nest sites were gathered. Aerial surveys were conducted to check if historical nests were still extant and, if so, to determine nest occupancy and productivity. During the aerial surveys nest sites were double checked using aerial photographs to allow comparison of topographical features to mapped locations. In 2004 comprehensive aerial surveys to search for new nests were conducted. Any new nests found were surveyed for occupancy and added to the list of nests to be surveyed each year.

Occupied nests were surveyed to determine chick production and fledgling success. Sources of mortality for dead eagles found in ND were tabulated. Based on observations of feeding and surveys of carcasses around nests prey species for golden eagles in ND were tabulated. Finally, 17 fledglings where captured and fitted with GPS satellite and backup VHF radio transmitters.

CONCERNS/SOLUTIONS

1. Population trend has significant deviation.
    a. Not seeing as many birds during survey.
    b. Not seeing young.
    c. Although we can not reliably compare data between years we have seen a consistency in the approximate % of occupied nest sites per year ranging from 7 – 9 %. This est. is also consistent with Roger Collins est. during his surveys in the 80's.
    d. This is the first year it dropped to 3.75
    e. Potential reasons
        i. Shifted nest site use to other areas to avoid increased land activities.
        ii. Weather huge wind gust.
        iii. Fewer birds nesting (mortality, low recruitment)
        iv. Using new nests that are not on our survey (again deviates from past).
        v. Observer difference (no – good delectability of nests photos taken for confirmation)
2. Low recruitment, high post fledging mortality
    a. Electrocution
    b. Shooting (pheasant, prairie dog towns, incidental) See map below migration patterns through pheasant areas.
    c. Lead poisoning (ingestion)
    d. On foot disturbances (Flushed incubating female – chick died)
    e. West Nile
    f. Collision (vehicle)
    g. Wind Storms

   h. Other Diseases
   i. Wind turbines? Future concern in CA highest cause of mortality in juveniles.
3. Land Activities around nest sites
   a. Seismic equipment below active nest site.
   b. Oil well with in 0.5 recommended distance.
   c. Oil well activity and construction with in distance during critical nesting time
   d. Trail building with in 0.5 and during nesting
   e. On foot (Locals, visitors, researchers, and surveyors)

SOLUTIONS

1. Population trend has significant deviation.
   a. Monitoring – user friendly database with nest photo interface.
   b. Annual comprehensive new nest surveys.
   c. Model for the effects of disturbance at different scales.
2. Low recruitment, high post fledging mortality
   a. EDUCATION – Lecture and brochures
   b. Work with Energy Industry – lectures and incentives.
   c. Promote raptor friendly hunting and reporting
   d. Ban lead shot.
   e. Communication with other researchers on the land, GPS.
   f. Use GPS locations not staking surveys.
   g. REHABILITATION – Establishing a center in West River: U of Minn. In progress. Saving every bird possible is crucial.
   h. Enforcement
   i. Telemetry
3. Land Activities around nest sites
   f. Monitoring
   g. Education
   h. Enforcement
   i. Use habitat suitability model to direct land activities away from high priority areas.
   j. Cotton wood / woody draw regeneration, conservation.

NEST SURVEYS METHODS

Current Field Work Methods

Two methodologies were used to meet the fieldwork objectives; 1) nest checks (known individual nest sites were flown directly to and from) were used to verify and identify the location, type, orientation, and occupancy of nest sites and to estimate minimum population size, densities and potential territories; 2) nest surveys (a specified area was flown to search for nest site locations) were used to estimate population size, distribution, densities. Historical information was compared with results derived from nest checks surveys to investigate potential population trends.

Nest Checks

Aerial nest checks were conducted from 2002-2007 to locate known existing nest sites. Information from these nest checks was used to: 1) confirm status, occupancy, and location; 2) document new nest sites; 3) estimate distribution, territories, and nest densities; and 4) update master database. Occupancy data were monitored, updated and available upon request during the field season and throughout the year for management agencies and consultants for mitigation of disturbances around nesting golden eagles. All confirmed nest sites were used in this study's nest surveys (third method), to evaluate detectability. These methods provide improved nest check techniques for identifying nest site location, status and data collection.

Nest check technique

Every potential nest site uncovered in the historical data and located during this study (either via new nest surveys or as other nest information became available) was field checked using aerial reconnaissance. A Piper PA-18 Super Cub plane was used, as opposed to a Cessna plane, because it was capable of slower flight speed allowing more time for the observer to accurately gather and record nest information (Hickman 1972). During these "known nests checks" I identified both "historical nest sites" and "extant nest sites". Historical nest sites are those that may no longer have a nest present yet were known to have once had a nest and clearly define potential nest habitat. These areas are included to check for rebuilt nests. "Extant nest sites" are those that remain intact and have been relocated. These known nest check were conducted via aerial surveys. Each field season (2002-2007) flight plans were constructed based on the historical data. Any new nests located during the new nest surveys were also entered into the master database. Funding received by this project in 2002 and 2007 was only provided by the USFS, therefore, nest checks were limited to only nest sites identified to be on USFS management lands. In 2002 and 2003 historical data and flight plans were all paper based using paper topographic maps and data sheets, together with a hand held GPS unit to revisit nest sites and record data. From 2004 on, all historical data were incorporated into a GIS database with a computer operated moving map program that interacted in real-time with the GPS unit, allowing for increased survey efficiency. The computer displayed the 30 m resolution aerial photographs of the survey area, allowing for accurate plotting of nest site locations. *(now using 10 meter and higher)* Data were entered both in an ArcMap Shapefile and a Microsoft Excel file was open to record additional corresponding nest site data. Flights between nest locations were conducted at higher altitudes and were not used to search for new nests. In 2005, weather and technical issues precluded flying all historical nest locations for that flight season and the missed nests were flown in the following year. If nests were occupied they were revisited at least once to determine nest productivity and nest success. Throughout the nest check flights the accuracy of the nest location was determined, repositioned if necessary, and all nests relocated were photographically documented to validate nest site location and to ensure accurate records of nest site location and associated information.

Because of numerous limitations the population size and densities calculated from nest checks only represents a minimum for a particular year. Between years comparisons can not be made for many reasons. First, not all known nests sites were checked every year, the total area covered any year was not known, and all nest sites within a potential territory were not known (Krebs 1989, Bookhout 1996, Scott et al. 2002). Consequently, in addition these results can not be used to infer trends in the population.

Nest Surveys

Nest surveys were conducted to: 1) estimate population size and densities, 2) determine detection rates, and 3) identify new nest sites. The results from these surveys were updated in the master database and all new and occupied nest sites were incorporated into the nest checks, to confirm locations and monitor occupancy. The methods used will also be used to assess the improved survey techniques for estimating population size and distribution.

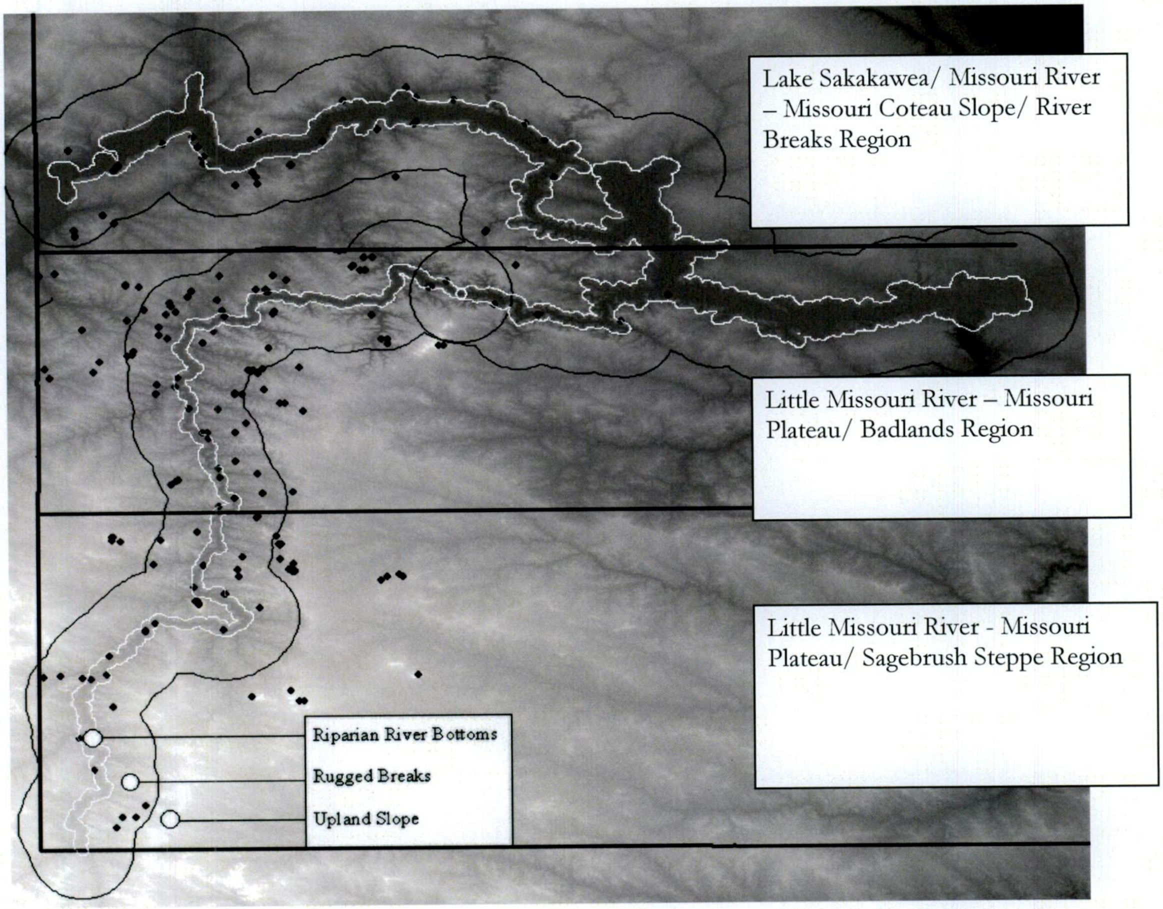


Figure 2. Geographic Regions.

This illustrates the geographic regions (3 horizontal bands) and topographic strata (different distances from the Missouri and Little Missouri Rivers). The gray scale indicates elevation with darker colors representing lower elevation.

To supplement the historical data, I conducted aerial surveys for new nest sites in 2004. New nest surveys were conducted using a block transect design. I determined that block transects are safer to fly than topographic surveys due to the regular flight path (per comm. Grier), are more efficient at searching new areas due to the compact flight path compared to linear transects, and are easier to place on the landscape relative to known nests and regional or topographic strata. Each block transect covered 50 square miles (5 mile by 10 mile block). A total of 88 non-overlapping block transects were placed across the study area with the constraint that all of the known extant nest sites, those from the historical data that were found in the field, were included in the block transects (Figure 3). The number of nest sites detected during the survey by the observer provided an assessment of nest detectability (Escano 1981, Grier et al. 1981). Transects were then placed uniformly to sample the remaining areas of their ND breeding range absent of nest locations. This ensures a sampling of all potential habitat types across the ND breeding range to gather presence and absence information for predicting occurrence and habitat preference.

The block transect was surveyed by flying the grid line from north-south (due to wind and sun conditions effecting flight safety) each grid line was flown twice (Figure 4). The observer searched out to a distance of 0.25

miles to the west on the first pass and 0.25 miles to the east on the second pass. Since the north-south flight lines were spaced 0.5 miles apart the entire area of the block was searched.

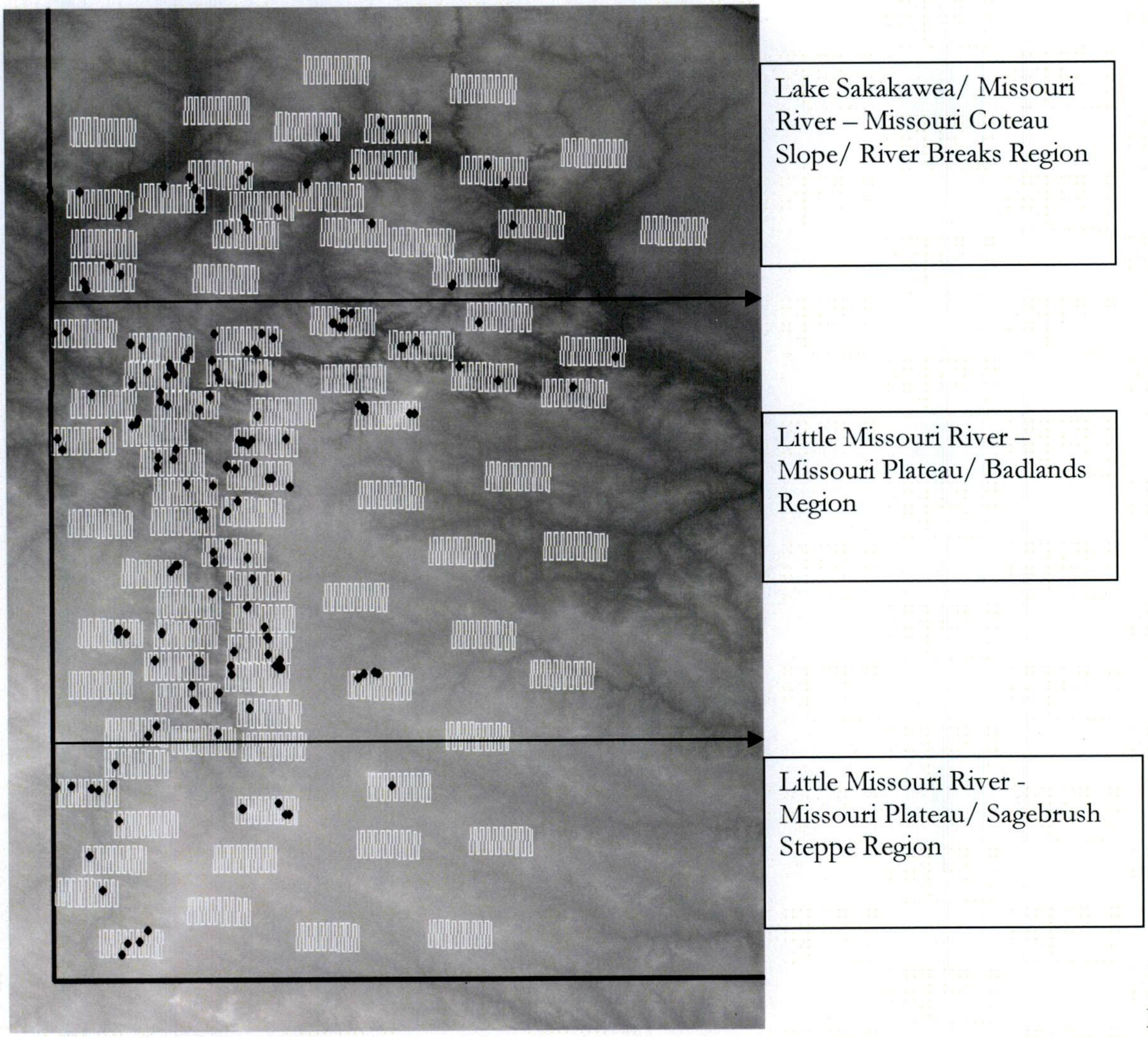


Figure 3. Distribution of Block Transects.

This illustrates the distribution of 88 block transects (white line segments) across the study area. Locations of known golden eagle nests are indicated with black dots. Topography is indicated with the grey scale background (with lower elevations indicated by darker shades). The three geographic regions are indicated by the horizontal arrows.

The pilot and observer were trained on equipment use and golden eagle nest and bird identification. One transect was used as a test to work out logistics and to familiarize the staff with the procedure. The type of plane and data gathering/recording were conducted in the same manner as for the nest checks.

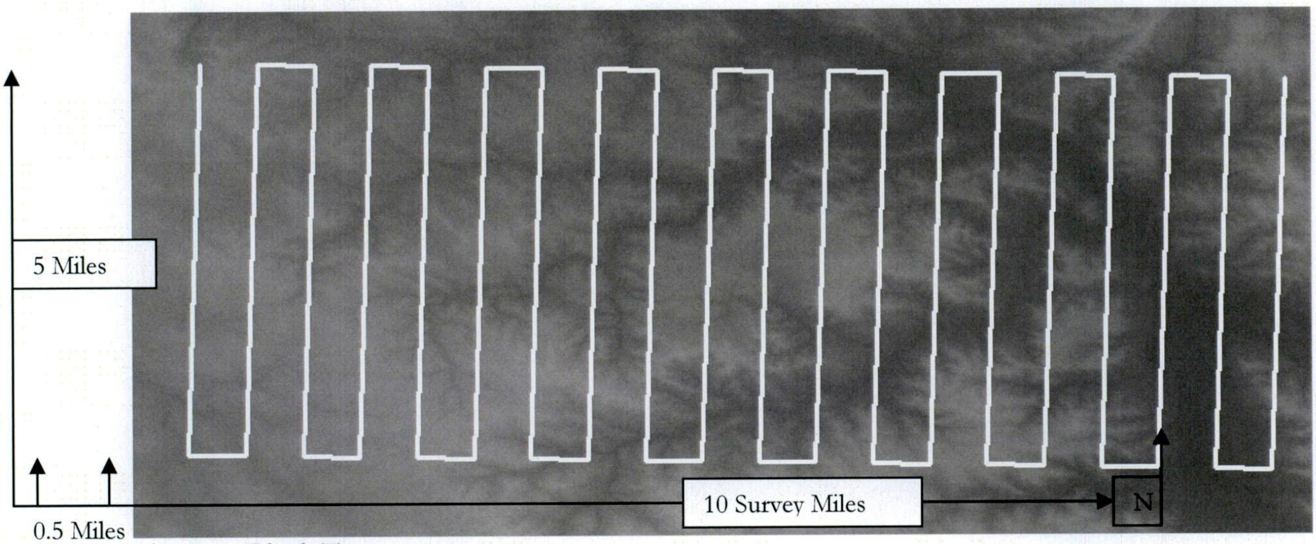


Figure 4. Block Transects.

This was designed for this project to conduct New Nest Surveys. White line shows flight path. Topography is shown in the background as gray scale.

42 Block transects were flown at a consistent height of approximately 100 - 200 feet from the ground. When a new nest was observed the pilot deviated from the transect to allow for data recording. Once the observer was ready to resume surveying the pilot continued flying the transect. Surveys were conducted from sun rise to just before sun set. Flights were grounded during high (>18-23 mph) or gusty winds and rain storms were avoided. Surveys were not conducted during times of snow cover. Transects that included treed habitat were flown before leaf-out to allow for the detection of potential tree nests. Nest site location and occupancy was collected for each nest found. The pilot did not deviate from the transect to check for occupancy, if a determination could not be made the nest received an "undetermined" status. New and occupied nest sites were added to the known nest checks for that year and further information was gathered then by a different observer and pilot.

Assessment of Detectability

Because some blocks encompassed known extant nests it was possible to estimate detection probabilities. The observer and pilot flying the new nest surveys did not have access to the location of the known nests, they had never previously participated nor surveyed nests prior to the nest survey, and they were not involved in decisions regarding the placement of the block transects. The locations of nests found were compared to locations of known nest-sites and any potential relocations were double checked using site photographs or by revisiting sites. The percentage of known nest sites relocated during the new nest survey served as an estimate of nest detectability. A detection rate was calculated and a correction factor was determined to estimating the potential number of nest sites in the survey area (Escano 1981). The corrected number of nests is calculated as: $P_n = n_f \times 1/N_d]$, where P_n = projected number of nest sites in the transects, n_f = total number of nests found, and N_d = % of known nest sites detected.

NEST SURVEYS RESULTS

Between the historical data and the new nest surveys conducted for this survey, 628 reliable nest sites (observed nest or strong documentation of a nest site) were identified. All analyses were based solely on these reliable nest records. The historical nest surveys differ considerably in methodology and accuracy. Therefore, I do not recommend using their results for comparison with or between this and other studies. However, they do offer information to assist future efforts and have provided over time a comprehensive nest location database to be used to monitor existing nest sites and mitigating for localized disturbances. Inconsistencies between data sources or within data records were discovered

The total number of documented nest sites (ranking >0) identified was 628. Of these nest sites 444 were confirmed as extant (Table 1). From these we identified 409 nest/nest complexes. An additional 133 historical nest sites with reliable information were never located during this study determined to be probably destroyed (Table 1).

Table 1. Reliability Ranking.

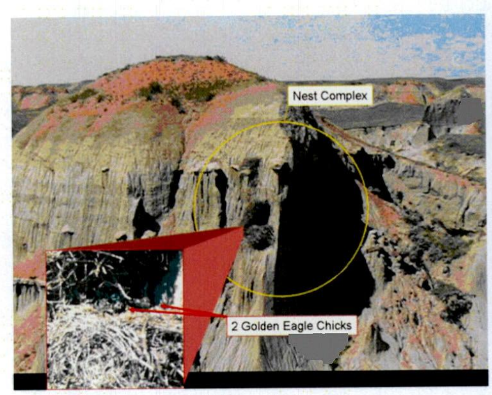
Rank	Number of Nests	Ranking Criteria
5	444	Confirmed to exist and accurately located: Extant - Multiple data records, mapped location, relocated at least once during study or photo documentation.
4	133	Undetermined: Historical – Never found during this study, many documented, consistent historical records, mapped location, probably destroyed and likely to have existed
3	2	Confirmed to exist accurately located: Extant - Plot was wrong is now correct. However, conflicts exist in historical information
2	5	Confirmed to exist accurately located: Extant -No data sheet
1	39	Confirmed to exist: Extant - Found during survey, inconsistent data, not able to confirm with photo, likely to exist close to plotted location.
1	5	Confirmed to exist accurately located: Extant - needs photo verification.
0	5	Not entered into flight plan
-1	2	Unable to relocate: Uncertain the records are accurate could not acquire information from consultant agency.
-2	56	Unable to relocate: Only general location known. Data sheets however no plot on maps exact location unknown
-3	28	Unable to relocate: Data sheet however only one or few observations; conflicts exist between records in historical data; not confirmed by photo; likely mistaken and miss plotted for adjacent known nest site

-4	5	Not a confirmed eagle nest: No photo or photos do not look reliable; possible magpie or hawk nest
-5	1	No data sheet to verify data entry

Nest Check Results: Table 2.

Table 2. Results from Nest Checks

	2002	2003	2004	2005	2006	2007	2010
# Nests Checked	197	457	520	421	641	416	400
# Nests Occupied	15	38	50	25	48	31	15
% Occupied Nests	7.61	8.32	9.61	5.94	7.49	7.45	3.75
# Occupied Territories	2	23	16	3	4	7	0
Not occupied	112	252	257	222	447	231	
Undetermined	70	167	213	174	146	154	
Minimum Estimated Population Size (pairs)	17	61	66	28	52	38	
# Nests Observed w/ Eggs	0	0	2	0	4	3	
# Nests Observed w/Incubating Adult	0	10	15	0	28	23	
# Downy Chicks Observed	2	15	15	-	39	9	
# Fledglings	19	33	44	27	39	-	
# Successful Nests	12	31	32	18	25	-	
# Fledglings/ Nest (SD)	1.26 (0.522)	1.30 (0.45)	1.00 (0.86)	1.08 (0.51)	0.81 (0.65)	-	



The range of the reliable nests extends throughout the Great Plains Region west of the Missouri River, with greatest concentrations centered on the Little Missouri River/Lake Sakakawea Badlands Regions of the western portion of North Dakota. The project clearly redefines the range of nesting golden eagles in ND, from that illustrated in (Kochert et al. 2002) and from what many had believed it to be, extending it east to the area around Flasher, ND. The mean minimum distance between nest sites was short, 1.179 km (SD = 67.33 m), and nearest neighbor distances were highly skewed toward short distances indicating a clumped distribution of nest sites. Based on nest spacing, I identified 207 potential territories (based on historical and extant nest sites) and 176 extant (nest sites found during survey) territories. The mean territory area was 8.95 km^2 (SD = 4.25 km^2, min = 3.09 km^2, max 26.65 km^2).

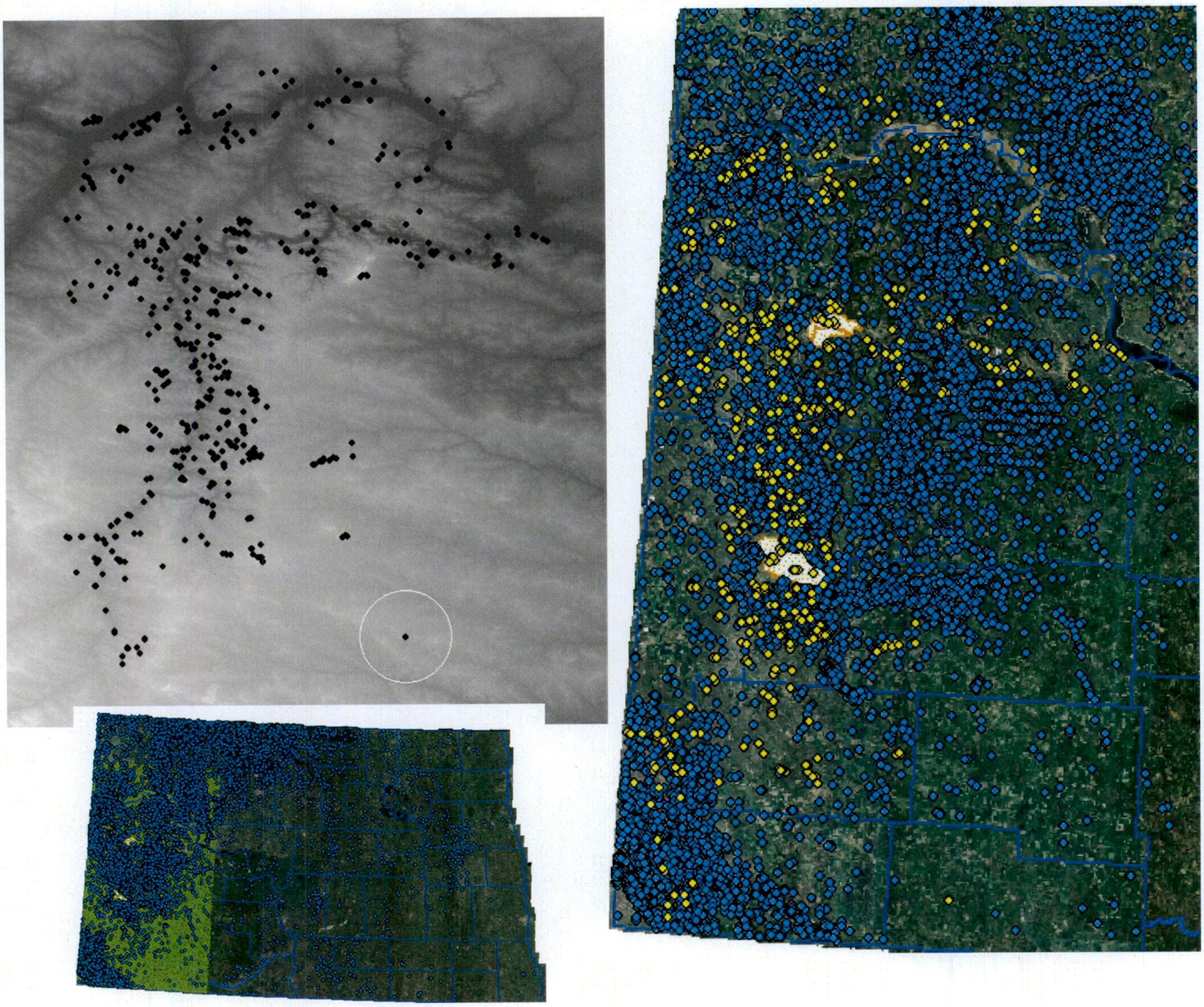


Figure 1. Breeding Range Map for ND Nesting Golden Eagles. Distribution of reliable (historical and extant) nest locations (black dots) overlaid over a digital elevation model of southwest North Dakota (darker gray indicates lower elevation). The two circled nests were occupied during this study however were determined to be outliers and eliminated from further analysis. Insert image: All oil wells in ND, the location of Theodore Roosevelt National Park and the roads with in the study area

THE LITTLE MISSOURI NATIONAL GRASSLANDS

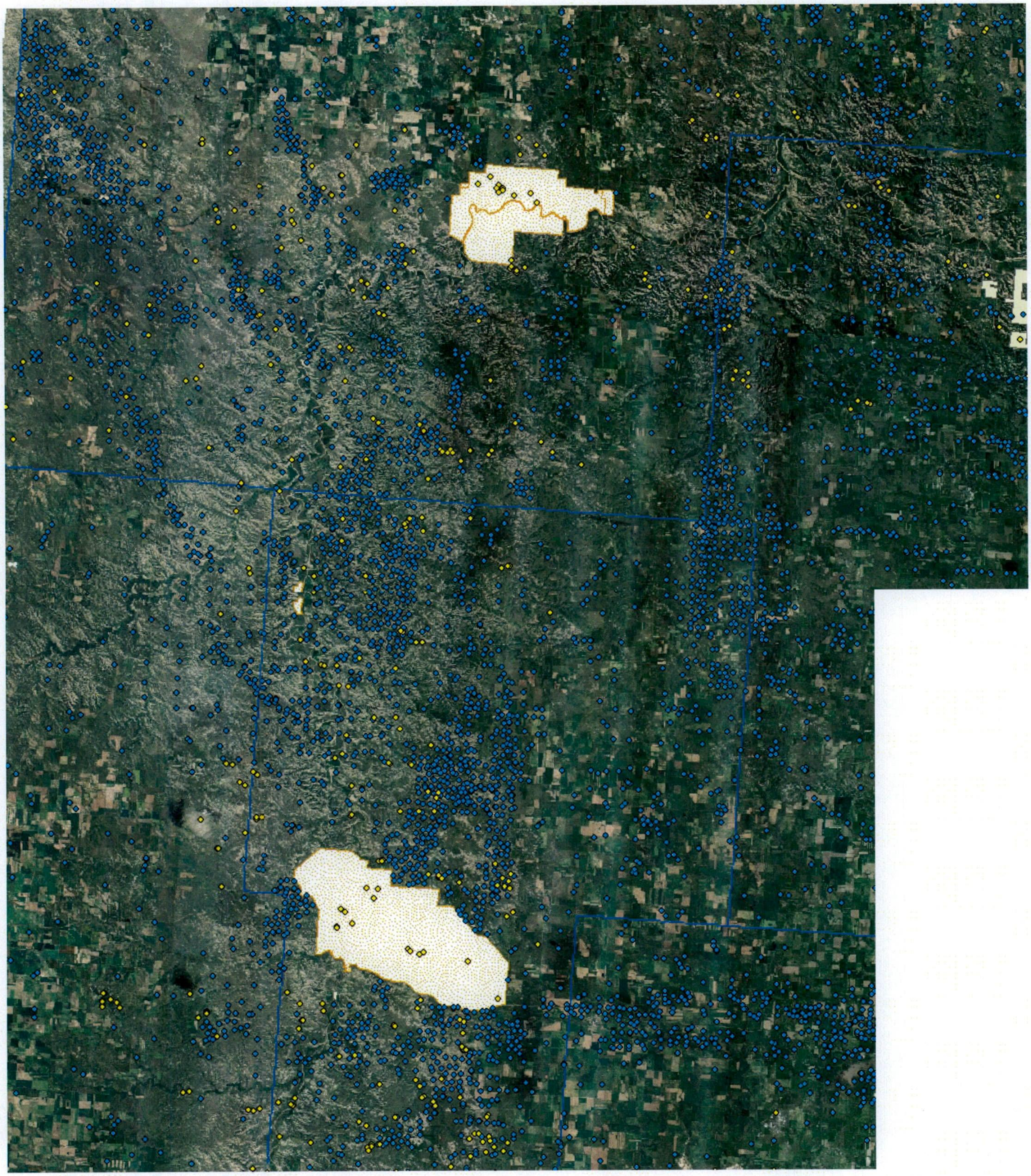
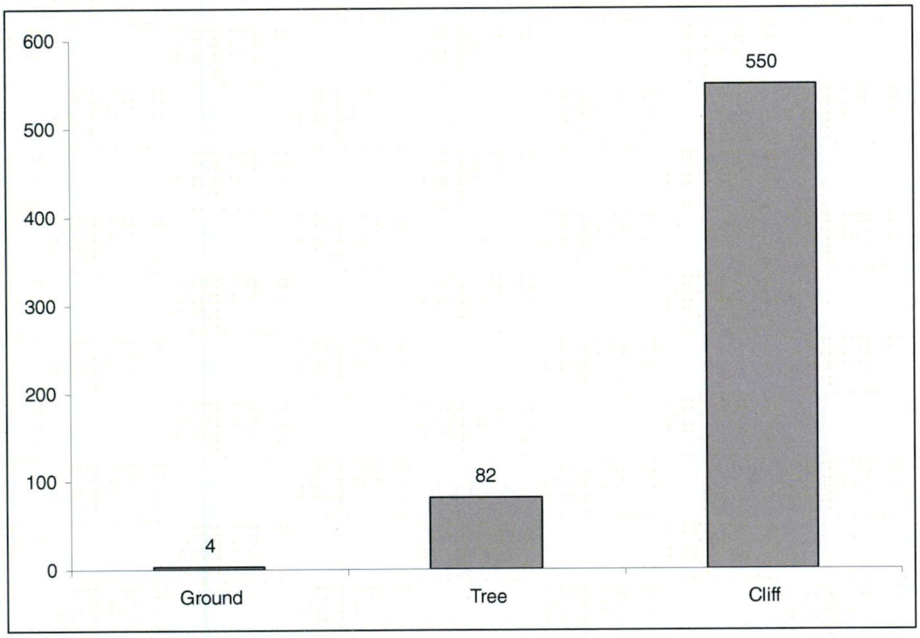


Figure 2. 176 extant (nest sites found during survey) golden eagle nesting territories (white dots). Insert image: blue dots oil wells yellow lines roads and white patches Theodore Roosevelt National Park.

Nests were found much more frequently on cliffs and tended to have a southerly (SW, S, SE) orientation. Survey effort varied across the 5 years and occupancy ranged between 10.09% and 19.87%. Due to methodological constraints on the historical nest surveys (primarily lack of detail regarding area searched and the potential effects of missed nests) year to year comparisons of occupancy rates and comparisons between this study and other studies are unreliable.



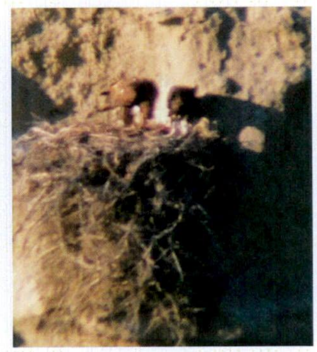
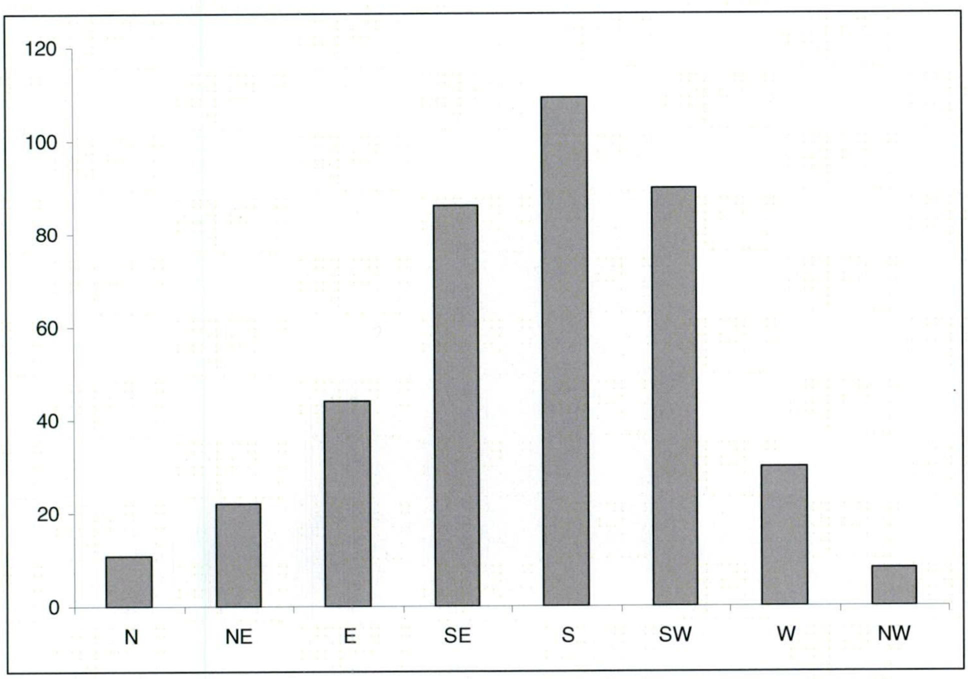


Figure 3. Nest Type.



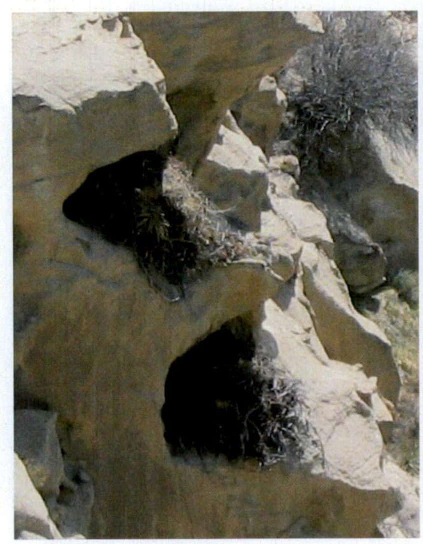


Figure 4. Illustrates the number of reliable (historical and extant) nest sites for each nest orientation. Not all nest sites had information for this determination.

Densities in 1pair /per km^2 for each geological regions and topographical strata were calculated for total nest (historical and extent), extant territory, survey nest, and survey occupancy densities. Nesting site density increases toward the rugged portions of the badlands/ bottomlands and there is a positive relationship between nesting site/occupancy density and distance to water.

A more reliable estimate of golden eagle nest density could be obtained from the comprehensive new nest surveys. Of the 225 total nests located during the new nest surveys in 2004, 106 were new nest sites, 32 nests were occupied, 110 nest were not occupied but 22 of those occurred in occupied territories, and for 83 nests occupancy could not be determined but 20 of those nests occurred in occupied territories. The new nest surveys covered a total area of 5568 km^2 and found 32 nesting pairs producing a minimum population density estimate of 1pair/174km^2. Based on missing 126 of a 245 known nest site detection was calculated to be 51.42%. Correcting for this detectability, I estimate 411 potential nest sites and 63 occupied nests in the area surveyed.

Because golden eagles are dependent on the combination of available nest site habitat and prey habitat, alterations and or reduction of landscape variables could change the distribution and availability of golden eagle habitat, and therefore, result in a potential change in the distribution or total numbers of the population of nesting golden eagles. Land activities such as agriculture, oil development and related road development have the potential of altering landscape variables that in turn influence the distribution of available nest and prey habitat. Investigating the variables that are influencing habitat selection for nesting golden eagles and the potential influence of disturbance will offer information to prioritize lands the according to suitability for eagles. The map developed from this study (Figure 6) can then be used to direct future surveys in areas identified as lands of high priority for nesting eagles and also to mitigate disturbance in these areas and to encourage and redirect activities to areas of low priority.

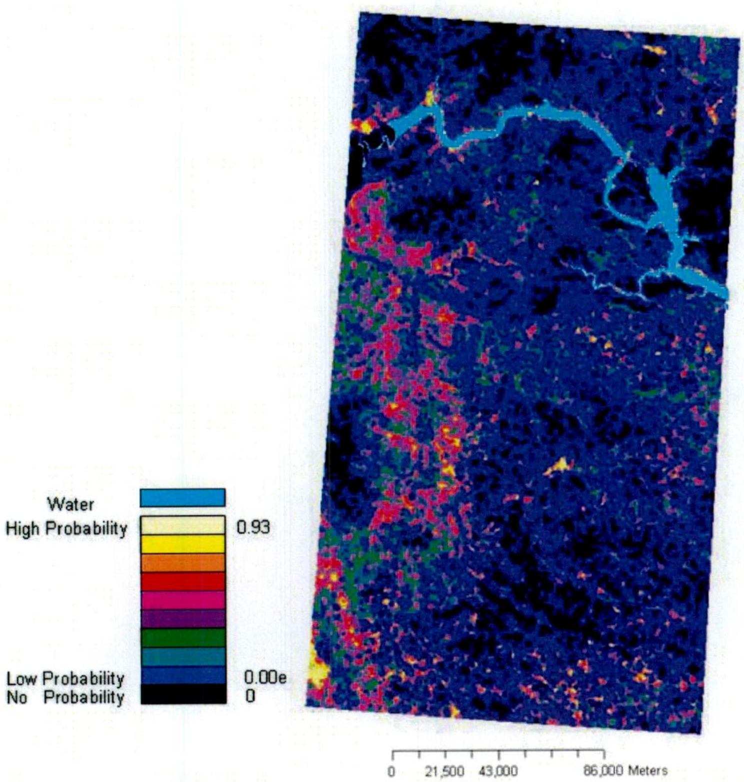


Figure 6. Habitat Suitability Map.

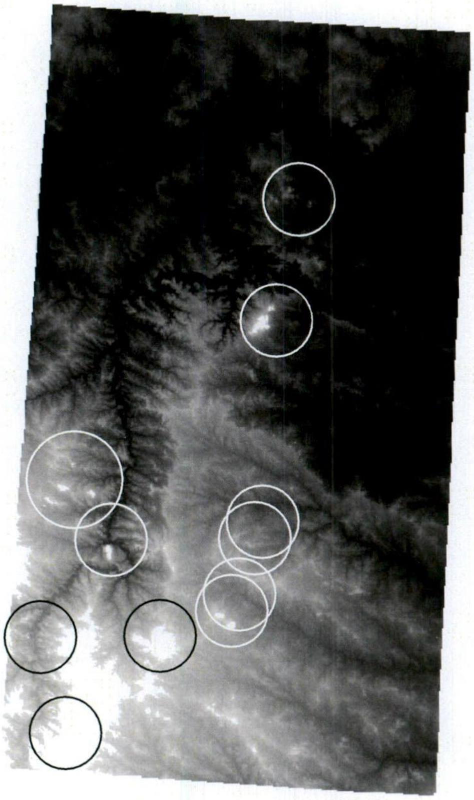


Figure 7. Distribution of Nest Sites on Major Buttes. Distribution of Topographic Relief of Study Area; a digital elevation model of southwest ND (darker gray indicates lower elevation). The brighter areas illustrate higher relief and the circles depict major buttes, all of which correspond with golden eagle nest sites locations (Figure 6).

PRODUCTIVITY, MORTALITY, DIET AND MOVEMENTS

Nest success was based only on nest sites that were found to be occupied which varied between survey years. Over the 5 years of the study, occupied nests successfully produced an average of 1.30-1.66 fledglings per nest. It was not uncommon to have breeding pairs successfully fledge 2 chicks and occasionally fledge 3 chicks. These estimates may be high due to the inability to detect nest initiation and potentially missing nest that were unsuccessful early on. It should also be noted that in most cases it was hard to confirm nest failure as it was unclear if the observer could not locate the fledged chick or if the chick had died.

Based on direct observations and examination of prey remains and pellets under occupied nests, I was able to tabulate prey species used by golden eagles. Prey species in North Dakota were consistent with previously reported prey for golden eagles. One interesting behavior that was observed, multiple times over multiple years, was group (3-4 adults) hunting, which has not previously been documented for golden eagles.

A variety of mortality causes have been documented in ND these consisted of both human and naturally caused deaths. The deaths from this project included undiagnosed disease, West Nile, electrocution, results of wind storm, exposure due to on foot disturbance flushing adults from chicks, and lead ingestion. Mortality was variable over the years. Caution does need to be taken with respect to "on foot" disturbance. Survey, researchers, and land activities should follow an aerial biological survey to ensure the ground activities will not interrupt incubation, feedings and cause additional stress to nesting birds.

Of the 17 tagged juveniles 9 lived long enough to collect movement data. Most juveniles stayed close to the natal nest site after the first flight from the nest. The fledglings moved in a gradual progression away from the nest site with successively longer flights. The entire range of all juvenile movements from the telemetry data extended from North Dakota south to the South Dakota border of Nebraska and north through Montana into the south central portion of Saskatchewan, Canada. The juveniles varied in their post fledging movements, some migrated to South Dakota, some migrated to the southern portions of North Dakota and some maintained residency near their natal area. One juvenile was a resident the first year then migrated the second year. All that had a distinct movement or migrated beginning in late fall.

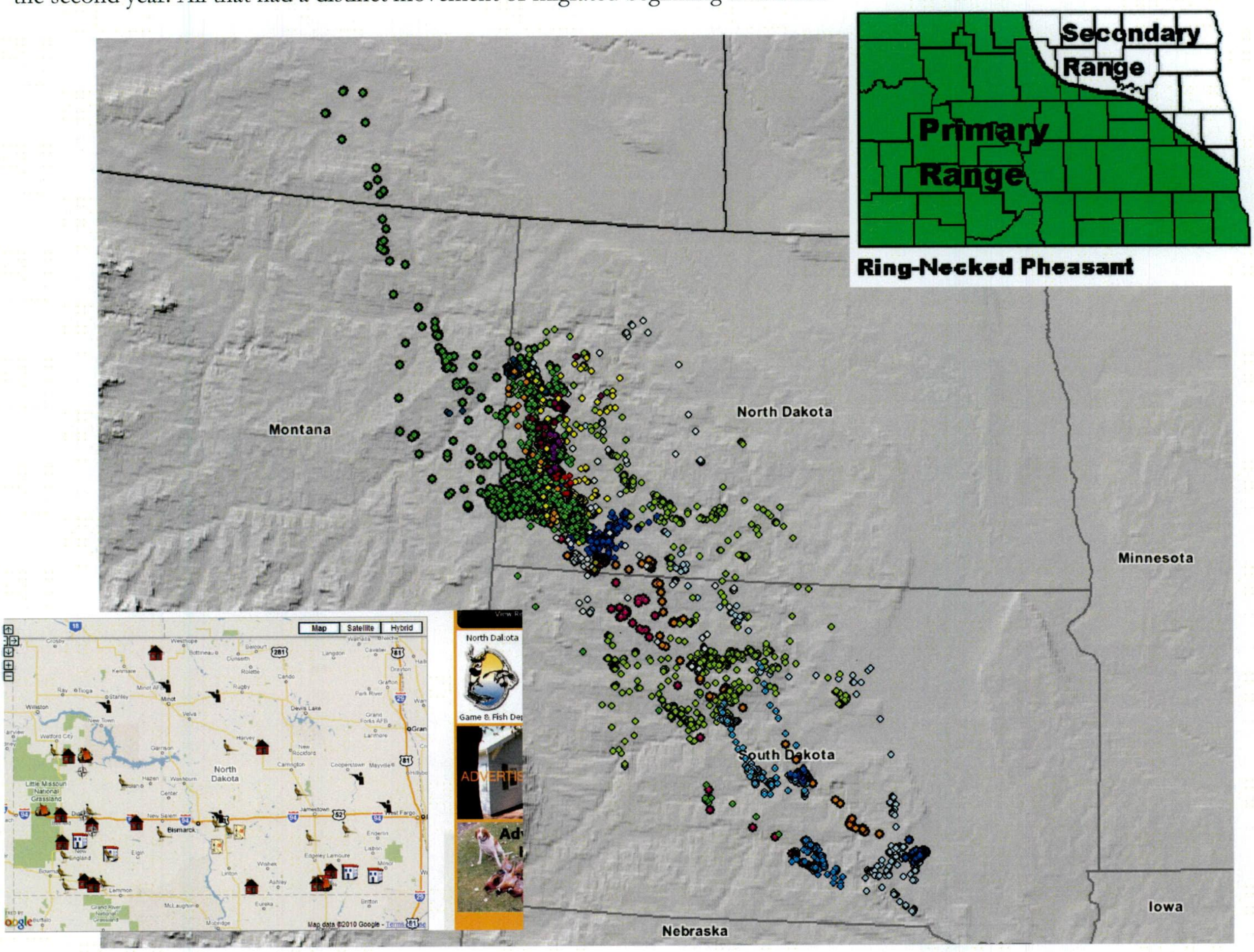


Figure 8. Range of all post fledgling movements. Different colored dots represent different birds
Left Insert image: http://www.ndpheasants.com/Directory.asp Right Insert Image ND Game and Fish Web site : http://gf.nd.gov/images/maps/pheasmap.gif

Sincerely,

A. MARGUERITE COYLE

Anne Marguerite Coyle PhD
Assistant Professor of Biology
Dickinson State University
Principal investigator of the Golden Eagle Project
Murphy Hall 140
Home / Office (701)483-2115
Cell (701)260-3753

North Dakota Golden Eagle Project

FINAL REPORT

Prepared by:

Anne Marguerite Coyle, PhD

Jamestown College, Jamestown ND

For:

US Fish and Wildlife Service and the US Forest Service

October 30, 2011

TABLE OF CONTENTS

INTRODUCTION

This document reports the results from a cooperative effort between the US Forest Service and the US Fish and Wildlife Service. Each agency provided funding for a portion of the project. The project consisted of a 3 year study (2009-2011) funded by the US Forest Service and a 3 year study (2010-2013) funded by the US Fish and Wildlife Service of nesting golden eagle (*Aquila chrysaetos*) in western North Dakota. The goal of the project was to continue the efforts of the North Dakota golden eagle project conducted from 2002 to 2007. The methods and results from the 2002-2007 study can be found in previous reports and Phd dissertation issued to the respective agencies as sited in this document (Coyle 2008). Data or methods from the 2002-2007 studies will be reported only when needed. The objectives, results, and deliverables for this study are outlined for each respective agency. Funding and effort were allocated appropriately for each grant. The funds for the USFWS were not limited to a geopolitical boundary with in North Dakota. However, the USFS funds and equipment were only used for research conducted on USFS managed lands. Because of the cooperative nature of the study and overlapping research goals I summarized all findings in this single report. This report will provide the agencies all information from this study necessary to make the best management decisions for the conservation of the golden eagle.

The project was terminated on August 16th, 2011. Consequently, the objectives were not completed. In addition weather limited the project's abilities to achieve all objectives for the 2011 field season. The details are provided in the methods section. A data disc accompanies this report and contains current data files from the study (2002- present) along with instructional documents.

Objectives for the US Forest Service

The purpose of this study (as stated in the cost-share agreement) was to cooperatively monitor golden eagle nests on the Little Missouri National Grasslands. The objectives of this study were to 1) continue to update the North Dakota Golden Eagle Master Database, correct discrepancies, and correlate nest site and habitat photographs with the ESRI shape file for all known nest site locations, 2) confirm known nest site locations, determine new nest site locations, nest status, occupancy, productivity, population estimate, and distribution of nesting golden eagles in the Little Missouri National Grasslands of North Dakota, and 3) purchase and download the backlogged and current telemetry data for the remaining tagged juvenile golden eagles.

Objectives for the US Fish and Wildlife Service

The purpose of the study (as stated in the cost-share agreement) was to conduct surveys for occupied golden eagle nests in western North Dakota, as well as data on the productivity of occupied nests, to compare with productivity data from 2004. The survey data was gathered with the intent to update current information on the geographical extent, specific locations, and numbers of occupied golden eagle nest in the state, and to provide trend information on nest productivity. The objectives of this study for the first year were to 1) continue to update the North Dakota golden eagle master database to correct discrepancies and correlate nest site and habitat photographs with the ESRI shape file for all known nest site locations. Objectives for year two were to confirm known nest site locations, determine new nest site locations, nest status, occupancy, productivity, population estimate, and distribution of nesting golden eagles in North Dakota.

For both sets of objectives I used three methods to obtain the necessary nest site information: 1) collating historical nest site information; 2) conducting "known nest surveys" (visiting known nest sites to determine nest status and occupancy), and 3) conducting new nest surveys (conducting comprehensive aerial surveys to search for new nests).

Study area

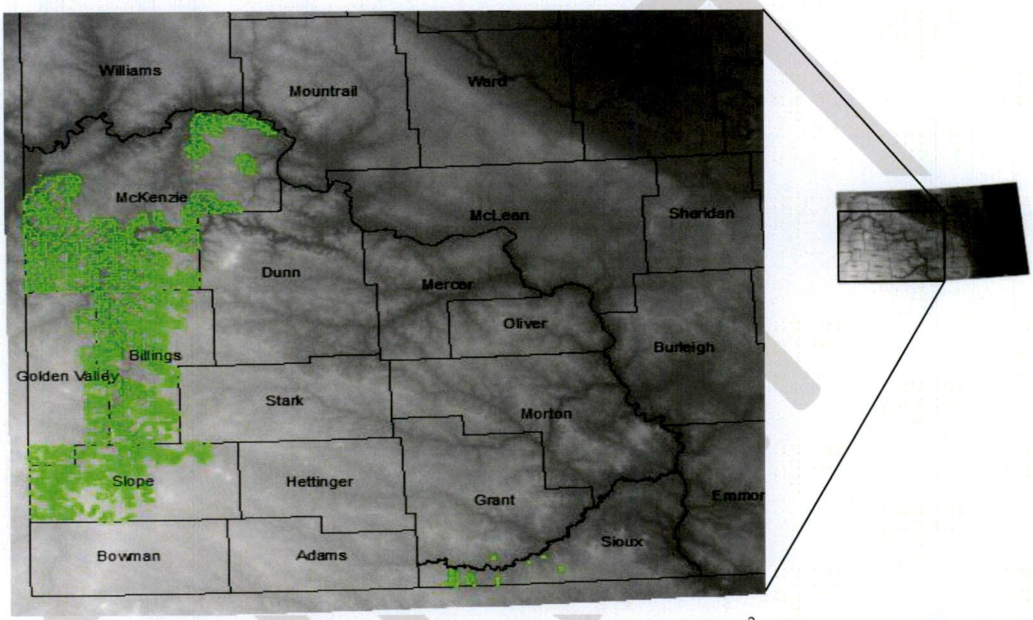


Figure 1. Study Area. The study area encompasses approximately 65,363km^2 of area west and just north of the Missouri River concentrating in and around the Little Missouri National Grasslands. The box located in the western portion of the ND outlined map depicts the location of this gray scale map. The gray scale relief map illustrates the elevation or topography of western North Dakota. The darker shade represents lower elevations or depressions in the topography such as the body of water in the top of the map; Lake Sakakawea, and the lighter areas represent higher relief such as buttes; Killdeer Mountains. The green outlined areas represent the US Forest Service managed National Grasslands.

First, the Coteau Slope is defined by rolling to hilly plains east of the Missouri River that have both erosional and glacial landforms, and encompasses Lake Sakakawea which floods the bottoms lands and dominates the northern portion of the Great Plains. The dominant grasslands vegetation of the Coteau Slope found on collapsed glacial outwash is needleandthread, plains muhly, prairie muhly, prairie junegrass, blue grama with saltgrass in alkaline areas. Other grasslands of the Coteau Slope include western wheatgrass, prairie junegrass, green needlegrass, bluestem, with prairie cordgrass, northern reedgrass found near wetlands.

Second, the Little Missouri Badlands encompasses the deeply eroded, rugged, hilly region surrounding the Little Missouri River extending from the confluence of the Missouri River to South Dakota. These regions are dominated by shortgrass prairie: western wheatgrass, blue grama, little bluestem, prairie sandreed. Rocky Mountain juniper can be found in the draws and on north facing slopes and scattered cottonwoods are located in riparian areas.

Third and fourth, the uplands consist of rolling to hilly plains are dominated by blue grama, wheatgrass/needlegrass association, little bluestem, prairie sandreed . These uplands surround the badlands and prominent buttes. The region extending to the west and north is called the McKenzie Upland and to the east is called the Missouri Slope Upland.

Finally, in very southwestern corner of North Dakota the vegetation that dominates this Sagebrush Steppe flatland is dwarf sagebrush, big sagebrush, with western wheatgrass, green needlegass, blue grama, Sandberg bluegrass, and buffalograss. (Bloomle, http://www.nd.gov/ndgs/) (Bryce et al. 1998).

METHODS

North Dakota golden eagle master database

Between 2002 and 2006 I compiled all historical data available to develop a list of all known nesting sites in North Dakota. Records, data sets, and observations extending back to the 1960's were gathered from multiple organizations including state and federal agencies (Coyle 2008). A ranking system was established based on the source, type, and quality of data, and information obtained in my own surveys (Coyle 2008). During this study nest information was updated and when possible determinations of accurate nest site locations were made, data errors were corrected and records were ranked according to reliability. This database serves as the North Dakota nesting golden eagle master database.

During the 2002-2006 study aerial surveys were conducted to check the status, occupancy, and productivity of all known nest sites in the database. During the aerial surveys nest sites were photographed. Unique topographic features were identified using nest site photos together with aerial photography (Digital Orthoquads) to precisely map new nest sites or correct the mapped location for known nest sites. During the study to increase the efficiency and accuracy of data entry a user friendly drop down menu program was developed and tested. Photographic documentation of the nest site each year provided accurate annual information on nest site status for comparison over time. This effort was continued in 2007 and 2010-2011.

The entire master North Dakota golden eagle package is located on the accompanying data disc and includes: The survey program, the master excel GEdatabase, the master ESRI GEshapefile for nest site location and the adjoining GEnest site and GEhabitat photos (jpgs), all nest site and hapitat photos by year, the telemetry data, and instruction documents.

Nest checks 2002-2011

Every potential nest site uncovered in the historical data and located during this study (either via new nest surveys or as other nest information became available) was field checked using aerial reconnaissance. A Piper PA-18 Super Cub plane was used, as opposed to a Cessna plane, because it was capable of slower flight speed allowing more time for the observer to accurately gather and record nest information (Hickman 1972). During these known nests checks I identified both historical nest sites and extant nest sites. Historical nest sites are those that may no longer have a nest present yet were known to have once had a nest and clearly define potential nest habitat. These areas were included to check for rebuilt nests. Extant nest sites are those that remain intact and have been relocated. These known nest check were conducted via aerial surveys. Each field season (2002-2007) flight plans were constructed based on the historical data. Aerial surveys determined nest location and nest variables nest condition, nest occupancy, presence of greenery, presence of white wash, number of adults, number of incubating adults, number of eggs, number of chicks, and number of fledglings. Any new nests located during the new nest surveys were also entered into the master database

Data entry program 2011

The project developed and tested a user friendly data entry program to increase the efficiency and accuracy of data entry for surveys. The pull down menu interfaced with Arc Map computer system (Coyle 2008) and restricts the user to standardized options for each data category. For example, the data field "general nest type" has three options; cliff, tree, or ground. For the data field "specific nest type" for "tree" the options are Ash, Cottonwood, or Pine. Each point for nest site location in the shapefile has a link to the nest site and habitat photo. During the flight the surveyor is able to click on the point to access each photo. This enables the surveyor to confirm nest site location prior to recording data and ensure accurate information is obtained for each nest site location.

Nest surveys

Nest surveys 2004

Nest surveys were conducted to: 1) estimate population size and densities, 2) determine detection rates, and 3) identify new nest sites. The results from these surveys were updated in the master database and all new and occupied nest sites were incorporated into the nest checks, to confirm locations and monitor occupancy.

In 2004, comprehensive aerial surveys for new nest sites were conducted, to supplement the historical data. New nest surveys were conducted using a block transect design. I determined that block transects are safer to fly than topographic surveys due to the regular flight path (per comm. Grier), are more efficient at searching new areas due to the compact flight path compared to linear transects, and are easier to place on the landscape relative to known nests and regional or topographic strata. Each block transect covered 50 square miles (5 mile by 10 mile block). The block was flown in a zigzag pattern (Figure 2).

A total of 88 non-overlapping block transects were placed across the study area with the constraint that all of the known extant nest sites, those from the historical data that were found in the field, were included in the block transects (Figure 3). The number of nest sites detected during the survey by the observer provided an assessment of nest detectability (Escano 1981, Grier et al. 1981). Transects were then placed uniformly to sample the remaining areas of their ND breeding range absent of nest locations. This ensures a sampling of all potential habitat types across the ND breeding range to gather presence and absence information for predicting occurrence and habitat preference.

The block transect was surveyed by flying the grid line from north-south (due to wind and sun conditions effecting flight safety) each grid line was flown twice (Figure 2). The observer searched out to a distance of 0.25 miles to the west on the first pass and 0.25 miles to the east on the second pass. Since the north-south flight lines were spaced 0.5 miles apart the entire area of the block was searched.

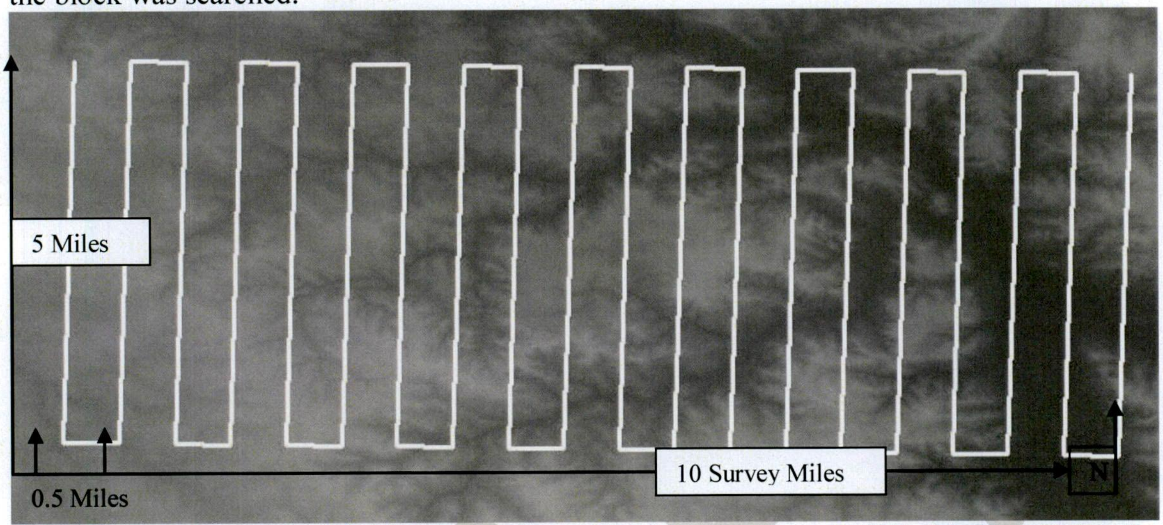


Figure 2. Block transects, designed for this project to conduct New Nest Surveys. White line shows flight path. Topography is shown in the background as gray scale.

Forty-four of the 88 possible block transects were flown in 2004 (Figure 3). Status and occupancy data were recorded for each new nest. Block transects were flown at a consistent height of approximately 100 - 200 feet from the ground. When a new nest was observed the pilot deviated from the transect to allow for data recording. Once the observer was ready to resume surveying the pilot continued flying the transect. Surveys were conducted from sun rise to just before sun set. Flights were grounded during high (>18-23 mph) or gusty winds and rain storms were avoided. Surveys were not conducted during times of snow cover. Transects that included treed habitat were flown before leaf-out to allow for the detection of potential tree nests. Nest status, site location, and occupancy were collected for each nest found. The pilot did not deviate from the transect to check for occupancy, if a determination could not be made the nest received an undetermined status. New and occupied nest sites were added to the known nest checks for that year and further information was gathered then by a different observer and pilot.

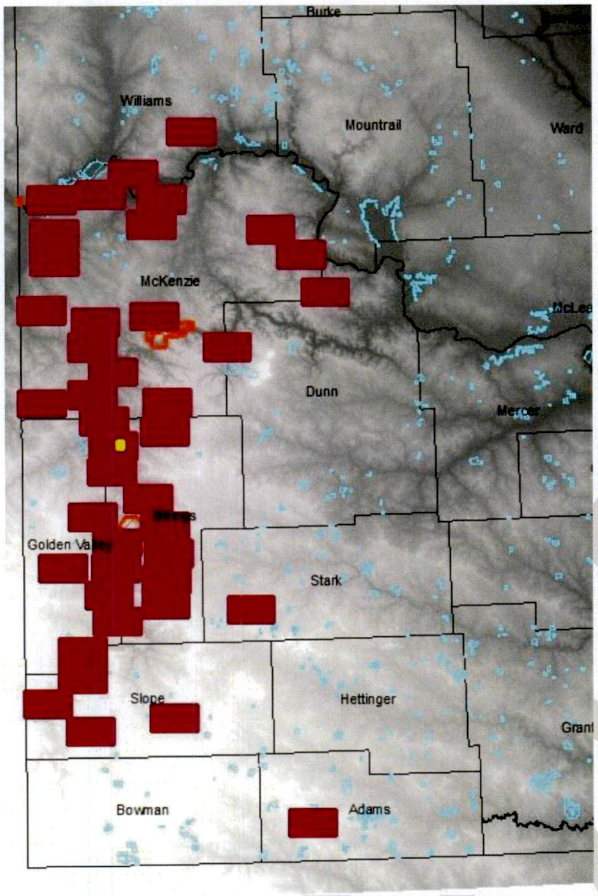


Figure 3. Illustrates the distribution of 44 completed block transects (white line segments) across the study area. Topography is indicated with the grey scale background (with lower elevations indicated by darker shades). The three geographic regions are indicated by the horizontal arrows.

Nest surveys 2011

In 2011 I attempted to repeat the 2004 comprehensive survey. Due to late snow melt, additional snow fall, numerous rain events, and other weather conditions flights were delayed or cancelled. Therefore, the objectives were not completed. To adjust for these issues I modified the survey. Areas were prioritized using information from the habitat suitability map and density results from the 2002-2007 study. The 2011 study focused on the Little Missouri River corridor, the north and south units of Theodore Roosevelt Park, and the eastern, relatively unexplored, portion of the golden eagle range (Figure 4).

To survey the Little Missouri River corridor I implemented couture transects survey. In 2005 I developed, tested, and implemented the couture transects survey technique to conduct bald eagle surveys along Missouri River in North Dakota. Using the couture transects survey the primary flood plain of the river is flown in consecutive passes at a distance of .25 miles apart. Each pass follows the contour of the river and is flown twice for searching on each side of the contour transect. Each pass covers one major section of the river. The flights are flown just above tree top or cliff top. All potential nesting habitat: trees, cliff, small knobs, and cut banks, with in the flood plain corridor are flown. This flight pattern is repeated up and or down the river creating a comprehensive survey of the entire river corridor. Tributaries and buttes extending beyond this the flood plain were omitted (Figures 4 & 5).

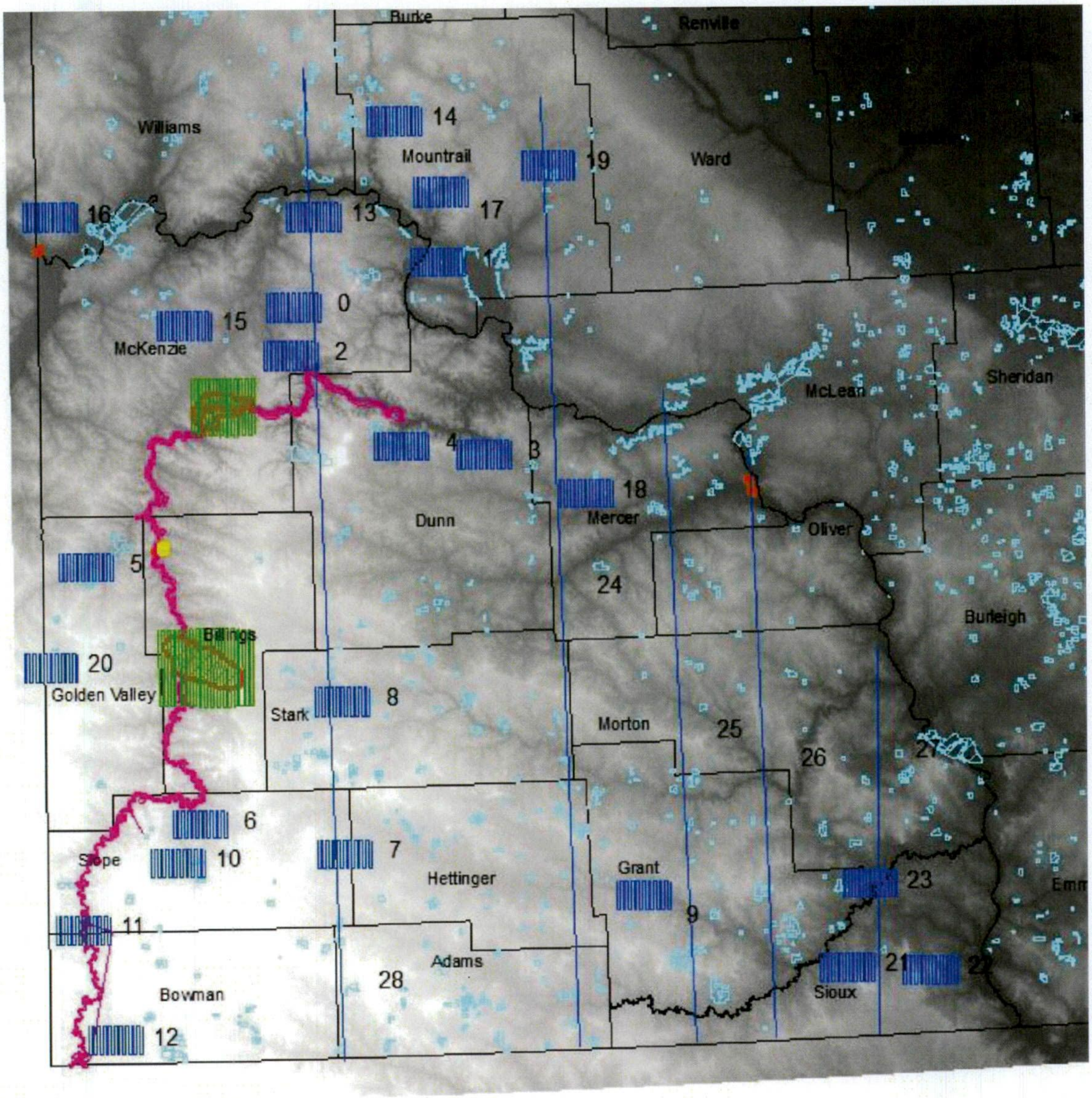


Figure 4. Illustrates the distribution of the 2011 block and line survey transects. The couture river transect (pink), all line transects (blue), the block transects (green) covering the TRNP units, and block transects (blue) numbered 22,22, & 23 were completed. Topography is indicated with the grey scale background (with lower elevations indicated by darker shades).

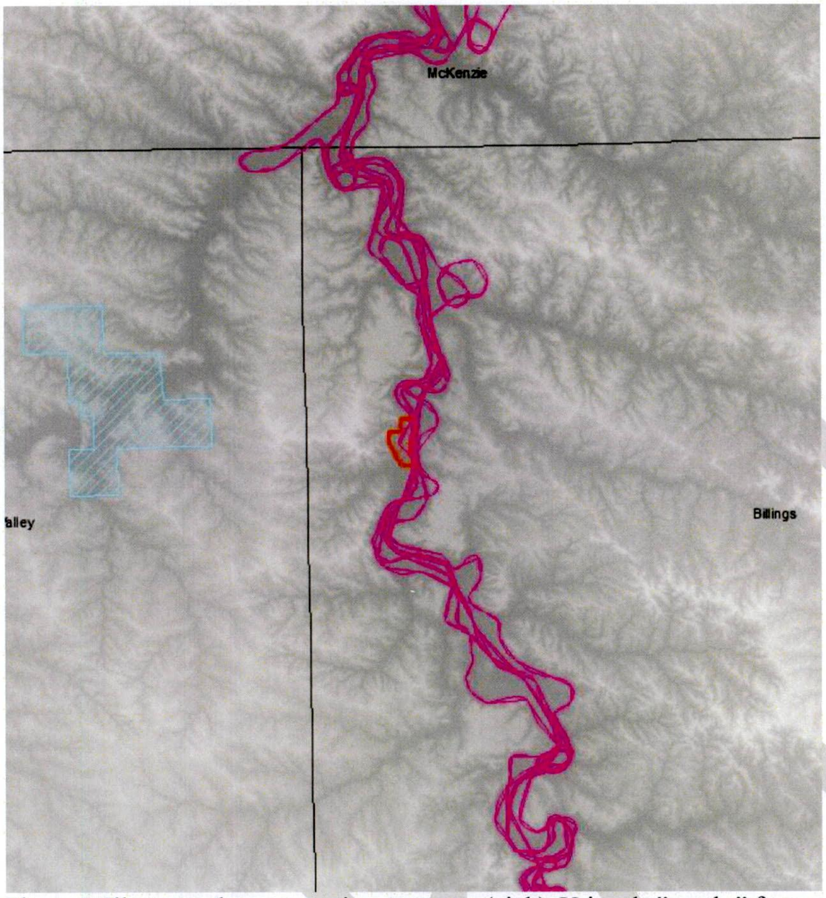


Figure 5. Illustrates the contour river transects (pink). Using the" tracks" feature on the GPS unit the precise flight pattern for the survey was recorded. The primary flood plain of the river is flown in consecutive passes at a distance of .25 miles apart. Each pass follows the contour of the river and is flown twice for searching on each side of the contour transect. Each pass covers one major section of the river. The flights are flown just above tree top. All potential nesting habitat: trees, cliff, small knobs, and cliffs, with in the flood plain corridor are flown. This flight pattern is repeated up the river creating a comprehensive survey of the entire river corridor. Tributaries and buttes extending beyond the primary flood plain were omitted. Topography is indicated with the grey scale background (with lower elevations indicated by darker shades). The light blue area is ND State land and the brown area is the TRNP Elkhorn Ranch.

Testing possible alternative survey techniques

It was suggested that I consider implementing the North American Breeding Bird Surveys (BBS) (http://www.pwrc.usgs.gov/bbs/) and/or other surveys (West, Inc. 2003) using a line transect method for estimating the population of golden eagles in North Dakota. These studies have implemented line transects surveys to estimate tends in golden eagle populations. I investigated the effectiveness of the line vs. block transects and the possibility of using the ND Breeding Bird Survey for estimating the population of golden eagles in North Dakota.

After discussing the possible methods for flights with project pilots, assessing the landscape and direction of prevailing winds, it was determined that North South line transects would be used. North south instead of east west line transects will minimize risks during flights, maximize the pilots ability to avoid obstacles such as towers and maximize visibility for identifying nest site locations.

To investigate the potential of using the NA BBS for estimating the population of golden eagles in North Dakota, I obtained the raw data for golden eagles in North Dakota from the NA BBS website, including routes surveyed, route locations, number of years each route was surveyed, number of siting's and the routes used in the summary trend analysis. The methods and results from the BBS were compared with information compiled and obtained during this 2002-2011 survey (Appendix A – separate file).

Identifying potential territories

Potential territories 2002-2006

From the mapped, known nest locations from 2002-2006 (including the new nests found in 2004), I observed the nest site distribution was clumped. I used a multiple step technique to identify clumps that may indicate potential territories. A Euclidean distance/directional analysis was then performed on all reliable nest site locations in ArcMap. This function produces a continuous contoured raster grid map, each cell containing a value for the distance and direction of every cell within a raster grid to the nearest source cell (nest site location). It calculates the distance and direction from the center of the source cells to the center of each of the surrounding cells, assigning values to each cell based on nest site location. A maximum distance can be set to define the extent of the contours of the raster created around each source cell (nest site location). The contours simply then define all potential nest sites that fall within the set distance from one another, across the study area. The final raster is an illustration of these groups of nest sites depicted as separate polygons, the shape of which is defined by the positioning of the group of nests sites within the polygon. The polygons for all potential historical and extant territories were delimited by reclassifying the raster to a binomial grid, 0 for no data and 1 for all cells within the polygon. These polygons represent the potential territories. A polygon shape file was created with a unique identifier for each potential territory and area statistics were calculated for each polygon.

Two techniques were applied; setting the contour distances, to refine the scale and validate the theoretical model developed using Euclidian distances and directions to define territory size and shape. 1) Literature Review: Information was gathered on the minimum distance between occupied nest sites to verify the scales used and distances around clumped nest sites were valid to define territory size. The Birds of North America Species Account for the golden eagle was used to obtain a national summery of potential distances (Kochert et al. 2002). The mean distance between occupied nest sites ranged from 3.1 to 8.2 km in Wyoming (Phillips et al. 1984). In North Dakota the only reported mean distance between occupied nests is 4.2 km in the area of the Missouri Breaks (Ward et al.). 2) Nest site occupancy location information from this study for all nest checks and the 2004 survey was also used. It is assumed that no two nest sites within a territory will be active in any given year. All occupied nest sites were plotted for each survey year and overlaid across the potential territories.

In 2006 the cluster analysis of a maximum Euclidian direction of 1,400m identified 207 potential territories (based on historical and extant nest sites) and 176 extant (nest sites found during checks) potential territories. The average minimum distance between nearest occupied nest sites between 2002-2006 was 6.32km, ranging between 7.20km and 3.85km. The mean territory area was 8.95 km2 (SD = 4.25 km2, min = 3.09 km2, max 26.65 km2).

Potential territories 2011
The same maximum Euclidian distance of 1,400m and cluster analysis was applied to the 2011 database.

Telemetry: Post fledgling movement and migration

Backlogged telemetry data was ordered (2007-2009), the units still transmitting signals were placed back into service (2009 – Aug, 2011) and data from the transmitting telemetry units on the remaining birds was received, purchased, downloaded, and parsed. The raw and processed data is on the data disc. For details on tagging procedures refer to Coyle, 2008.

RESULTS / DISCUSSION

Nest checks & surveys

Nest data
Between the historical data and the new nest surveys conducted for this study, 646 confirmed / 708 potential nest sites (observed nest or strong documentation of a nest site) were identified. All analyses were based solely on these reliable nest records. The historical nest surveys differ considerably in methodology and accuracy. Therefore, I do not recommend using their results for comparison with or between this and other studies. However, they do offer information to assist future efforts and have provided over time a comprehensive nest location database to be used to monitor existing nest sites and mitigating for localized disturbances. Further clarification on potential nest sites is needed.

Of the 646 confirmed / 708 potential nests identified and surveyed in 2011, 60 were new nest sites and 52 nests were occupied. Nest success could not be calculated for numerous reasons. Only two comprehensive nest checks were conducted. The length of time it took to conduct one comprehensive check of all 708 nest sites spread across 65,363km^2 coupled with the variability of nest site initiation between pairs, did not allow for an accurate determination of all potential nest sites that might have been initiated. This challenge was exacerbated by long flight delays resulting from inclement weather. However, the surveys determined minimum success of 25 fledglings produced from the 25 occupied nests, ranging from 1-2 fledglings.

Nesting golden eagle range map
The range of the reliable nests extends throughout the Great Plains Region west of the Missouri River, with greatest concentrations centered on the Little Missouri River/Lake Sakakawea Badlands Regions of the western portion of North Dakota (Figure 6). The project clearly redefines the range of nesting golden eagles in ND, from that illustrated in (Kochert et al. 2002) and from what many had believed it to be, extending it east to the area around Flasher, ND (Coyle 2008). Results from our 2002- 2007 study indicated the potential habitat for nesting golden eagles extend east to the Missouri River. As predicted additional nesting sites were found. During the 2011 surveys 13 new nest sites were identified in Grant, Morton, and Sioux counties verifying the extent of golden eagle's range and the need for further research in this area. Applying the methods used in the 2002-2007 study together with the2001 database 223 potential territories were identified.

Potential Territories 2002-2006

The cluster analysis of a maximum Euclidian direction and distance of 1400m nearest neighbor, identified 207 potential territories (based on the location of historical and extant nest sites) and 176 extant (nest sites found during2002-2006 nest checks) potential territories (Figure 7). The mean territory area was 8.95 km^2 (SD = 4.25 km^2, min = 3.09 km^2, max 26.65 km^2).

Potential Territories 2011

The cluster analysis of a maximum Euclidian direction and distance of 1400m nearest neighbor identified 223 potential territories (based on historical and extant nest sites). This illustrates the need for continuing to survey for new nest site locations. As described in detail (Coyle 2008) these sites are dynamic and eagles maintain multiple nest sites within one territory.

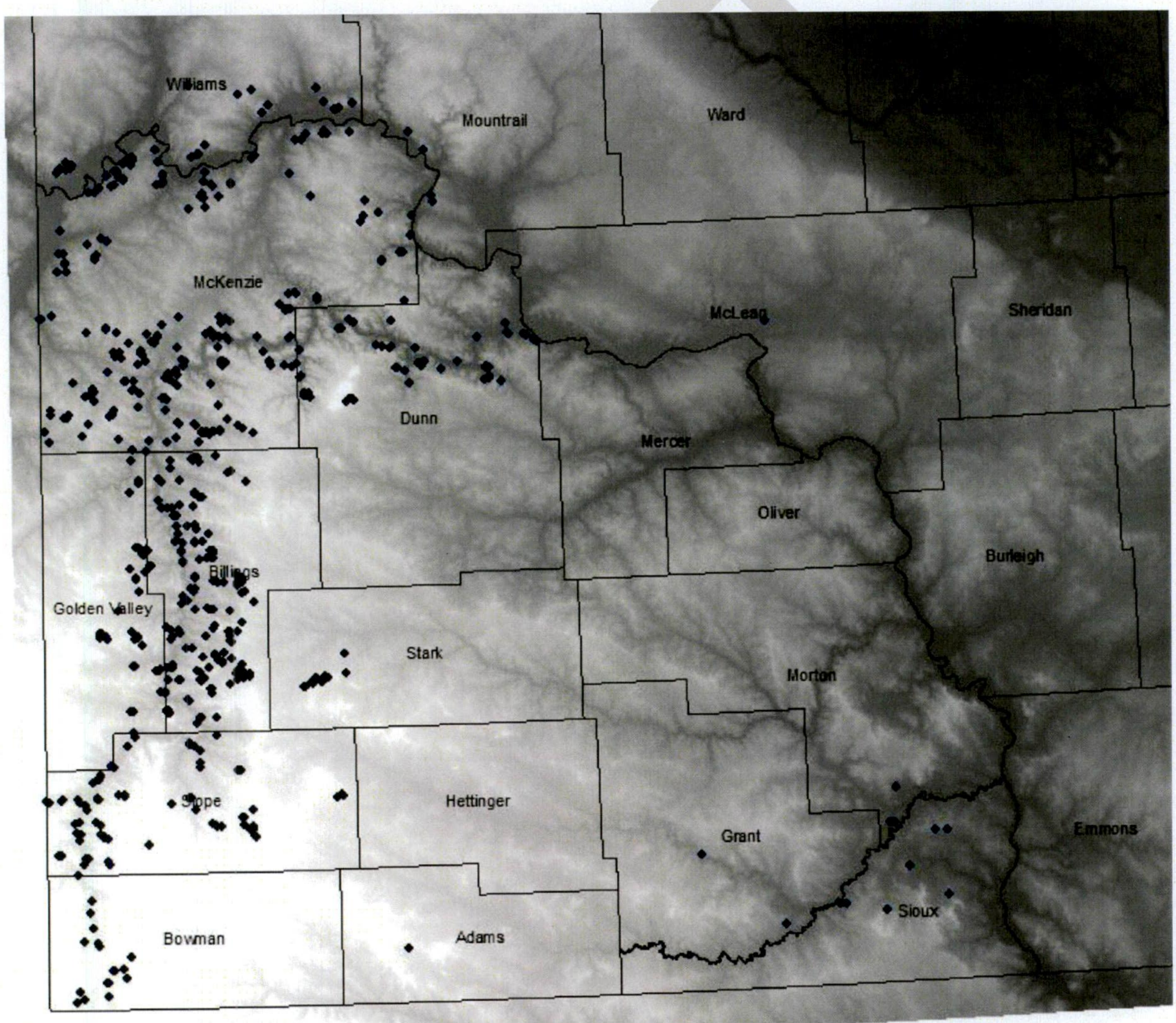


Figure 6. 2011 distribution of reliable (historical and extant) nest locations (dark-blue dots) overlaid over a digital elevation model of southwest ND (darker gray indicates lower elevation). The two circled nests were occupied during this study however were determined to be outliers and eliminated from further analysis.

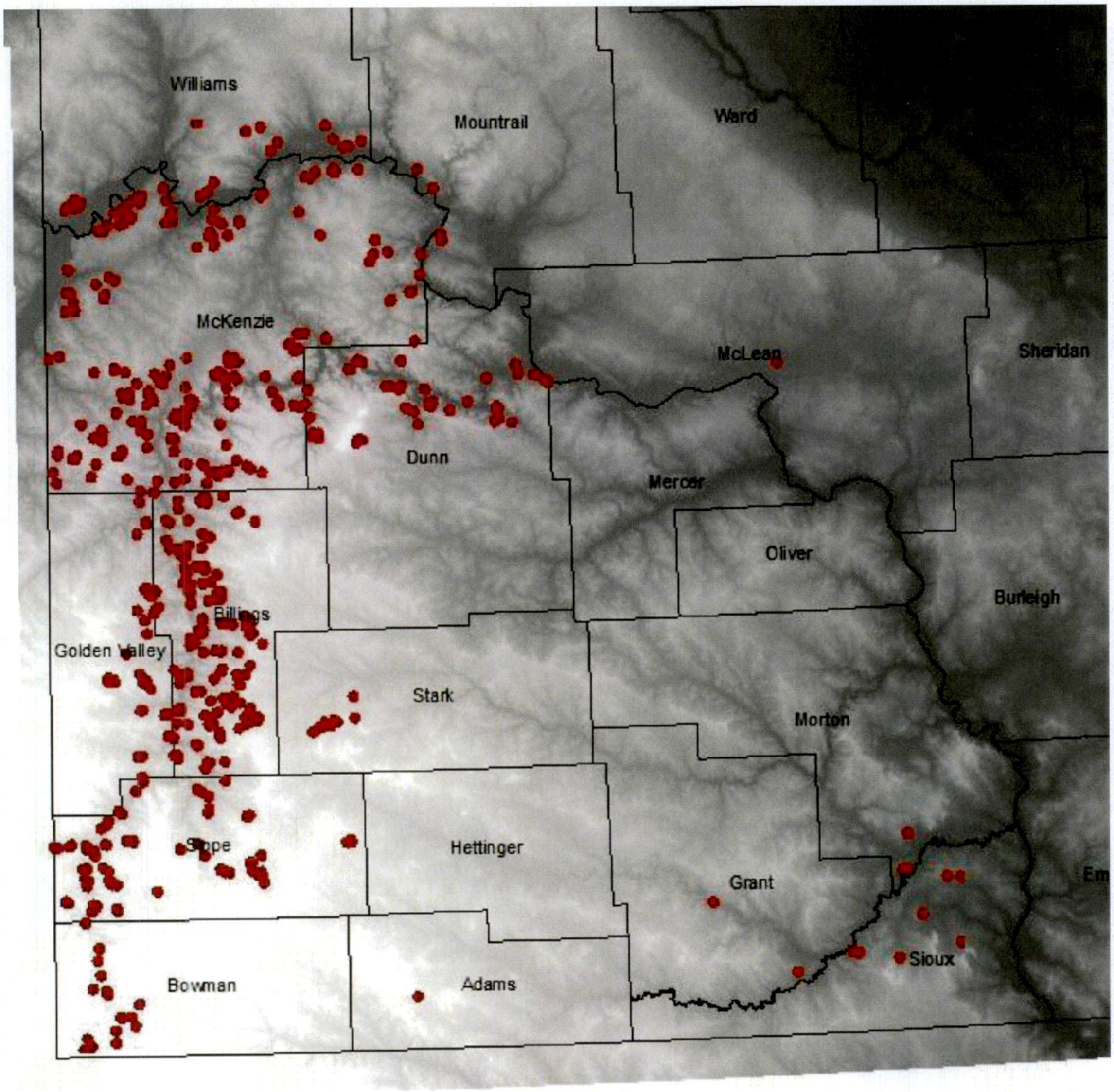


Figure 7. Illustrates the potential territories using cluster analysis of a maximum Euclidian direction and distance of 1400m nearest neighbor based on the location of historical and extant nesting golden eagle nest sites (red dots).

Recommended survey techniques

After evaluating the alternative survey techniques, linen transects and breeding bird surveys it was determined that these are not sufficient to estimate the population of breeding golden eagles in North Dakota. First, line transects can be used for estimating the distribution of territories. It is important however that they cover a sufficient area to be certain to cross multiple territories. However, alone these are not sufficient for estimating the population. They are not adequate for detecting the clumped nest sites that are located within a territory. Block transects are much more effective to obtain this objective. The breeding bird surveys are not effective in estimating the population of golden eagles in North Dakota for the following reasons. 1) they implement line transects with relatively short distances, 25 miles, that may cross only three or four territories and in some cases cover unsuitable habitat in which case the may only touch on one territory. 2) The trends are extrapolated from an extremely small sample size; a) only 18 records between 1967-2010 list siting's, b) from 9 out of a potential 15 (within the range and 4 additional on the edge) individual transects, c) with no more than two birds being located at only one stop (out of 50 potential stops) on any given transect. 3) The NA BBS uses this data to project a potential increase in the population. However, a number of the transect used did not start collection data until the 80's or later which would create a bias favoring more recent years of collection. 4) Also, historical data shows that birds were in fact nesting in the territories on or near transect lines that do not have record of birds at the time. 5) These surveys have no way to confirm that the birds are in fact nesting. Juvenile telemetry data illustrates a great deal of movement with in these territories and there birds could easily be mistaken for nesting birds. 6) The telemetry data and field observations also suggest that "recapture" or counting a bird twice along a transect is very possible. 7) Finally, studies have determined on foot and vehicle observations have low detectability. Aerial surveys are the most effective for locating nest sites and birds (Coyle 2008). These survey techniques may be effective for other species however I do not recommend using them or the data obtained from them to determine trends in the population of nesting golden eagles in North Dakota.

Therefore, I recommend an adaptive sampling technique be used (Krebs 1999). First, line transects can be randomly place across the range of nesting golden eagles ensuring that all potential habitat types are sampled with a measurable delineation. The known nest site locations and potential habitat layers can be used to prioritize survey transects. Second, when a nest site location is detected a block (quadrat) transect is placed over the nest area to survey for the distribution of nest sites with in a territory; clumped data (Norton-Grffiths 1975). This will increase the accuracy of data for estimating the population.

Telemetry: Post fledgling movement and migration

Of the 17 tagged juveniles 1 lived to the end of this study (Appendix B). The bird was tagged on July 5th 2006 at nest site GE-396b with GPS-PTT unit 49010. GPS locations from data (excluding missing data from 2007-2009) are contained in the area west of the Missouri River into eastern Montana (Figures 8 & 9). Birds use the natal and alternative nest sites frequently during and after fledging. They is a strong concentration of locations close to their natal site indicating they favor the area in their natal territories. The results illustrate the need to manage nest sites beyond the critical nesting period given that these natal and alternative nest sites are being used by juveniles beyond fledging. It is also important that alternative nest sites and all nest sites within a territory be managed carefully with respect to disturbance. The results illustrate the important role these alternative nest sites play in the fledging and dispersal of juvenile golden eagles. There is significant variability in the patterns of migration movement between and within birds. High mortality rates, 16/17 birds, indicates a need for future research to determine the viability of this population. Previous result indicate a potential significant impact from electrocution, shootings, lead poisoning, collision, and other natural and unnatural causes of mortality. It is important that management find ways to minimize mortality and protect suitable habitat to ensure a viable population of nesting golden eagles in western North Dakota.

Figure 8. Illustrates the movements of the juvenile golden eagle tagged with unit 29010 on 057-05-2006 . The unit was still transmitting at the time the project was terminated on August 14th, 2011 the bird is presumed to still be alive. The black box illustrates the area depicted in figure . The lines represent the distance between the GPS-PPT locations not the path flown by the bird; white = 2006- 2007, yellow = 2007, orange = 2009-2011. Locations plotted on Google Earth 6 (http://www.google.com/earth/index.html).

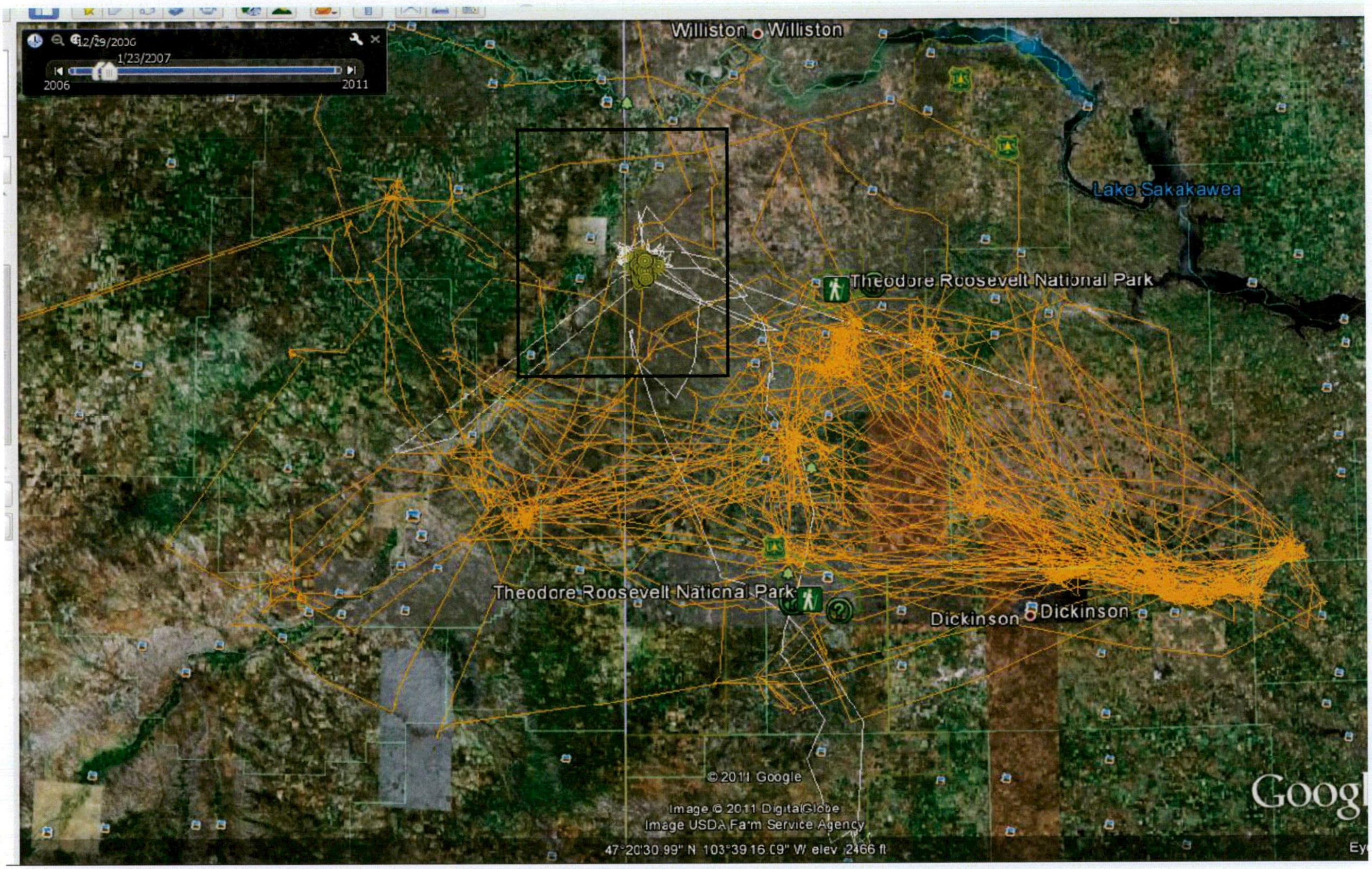


Figure 9. Illustrates the movements of the juvenile golden eagle tagged with unit 29010 on 057-05-2006 . The unit was still transmitting at the time the project was terminated on August 14th, 2011 the bird is presumed to still be alive. The lines represent the distance between GPS-PTT locations not the path flown by the bird; white = 2006- 2007, yellow = 2007, orange = 2009-2011. Locations plotted on Google Earth 6 (http://www.google.com/earth/index.html).

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Appendix B: Data sheet for eagle 49010 tagged on 07-05-2006 the only one still alive.

Date: 07/05/06	Weather Condition: SUNNY, 15 MPH WIND, LOW
Time: 13:15	Bait: N/A
Observer: KC, LL, MC	Call: N/A
Nest Number: GE-396B (SIDNEY)	Trap:
Transmitter Number: 49010	County: MACKENZIE
Species: GOLDEN EAGLE	UTM:

Anne
Madison
Susie

- [x] Transmitter Applied
- [x] Figure Test – Size should be fingered width from nap of neck.
- [x] Flip Test Should be 1"5/8 lift in the back – 1"3/4-1"7/8 lift in the front.
- [x] Feather Test No feathers should cover solar panel
- [x] Straps Test All straps should be flat against the body
- [x] Radio - Transmitter Magnet Removed – Save this in proper box
- [x] Satellite - Transmitter Magnet Removed - Save this in proper box

Estimated Age (by molt): JUVENILE (1st YEAR)

Estimated Sex (by size): MALE

Estimated Health (by Keel): YOUNG, VERY PROTRUDING, SLEEPY

Weight: 5 lbs 10 oz

Wing Span: 33 INCHES Body Length (Beak to Tail): 28 INCHES

TOP Beak Length: 40.0mm BOTTOM BEAK LENGTH: 19.7mm

Talons Length: TR1 40.9mm TL1 40.9mm TRB 46.1 mm TLB 46.3 mm

Tarsus Width: NR 12.3mm NL 12.3mm WR 12.9mm WL 12.8mm

- [x] DNA - Blood Sample 7-9 drops of blood pink vile
- [x] West Nile – Blood Sample 7-9 drops of blood green vile

Little Missouri National Grassland Golden Eagle Project

FINAL REPORT

Prepared by:

Anne Marguerite Coyle, MS

For:

North Dakota Game and Fish Department

June 2007

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EXECUTIVE SUMMARY

This report presents the findings from a 5 year study (2002-2006) of golden eagle (*Aquila chrysaetos*) nest sites in southwestern North Dakota. Historical records of golden eagle nest sites were gathered. Aerial surveys were conducted to check if historical nests were still extant and, if so, to determine nest occupancy and productivity. During the aerial surveys nest sites were double checked using aerial photographs to allow comparison of topographical features to mapped locations. In 2004 comprehensive aerial surveys to search for new nests were conducted. Any new nests found were surveyed for occupancy and added to the list of nests to be surveyed each year.

Occupied nests were surveyed to determine chick production and fledgling success. Sources of mortality for dead eagles found in ND were tabulated. Based on observations of feeding and surveys of carcasses around nests prey species for golden eagles in ND were tabulated. Finally, 17 fledglings where captured and fitted with GPS satellite and backup VHF radio transmitters.

Nest surveys

Between the historical data and the new nest surveys conducted for this survey, 628 reliable nest sites (observed nest or strong documentation of a nest site) were identified. All analyses were based solely on these reliable nest records. The historical nest surveys differ considerably in methodology and accuracy. Therefore, I do not recommend using their results for comparison with or between this and other studies. However, they do offer information to assist future efforts and have provided over time a comprehensive nest location database to be used to monitor existing nest sites and mitigating for localized disturbances.

The range of the reliable nests extends throughout the Great Plains Region west of the Missouri River, with greatest concentrations centered on the Little Missouri River/Lake Sakakawea Badlands Regions of the western portion of North Dakota. The project clearly redefines the range of nesting golden eagles in ND, from that illustrated in (Kochert et al. 2002) and from what many had believed it to be, extending it east to the area around Flasher, ND. The mean minimum distance between nest sites was short, 1.179 km (SD = 67.33 m), and nearest neighbor distances were highly skewed toward short distances indicating a clumped distribution of nest sites. Based on nest spacing, I identified 207 potential territories (based on historical and extant nest sites) and 176 extant (nest sites found during survey) territories. The mean territory area was 8.95 km^2 (SD = 4.25 km^2, min = 3.09 km^2, max 26.65 km^2).

Nests were found much more frequently on cliffs and tended to have a southerly (SW, S, SE) orientation. Survey effort varied across the 5 years and occupancy ranged between 10.09% and 19.87%. Due to methodological constraints on the historical nest surveys (primarily lack of detail regarding area searched and the potential effects of missed nests) year to year comparisons of occupancy rates and comparisons between this study and other studies are unreliable.

Densities in 1pair /per km^2 for each geological regions and topographical strata were calculated for total nest (historical and extent), extant territory, survey nest, and survey occupancy densities.

Nesting site density increases toward the rugged portions of the badlands/ bottomlands and there is a positive relationship between nesting site/occupancy density and distance to water.

A more reliable estimate of golden eagle nest density could be obtained from the comprehensive new nest surveys. Of the 225 total nests located during the new nest surveys in 2004, 106 were new nest sites, 32 nests were occupied, 110 nest were not occupied but 22 of those occurred in occupied territories, and for 83 nests occupancy could not be determined but 20 of those nests occurred in occupied territories. The new nest surveys covered a total area of 5568 km^2 and found 32 nesting pairs producing a minimum population density estimate of 1pair/174km^2. Based on missing 126 of a 245 known nest site detection was calculated to be 51.42%. Correcting for this detectability, I estimate 411 potential nest sites and 63 occupied nests in the area surveyed.

Productivity, mortality, diet and movements

Nest success was based only on nest sites that were found to be occupied which varied between survey years. Over the 5 years of the study, occupied nests successfully produced an average of 1.30-1.66 fledglings per nest. It was not uncommon to have breeding pairs successfully fledge 2 chicks and occasionally fledge 3 chicks. These estimates may be high due to the inability to detect nest initiation and potentially missing nest that were unsuccessful early on. It should also be noted that in most cases it was hard to confirm nest failure as it was unclear if the observer could not locate the fledged chick or if the chick had died.

Based on direct observations and examination of prey remains and pellets under occupied nests, I was able to tabulate prey species used by golden eagles. Prey species in North Dakota were consistent with previously reported prey for golden eagles. One interesting behavior that was observed, multiple times over multiple years, was group (3-4 adults) hunting, which has not previously been documented for golden eagles.

A variety of mortality causes have been documented in ND these consisted of both human and naturally caused deaths. The deaths from this project included undiagnosed disease, West Nile, electrocution, results of wind storm, exposure due to on foot disturbance flushing adults from chicks, and lead ingestion. Mortality was variable over the years. Caution does need to be taken with respect to "on foot" disturbance. Survey, researchers, and land activities should follow an aerial biological survey to ensure the ground activities will not interrupt incubation, feedings and cause additional stress to nesting birds.

Of the 17 tagged juveniles 9 lived long enough to collect movement data. Most juveniles stayed close to the natal nest site after the first flight from the nest. The fledglings moved in a gradual progression away from the nest site with successively longer flights. The entire range of all juvenile movements from the telemetry data extended from North Dakota south to the South Dakota border of Nebraska and north through Montana into the south central portion of Saskatchewan, Canada. The juveniles varied in their post fledging movements, some migrated to South Dakota, some migrated to the southern portions of North Dakota and some maintained residency near their natal area. One juvenile was a resident the first year then migrated the second year. All that had a distinct movement or migrated beginning in late fall.

COMPILATION OF HISTORICAL DATA AND NEW NEST SURVEYS

INTRODUCTION

Similar to bald eagles (*Haliaeetus leucocephalus*; Buehler 2002), golden eagles, *(Aquila chrysaetos*), have experienced high rates of both intentional, poisoned or shot, and accidental, trapping or electrocuted, mortality due to humans. As a result, their populations experienced a decline in the contiguous US (Kochert et al. 2002). Although the decline of the golden eagle did not warrant listing under the Endangered Species Act (7 U.S.C & 136, 16 U.S.C & 1531 et seq.) there was enough concern that they were protected under the Bald Eagle Act which then became known as the Bald and Golden Eagle Protection Act (16 U.S.C. 668a-d).

Both direct and indirect anthropogenic disturbances contribute to mortality of eagle populations and continue to be a threat today (Kochert et al. 2002). Direct disturbances remove reproductive adults or juveniles from the population thereby reducing population growth. Eagles form exclusive breeding pairs (Kochert et al. 2002) and, therefore, removal of either the male or female can affect fecundity. Golden eagles, although federally protected, are frequently shot either in response to livestock or upland game bird depredation or simply for recreation (per comm. USFWS Special Agent Grosz). In some cases eagles are hunted for the sale of body parts (feathers, talons, etc) on the black market (per comm. USFWS Special Agent Grosz). Eagles can be accidentally poisoned by consuming poisoned bait left for other species (e.g., coyotes or magpies; per comm. USFWS Special Agent Grosz). Finally, collisions with power lines and wind towers are often fatal (Hunt et al. 1995, Kochert et al. 2002).

Indirect disturbances do not cause mortality to reproductive birds yet can still cause a decrease in the population by negatively affecting reproductive output. A well documented indirect effect is the negative effects of pesticides. The metabolite of DDT, DDE, has been the most studied and publicized (Buehler 2002). There has been a nationwide ban on DDT use in the US since 1972 (Buehler 2002). Golden eagles are now making a recovery in most parts of the US. There are not many studies on the effects of ingestion of lead and other chemicals (Kochert et al. 2002) yet eagle mortalities with high levels of lead in the blood have been documented (Coyle 2005). Chronic exposure, even at lower levels, may reduce the health of eagles causing weakness and increasing the chances for injury or predation (Kochert et al. 2002), increasing susceptibility to disease and decreasing reproductive success (Buehler 2002, Kochert et al. 2002). Ingestion by young may effect development (Kochert et al. 2002). Eagles are territorial and consequently the number of pairs that can occupy an area are limited. Consequently, loss of nesting habitat can reduce the number of available territories, reducing the number of nesting pairs and in turn lowering reproduction. A number of anthropogenic disturbances, including development, mineral exploration, vehicle traffic, and recreational use, can cause nest/ territory abandonment or prevent nesting habitat from being occupied.

During the 1970s and 1980s, activities such as mineral exploration increased on the nations public lands (Escano 1981, Ward et al. 1983, Allen 1987, McCarthy et al. 1992). Much has been done to counteract the effects of these disturbances on eagle populations. For cases where activity takes place on public land, federal agencies must comply with legislative mandates such as the National Environment Policy Act (NEPA) of 1969, the Migratory Bird Conservation Act, the National Forest Management Act (NFMA) of 1976 and the Bald and Golden Eagle Act (BGEPA) of 1962. In efforts to comply with many of these acts, the US Fish and Wildlife Service (USFWS) in many states began to survey local raptor populations. The results from these studies across the nation indicate that not only chemical pollution, but also an increase in land-use disturbances such as development of mineral exploration and agriculture may be causing the decline of many raptor species (Buehler 2002, Kochert et al. 2002). As a result a number of stipulations have been placed on timber harvest and oil and mineral development to minimize disturbance to nesting eagles.

In North Dakota, raptor surveys were conducted in the late 1960s and 1970s (Escano 1981, Ward et al. 1983, Allen 1987, McCarthy et al. 1992). However, the federal agencies' first major response to the concern about a possible decline was in the early 1980s (per comm., Roger Collins, USFWS Bismarck, ND). Initially, the Bureau of Land Management (BLM) funded raptor surveys, including nesting golden eagles, as part of a wildlife resource inventory for federal coal management areas in the western portion of North Dakota. The USFWS conducted the surveys with help from the Sheridan Wildlife Research Branch of Sheridan, WY (per comm., Roger Collins, USFWS Bismarck, ND). The USFWS began efforts by conducting raptor surveys in areas of the state, regardless of land ownership, proposed for, or currently under, mineral development (per comm Roger Collins, USFWS Bismarck, ND; Ward et al. 1983). In the years following, the USFWS in Bismarck, ND, in conjunction with the US Forest Service (USFS) continued and expanded the surveys in and around the Little Missouri National Grasslands (LMNG). The surveys continued into the early 1990's and were designed and implemented only to collect site specific occupancy information in areas proposed for mineral development. These data were used by managers to advise oil development on well locations to avoid disturbance to golden eagle nest sites. The surveys were neither designed nor conducted to asses or estimate eagle population levels (per comm Roger Collins, USFWS Bismarck, ND).

All agencies, including the United States Forest Service (USFS), are required by, the National Environmental Protection Act (NEPA) of 1969, to conduct environmental impact assessments for any action conducted on the public lands they manage. Many changes and development occurred in the management of the LMNG since the 1980s. Therefore, environmental impact statements (EIS) were conducted by USFS for the LMNG in 1992 (north portion of LMNG), 1995 (south portion LMNG) and 2001 (for a new management plan) for oil exploration and development. The golden eagle is listed as a "key species" according to the USFS EIS (Curriden et al. 1995). Different stipulations have resulted for each EIS to apply the no surface occupancy (NSO) based both on distance and timing to mitigate for nesting golden eagles. These have changed over time, for example: the original Custer Forest Plan applied a ¼ mile buffer around eagle nesting sites (Curriden et al. 1995). The ½ mile, year round, NSO buffer recommendation and time period of February 1 through July 31, resulted from the Beartooth Oil and Gas Leasing EIS (EIS; Sutter and Jones 1981, Curriden et al. 1995). Management for road disturbances was not defined before 1994. However, the ¼ mile buffer was used around "active" nest sites. The 1995 EIS listed a recommendation of ½ mile buffer around "active nests" for road development (Curriden et al. 1995).

The current USFS management plan for LMNG restricts activities, including seismic activities used for oil and gas development, prescribed burning, large recreation events, construction, and reclamation activities, in areas of raptor nest sites and winter roost sites (Curriden et al. 1995, Bosworth and Cables 2001). Oil and gas structural developments can not occur within ½ mile of golden eagles nest sites and winter roosts and any noise or activity can not occur between February 1 and July 31. Many other disturbances occur on the National Grasslands, from road development, road use/traffic, off-road vehicle use, towers, other development, and tourist activities. All of these activities may have a potential effect on the success of nesting golden eagles. The USFS goal is to identify how they can most effectively manage the public grasslands under the mandate of multi-use without detrimental effects on populations of golden eagles (Curriden et al. 1995, Bosworth and Cables 2001).

In the past, up into the 1990's, the USFWS Ecological Services Office in Bismarck, ND, acted as the repository for the state's raptor information. Records were also maintained by the BLM and USFS Ranger stations for each of the agencies respective managed lands. The collective results from state surveys conducted by these agencies for nesting golden eagles from the 1980s into the early 1990s estimated that more than 300 - 350 nests existed on the lands of western North Dakota. Of these nests, surveyors suggested that approximately 25 - 30 nests were occupied in any given year (per comm Roger Collins, USFWS Bismarck, ND). However, because most of these surveys only covered a portion of the potential eagle habitat, the actual area surveyed was not recorded, and only a portion of known nest sites were visited in a given year the total number of occupied Golden eagles nests is unknown in North Dakota.

Past Surveys in North Dakota

USFS 1981 conducted by Escano

A survey conducted by Ronald E. F. Escano in 1981 was part of a coal unsuitability analysis. The study area encompassed 642,500 acres of proposed coal development, within the Little Missouri National Grasslands. The purpose of the study was to identify key habitats for raptors, including golden eagles, with in the study area. The survey used road transects and covered 418 miles in 5 days. There were 15 known golden eagles nest sites identified from the literature and discussions with field biologists. Four of the known nest sites and six new nests were located during the survey, for a total of ten golden eagle nest sites. Occupancy was not recorded. The report identifies two methods to measure effectiveness. First, the entire study area was used to estimate detection and the second using only the mile buffered road transects. Of all 15 known nest sites with in the entire study area only 4 were found; resulting in a 26.66% effectiveness rating. The second is a measurement of the survey corridor which extends a one mile buffer on either side of the survey roads. Of the nine nest sites known to exist with in the mile buffer of the road, seven were found, yielding a 78% reliability rating. It appears that the confidence of relocating nest sites from road transects would be accurate at the 26% detection rate, which they used to estimate the number of potential nest sites in the survey area. They also used the 10 identified nest sites and 3 additional potential nest sites to estimate 48 nest sites. Without occupancy information the survey can not estimate golden eagle population levels. Habitat information indicated only one tree nest with the rest as cliff nests, and a westerly nest orientation preference for 70% of known nest sites. The challenges with road transect surveys is that many nest sites are behind cliffs and buttes or located in bottom lands below line of sight of the observer. This survey was seriously compromised by limited time and visibility of potential nesting sites.

USFWS 1982 conducted by Ward, Hanebury, and Phillips

In 1982, J.P. Ward, L.R. Hanebury and R.L. Phillips conducted an intensive survey for the USFWS to inventory raptors in coal areas of western North Dakota. The aerial survey was conducted with various types of aircrafts and 2 observers. The study area was broken into 5 units and all potential golden eagle habitats within the units were systematically flown. Areas with deciduous trees were flown before leaf out and a few "test areas" were ground checked to determine the accuracy of the survey. Although this accuracy assessment was not mentioned further. A total of 124 nest sites were located, and 25 of these were occupied. From these 46 territories were identified. The greatest nest density was recorded in the Little Missouri River Breaks region at 1 pair / 171 km^2 with the mean distance between occupied nest sites equaling 4.2 km (Table1).

	McKenzie –Williams	Dickinson Addition	Southwest	Bennie Pierre	Little Mo. River Breaks	All units
Nests found	37	5	14	6	62	124
Nests estimated occupied	9	-	4	-	12	25
Estimated territories	13	1	4	2	26	46
Density (Pair/km^2)	1/714	-	1/2,691	-	1/171	1/1192
Area of sampling unit (km^2)	7,138	4,447	8,073	392	2,224	22,274
Mean distance between occupied nest sties (km)	-	-	-	-	4.2	-

Table 1. Golden eagle nests found on the North Dakota study area and estimated number of breeding territories represented by these nests (Ward et. al. 1983). Findings are divided between survey units (column headings). Area of the survey unit is included, though it is unclear how much area was actually surveyed. Additionally, detectability was not factored into nest or density estimates.

Ward et al. (1983) documented nest site orientation nesting site type. Golden eagles do appear to prefer cliff nests over all other available substrate (85% of observed nests) and trees were the next most frequently used at 8% (Table 2). The researchers recorded vertical ¼ of the cliff the nest were located. Bottom ¼, lower middle ¼, upper middle ¼ and top ¼ . Of the cliff nesting sites 90% were located in either the upper middle ¼ (62) or top 1/4 (49) of the cliffs. A south/southwesterly nest orientation is most common with 30 and 28 nest sites respectively. Sixteen of the nest sites had a west orientation and 19 had an east orientation.

	McKenzie –Williams	Dickinson Addition	Southwest	Bennie Pierre	Little Mo. River Breaks	Total (Percentages)
Cliff	23	5	12	6	59	105 (85%)
Tree	8	-	-	-	2	10 (8%)
Ground	1	-	-	-	-	1/(1%)
Pinnacle*	-	1	-	-	-	1/ (1%)
Rock Outcrop	-	-	-	-	-	0
Hilltop	-	-	-	-	-	0
Knob	-	-	-	-	-	0
Hillside	5	-	2	-	1	8 (6%)
Rock Column	-	-	-	-	-	0
Cliff Top	-	-	-	-	-	0
Total Nests	37	6	14	6	62	124 (100%)

Table 2. Nest type by survey region for esting golden eagle nests found on the North Dakota study area (Ward et. al. 1983). *The table in the report recorded one pinnacle nest however the total did not include this nest. It is uncertain where or not one existed or not.

It is uncertain how much of the study area was actually surveyed. The methods did not mention transects and only stated that area with potential eagle habitat was systematically surveyed. From most conversations with Roger Collins and other biologists who were active in other surveys it is likely the surveys follow topography. Also there is no estimation of detection rates. It is uncertain exactly how many km^2 were covered and with what certainty therefore population estimates and predictions are questionable. It does indicate a minimum population estimate, provide some idea of nesting densities and is one of the most extensive historical surveys for nesting golden eagles in North Dakota.

NDSU 1982 conducted by Allen and Grier

The only estimate for the total number of breeding golden eagle pairs for the LMNG area was developed by George Allen. In 1987, he published his results in his Ph.D. dissertation at North Dakota State University and estimated that approximately 95 pairs of golden eagles had nested in the area of the LMNG. However, due to the challenge of gathering data in this difficult terrain, his results were derived from very few occupied nests over the study, six in total over the three years. The results were then extrapolated over a large area resulting with a large range of potential error of ±79 occupied nests.

USFWS for the USFS 1992 conducted by McCarthy, Jenson, Collins, and Sanchez
An aerial survey of the Medora Ranger District of the USFS LMNG was conducted by the USFWS in 1992. The survey used linear east to west transects, with a survey distance between them of a ¼ mile or less. The survey area covered 1,239 km^2, and was locate south of Medora and was divided into five units. All potential eagle nest habitat with in the unit was searched comprehensively using the transect method. It is uncertain whether the survey actually covered all the miles with in the quad or just those identified as potential habitat. After speaking with Roger Collins he believes only likely habitat was probably covered. If the transects did not cover all area within the quadrangles then the population estimate for this area would not be accurate. However, it does give some indication of the area covered which provides much more information other surveys in which area covered is completely random and uncertain.

Of the 74 nest found (73 cliff nests and 1 tree nest) 18 were occupied nest sites. It was noted that tree nests may have been difficult to identify due to early "leaf-out" that year. Of the total nest sites located, 24 were new nests. There were 50 known nest sites included in the survey area, of these 33 were relocated and 17 were undetermined. These results indicate a potential density of approximately 1pair/68 km^2. The undetermined nest sites could have been missed or destroyed. If the researchers were able to differentiate between the types of nest sites (destroyed vs. not found), then this would provide and measurement of "detection" or "re-sightability". However, this information was not offered. Still it indicates, worst case scenario, a 66% detection rate. This detection rate could be higher then the actual detection rate if the observer and pilot have previously visited the known nesting sites. Again this information was not provided. In the case that they had previous knowledge of the known nest sites, this would over estimate the detection rate and the ability of the observer to detect new nest sites. In this case the data would result in an underestimate of the population.

All past surveys
Previous studies clearly indicate a low detection rate for relocating known nest sites McCarthy et. al. (1992) estimated a detection rate of 66% while Escano (1991) estimated a detection rate of 26%. Detectability varies between observers, survey types, nest sites, and weather conditions, therefore, it is questionable how many of the known nests designated to be destroyed were actually not found or were originally miss-plotted. All the past surveys were not comprehensive, the area between nest sites were not surveyed, and therefore this can not serve to predict the population nor estimate the number of nesting pairs in the badlands during this year.

Of all the previous nest surveys conducted in ND only McCarthy (1992) conducted a repeatable survey with an estimation of detection. The study by Ward et al. (1983) is the only other survey that could even be considered for comparison. The other surveys used on the ground methods, had limited samples and in the case of Escano (1991) occupancy was not determined. However, the study from Escano (1991) does illustrate the low rate of detection from road surveys and supports the need for aerial surveys.

Year Study	Survey Type	# Nest Sites Known To exist	# Known Nests Found	# New Nests	# Total Nest Sites found	# Occupied Nests	Other Information
1981 Escano	Road Trans.	15	4	6	10	Data Not collected	26% Detection est.
1982 Ward et. al	Aerial Systematic	NA	NA	NA	124	25	1pair /1,192km^2
1982-1884 Allen	On Foot	NA	NA	NA	NA	6 over 3 years	Population Est. = 94 pairs p = +/-79 So 19-171?
1992 McCarthy/ Jensen/ Sanchez/ Collins	Linear Aerial Transects.	67	74	24	17	18	1 pair / 68 km^2 66% Detection est. 29 pairs est.
2001 Knowles	Aerial – Known nest only	NA	110 97 (good or fair)	13	116	15	213 nest sites were previously identified however it is uncertain how many existed at the time of the survey

Table 3. A summary of golden eagle nest information for all major nest surveys in North Dakota.

One hope of many agencies is that the collation of historical data can be used to assess population changes over time or make inferences regarding the effects of disturbance on the population of nesting golden eagles or other raptors. One of the major limitations of using historical data to assess population change is that many times the method of data collection are not clearly described. In particular, population inferences from survey data will rely on accurate knowledge of the area searched (Grier et al. 1981, Lancia et al. 1996) and detectability of eagle nests in the field (Grier et al. 1981, Lancia et al. 1996) If this information is unavailable then survey data are hard to compare.

Utility and concerns with nest surveys

In order to determine an increase or decrease in the eagle population it is necessary to be able to locate the reproducing individuals of the population. Unfortunately, golden eagle censuses can be difficult; mortality rates are hard to estimate, nesting sites are located in rugged terrain, number of chicks is difficult to obtain. Their reproduction and survival rates can be highly variable between years. Therefore, estimating populations is difficult.

Other aspects of eagle ecology create difficulties in assessing the population. Detection rates are often low and highly variable (Escano 1981, McCarthy et al. 1992) making it difficult to compare between studies. Low detection rates of nesting site locations can be influenced by the location of nest site, type of nest site and quality of nest site. Spatial distribution of the birds can also affect the ability to predict the population. Nest sites tend to be clumped versus randomly spaced. This results from nesting pairs that can have many alternate nest sites with in a territory. However, the distribution of the territories likely is dependent on the habitat availability and landscape pattern of potential habitat. Surveys need to be conducted in a way that samples the different habitat types proportionately to accurately asses how nesting golden eagle are using the habitat and are distributed across the landscape. Although some cliff nests may be obvious, many are not (Grier et al. 1981). Nests may be located in crevasses of rocks or holes, nests may be located in a shadow during the survey or behind a bush. Others fill in with mud and become difficult to discern from the morphology of the butte or cliff it is located. The visibility of tree nests is reduced considerably after leaf out or due to the type of tree it is in (Grier et al. 1981). Different observers, and the number of observers, type of plane and speed can effect nest detection (Grier et al. 1981). Detection is also function of search effort and nest density. Detection is more likely to increase with increase in nest site density. Studies of aerial surveys testing the sighting probability of Elk have shown that searches are more successful in sighting larger groups (Samuel et al. 1987, Lancia et al. 1996). Vegetative cover also effected sightability in this study (Samuel et al. 1987, Lancia et al. 1996). Therefore, territories with fewer nest sites are more likely to be missed during surveys and surveys with multiple observers are likely to yield better detection rates. The cryptic coloration of the adult bird can make it difficult to determine occupancy during incubation.

Factors beyond the ecology of the bird may also influence detection. The type and speed of the plane can also have an effect on detection. Cessna are faster yet super cubs can slow to assist with nest searching (Hickman 1972). In some planes the observer may sit next to the pilot or behind. The view from the plane can also affect the observer's ability to located nest sites. Some observers have better abilities than others and their abilities can also be affected by the amount of motion sickness they experience. The type of equipment or method of data recording can also influence the quality of data and therefore affect the ability to accurately estimate the population.

Objectives

The objectives of this study are to 1) determine nest site location, 2) occupancy, 3) population estimate, and 4) distribution of nesting golden eagles in North Dakota. I used three methods to obtain the necessary information: 1) collating historical nest site information; 2) conducting "known nest surveys" (visiting known nest sites to determine nest status and occupancy), and 3) conducting new nest surveys (conducting comprehensive aerial surveys to search for new nests).

METHODS

Historical data

To develop a list of all known nesting sites in North Dakota, I compiled all the historical data available (Table 4). Data sets and observations were gathered from multiple organizations including state and federal agencies. The government agencies maintain records for the respective lands they managed. Data was available in a number of different forms – grey literature such as government reports and theses or raw data such as paper data sheets or maps. Furthermore, I interviewed a number of field biologists to help standardize the data across agencies and to fill in details that had not been recorded. The data were gathered over various years by each agency, researcher or hired consultant using a number of different collection methods.

COLLECTION SOURCE	COLLECTION CONTACTS & INFORMATION TYPE
US Fish and Wildlife Service	Government Reports, interview staff, known nest locations, data sheets, topographic maps.*
The US Forest Service Medora District Ranger Station	Government Reports, interview staff, known nest locations, data sheets, topographic maps.*
The US Forest Service McKenzie District Ranger Station	Government Reports, interview staff, known nest locations, data sheets, topographic maps.*
The US Bureau of Land Management	Government Reports, interview staff, known nest locations, data sheets, topographic maps.*
North Dakota Game and Fish Department	Interview staff - known nest locations, records, data sheets, maps.
National Park Service	Interview staff, known nest locations.
North Dakota State University	Doctoral Dissertation and interview researchers
Colorado State University	Theses, phone interviews with researchers.
Consultants	Interview - known nest locations, records, data sheets, maps.
Private Contributors	Interview – known nest locations, records, data sheets, maps.

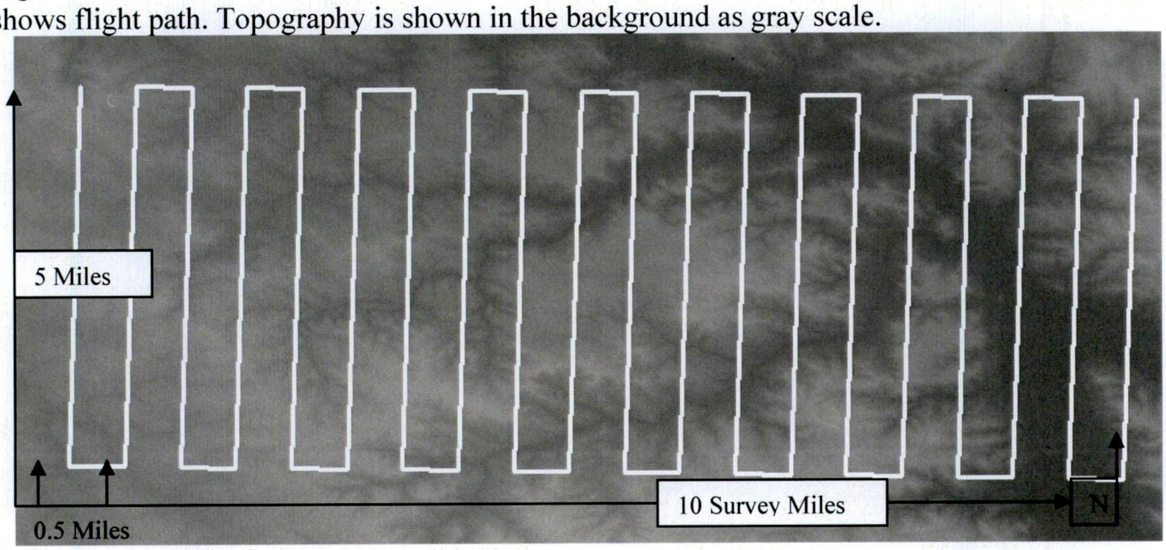
Table 4. Type and source of historical data on golden eagle nests collected and collated. *This includes any reports or data provided by different consulting firms hired by the agency.

Generally, in the late 1970's and early 1980s the nest information was first recorded by searching areas proposed for or under mineral development. In some cases comprehensive surveys were conducted in which the survey area was accurately documented. However, in most cases the area surveyed was flown topographically and the exact area covered was not recorded. Also, many locations were documented on a case by case basis as they were discovered by field personnel. Once nest site locations were known the agencies would conduct known nest checks to determine occupancy for that particular year. The area between these nest sites were not searched for nest locations. Consequently, most nest site records provide presence, location, and occupancy information and little information pertaining to absence, productivity, or nest success. Inconsistencies between data sources or within data records were discovered. When possible determinations were made, data errors were corrected and records were ranked according to reliability. Ranking was based on the source, type, and quality of data, and information obtained in my own surveys (see Results section). This database served as the foundation for the master nesting golden eagle database and was updated with newly acquired information throughout the study.

New nest surveys

To supplement the historical data, I conducted aerial surveys for new nest sites in 2004. New nest surveys were conducted using a block transect design. I determined that block transects are safer to fly than topographic surveys due to the regular flight path (per comm. Grier), are more efficient at searching new areas due to the compact flight path compared to linear transects, and are easier to place on the landscape relative to known nests and regional or topographic strata. Each block transect covered 50 square miles (5 mile by 10 mile block). The block was flown in a zigzag pattern (Figure 1). Surveying was conducted on the longer north-south flights (due to wind and sun conditions effecting flight safety) which were each flown twice. The observer searched out to a distance of 0.25 miles to the west on the first pass and 0.25 miles to the east on the second pass. Since the north-south flight lines were spaced 0.5 miles apart the entire area of the block was searched.

Figure 1. Block transects, designed for this project to conduct New Nest Surveys. White line shows flight path. Topography is shown in the background as gray scale.



Block transects were flown at a consistent height of approximately 100 - 200 feet from the ground. When a new nest was observed the pilot deviated from the transect to allow for data recording. Once the observer was ready to resume surveying the pilot continued flying the transect. Surveys were conducted from sun rise to just before sun set. Flights were grounded during high (>18-23 mph) or gusty winds and rain storms were avoided. Surveys were not conducted during times of snow cover. Transects that included treed habitat were flown before leaf-out to allow for the detection of potential tree nests. Nest site location and occupancy was collected for each nest found. The pilot did not deviate from the transect to check for occupancy, if a determination could not be made the nest received an "undetermined" status. New nests were added to the known nest survey for that year and further information was gathered then by a different observer and pilot.

The current range of golden eagles of North Dakota was estimated from the locations of all known golden eagle nest sites identified from the historical data. The study area was divided into three geographic regions and three topographic strata based on geological and ecological distinctions; described by Bloomle (http://www.nd.gov/ndgs/) and eco-regions (Bryce et al. 1998). A buffer was created around the Missouri and Little Missouri Rivers at the distances of 1 and 7 miles to consistently delineate boundaries of the topographic strata (Figure 2).

A total of 88 non-overlapping block transects were placed across the study area with the constraint that all of the known extant nest sites, those from the historical data that were found in the field, were to be included in the block transects (Fig. 3). This was done to allow for an assessment of nest detectability (Escano 1981, Grier et al. 1981). Transects were then placed uniformly to sample the remaining areas of their range absent of nest locations. This ensures a sampling of all potential habitat types across the range to gather presence and absence information for predicting occurrence and habitat preference.

Assessment of detecability

By including the known extant nests it was possible to estimate the probability of finding a nest. The observer and pilot flying the new nest surveys did not have access to the location of the known nests, they had never flown nor surveyed nests prior to this survey, and they were not involved in decisions regarding the placement of the block transects. The locations of nests found were compared against the known nests and any possible relocation was double checked using site photographs or revisiting sites. The percentage of known nest sites relocated during the new nest survey served as an estimate of nest detectability. From this a detection, a correction factor can be constructed to include detectability when estimating the potential number of nest sites in the survey area (Escano 1981). The corrected number of nests is calculated as:

$$P_n = n_f \times 1/K_d$$

where P_n = projected number of nest sites in the transects, n_f = number of nests found, and K_d = known nest sites detected.

Figure 2. Illustrates the geographic regions (3 horizontal bands) and topographic strata (different distances from the Missouri and Little Missouri Rivers). The gray scale indicates elevation with darker colors representing lower elevation.

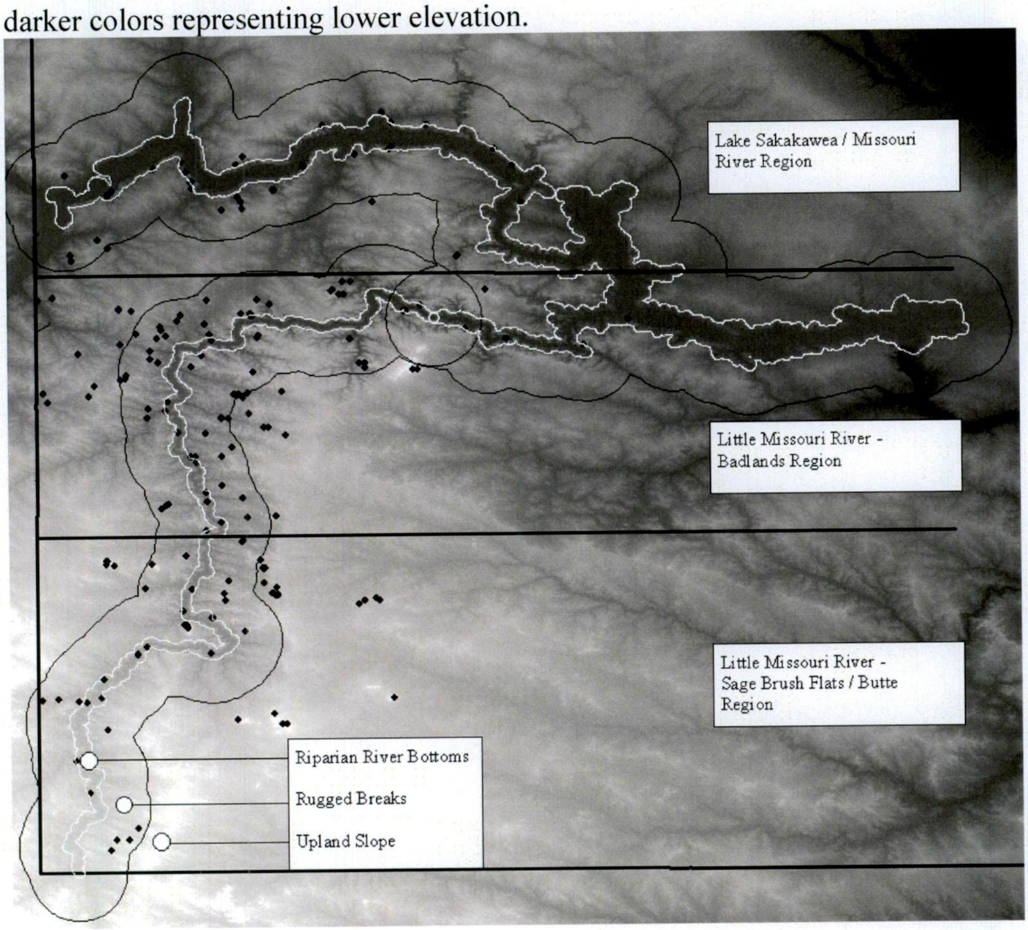
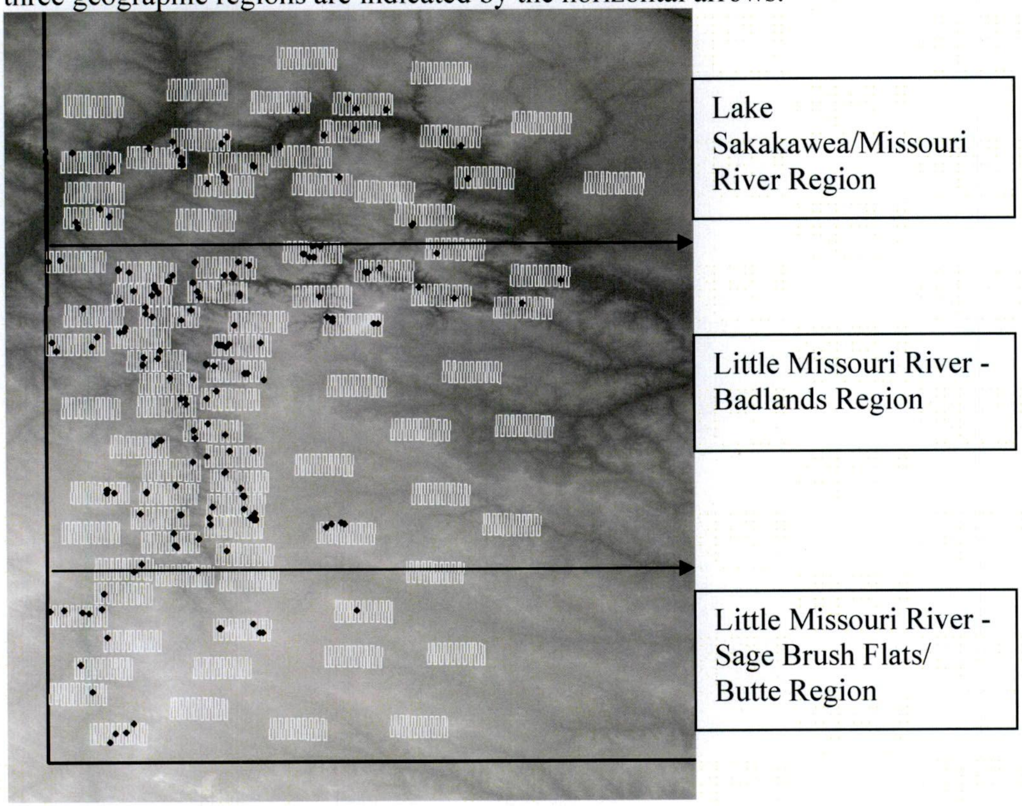


Figure 3. Illustrates the distribution of 88 block transects (white line segments) across the study area. Locations of known golden eagle nests are indicated with black dots. Topography is indicated with the grey scale background (with lower elevations indicated by darker shades). The three geographic regions are indicated by the horizontal arrows.



Known nest check surveys

Nest check technique

Every potential nest site uncovered in the historical data and located during this study (either via new nest surveys or as other nest information became available) was field checked using aerial surveys. During these "known nests" checks we identified both "historical nest sites" and "extant nest sites". Historical nest sites are those that may no longer have a nest present yet were known to have once had a nest and clearly define potential nest habitat. These areas are included to check for rebuilt nests. "Extant nest sites" are those that remain intact and have been relocated. These known nest check surveys were conducted via aerial surveys. Each field season (2002-2006) flight plans were constructed based on the historical data. Aerial surveys determined nest location and nest variables – nest condition, nest occupancy, presence of greenery, presence of white wash, number of adults, number of incubating adults, number of eggs, number of chicks, and number of fledglings. Any new nests located during the new nest surveys were also entered into the master database. In 2002 and 2003 historical data and flight plans were all paper based using paper topographic maps and data sheets, together with a hand held GPS unit to revisit nest sites and record data. From 2004 on all historical data was incorporated into a GIS computer operated moving map program that interacted in real time with the GPS unit allowing for increased survey efficiency. Flights between nest locations were conducted at higher altitudes and were not used to search for new nests. In 2005, weather and technical issues precluded flying all historical nest locations for that flight season and the missed nests were flown in the following year. If nests were occupied they were revisited at least once to determine nest productivity and nest success. During these flights the accuracy of the nest location was determined, repositioned if necessary, and all nests relocated were photographically documented to validate nest site location and to ensure accurate records of nest site location and associated information.

Master database: assessment of reliability

A comprehensive master data base was compiled using all historical nest site locations and all new nests identified throughout this study. New nest locations were identified during known nest surveys, new nest surveys, ground checks, and from other sources such as volunteers or field personnel. Nest location data was validated by comparing photos of nest locations to topographical features around the proposed location in aerial photographs. If the photos revealed that a nest site had been located in the wrong place the location was corrected using features in the aerial photograph. If the photos revealed that the observer had mistaken one nest for another survey data was attributed to the correct nest. Finally, if the photos revealed that there were in fact multiple nests in an area thought to have a single nest all the new nest sites were plotted based on features in the aerial photos.

The number of nest sites never observed over the 5 years of this study was identified. Nest sites that had solid historical nest site information and reliable nest locations but could not be found during the 5 years of surveying were considered to have been destroyed. Nest sites that had either sparse or inconsistent historical data and were not found during the 5 years of surveying could have been destroyed or may not have existed (potentially due to misplotting or double-counting nests in the original data). All of this information was used to rank the data's reliability for each nest site location.

Distribution

From the mapped, known nest locations (including the new nests found in 2004) I determined nest site distribution using a nearest neighbor analysis, mean distance between nests, and nest densities.

The program Biotas (Ecological Software Solutions: Version 2.0 for Biotas™) "nearest neighbor index" and "Contiguous Quadrats – Negative Binomial" functions were used to estimate the pattern of distribution for golden eagle nesting sites. The program compares the distribution of the data to the expected random distribution of the same number of nest sites across the extent of the study site. From this analysis it was possible to identify clumps of golden eagle nests, and thereby, to determine possible territories for both historical territories and extant territories.

A Euclidean distance/directional analysis was performed on all reliable nest site location in Arc Map. This was performed at different scales; to identify the possible size and shape of nest clumping pattern. This function produces a continuous contoured raster grid map, each cell containing a value for the distance and direction of every cell within a raster grid to the nearest source cell (nest site location). It calculates the distance and direction from the center of the source cells to the center of each of the surrounding cells, assigning values to each cell based on nest site location.

The maximum distance between points calculated was reduced until a random and uniform distribution was obtained. It was assumed from previous analysis that nearest neighbor distance values will be random or uniform with in territories. By placing a limitation on the maximum nearest neighbor value calculated for each cell, this eliminates distance values that occur between "clumps", the remaining values should therefore represent distances between nest sites with in the "clumps" or territories. Therefore, a random or uniform distribution should dominate at the territory defining scale. The results for each were compared to results calculated from simulated nest data representing both random and uniform distributions; with same number of nests distributed over the same extent.

Two techniques were applied to refine and validate the theoretical model developed using Euclidian distances to define territory size and shape. 1. Literature Review: Information was gathered on the minimum distance between occupied nest sites to verify the scales used and distances around clumped nest sites were valid to define territory size. The Birds of North America Species Account for the golden eagle was used to obtain a national summery of potential distances (Kochert et al. 2002). 2. Nest site occupancy location information from all nest surveys was also used. It is assumed that no two nest sites with in a territory will be active in any given year. All occupied nest sites were plotted for each survey year and overlaid across the potential territories.

The polygons for all potential historical and extant territories were delimited by reclassifying the raster to a binomial grid, 0 for no data and 1 for all cells with in the territory distance. A polygon shape file was then created from each of these raster's, creating an identifier for each potential territory and area statistics were calculated for each polygon. The centroids of each polygon were identified and the Nearest Neighbor function was then performed to determine the spatial distribution of the proposed territories.

Densities

Nest site and pair densities for each geological region and topographical stratum were calculated. Densities were determined by estimating the number of nest sites or breeding pairs per km^2 in a particular topographic stratum within each geographic region (Ward et. al 1983). The calculations were applied to estimate: a) total nest site density (historical and extant nest sites), b) extant territory density, c) nest density only using nests found during the new nest survey and d) density of occupied nests found in the new nest survey. The areas used to determine densities for a) and b) were calculated using the entire area of the particular strata with in the geological region. These are only estimates because we are unable to determine the total area that was surveyed to locate these nest sites. Therefore, this data can only be used to identify potential trends. The areas used for determining the densities for c) and d) were calculated using the total area surveyed using the block transects with in the particular strata with in the geological region. The exact amount of area surveyed in known therefore, these data are reliable to estimate potential differences between the strata and regions. Also, they can be used to compare with the total nest site and extant densities to determine similarities or differences.

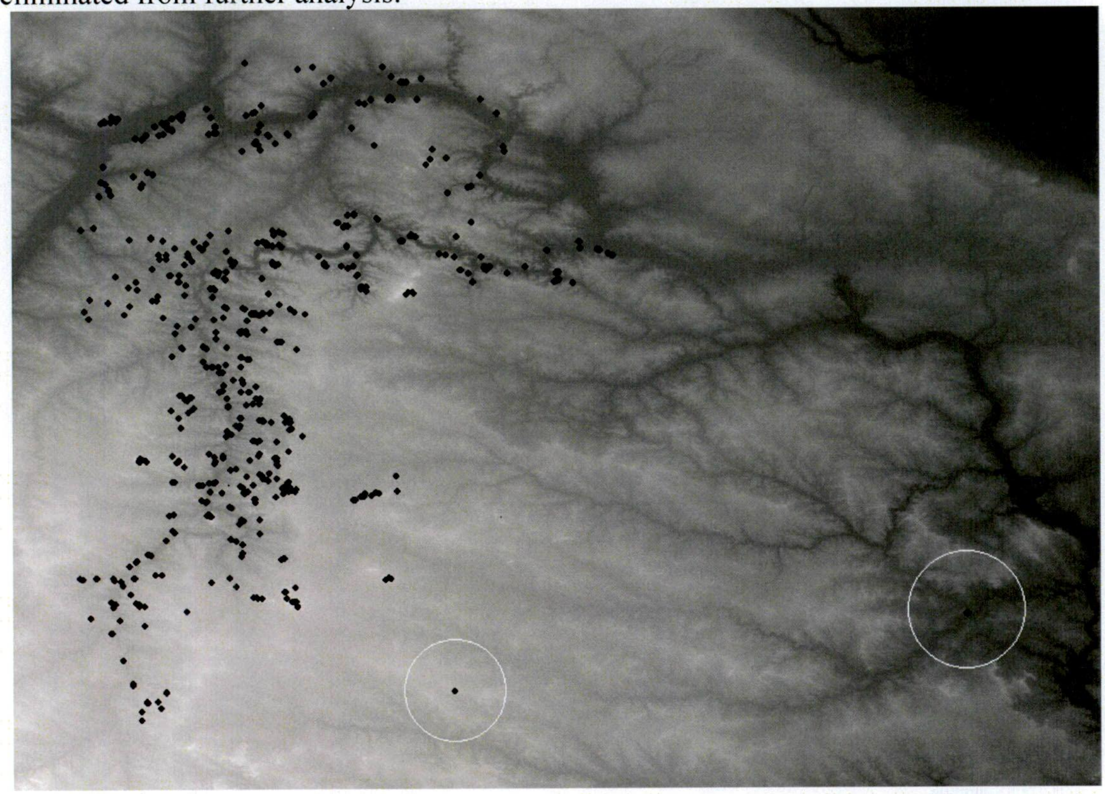
RESULTS

Historical and current data

Ranking reliability
Each nest type was ranked according to the reliability based on nest record source, type and information collected during nest surveys (Table 5). The total number of reliable nest sites (ranking >0) identified was 628. All subsequent analyses will be based solely on these reliable nest records.

Nesting golden eagle range map
The range of the reliable nests extends throughout the Great Plains Region west of the Missouri River, with greatest concentrations centered on the Little Missouri River/Lake Sakakawea Badlands Regions of the western portion of North Dakota (Fig. 4).

Figure 4. Distribution of reliable (historical and extant) nest locations (black dots) overlaid over a digital elevation model of southwest ND (darker gray indicates lower elevation). The two circled nests were occupied during this study however were determined to be outliers and eliminated from further analysis.

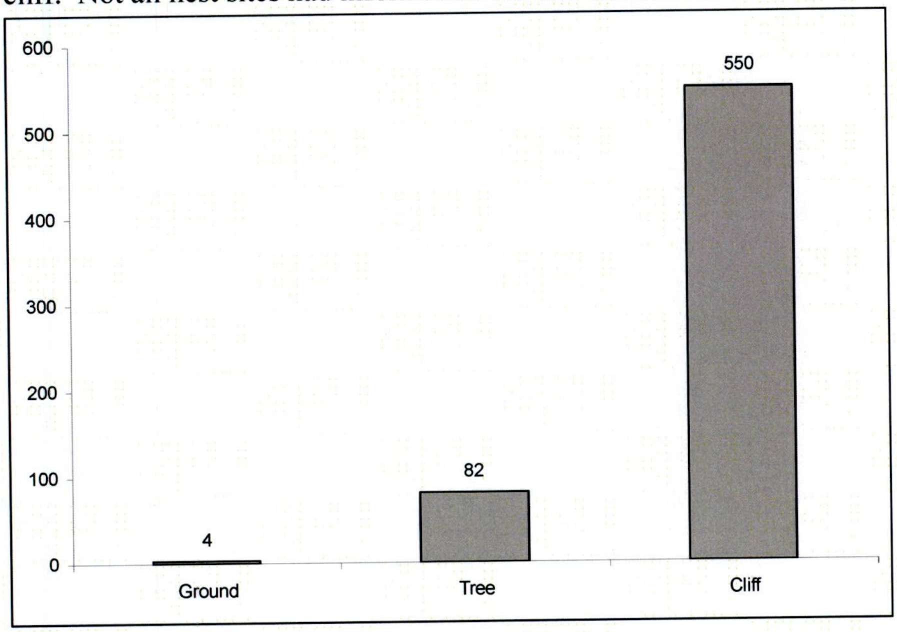


Rank	Number of nests	Ranking criteria
5	452	Confirmed to exist and accurately located: Extant - Multiple data records, mapped location, relocated at least once during study or photo documentation.
4	133	Undetermined: Historical – Never found during this study, many documented, consistent historical records, mapped location, probably destroyed and likely to have existed
3	2	Confirmed to exist accurately located: Extant - Plot was wrong is now correct. However, conflicts exist in historical information
2	5	Confirmed to exist accurately located: Extant -No data sheet
1	40	Confirmed to exist: Extant - Found during survey, inconsistent data, not able to confirm with photo, likely to exist close to plotted location.
1	5	Confirmed to exist accurately located: Extant - needs photo verification.
0	5	Not entered into flight plan
-1	2	Unable to relocate: Uncertain the records are accurate could not acquire information from consultant agency.
-2	56	Unable to relocate: Only general location known. Data sheets however no plot on maps exact location unknown
-3	28	Unable to relocate: Data sheet however only one or few observations; conflicts exist between records in historical data; not confirmed by photo; likely mistaken and miss plotted for adjacent known nest site
-4	5	Not a confirmed eagle nest: No photo or photos do not look reliable; possible magpie or hawk nest
-5	1	No data sheet to verify data entry

Table 5. Reliability ranking for golden eagle master database used for both historical and all extant nesting sites. A rank of 5 is most reliable and -5 most unreliable.

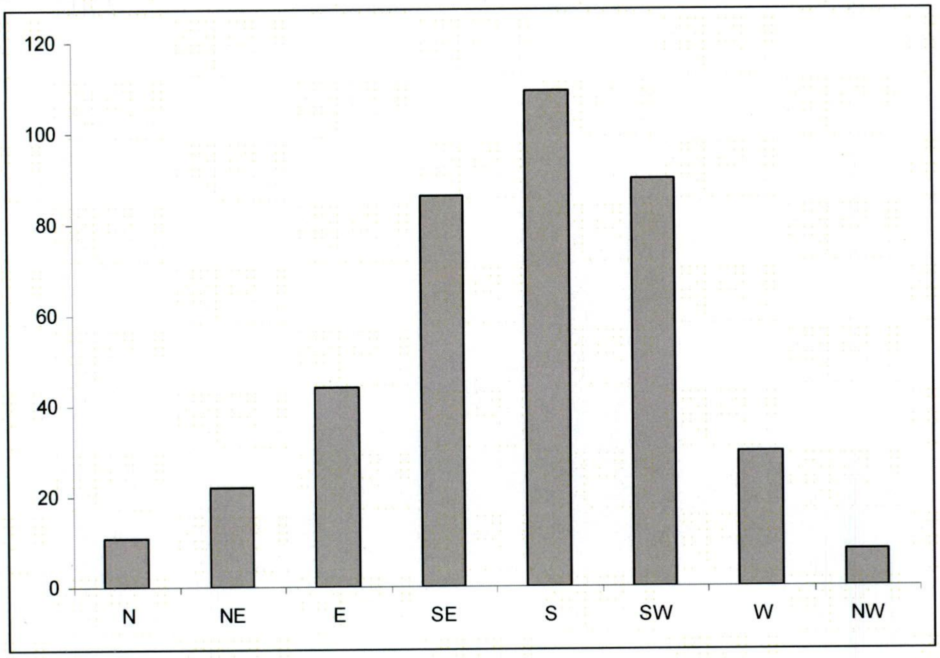
Nest type and orientation
Nests were found much more frequently on cliffs than would be expected by chance (Fig. 5; goodness of fit test $\chi^2 = 822.68$, $df = 2$, $p < 0.0001$).

Figure 5. The number of reliable (historical and extant) nest sites for each nest type; ground, tree and cliff. Not all nest sites had information for this determination.



Only 400 cliff nests had a value for nest site orientation, 150 had no data. The nest site orientation was greatest to the southerly directions (Fig. 6; goodness of fit test $\chi^2 = 217.64$, $df = 7$, $p < 0.0001$).

Figure 6. Illustrates the number of reliable (historical and extant) nest sites for each nest orientation. Not all nest sites had information for this determination.



New nest survey information

Of the 225 total nests located during the new nest surveys 106 were new nest sites. Of the 225 total nests located 32 were occupied, 110 nests were not occupied but 22 of those occurred in occupied territories, and for 83 nests occupancy could not be determined but 20 of those nests occurred in occupied territories. The types of nests are as follows; 166 cliff, 47 tree, and 1 ground nest. The new nests surveys covered a total area of 5568 km^2 and found 32 nesting pairs producing a minimum population density estimate of 1pair/174km^2.

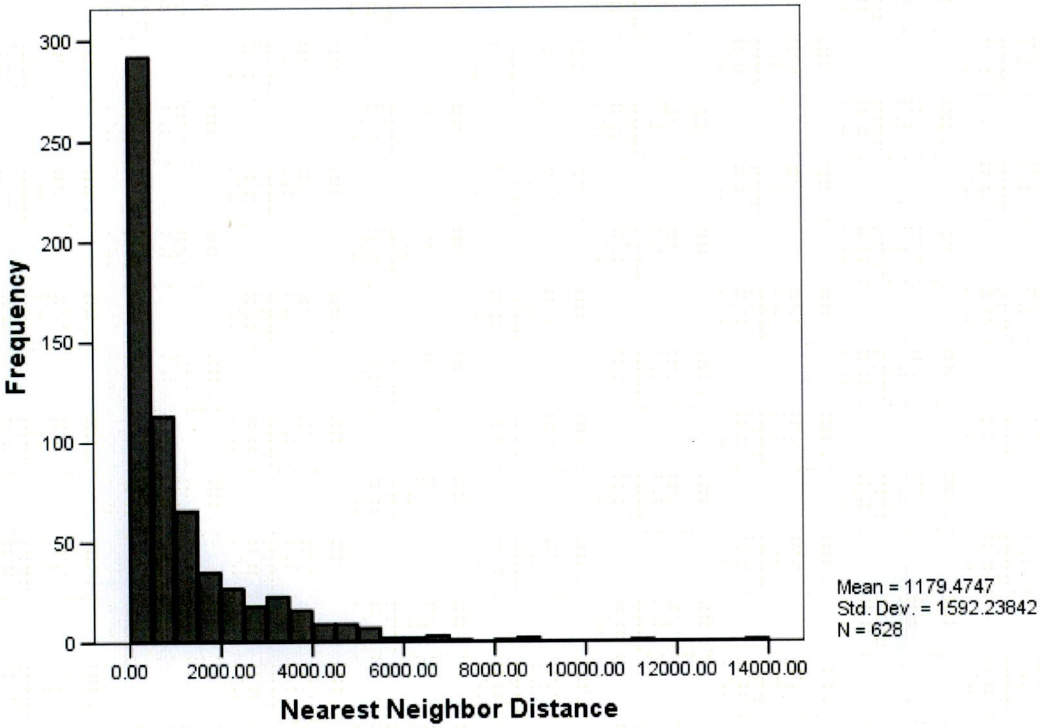
The number of missed known nest sites was estimated to be 126 of a possible 245 known nest sites included in the transect surveys. The nest site detection was calculated to be 51.42%. Using a correction factor of 225*1/0.5142 = 441; therefore 411 potential nest sites exist in the area surveyed. All other variables being constant, potentially 63 total occupied nest sites might exist in the total area surveyed.

Nest site distribution

Historical and extant data

The nearest neighbor index was used to estimate the pattern of distribution for golden eagle nesting sites. The mean minimum distance between nest sites was 1.179 km (SD = 67.3 m) which was significantly more clumped than expected if nests were randomly distributed (expected mean = 3.11 km, $Z = -28.71$, $p < 0.0001$). Furthermore, nearest neighbor distances were highly skewed toward short distances (Fig. 7).

Figure 7. Distribution of observed nearest neighbor distances from all reliable nests (n = 628).



Identifying clumps in nest location data: define potential territories

The cluster analysis of a maximum Euclidian direction and distance of 1400m nearest neighbor, identified 207 potential territories (based on historical and extant nest sites) and 176 extant (nest sites found during survey) potential territories (Fig. 8). The mean territory area was 8.95 km^2 (SD = 4.25 km^2, min = 3.09 km^2, max 26.65 km^2).

Figure 8. Extant golden eagle nesting territories (white dots).

Nest densities

Nesting site density increases toward the rugged portions of the badlands/ bottomlands and a positive relationship between nesting site density and distance to water. Densities in 1 pair/km^2 for each geological regions and topographical strata were calculated for total nest density (all historical and extant nest sites found in each particular topographical stratum within each geological region; Table 7), extant territory density (all extant nest sites found in each particular topographical stratum within each geological region; Table 8), new nest density (all nest sites located during new nest survey in each particular topographical stratum within each geological region; Table 9), and occupied nest density (all occupied nest sites located during new nest survey in each particular topographical stratum within each geological region; Table 10).

Strata / Region	*Riparian River Bottoms*	*Rugged Breaks*	*Upland Slope*
Lake Sakakawea / Missouri River Region	A = 857.13 TN = 38 TD = 1/22.56	A = 2,596.45 TN = 51 TD = 1/50.91	A = 8,629.66 TN = 22 TD = 1/392.26
Little Missouri River - Badlands Region	A = 903.73 TN = 71 TD = 1/12.73	A = 4,336.80 TN = 169 TD = 1/25.66	A = 9,034.64 TN = 66 TD = 1/136.89
Little Missouri River – Sage Brush Flats / Butter Region	A = 509.78 TN = 42 TD = 1/12.14	A = 3,353.65 TN = 96 TD = 1/34.93	A = 16,562.91 TN = 73 TD = 1/226.89

Table 7. Total nest density by region and topographical strata. A = Region area (km^2), the entire area of each particular topographical strata within each geological region. The area was not comprehensively surveyed, the nests represent what has been found over time taken from master database. TN = Number of reliable nest sites, TD = estimated nest site density (1 nest / km^2).

Strata / Region	*Riparian River Bottoms*	*Rugged Breaks*	*Upland Slope*
Lake Sakakawea / Missouri River Region	A = 857.13 ETN = 16 ETD = 1/53.58	A = 2,596.45 ETN = 11 ETD = 1/236.04	A = 8,629.66 ETN = 11 ETD = 1/784.51
Little Missouri River - Badlands Region	A = 903.73 ETN = 18 ETD = 1/50.20	A = 4,336.80 ETN = 44 ETD = 1/98.56	A = 9,034.64 ETN = 23 ETD = 1/392.81
Little Missouri River – Sage Brush Flats / Butter Region	A = 509.78 ETN = 14 ETD = 1/36.41	A = 3,353.65 ETN = 26 ETD = 1/128.99	A = 16,562.91 ETN = 13 ETD = 1/1,274.06

Table 8. Extant territory density by region and topographical strata. A = Region area (km^2), the entire area of each particular topographical strata within each geological region. The area was not comprehensively surveyed; the nests represent what has been found over time taken from master database. ETN = Number extent territories. ETD = Density extent territory (1 nest/km^2).

Strata / Region	*Riparian River Bottoms*	*Rugged Breaks*	*Upland Slope*
Lake Sakakawea / Missouri River Region	TA = 189.88 SN = 13 SD = 1/14.60	TA = 580.19 SN = 26 SD = 1/22.30	TA = 507.5 SN = 12 SD = 1/42.29
Little Missouri River - Badlands Region	TA = 212.75 SN = 17 SD = 1/12.51	TA = 1,387.00 SN = 36 SD = 1/38.52	TA = 850.60 SN = 26 SD = 1/32.71
Little Missouri River – Sage Brush Flats / Butter Region	TA = 215.97 SN = 12 SD = 1/18.00	TA = 989.22 SN = 39 SD = 1/25.36	TA = 964.40 SN = 34 SD = 1/28.36

Table 9. New nest density by region and topographical strata. TA = Total block transect area surveyed (km^2), within the area of each particular topographical strata within each geological region. The area was comprehensively surveyed, the nests represent what was found; this does not include correction factor. SN = Number of nest sites SD = Density of nest sites (1 nest/km^2).

Strata / Region	*Riparian River Bottoms*	*Rugged Breaks*	*Upland Slope*
Lake Sakakawea / Missouri River Region	TA = 189.88 SNO = 2 SDO = 1/94.94	TA = 580.19 SNO = 0 SDO = 0	TA = 507.5 SNO = 3 SDO = 1/169.16
Little Missouri River - Badlands Region	TA = 212.75 SNO = 5 SDO = 1/42.55	TA = 1,387.00 SNO = 3 SD = 1/462.26	TA = 850.60 SNO = 3 SDO = 1/283.53
Little Missouri River – Sage Brush Flats / Butter Region	TA = 215.97 SN = 4 SDO = 1/54.00	TA = 989.22 SNO = 6 SDO = 1/164.87	TA = 964.40 SNO = 2 SDO = 1/482.2

Table 10. Occupied nest density by region and topographical strata. TA = Total block transect area surveyed (km^2), within the area of each particular topographical strata within each geological region. The area was comprehensively surveyed, the nests represent what was found; this does not include correction factor. SNO = Number of nest sites occupied. SDO = Density of nest sites occupied (1 nest/km^2).

DISCUSSION

Historical and current data

Ranking reliability

The historical data base can provide nesting golden eagle locations. Now that the discrepancies and any questionable data have been identified it is able to be used more effectively with a clear understanding of its limitations. The nest surveys over time differ considerably in their methodology and accuracy. Therefore, I do not recommend using their results for comparison with or between this and other studies. However, they do offer information to assist future efforts and have provided over time a comprehensive nest location database to be used to monitor existing nest sites and aid in mitigating for localized disturbances. It will assist field biologists and managers to direct oil developers away from nesting sites to prevent potential nest abandonment. The ability for our observers to relocate known nest sites both during known nest surveys over the fives years and the new nest survey conducted in 2004 illustrates the difficulties with this type of survey work. Other studies have discussed challenges in detection of raptors during aerial and ground surveys and this study supports those findings (Hickman 1972, Grier et al. 1981, Ayers 1996). Over the course of five years different observers relocated and missed different nesting sites. Nest sites that are clumped may be more likely to be relocated and found, while isolated nest sites and nests that are obscured via foliage or shadows are likely to be missed. Therefore, great care needs to be taken in making any population estimates. The identification of potential territories helps us to begin to identify the potential carrying capacity of the region.

Nesting golden eagle range map

The project clearly redefines the range of nesting golden eagles in ND, from that illustrated in (Kochert et al. 2002) and from what many had believed it to be, extending it east to the area around Flasher, ND. I predict there will be more nests sites found in these eastern regions and further surveys, habitat suitability models, and assimilation of local knowledge to assess golden eagle nest sites in this more eastern region seems warranted.

Nest type and orientation

Golden eagles in ND have used ground nest sites, trees and cliffs and despite the unconsolidated materials of clays and scoria. Other studies (e.g., Beecham 1970, Craig 1980, Escano 1981, Ward et al. 1983) also show a preference of cliff nests over tree nests, with very few or no ground nest. In Idaho the scarcity of trees explains why cliff nests were the dominate nest choice (Beecham 1970). In Wyoming 81% of the nest sites were tree nests and they determined the cause to be the lack of available cliffs (Phillips and Beske 1981). Available habitat may be determining the number of tree nests versus cliff nests in the badlands of western North Dakota as well. Also, tree nest sites are very difficult to locate especially after leafout and this issue of visibility may also be influencing the results. Finally, most surveys in and around the badlands focused on the topography of the areas surveyed. Trees may have been a secondary feature to check contributing further to the greater number of cliff nest sites found over time. However, during the new nest survey a greater number of cliff nest over tree nests were also discovered. Because of the greater availability of cliff nest sites and limited tree growth habitat availability is likely influencing the results. The dynamics of the region and the highly erodible geology creates a turn over of nesting sites. Therefore, frequent surveys need to be conducted to monitor for destroyed and newly built nest sites. Also, protection of woody draws and the cotton wood regeneration in the riparian bottom lands is important to maintain available tree nesting habitat.

Evidence from nest site orientation indicates that wind storms may dictate the nest orientation preferences. The majority of wind storms over the course of the study originated from the northwest. Few nest sites were located on these slopes, although they were available. The south, southeast and southwest facing slopes may be preferred to provide protection from these storms and to add additional warmth during early spring months when snow is common.

Nest survey information

Known and new nest survey information

The known nest surveys only visit historical or extant nest sites, alternative nest sites or areas void of nest sites are completely unknown and were not surveyed for except during the new nest surveys which were only conducted in one year. Due to these limitations, comparisons from year to year can not be made concerning an increase or decrease it the number of occupied nest sites. Nor can any inferences be made to the population of nesting golden eagles at any given time or over time. What may appear to be a change in the percentage of nest occupied may be the result of numerous factors: the lack of complete information on how many nest sites were initiated, a lack of knowledge of alternative or newly built nesting sites that may be in use and unknown to the observer, weather events that may have cause the failure or some pairs not to nest that particular year, some pairs may nest alternate years, nest sites that were not located by one observer one year may have been missed or status incorrectly determined by the observer the next year or vice versa, a different species nesting in a nest may have been miss identified for a golden eagle (Grier et al. 1981, Kochert et al. 2002, Steenhof and Newton 2005). All of these biases and challenges have been identified to have occurred during the five years of this study and are likely to have occurred over time. We have recorded many areas during the five years of the study that were occupied territories with out locating the occupied nest site. The terrain and vegetation and vast expanse of potential available habitat make it difficult to locate nesting sites (Hickman 1972, Grier et al. 1981). Many of the nest sites that were found over the course of the study were large and based on the height of the nest's they had obviously been in existence for many years. It is apparent that the earlier nest surveys were missing existing nest sites and the abilities of the observers to comprehensively survey for nests were limited, as was known nest surveys in this study. The new nest surveys support this theory with only a 51% relocation of extant nest sites that were located within the survey transects, yet 106 new nest sites were identified. Whether or not these nest sites were missed or inaccurately located, this clearly illustrates that with out a thorough, long-term study design for repeated surveys over 10 - 20 years we are unable to make any determinations concerning the population's stability or trends over time.

Nest site distribution

Identifying clumps in data: define potential territories

The distribution of nest sites revealed a clumped distribution of nesting sites, as would be expected. If alternative nest sites are common for golden eagles and they also maintain a territory around the nest site (Kochert et al. 2002), then it is not surprising to find the data distribution to be clumped. The delineation of potential territories will provide information to be incorporated into the habitat model to predict habitat preference and offer some indication of the potential carrying capacity (number of nesting pairs able to occupy the available habitat).

Nest densities

The data used to determine the total nest site density and extant territory densities are suspect, because the area surveyed to identify all of the nest sites over time is unknown, and we have no record of the areas absent of nest sites. Therefore, nesting site and extant territory densities can at best illustrate possible trends in eagle nests. The trend indicates an increase toward the rugged portions of the badlands/ bottomlands and a positive relationship between nesting site density and distance to water. The methods for data collection used in the new nest survey are more reliable and provide a specific area surveyed. The results from the new nest survey support the general trend of the known nest survey densities.

It should also be noted the model does not factor in vertical relief and future research may want to consider this variable. The vertical relief adds to the surface area of these rugged regions offing more potential nest site habitat. With this increase in topographical relief there is also an increase in vegetative diversity and potentially an increase in the number of prey available. Trees also provide nest site habitat as well, the river bottoms although lacking in the dramatic topography, have large cotton wood trees protected from the winds in the uplands.

Management recommendations

In order to identify potential trends in the population over time long term monitoring using techniques used for the new nest survey are highly recommended. The quality of the pilot and technician, the time of year, the area covered, the equipment used should all be considered seriously. Observer bias is common in these types of surveys and relocation of nest sites extremely difficult. Having well trained personnel who are comfortable in a small plane using computer technology will minimize the number of nest sites missed.

PRODUCTIVITY, MORTALITY, DIET AND MOVEMENTS OF GOLDEN EAGLES IN NORTH DAKOTA

INTRODUCTION

Nesting and productivity

Golden Eagles pair when they return to breeding areas (Kochert et al. 2002). In cases of resident eagles they may remain paired on the breeding territory year round (Kochert et al. 2002). . Courtship and nest building can start in late January (Kochert et al. 2002). Nest type depends on the availability of habitat; they are typically found on cliffs, rocky out crops, large coniferous or deciduous trees and occasionally, though rarely, on the ground. Nests typically are placed with a vantage point in close proximity of potential hunting grounds (Kochert et al. 2002). They are large stick nests, usually using larger branches of various types, and the bowl is constructed of softer vegetative material such as yucca and grasses (Kochert et al. 2002). . The size can vary some studies they range from 53.3 – 264.2 cm long and 38.4 – 203.2 cm wide (Kochert et al. 2002).

Starting as early as late January to early February golden eagles usually lay 1-2, and rarely 3, eggs per breeding pair (Kochert et al. 2002). In Montana and Idaho studies found an average of 2.1 eggs per clutch (McGahan 1968, Beecham 1970). The number of young to reach fledging usually is used to determine nest success (Steenhof and Newton 2005). A study in Scotland (Watson et al. 1992) found that food can affect breeding success; they found a positive correlation between the amount of live prey and breeding success. Age can also affect success; adult pairs had higher reproductive rates then mixed pairs (adult/immature) (Sanchez-Zapata et al. 2000). Nest success varied between 1.2 - 1.5 young fledged on average (McGahan 1968, Beecham 1970, Leslie 1992)

The female is the main incubating adult with intermittent breaks provided by the male (Kochert et al. 2002). Both parents bring prey to the nest site, though females directly feed the young in most cases. By 34-37 days old the young feed themselves. In some studies siblings attack younger siblings (siblicide) when food is limited, in these situations the larger chick may force the younger chick to starve or to leave the nest prematurely. Losses of chicks can range from only 7% in southwestern Idaho to 40% in central Europe (Kochert et al. 2002). Prey remains and expelled pellets can gather beneath the nest site though some adult eagles will remove or consume uneaten prey. In some cases parents may bring fresh vegetation to cover the nest bowl (Kochert et al. 2002). Few studies have studied parental care of young after fledgling (Kochert et al. 2002). Fledglings start flapping their wings more and more prior to first flight attempts. Mean age at first flight was 10.1 weeks out of a sample of 28 fledglings (O'Toole 1997a). Fledglings can leave the nest anywhere from 45 to 81 days old (Kochert et al. 2002). The flight is usually short with uncontrolled landings and sometimes the young are grounded. The parents usually continue to feed the young but may delay feedings to encourage fledging (Kochert et al. 2002). Fledglings stay with parents up to 6 months and in Idaho males were the main prey provider for fledged young (Kochert et al. 2002). Very little information on post fledging movements is available (Kochert et al. 2002). O'Toole (1997a) found the young stayed in close proximity of one another, showing no aggression to each other, while wandering around the natal area.

Mortality

Specific cause of mortality is difficult to obtain for golden eagles because once the birds leave the nest tracking them is difficult (Beecham 1970). A number of potential mortality sources, both natural and due to humans, have been suggested in the literature (Table 11). Mortality due to humans includes causes such as shooting to on foot disturbances. On foot disturbances include, but are not limited to, climbers, surveyors, researchers, and tourists. When people approach a nest adult eagles will flush and, subsequently, young chicks or eggs can die from exposure to cold/ hot temperatures, or if the disturbance persists long enough adults my abandon a nest. Finally, on foot disturbances can flush young that can not yet fly from the nest and they die from impacting the ground.

Type	Sources of mortality	Citation
Human Caused	Shooting	(McGahan 1968, Beecham 1970, Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Incidental trapping	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Incidental poisoning	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Mercury poisoning	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Lead poisoning	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Collisions: Wind Turbines /Fence	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Electrocution	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	Pesticide poisonings	(Hunt et al. 1995, Kochert et al. 2002)
Human Caused	On Foot Disturbance	(Kochert et al. 2002)
Human Caused	Research caused mortality: fledgling drowned during capture attempt.	(Beecham 1970, Kochert et al. 2002)
Human Caused	Human removal	(McGahan 1968, Beecham 1970))
Human Caused	Car Collision	(Hunt et al. 1997)
Natural Caused	Fledging	(Hunt et al. 1997)
Natural Caused	Nestling –heat exposure	(Hunt et al. 1995)
Natural Caused	Siblicide	(Beecham 1970, Hunt et al. 1995, Kochert et al. 2002)
Natural Caused	Porcupine quills	(McGahan 1968)
Natural Caused	Killed by eagle	(Hunt et al. 1997)
Natural Caused	Botulism	(Hunt et al. 1997)

Table 11. Different causes of mortality for Golden Eagles found in the literature. Mortality sources are divided between human and natural causes.

Diet composition

Eagles forage opportunistically and, therefore, prey depends on species available and varies according to region and habitat (Kochert et al. 2002). A broad array of prey items have been recorded in the literature (Table 12). Most studies have determined prey from collection at the nest site or by observation. Eagles may hunt from perch sites (cliff edges, tree tops), from soaring, or by flying just above the ground (Kochert et al. 2002, Coyle 2003).

	Prey Species		
Taxonomic Group	**Common Name**	**Scientific Name**	**Citation**
Mammals	Whitetail jackrabbit	*Lepus townsendii*	(McGahan 1968)
	Blacktail jackrabbit	*Lepus californicus*	(Beecham 1970)
	Richardson's ground squirrel	*Citellus richardsonii*	(McGahan 1968)
	Mule deer (fawn)	*Odocoileus hemionus*	(McGahan 1968) (Beecham 1970)
	Longtail weasel	*Mustela frenata*	(McGahan 1968) (Beecham 1970)
	Vole (longtail, Richardson's and others)	*Microtus* spp.	(McGahan 1968)
	Pronghorn antelope (fawn)	*Antilocapra americana*	(McGahan 1968)
	Townsends ground squirrel	*Spermophilus townsendii*	(Beecham 1970)
	Snowshoe hare	*Lepus americanus*	(Beecham 1970)
	Ord's Kangaroo rat	*Dipodomys ordii*	(Beecham 1970)
	Bobcat (kitten)	*Felis rufus*	(Beecham 1970)
	Coyote (pup)	*Canis latrans*	(Beecham 1970)
	Yellow-bellied marmot	*Marmota flaviventris*	(McGahan 1968, Beecham 1970)
	Unidentified Mammals		(Beecham 1970)
	Porcupine	*Erethizon dorsatum*	(McGahan 1968)
	Bushytail woodrat	*Neotoma cinerea*	(McGahan 1968, Beecham 1970)
	Muskrat	*Ondatra zibethicus*	(McGahan 1968, Beecham 1970)
	Domestic lamb	*Ovis spp.*	(McGahan 1968)
	Striped skunk	*Mephitis mephitis*	(McGahan 1968)
Birds	Black-billed Magpie	*Pica pica*	(McGahan 1968, Beecham 1970)
	Gray Partridge	*Perdix perdix*	(McGahan 1968, Beecham 1970)
	Blue Grouse	*Dendragapus obscurus*	(McGahan 1968)
	Sage Grouse	*Centrocercus urophasianus*	(McGahan 1968)
	Great Horned Owl	*Bubo virginianus*	(McGahan 1968)
	Red Shafted Flicker	*Colaptes cafer*	(McGahan 1968)
	Ring-necked Pheasant	*Phasianus colchicus*	(McGahan 1968, Beecham 1970)

	Short-eared Owl	*Asio flammeus*	(McGahan 1968)
	Prairie rattlesnake	*Crotalus viridis*	(McGahan 1968)
	Bull snake	*Pituophis melanoleucus*	(Beecham 1970)
	Long-eared Owl	*Asio otus*	(McGahan 1968, Beecham 1970)
	Sharp-tailed Grouse	*Pedioecetes phasianellus*	(McGahan 1968)
	March Hawk	*Circus cyaneus*	(McGahan 1968)
	Sparrow Hawk	*Falco sparverius*	(McGahan 1968)
	Rock Dove	*Columba livia*	(McGahan 1968)
	Hawk (nestling)		(McGahan 1968)
	Pigeon	*Columba spp.*	(Beecham 1970)
	Chukar	*Alectoris chukar*	(Beecham 1970)
	Hungarian Partridge	*Perdix perdix*	(Beecham 1970)
	Ruffed Grouse	*Bonasa umbellus*	(Beecham 1970)
	Mallard	*Anas platyrhynchos*	(Beecham 1970)
	Barn Owl	*Tyto alba*	(Beecham 1970)
	Long-billed Curlew	*Numenius americanus*	(McGahan 1968)
	Marten	*Martes americana*	(Hatler 1974)
	Ptarmingan	*Lagopus spp.*	(Hatler 1974)
	Unidentified Bird		(Beecham 1970)
Herptiles	Unidentified Snake		(McGahan 1968, Beecham 1970)
	Prairie rattlesnake	*Crotalus viridis*	(McGahan 1968)
	Bull snake	*Pituophis melanoleucus*	(Beecham 1970)
Fish	Unidentified Fish		(Beecham 1970)

Table 12. Prey species consumed by golden eagles based on studies found in the literature.

Post fledgling movement and migration

Migratory timing, patterns, and distances are influenced by bird age, geographic origination and nesting regions. There is little information on the movements of golden eagles (Kochert et al. 2002). Migration usually takes place in the fall for birds that migrate (Kochert et al. 2002). Northern birds migrate longer distances than southern birds (Kochert et al. 2002). Immature birds usually migrate earlier in the year then adults with the reverse being true for spring migration back to breeding grounds (Kochert et al. 2002). Migratory routes may differ for juviniles and adults (Kochert et al. 2002). Data for specific migration routes is difficult to obtain with radio transmitter units and the advancement of satellite telemetry has provided detailed information to confirm migration patterns for tagged individuals of populations such as in Northern Quebec (Brodeur et al. 1996). In Idaho, young returning to nest were 4-7 years old before establishing a breeding territory (Kochert et al. 2002). In Alaska 48 juveniles were tagged with GPS PTTs satellite telemetry units, most fledglings left their natal area in September and October and migration dates were similar between years (McIntyre and Collopy 2006). Departure of offspring did not depend on hatching date nor did it vary between year, sex, or brood size. However, it is uncertain if the parental departure triggers the movements of their offspring (McIntyre and Collopy 2006). The average departure data between siblings from natal nest site areas was 4.3 $\pm$ 3.0 days, $n = 5$ (McIntyre and Collopy 2006).

Golden eagles in North Dakota

There have been few studies focused on the ecology or demographics of eagles in North Dakota. Productivity was determined for thirteen of the 25 occupied nest sites in a survey of North Dakota conducted in 1983. Three of the nest sites failed, adults but no young observed on one nest, and the 9 remaining nest sites produced 16 eaglets (1.8/nest) of various ages (Ward et al. 1983). O'Toole (1997a), conducted her Master of Science research project on nesting golden eagles of North Dakota. She tagged 28 juvenile birds over a two year period; 1993-1994 and collected data on post fledging behavior. She used this data to investigate extended parental care, asynchronous hatching, and incidences of siblicide in golden eagles. As the young mature, these factors could increase the chances for conflict between siblings, and between the young and patents. She argued conflicts between siblings and between juveniles and parents could influence the fledgling behavior of juveniles, possibly, resulting in increased independence and dispersal.

The study conducted by (O'Toole 1997b), revealed no aggression between offspring nor between offspring and parents. In fact siblings were observed to be at play on occasion. O'Tool et al. (1999) also noted that distance from the nest site increased over time as a result of increased mobility from advanced flight abilities. Rather then developed independence from one another siblings remained in close proximity of one another from fledgling until they left the parental home range. Calling rates from juveniles did not change over time. Although, calling rates did appear to be increase when a parent was in sight. Few feedings from parents to young were observed on only a reference to an unknown species of snake and rodent were mentioned.

Purpose

The purpose of this portion of the project was to gather ecological and demographic information on the population of nesting golden eagles of North Dakota that would serve as baseline data to aid in future analysis of the population's viability.

METHODS

Nest success and productivity

Between 2002 and 2006, known Golden Eagle nests (see previous chapter) were surveyed by airplane to determine occupancy. Occupied nests were resurveyed at lease once to determine nest success and productivity. These surveys were begun somewhere between March and early May depending upon weather and pilot availability. Observations during this study determined that golden eagles in ND can begin nest initiation as early as February (Kochert et al. 2002, Coyle 2003), therefore, I was unable to determine nest initiation. The number of adults, eggs, downy chicks, and fledglings in the nest were recorded when possible. Many times the eggs or downy chicks were not visible under the incubating adult. In 2005, weather and technical issues precluded flying all historical nest locations for that flight season and the missed nests were flown in the following year.

During 2005 follow up flight nest checks for occupancy were not conducted, all data on nest success or status was conducted by ground checks. In all years, all accessible nest sites were ground checked. Many occupied nest sites were inaccessible, either because of rugged locations, limited time, or the nest was on private land and the land owner could not contact for permission to access the nest.

Mortality sources

Sources of mortality for golden eagles in North Dakota were determined from any eagle carcasses found during ground-based nest checks. Additional information on morality of golden eagles was obtained from paper records obtained from different agencies: the USFWS, the Dakota Zoo, the University of Minnesota Raptor and Rehabilitation Center, local volunteers and landowners.

Diet composition

Information on golden eagle diet was obtained during nest checks. Diet was determined by direct observations of feeding or surveying remains of prey items found around occupied nests.

Post fledgling movement and migration

In order to tag the fledgling for the telemetry portion of the study, occupied nests were located and the number of chicks identified. The nest sites were checked by air and ground to determine accessibility and proximity. Because of the rugged landscape and limited road access to some nest locations sites were chosen based on their accessibility. Most nest sites were located in trees and on cliffs, extremely dangerous unconsolidated sandstones, and scoria and clay cliff sides made repelling and climbing impossible. Sites were then chosen based on ability to flush the fledgling from the nest with safety considerations for both the bird and the researcher. Most nest sites trapped were in the northwest portion of North Dakota. Alternative nest sites in the central portion were used in 2006. Nests were observed until birds were ready to fledge at which point fledglings were captured by hand.

Captured birds were fitted with GPS Satellite Transmitters (Solar Powered Satellite Transmitters (PTTs) 100 70gram; purchased from Microwave Telemetry; McGrady et al. 2003) with backup VHF-A2930/40ppm Radio Transmitters (ATS). The back up radio transmitter has a life span of only 1 ½ years. It is used to located faulty, down or dead birds that may have lost power and transmission of the GPS solar paneled transmitter. The transmitters were applied using a backpack application using Teflon ribbon and biodegradable cotton thread (Coyle 2005). We tagged 2 fledglings in 2004, 8 in 2005 and 6 in 2006. The PTTs locations were logged every hour for 8 hours a day. Locations were obtained from the Argos satellite tracking system which provided 1 m resolution. The PTTs were programmed to transmit a signal from the transmitter to the receiving satellite every three days and the data was downloaded to the satellite station and emailed directly. Location data were parsed using the Microwave Inc. Parsing Software Package and were plotted in Arc Map to illustrate post fledgling movements, fall and spring migration patterns, and over wintering areas.

RESULTS

Nest Success and Productivity

Nest success was based only on nest sites that were found to be occupied which varied between survey years. Occupied nests over the 5 years of the study successfully produced an average of 1.30-1.66 fledglings per nest (Table 13). It was not uncommon to have breeding pairs successfully fledge 2 chicks and occasionally fledge 3 chicks. It should be noted that in most cases it was hard to confirm nest failure as it was unclear if the observer could not locate the fledged chick or if the chick had died.

	2002	2003	2004	2005	2006
# Nests Checked	197	457	434	421	641
% Occupied	13.33	19.87	10.09	26.31	16.86
# Nests Occupied	15	23	43	16	38
# Eggs / Incubating Adult	0/0	0/0	4/15	0/0	8/20
# Downy Chicks	2	0	15	11	33
# Fledglings	20	30	44	19	37
# Successful Nests	12	23	28	13	27
# Fledglings/ Successful Nest	1.66	1.30	1.57	1.46	1.37
# Nests w/ 1 Fledglings	4	15	14	7	13
# Nests w/ 2 Fledglings	8	8	12	6	9
# Nests w/ 3 Fledglings	0	0	2	0	2

Table 13. Lists the results from nest checks of occupied nests, and nest success.

Diet composition

Birds were observed bring food to the nest or to fledglings. Also prey remains and pellets were retrieved from beneath the nest site. Prairie dogs and rabbits were the most common prey items found, however, the type and amount of food varied between nest sites. The inconsistencies prevented us form making any conclusions on prey preferences or percentages. Some nests that fledged two young had no prey remains under the nest. Because of the inability to accurately sample prey items at any nest site we could only list the prey found during the study (Table 14).

Prey Species		
Taxonomic Group	**Common Name**	**Scientific Name**
Mammals	Jackrabbit	*Lepus* spp
	Cottontail	*Sylvilagus* spp or *orycotolagus* spp
	Longtail weasel	*Mustela frenata*
	Pronghorn antelope (fawn)	*Antilocapra americana*
	Coyote (pup)	*Canis latrans*
	Striped skunk	*Mephitis mephitis*
	Porcupine	*Erethizon dorsatum*
	Blacktailed prairie dog	*Cynomys ludovicianus*
	Big horn sheep (lambs) (per comm. NDGF)	*Ovis cnadensis*
	Unidentified Mammals	
Birds	Sage Grouse (per comm. NDGD)	*Centrocercus urophasianus*
	Great Horned Owl	*Bubo virginianus*
	Ring-necked Pheasant	*Phasianus colchicus*
	Turkey	*Meleagris gallopavo*
	Mallard and other ducks and geese	*Anas platyrhynchos*
	Unidentified Bird	
Herptiles	Unidentified Snake	
	Prairie rattlesnake	*Crotalus viridis*
	Racer	*Coluber spp*
	Bull snake	*Pituophis melanoleucus*
Fish	Unidentified Fish	

Table 14. List of prey species found or reported during the study.

Mortality

A variety of mortality causes, both natural and due to humans, have been documented in ND. The deaths from this project included undiagnosed disease, West Nile, electrocution, results of wind storm, exposure from on foot disturbance, and lead ingestion (Table 15).

Causes of Mortality in ND	Source
Collision w/ Vehicle	University of Minnesota Raptor Center
Projectile	University of Minnesota Raptor Center
Toxicity	University of Minnesota Raptor Center
Disease	University of Minnesota Raptor Center
Undiagnosed Disease	University of Minnesota Raptor Center (Coyle 2006)
Unknown Trauma	University of Minnesota Raptor Center
Electrocution	USFWS (Coyle 2006)
Lead shot ingestion	USFWS (Coyle 2006)
Collision – Contacted oil equipment when being chased by smaller bird	USFWS
Shot (recreation, by pheasant advocates)	USFWS
Compound fracture – wings – possible collision – euthanized.	USFWS
Unknown – broken leg	USFWS
Road kill or power line	USFWS
West Nile	USFWS / Dakota Zoo / (Coyle 2003) (Coyle 2005)
Wind storm – broken neck below nest	(Coyle 2003) (Coyle 2005)
Wind storm – stuck in mud	(Coyle 2003) (Coyle 2005)
Wind storm – under fallen nest	(Coyle 2003) (Coyle 2005)
Exposure – chick during surveying activity and on foot disturbance	USFS / Volunteer (Coyle 2005)
Incidental trapping and poisoning	USFWS / Landowners
Shot	USFWS / Dakota Zoo / Via Phone Conversation Dr. Mc Ewen, CO, / Landowners
Power line Strike	USFWS / Power company
Unknown	USFWS / (Coyle 2006)

Table 15. Lists of all types of mortalities known to have occurred in North Dakota and the source of the documentation.

Post fledgling movement and migration

Of the 17 tagged juveniles 9 lived long enough to collect movement data (Appendix A). Most juveniles maintained a range close to the natal nest site after the first flight from the nest. Adults were observed luring the fledglings from the nest by reducing the number of feedings at the natal nest site and by placing prey on adjacent buttes or ridges. The fledglings moved in a gradual progression away from the nest site with successively longer flights. They used the natal nest sites and alternate nest sites in many cases. Juveniles many times were observed next to one another on the butte. Parents were observed bringing prey to fledglings that were located away from the natal nest site. No aggressive behavior between siblings was observed. Juveniles could be heard calling to the parents when the parents were in visible range even after having flown from the nest.

The entire range of all juvenile movements from the telemetry data extended from North Dakota south to the South Dakota border of Nebraska and north through Montana into the south central portion of Saskatchewan CA (Fig. 9). The juveniles varied in their post fledging movements, some migrated to South Dakota, some migrated to the southern portions of North Dakota and some maintained residency near their natal area. One juvenile was a resident the first year then migrated the second year (Fig. 10-17). All that had a distinct movement or migrated began in late fall (Appendix A).

Figure 9. Range of all post fledgling movements. Different colored dots represent different birds

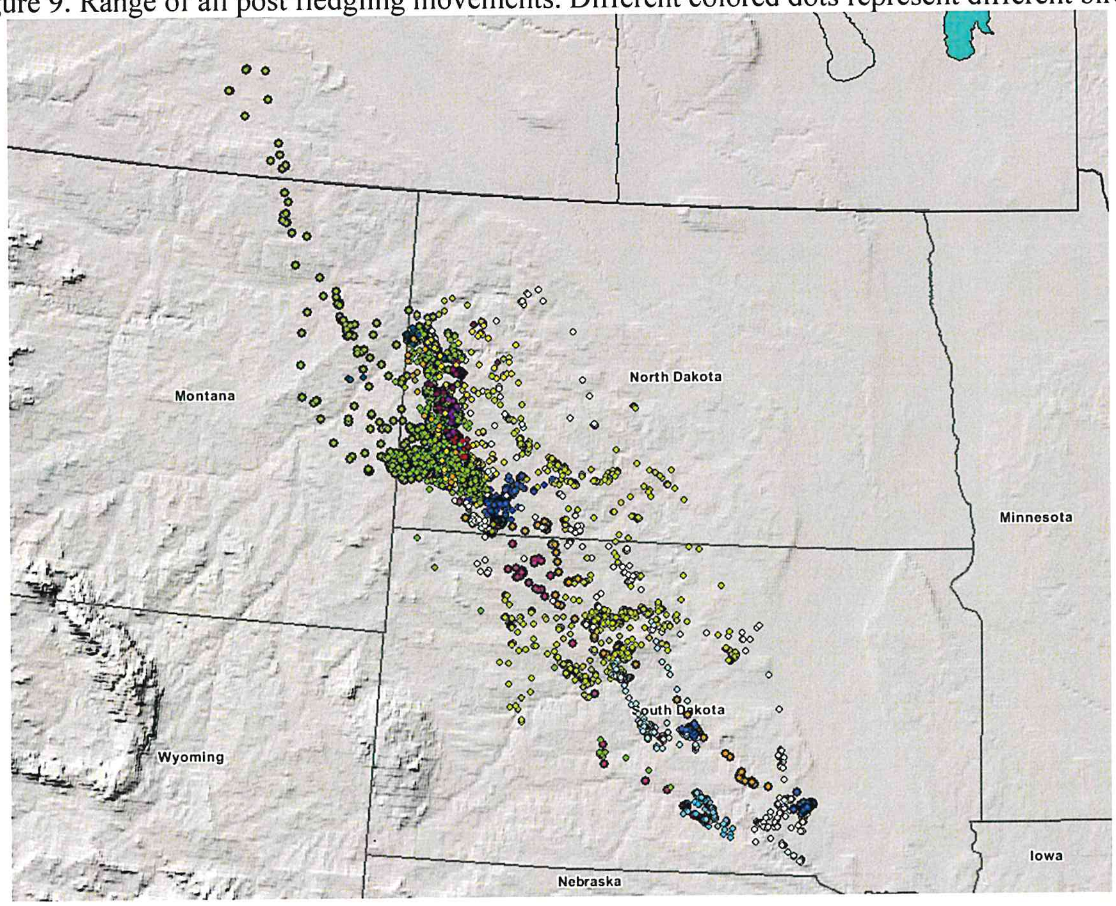


Figure 10. Individual post-fledgling movements. Bird 49016B, ND migrant, tagged 07/05/2006, last signal date 01/21/2007.

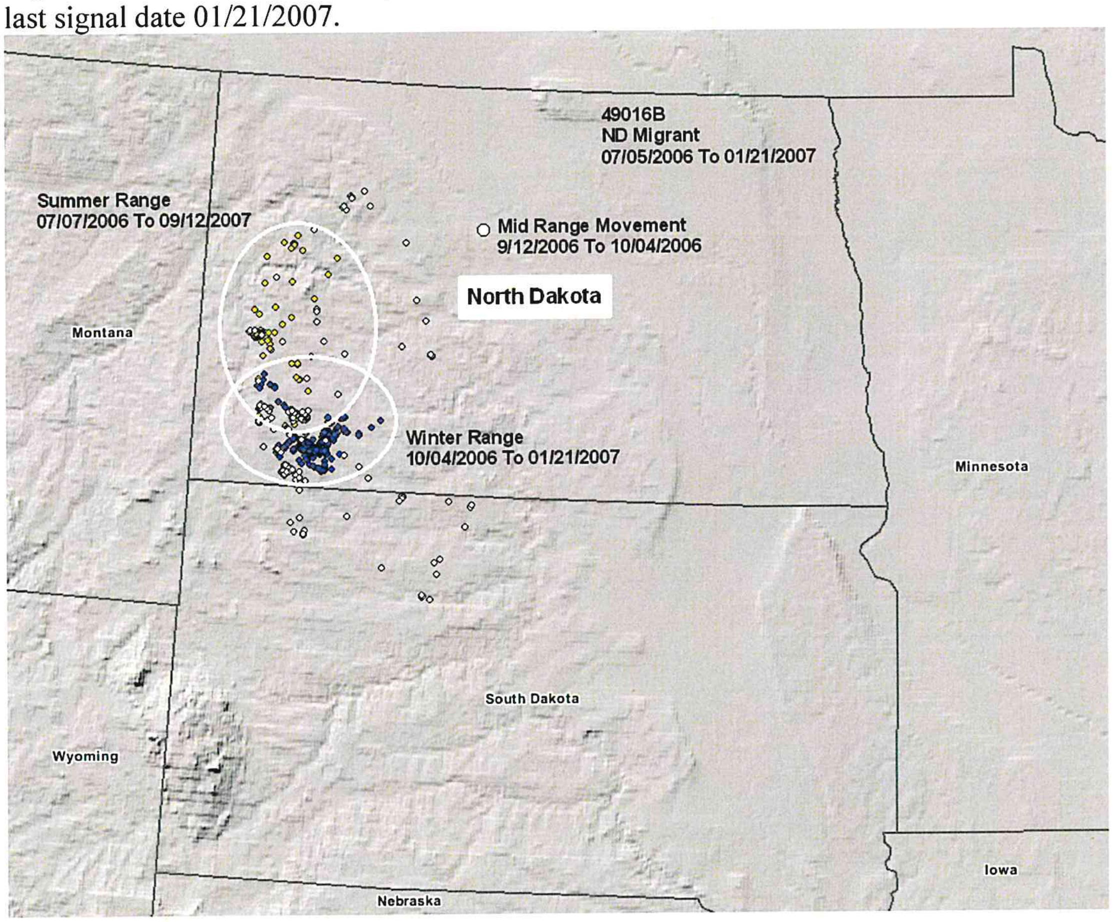


Figure 11. Individual post-fledgling movements. Bird 49007A SD migrant, tagged 07/17/2004 and died 08/30/2005.

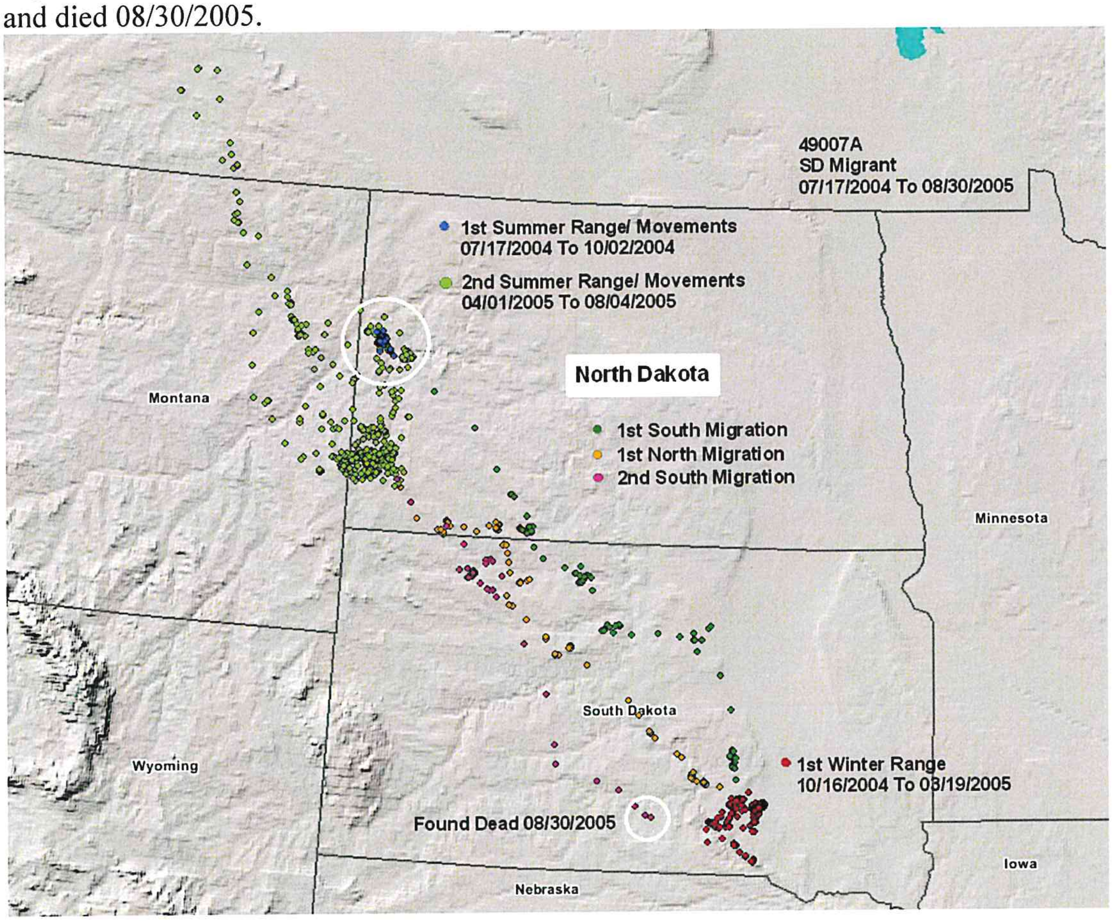


Figure 12a. Individual post-fledgling movements. Bird 49008, for the year of 2004, SD migrant, tagged 07/21/2004, last signal 01/23/2007.

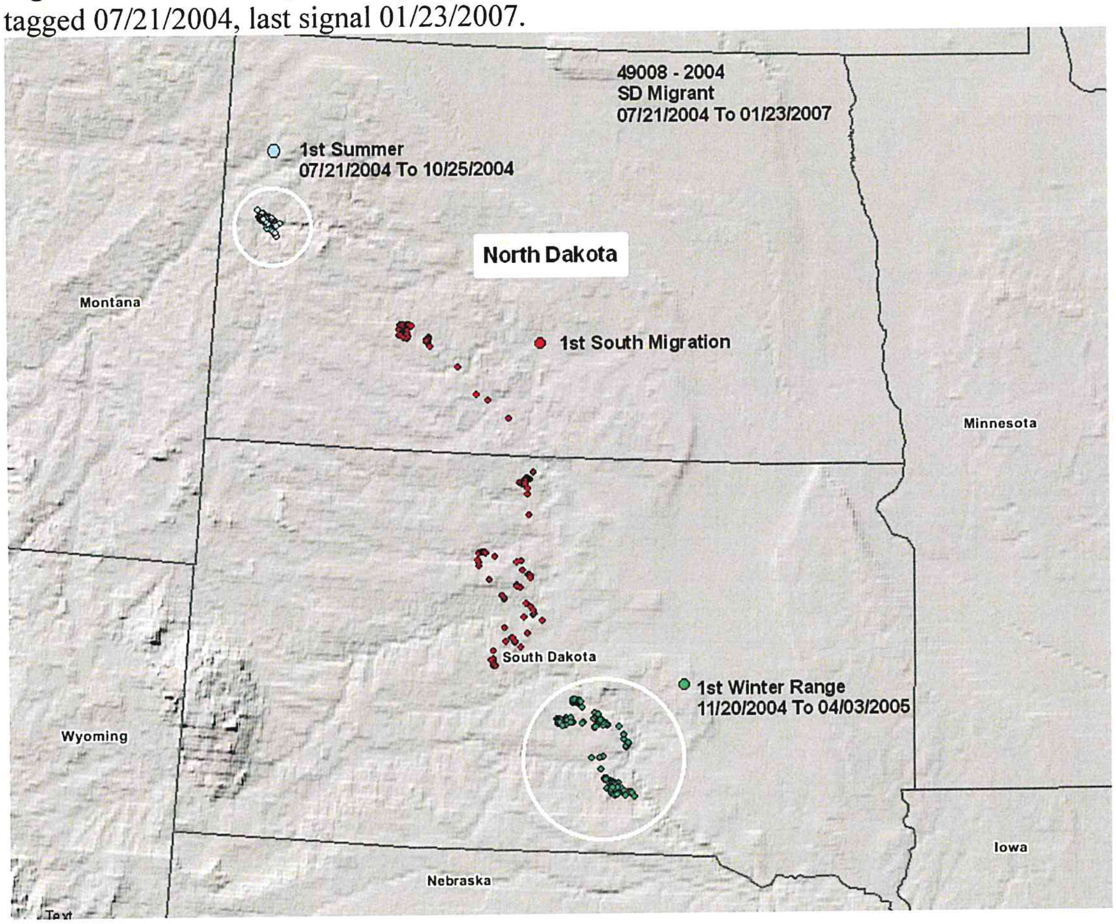


Figure 12b. Individual post-fledgling movements. Bird 49008, for the year of 2005, SD migrant, tagged 07/21/2004, last signal 01/23/2007.

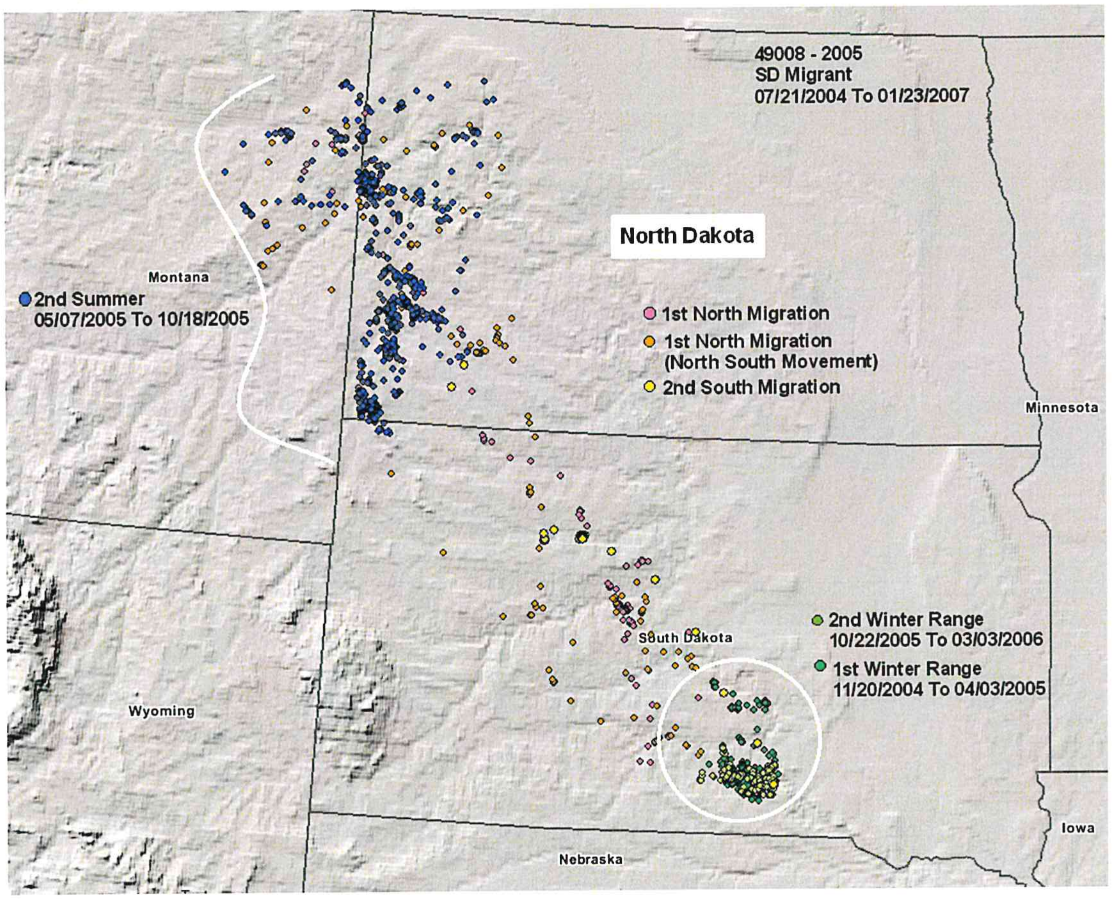


Figure 12c. Individual post-fledgling movements. Bird 49008, for the year of 2006, SD migrant, tagged 07/21/2004, last signal 01/23/2007.

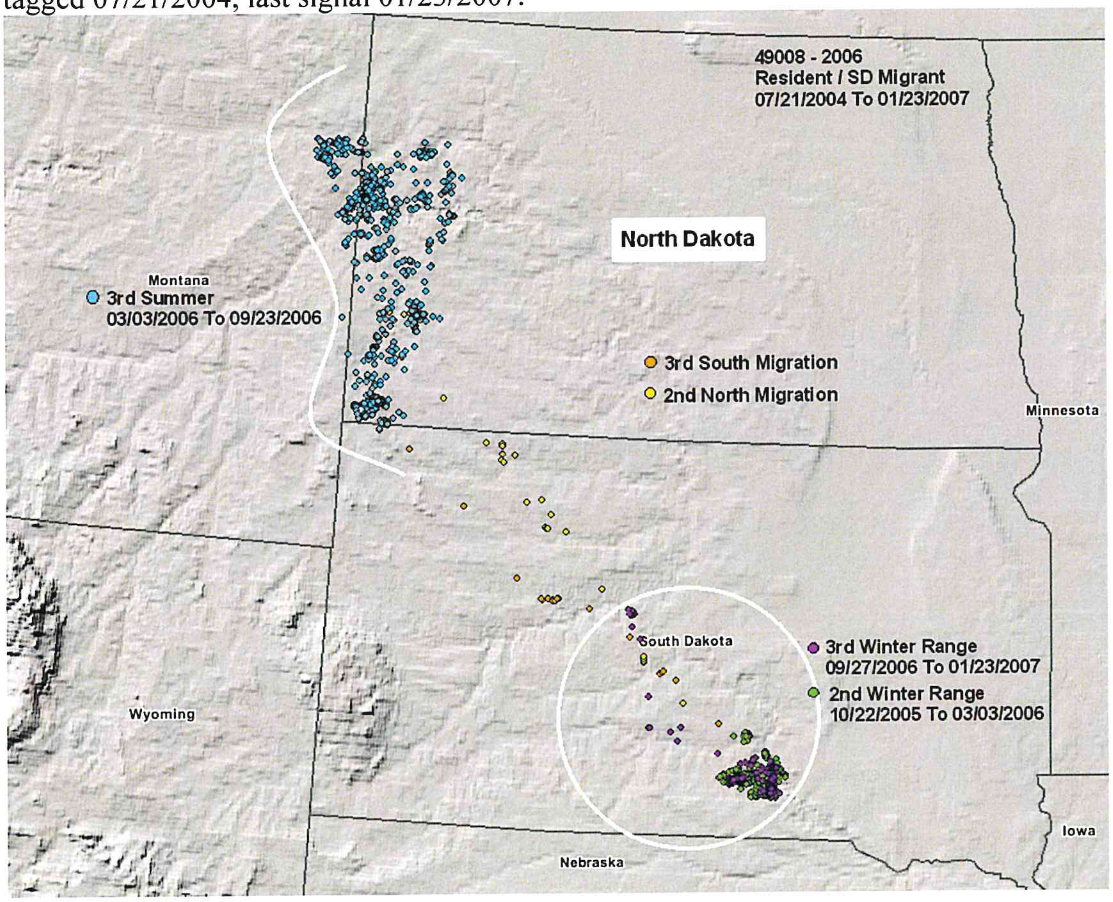


Figure 13. Individual post-fledgling movements. Bird 49009, ND resident, tagged 06/26/2006, last signal 01/21/2007.

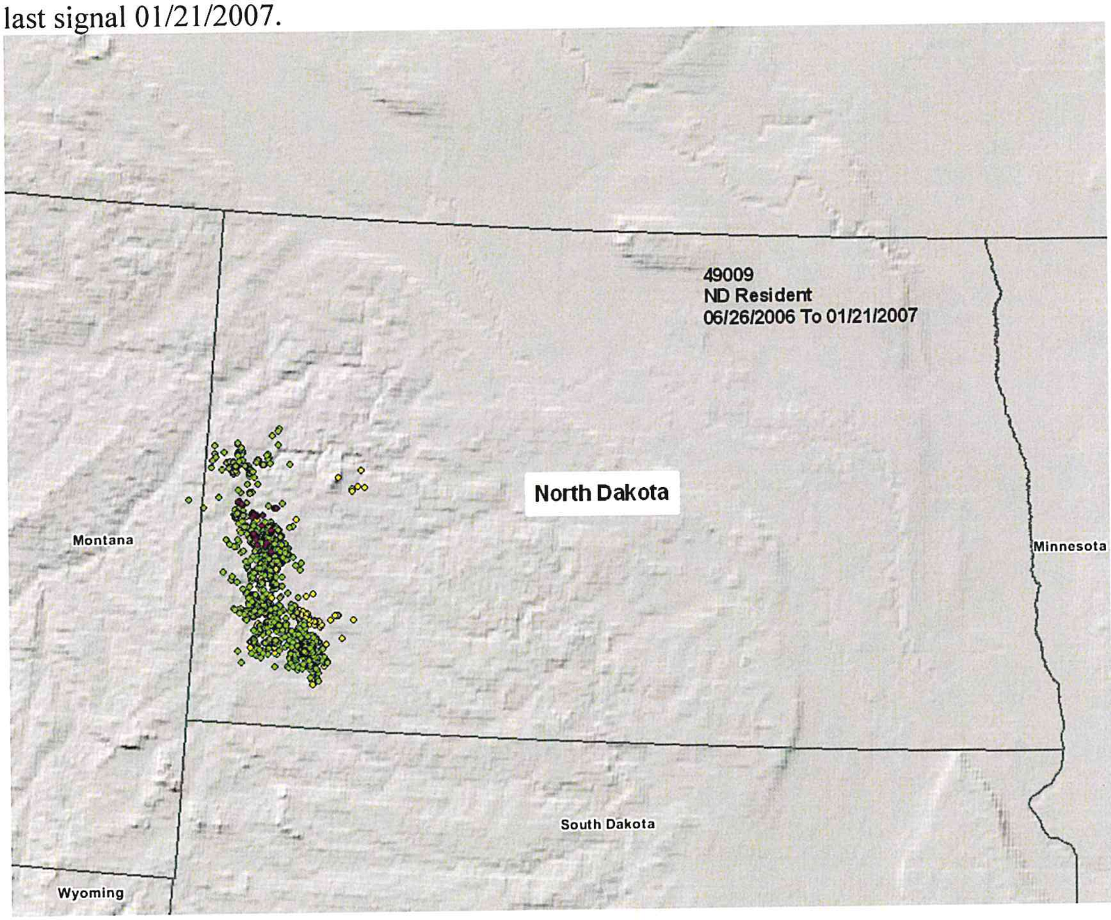


Figure 14. Individual post-fledgling movements. Bird 49010B, ND resident, tagged 07/05/2006, last signal 01/23/2007.

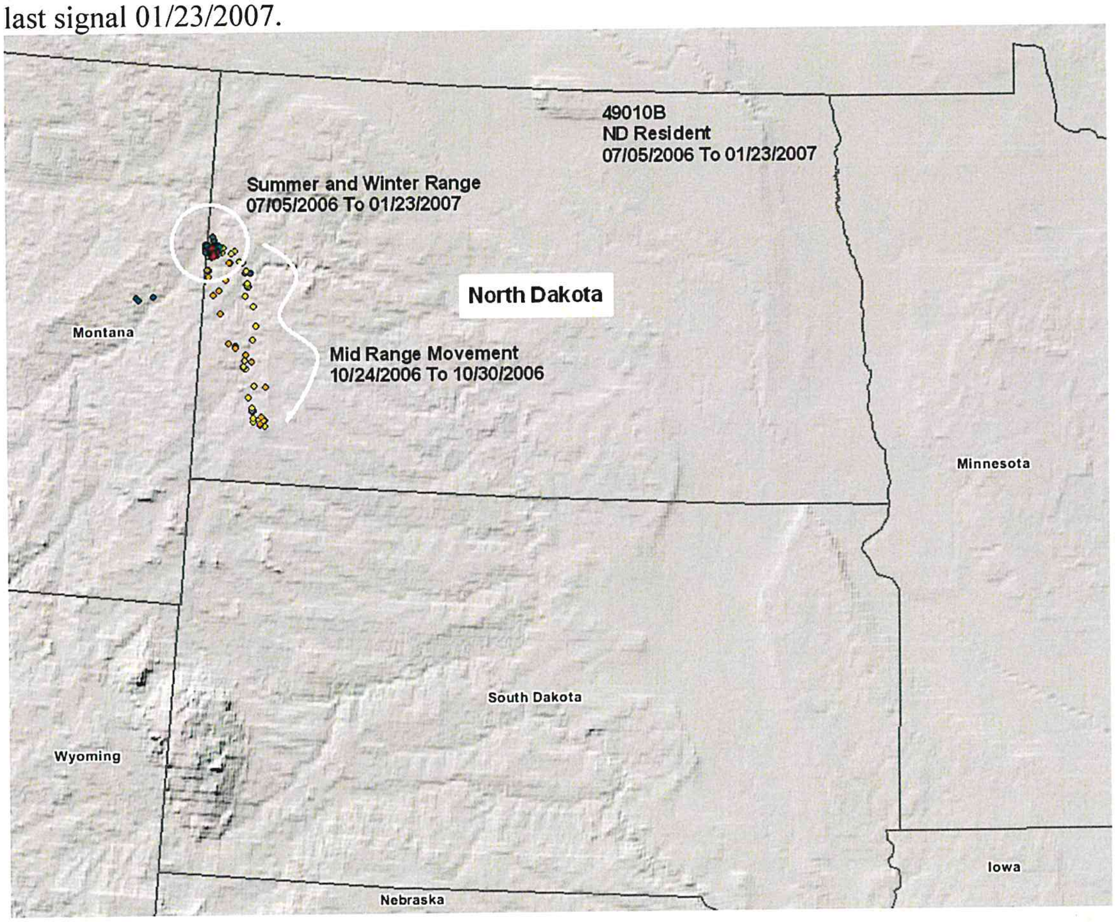


Figure 15. Individual post-fledgling movements. Bird 49001, ND resident, SD migrant, tagged 06/27/2005, last signal01/21/2007.

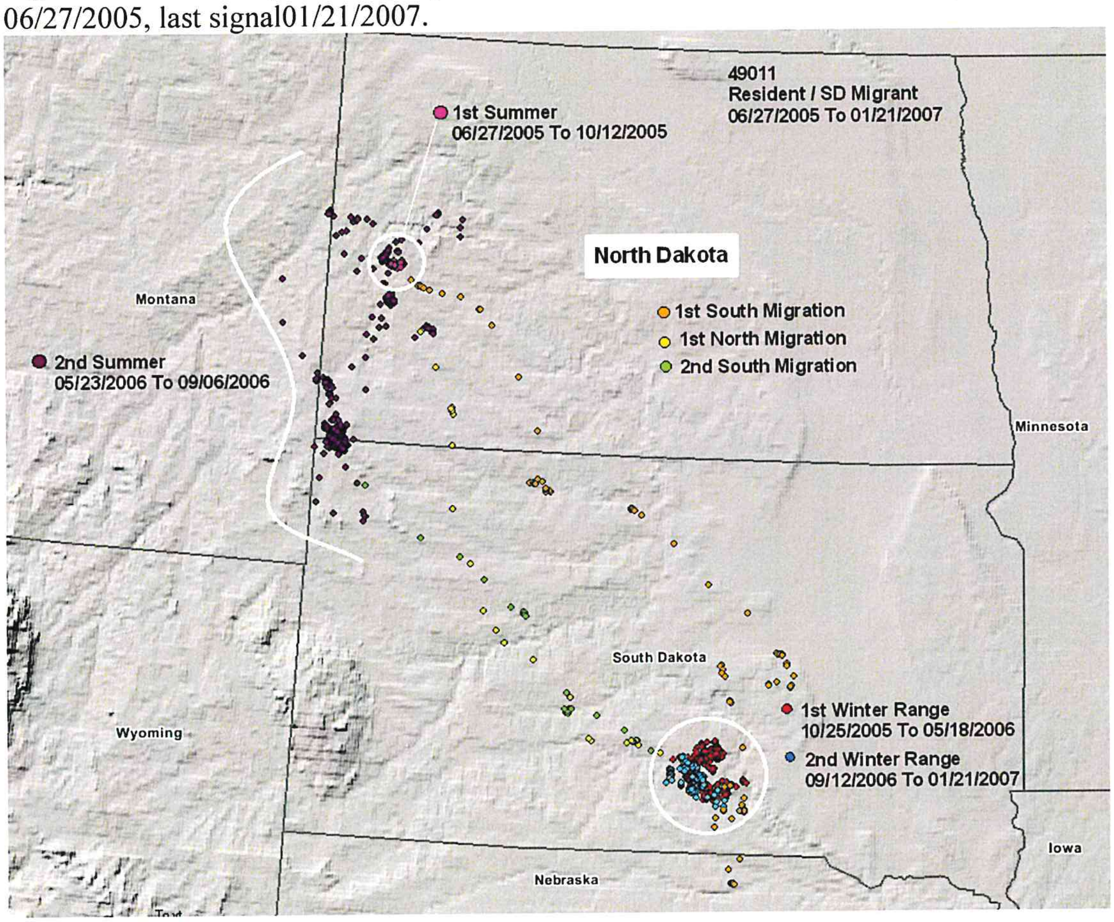


Figure 16. Individual post-fledgling movements. Bird 49013B, ND resident, tagged 07/08/2006, last signal 01/21/2007.

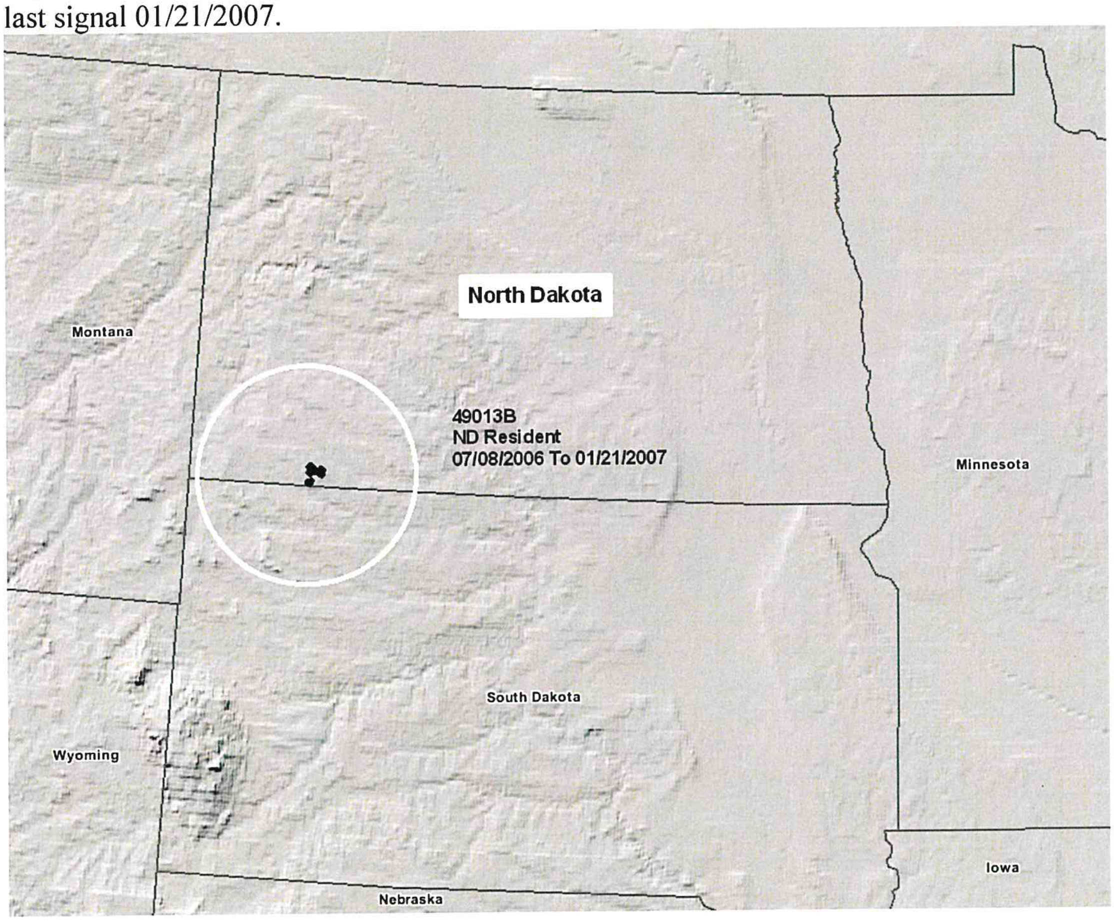
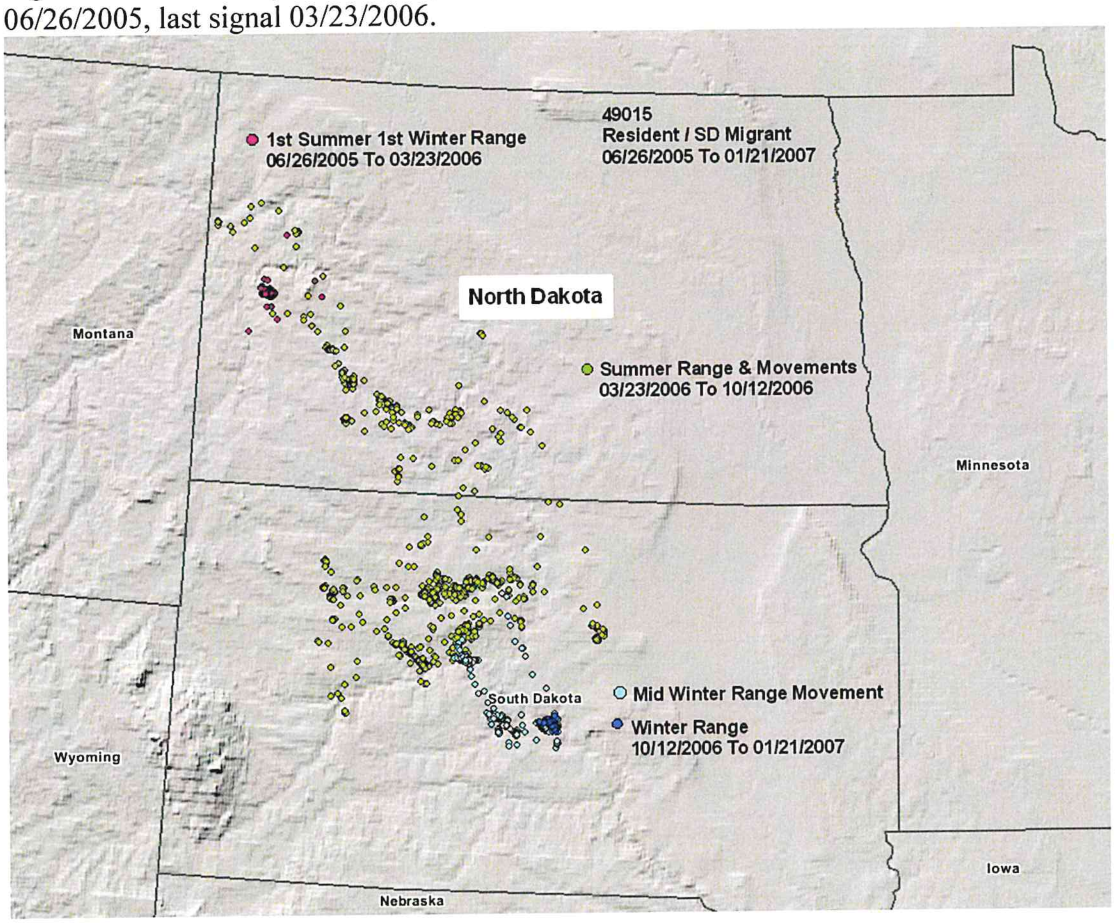


Figure 17. Individual post-fledgling movements. Bird 49015, ND resident, SD migrant, tagged 06/26/2005, last signal 03/23/2006.



DISCUSSION

Nest success and productivity

I was unable to determine actual nest success since I could not survey nests at the time of nest initiation. Furthermore, except for the new nest surveys in 2004, all occupancy data is based on known nests not a comprehensive survey and would not include all nests in an area. Therefore the nest success and productivity over a given area is unknown. However, the results from nest sites determined to be occupied offer information on the success of occupied nest sites.

Mortality

Mortality of fledglings is important for population studies of raptors, and other bird species, to determine recruitment and nest success. Most eagle survey studies determine the success of a nest to be when young birds reach the age of fledging (with adult flight feathers, taking first flights from the nest; Steenhof and Newton 2005). In some cases the nests were only checked twice: once to determine occupancy, adults nesting, incubating and a second to determine success of the young bird's fledgling (Steenhof and Newton 2005). In more extensive studies more visits are conducted. However, if surveys used to gather population information and nest success stop once the birds have fledged we may not have the best information. One reason for this is because post fledging birds are sometimes difficult to locate given the time and money allocated to these surveys, especially in areas with vast expanses and those that include a variety of different land ownerships such as all of western ND. As a result the success of juveniles beyond this point is not well known (Kochert et al. 2002). Secondly, some studies are conducted primarily from the air also making it difficult to determine fledgling accurately. This is because mortalities that are on the ground go undiscovered and if these birds were last seen in the nest with full flight feathers or taking first flights they are many times assumed to be fledged. This is often the case in very rugged remote areas, areas where there are too many nest sites to check or where access onto private land is limited. In these cases productivity and nest success may be overestimated, or properly estimated and dispersal/juvenile success unknown.

Like many studies once the bird reached fledgling stage we assumed success. In 2002 no mortalities were recorded. In 2003 we determined 3 nest failures as a result of natural nest destruction; one cliff erosion in which eggs were lost and two wind induced tree collapses. In the case of the tree falls one chick was lost in each case and the other sibling had already successfully fledged. In addition a local volunteer discovered one nest failed as a result of disturbance from surveyors. The chick was young in natal plumage and the surveyors were close enough to keep the parents off the nest for a couple of hours exposing the chick to harsh weather; resulting in mortality due to exposure. And finally we had one case of undetermined cause of mortality in which both fledged chicks were found dead at the natal nest site at separate times. Because of the difficulty in terrain and the location of many other nests it was impossible to determine the fate of all the fledglings. In 2004 we had three unknown mortalities in which the fledglings were found beneath the nest, wind storms or accidental fall are suspected in all cases. One of the young found beneath the nest had a stick from the nest in its clutches and a broken neck. In 2005 we had a single mortality. The eagle was found stuck in the brush beneath the nest and exhausted. It was delivered to the Dakota Zoo for rehabilitation and died of West Nile. That winter we also received another rehab eagle that was delivered to the University of Minnesota Raptor Center, which died of lead poisoning. In 2006, two fledglings died of undiagnosed disease or poisoning (Table 15).

Mortality was variable over the years. Wind storms did result in mortality; however, it is uncertain if the storm was the primary cause in all cases. In two separate cases we recovered a grounded bird and sent them in for rehabilitation. Both birds tested positive for West Nile (Table 15) and ultimately died from the disease. It is possible that once grounded by the storm the birds became susceptible to West Nile, or possible that they were weakened by the disease and grounded.

Caution does need to be taken with respect to "on foot" disturbance. Survey, researchers, and land activities should follow an aerial biological survey to ensure the ground activities will not interrupt incubation, feedings and cause additional stress to nesting birds.

Diet composition

The diet composition data that I obtained indicates golden eagles are able to feed on many types of species and are opportunistic. Prairie dogs and rabbits were the most common prey items found. There seems to be an association between occupied nest sites and prairie dog towns. Resident eagle may also be taking advantage of these towns given that the dogs provide a local stable food source and do come out during the winter months as well. Although there have been considerable and good efforts made to record the location of prairie dog towns in ND, it has impossible to have collected all possible dog towns throughout the entire range of nesting golden eagles. Therefore with out a comprehensive field survey around each occupied nest to confirm the presence or absence of prairie dog towns we were unable to fully investigate this possibility. Other researchers and surveyors have also mentioned the possible correlation and have recommended further investigation into this possibility (Escano 1981, Knowles 2001). Local land owners, oil workers and birders have noted that adult eagle will use prairie dogs to teach the juveniles how to hunt and maneuver in the air by tossing prairie dogs in the air and letting the juveniles catch them or pick them up from the ground.

Nesting golden eagles appear to do well in providing food for the offspring. It is rare to have nest sites produce three young and I observed two nests successfully fledge three young. Other studies indicate sibling aggression is a result of food limitations (Kochert et al. 2002). I observed no direct aggression between siblings even during feedings and my observations of siblings staying close after leaving the nest site is in agreement with the work of O'Tool et al. in ND (1999).

One interesting behavior that was observed was group hunting. Eagle are thought to be territorial during nesting (Kochert et al. 2002), although they do group hunt as nesting pairs (Collopy 1983). In these hunts the male and female both hunt in "tandem" scanning the landscape for prey, usually with the male leading while the female follows and males attempting more prey captures than females (Collopy 1983). Only two tandem hunt captures were observed one by male and one by the female (Collopy 1983). Eagles also group hunt during winter migration and have been known to scavenge on carcasses together (Kochert et al. 2002). I had 8 separate groups of three or four adult golden eagles grouped. Each group was located with in an occupied territory. The groups were observed hunting in tandem wing tip to wing tip back and forth at tree top level or lower. I observed this multiple times over multiple years. In one area all three pairs from three neighboring occupied territories grouped up and were located above one of the occupied nest sites perched in a row along the ridge. I never observed a successful hunt to know how the birds respond to one another once a prey item is obtained. However, no aggression was ever observed between the adults. I have spoken to other raptor biologist and have found no other accounts of such behavior (per comm. Brian Latta, Predatory Bird Group Santa, Cruz CA, Dan Svingen, USFS-DPG, Bismarck ND).

Post fledgling movement and migration

Migration and post fledging movements of golden eagles differs depending on region. In Scotland golden eagles do not migrate and only expand their territory range during the winter (Watson et al. 1992). Yet other populations in Alaska (McIntyre and Collopy 2006) and Québec (Brodeur et al. 1996) that have used similar GPS tracking technology to this study have also identified migration and post fledging movements. The post fledging movements of juvenile confirm that some birds do remain in the state on or around their natal areas (Figures 13 and 16), this finding is similar to observations in Scotland (Watson et al. 1992). Some of these residents appear to attempt or have a major movement around the same time a migration would be expected (Figures 14), while other appear to migrate a very short distance and set up a new winter range (Figure 10). Other birds migrate and over winter in to the southern portion of South Dakota (Figures 11, 12, and 15,). The timing of the movements and migration of juveniles from this study are similar to both studies from Alaska and Québec. They begin departing from their natal grounds in September and October and returning in March – May. However, the patterns are not always consistence for each bird. One bird remained in ND the first winter and migrated the second (Figure 17). It is uncertain what is driving the movements and whether the juveniles are following the parents.

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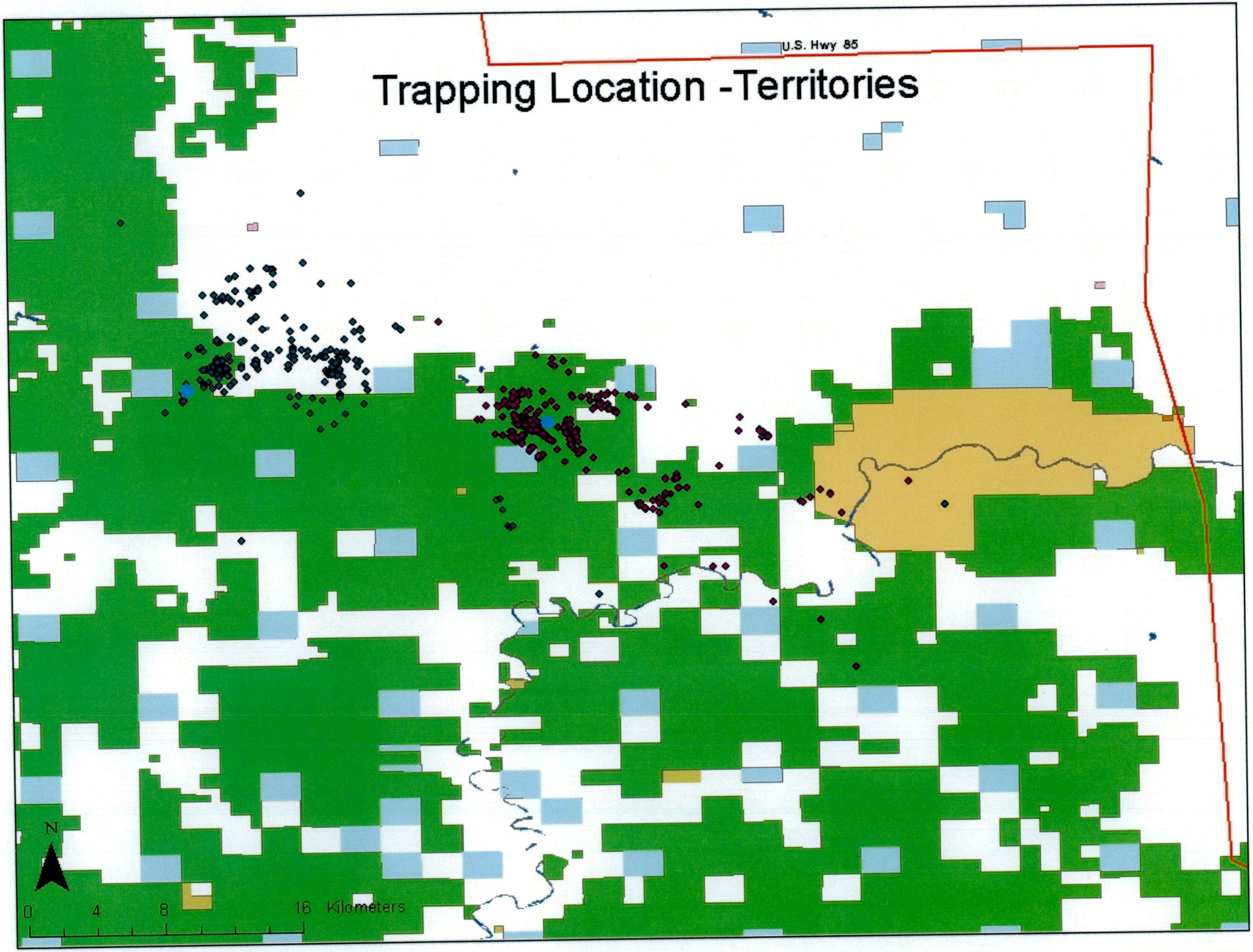
Appendix A: Collection log for tagged and dead golden eagles.

Report Number	*GPS Transmitter Number*	*Date Recovered*	*Land Ownership Recovered*	*Condition Recovered*	*Comments*	*Type of Location Method*
GED0-06262003	NA	2003	USFS	Dead-dried	Found while on a USFS staff field trip.	Ground Find
GERHD1-06262003	NA	6/26/2003 2:00pm	ND State School Land	Alive - sent to rehab - ND Zoo - Died	Found stuck in the mud below nest: nest had fallen and bird was sent to ND zoo for rehab.	Ground Find
GED2-07142003	NA	2003	USFS	Dead - Nest and chick blown down fairly recent!	Chick found under fallen nest. Wind storm	Ground Find
GED3-08292003	NA	2003	USFS	Dead-Dried	Unknown found while on BTPD surveys. Later second chick also found dead? Unknown cause?	Ground Find
GED4-08292003	NA	2003	USFS	Dead-Dried	Found while recovering first chick this second chick was also found dead.Cause unknown.	Ground Find
GED5-07262004	NA	2004	USFS	Dead-Dried	Appears to have fallen from nest branch in talons. Young juv. Found when trapping other young.	Ground Find

Report Number	*GPS Transmitter Number*	*Date Recovered*	*Land Ownership Recovered*	*Condition Recovered*	*Comments*	*Type of Location Method*
GED6-08062004	NA	2004	Private Conservation Plots Land	Dead	Found under tree.	Ground Find
GERHD7-07262005	NA	2005	USFS	Alive - sent to rehab - Univ. Minn - Died	This bird was found alive and sick - was sent to the Univ. of Minn. Raptor Center. Later Died of West Nile. The birds case number is 05-435 they sent the bird to the repository and will send us the Necropsy.West Nile	Ground Find
GED8-07282005	NA	2005	USFS	Dead dried	Found Dead At site juvenile dried either from last year assumed; or from another nest this year? Below nest site/ below tree - wind storm or west Nile or another eagle?	Ground Find
GED9-49016-08102005	GE49016	2005	USFS	Good	Below nest site in ditch (after wind storm) stuck in mud	Ground Find
GED10-49014-08262005	GE49014	2005	USFS	Fair-dried and torn	On hill side west of nest site (West Nile?) head detached another eagle or scavenged?	Taerial location of radio transmittion and then on third try: Ground Find

Report Number	GPS Transmitter Number	Date Recovered	Land Ownership Recovered	Condition Recovered	Comments	Type of Location Method
GED11-49010-09282005	GE49010	2005	Private	Dead dried	On hill side dead: cause unknown	Ground Find
GED12-49012-10022005	GE49012	2005	Private	Fair dried and torn	On hill side above nest site (West Nile?)	Ground Find
GED13-49013-03142006	GE49013	Found by plane and ground 3/14/2006	Private	Dead	Found under power pole by water tank: likely electrocuted	Plane/Ground Find
GED14-49007-06102006	GE49007	9/16/2005 - Plane located 6/10/2006 - Ground collected	Private - Corn Field, SD	Dead disked field	Unknown	Arial location on radio transmittion: ground find later after federal agent allowed us into the area: they had recon going on so we had to wait.
GED15-06132006	NA	2006	USFS	Dead	Found Dead: at nest site probably this year.	Ground Find
GED16-49014-07262006	GE49014	2006	Private Conservation Plots Land	Dead	Juvinile fount near buildings cause of death unknown.	Ground Find
GED17-07272006	NA	2006	USFS	Dead	Dead and dried looks like from a previous year, juvenile.	

Report Number	***GPS Transmitter Number***	***Date Recovered***	***Land Ownership Recovered***	***Condition Recovered***	***Comments***	***Type of Location Method***
GED18-08082006	NA	2006	USFS	Already dead; sibling died while recovering transmitter.	Most likely died of illness/poison ? when applied transmitter sibling was very lethargic and not very responsive.	Ground Find
GED19-49007-08082006	GE49007	2006	USFS	Died while recovering transmitter; sibling already dead.	Most likely died of illness/poison ? when applied transmitter very lethargic and not very responsive.	Ground Find
GED20-49012-12052006	GE49012	Ground recovery 12/5/2006	Private/Road-side easement	Good	Death unknown	Ground/Aerial



Trapping Location -Territories
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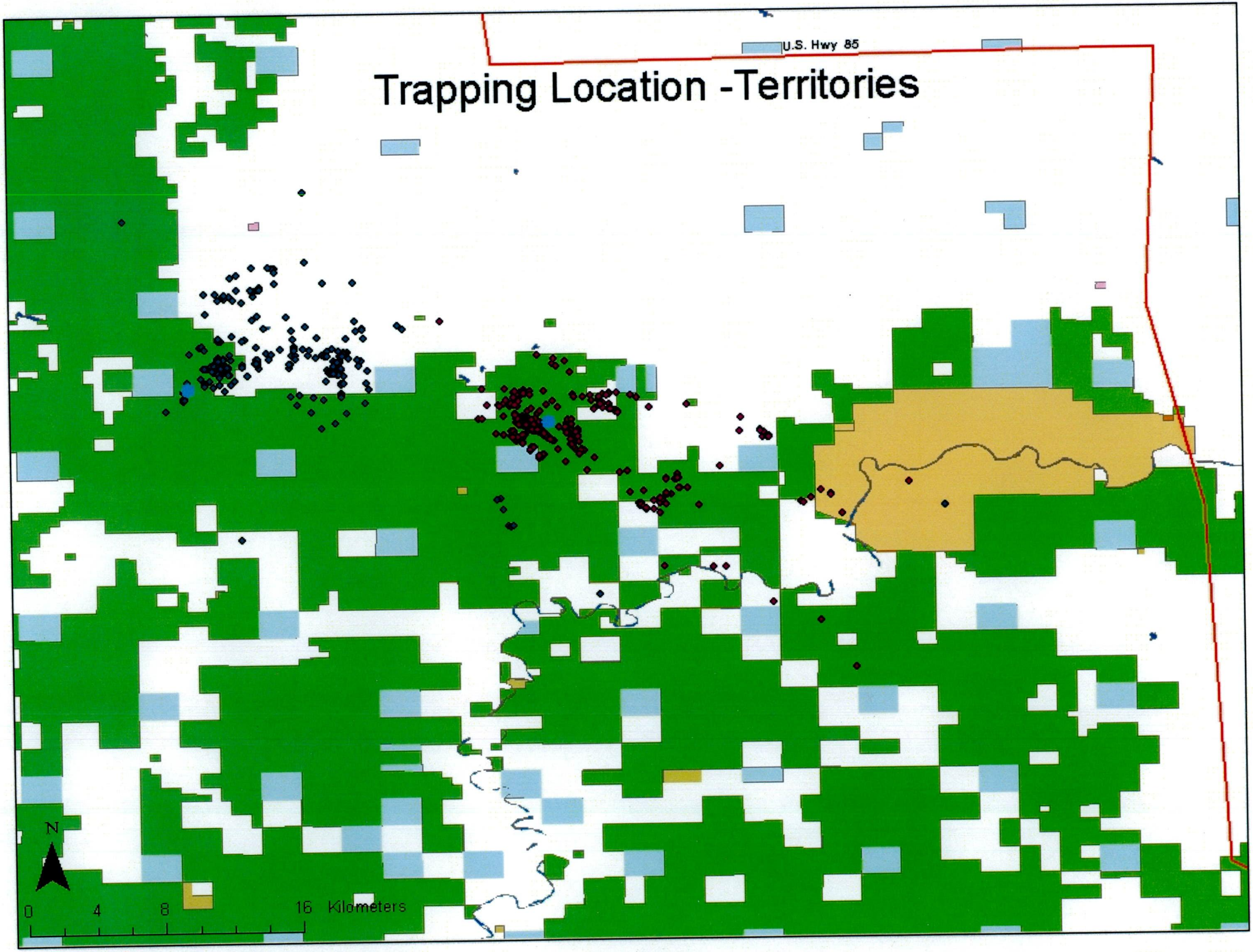
N
0
4
8
16 Kilometers



Trapping Location -Territories
U.S. Hwy 85
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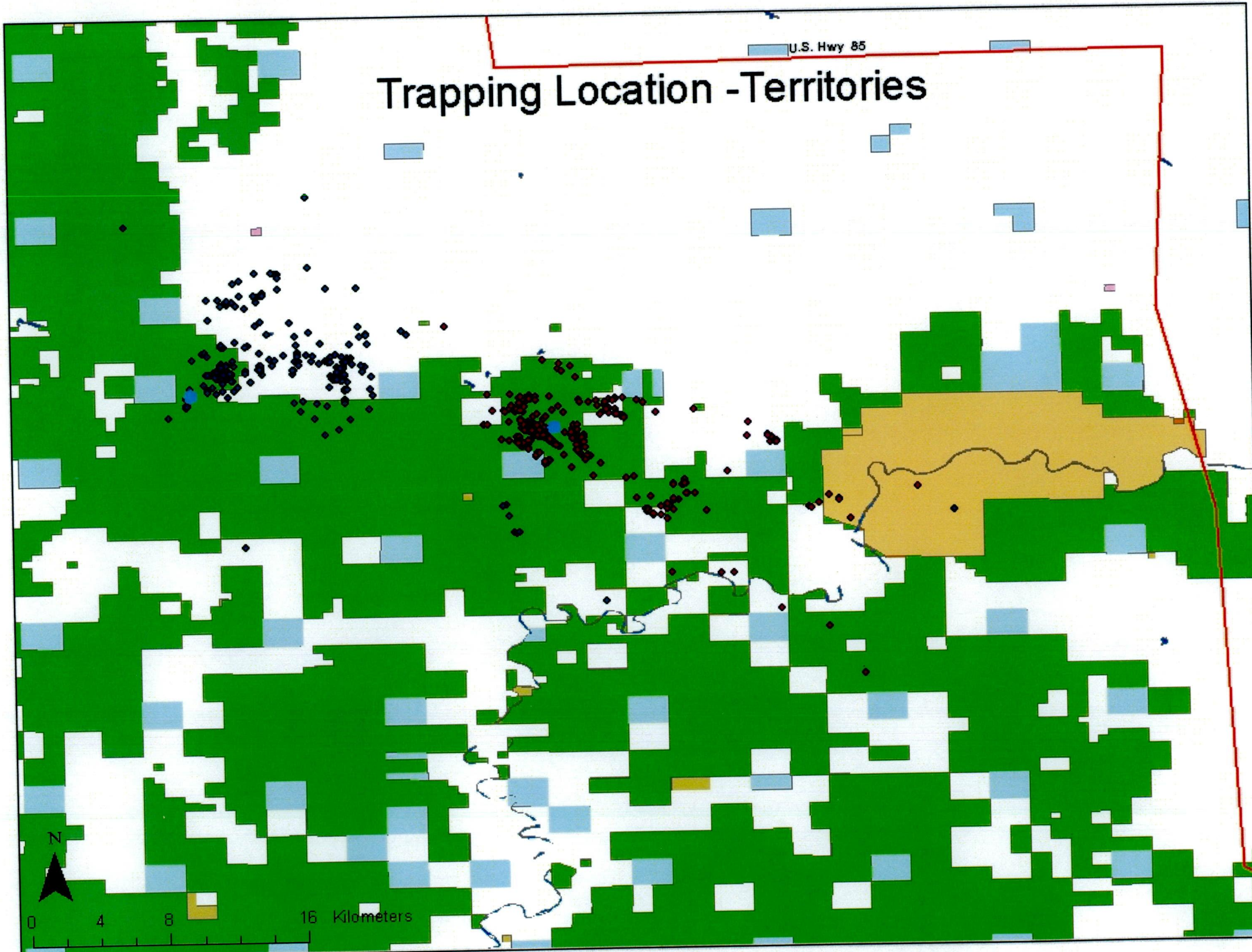

Trapping Location -Territories
U.S. Hwy 85
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