

# Environment and Natural Resources Trust Fund

## Research Addendum for Peer Review

Project Manager Name: Erika Butler

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Project Title: Determining causes of death in declining moose population

Project number: 009-A1

### ABSTRACT

Minnesota's moose are dying at rates much higher than elsewhere in North America. Moose numbers in northwestern (NW) MN have plummeted from over 4,000 to fewer than 100 animals in just the past 2 decades and recent studies of moose in the northeast (NE) suggest this population is also declining, albeit at a less precipitous rate. Recent study of the NE moose herd reported non-hunting mortality rates of 15-26% per year, which was significantly higher than for other northern moose populations (8-12% per year) outside of MN. The specific causes of non-hunting mortality remain unknown as this information has not been identified as a research priority in past or ongoing research. This study will determine cause-specific mortality by deploying GPS collars on 100 moose in NE Minnesota and by preparing an extensive network of responders highly trained in conducting field necropsies. Moose mortalities will be thoroughly investigated within 24 hours of death to identify the proximate cause of mortality and to examine the influence of potential contributing factors. Specifically, the influence of nutrition on moose survival and cause-specific mortality is unclear and will be evaluated via indicators of nutritional stress (i.e., urine chemistries and ultrasonic measurements of rump fat). Once causes of death and major influential factors are identified, appropriate management actions may be taken to address the population decline.

### BACKGROUND

Historically, moose were found throughout the forested zone of northern Minnesota. By the 1960's there were two distinct populations, the NW population of the aspen parklands and NE population of the boreal forest (Fuller 1986). In the mid-1980's the NW population began a precipitous decline, falling from 4,000 to <100 animals (Murray et al. 2006, Lenarz 2007). Murray et al. (2006) identified pathogens, including liver flukes (*Fascioloides magna*) and brainworm (*Paralaphostrongylus tenuis*), as the principal cause of death for 37-62% of radio-collared animals; 25% of additional mortalities were likely pathogen-induced, but limited necropsy evidence was inconclusive. They also observed that many moose in NW MN dying of natural causes were malnourished, as evidenced by 51.4% of carcasses having bone marrow fat (BMF) contents below a critical threshold (< 30%) and trace mineral deficiencies (i.e., copper and selenium). No age or sex effects were identified.

Subsequently, in NE MN, Lenarz et al. (2009) reported an average non-hunting mortality rate for radiocollared males and females of 21% (15-26%), which was much higher than the 8-12% reported for moose elsewhere in North America (Larsen et al. 1989, Ballard 1991, Kufeld and Bowden 1996). Estimates of survival and fertility suggest the NE moose population is declining, with a possible long-term annual decline of as much as 33% (Lenarz et al. 2010). Although most aerial survey results from 2005 to 2010 do not show a statistically significant decline, (Lenarz 2010), other measurements of herd productivity, including calf:cow ratios, calving rates,

twinning rates, and hunter-success rates are also decreasing (Lenarz 2010). Anecdotal reports from local residents also indicate fewer moose in NE MN. Specific causes of most of the non-anthropogenic mortality (89%) could not be determined, as assessing cause-specific mortality was not the primary objective of the study (Lenarz et al. 2009). Many of the deaths appeared health-related, with prime age animals dying during unusual times of the year or carcasses found intact with little evidence of scavenging. Butler et al. (2010) documented evidence of exposure of NE MN moose to a variety of disease agents (e.g., West Nile Virus, eastern equine encephalitis, malignant catarrhal fever), which could be potential mortality factors. Additionally, sick moose reported by the public have been found to be infected with a variety of disease agents, including brainworm, liver flukes, arterial worm (*Elaeophora schneideri*), and possibly *Setaria* sp. (Minnesota Department of Natural Resources [MNDNR], unpublished data). Brainworm and arterial worm are known mortality factors of moose (Anderson 1964, Worley et al. 1972, Pessier et al. 1998). Researchers have hypothesized that brainworm was responsible for historic declines in moose populations (Karns 1967, Prescott 1974, Lankester 1987), but it is questionable whether brainworm represents a major threat to the NE MN population; clinical signs consistent with brainworm infection were first reported in MN moose in 1912 (Fenstermacher and Olson 1942). Lenarz et al. (unpublished data) found that brainworm may have caused an average 19% (0-32%) of the population's total annual mortality.

The relationship between diseases, parasites, and nutritional restriction of ungulates can be very complex, and moose numbers may be influenced by interactions among these factors (DelGiudice et al. 1997). All can act either singularly or in concert to negatively affect survival. Poor body condition, potentially related to nutritional deficiencies, was reported in some NE MN moose (Lenarz et al. 2009). Using ultrasonographic measurements of rump fat and body condition scoring, DelGiudice et al. (2010) found that 21.1% of radiocollared adult females may have been seriously challenged by poor condition in 2003. A strong relationship exists between maximum depth of rump fat (Maxfat) and ingesta-free body fat (IFBF) of moose; when rump fat is depleted, IFBF is no more than 5.6% (Stephenson et al. 1998). Cook et al. (2004) reported that the probability of winter survival for northern Yellowstone elk with at least 5.0% IFBF during February-March was good to excellent. Urine collected from snow (snow-urine) can be chemically analyzed for urea nitrogen (UN), potassium (K), and creatinine (C). Urinary UN:C and K:C ratios have been used to assess the degree of nutritional restriction and endogenous protein catabolism in Isle Royale moose (DelGiudice et al. 1997) and Yellowstone elk (*Cervus elaphus*) and bison (*Bison bison*) (DelGiudice et al. 2001). (DelGiudice et al. (1997) showed that UN:C data indicated abnormally severe nutritional restriction in a high proportion of moose from 1988 to 1990, coinciding with a 26% decline in the population, and they reported a negative correlation between population rate-of-increase and UN:C ratios, suggesting that nutritional restriction and an associated winter tick (*Dermacentor albipictus*) infestation may have contributed to the population decline on Isle Royale during 1988-1990. Assessment of body condition at the individual and population levels is essential to better understand relations of seasonal heat stress, body condition, habitat use, demographic parameters and performance of this population (DelGiudice et al. 2010).

The primary goal of this project is to improve our understanding of non-anthropogenic (i.e., health-related) mortality of the NE MN moose population. Our objectives are to determine causes of non-hunting mortality (i.e., identify specific disease and parasite agents), assess the role nutrition plays as a contributing factor, and assess the nutritional status of the population at large. Our hypotheses are:

H<sub>1</sub>: Health-related causes (pathogens) of mortality are primarily responsible for the non-anthropogenic mortality affecting the survival rates of moose in this population.

H<sub>2</sub>: Seasonal nutritional restriction and deterioration of body condition is a biologically significant factor interacting with pathogens and negatively impacting the survival of moose in NE MN.

Additionally, we will use these data to test the following predictions based on findings from Lenarz et al. (2009, 2010):

- Overall annual survival of moose in the NE MN population is lower than the average reported for moose elsewhere in their continental range.
- Non-anthropogenic mortality is having a greater impact on the overall annual survival of moose than human-related causes.
- Seasonal mortality rates of adult moose will be highest in late winter-early spring, but consistent with Lenarz et al. (2009), will be higher than expected (i.e., compared to reports elsewhere in the continental moose range) during non-winter months.
- Annual mortality rates will be consistent with regression predictions (Lenarz et al., 2009) of higher mortality rates (likely health or nutrition-related) associated with higher winter temperatures.
- Non-anthropogenic mortality rates of adult moose will be affected by age.

## METHODOLOGY

### Study Area

We will be radiocollaring and monitoring moose within a 3,732.8 km<sup>2</sup> study area located between 47°12'N and 47°95'N latitude and 90°33'W and 91°72'W in NE MN (Figure 1).

The study area is classified as the Northern Superior Upland region (MNDNR 2007), and includes a variety of wetlands (e.g., bogs, swamps, lakes, streams) and multiple species of conifers, such as northern white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*) in the lowlands and balsam fir (*Abies balsamea*) and jack (*Pinus banksiana*), white (*P. strobes*), and red pines (*P. resinosa*) in the uplands. Deciduous trees, including quaking aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*) are intermixed with conifers on uplands. Potential predators of moose include wolves (*Canis lupus*) and black bears (*Ursus americanus*).

Annual moose hunting occur within the study area, with limited numbers of tags issued to State and Tribal hunters. Approximate moose densities within the study area are 0.02–0.08 moose/km<sup>2</sup> (MNDNR, unpublished data).

### Moose Capture and Handling

In February 2012, we will capture 100 moose (75 females, 25 males) by aerial darting with carfentanil (0.01 mg/kg) from a helicopter; immobilizations will be reversed with 1 mg/kg of naltrexone (Kreeger and Arnemo 2007). Blood (serum and whole blood) will be collected at capture by venipuncture of the jugular vein. Serum will be screened for evidence of exposure to 21 disease agents (Table 1) following the same protocol as described by Butler et al. (2009). Additionally, serum will be analyzed for chemistries, metabolic and reproductive hormones (i.e., progesterone) to assess physiological status, overall health, and pregnancy status (Franzmann and LeResche 1978, Haig et al. 1982, Duncan et al. 1994). We will prepare smears from whole blood for complete and differential blood cell counts, which may be indicative of condition and health status (Duncan et al. 1994), and for screening for tick-borne illness. We will remove an incisor for aging by cementum annuli (Sergeant and Pimlott 1959). A general fecal floatation examination for parasites will be performed, as well as a culture for *Mycobacterium*

*paratuberculosis*. We will catheterize female moose for urine; specimens will be analyzed for UN, C, and K (DelGiudice et al. 1997), and we will measure rump Maxfat (cm) by ultrasound to assess body condition and nutritional status (Cook et al. 2010, DelGiudice et al. 2010). A thorough physical examination will be performed, including assessment of winter tick load and hair loss. We will measure total body length and hind leg length (cm) (Franzman et al. 1978) and use them to estimate body weight of moose and to standardize estimates of IFBF from Maxfat (Stephenson et al. 1998, Cook et al. 2010).

We will fit moose with Global Positioning System (GPS) radiocollars which function with Iridium satellites (C. Kochanny, Sirtrack, personal communication). We will program collars to obtain a location once daily. Battery life of 3-4 years is expected. Collars include a mortality signal triggered by a motion-sensitive switch. In turn, the mortality signal will trigger a text message to be sent to the research team, alerting us that the moose has died, and including carcass (i.e., collar) location (GPS coordinates).

To maintain our annual starting sample size at 100 moose, in 2013 and 2014, we will capture (using the same capture and handling protocols) additional moose to replace those that have died during the previous year. Collars collected from dead moose will be refurbished at a reduced cost and redeployed on new study animals.

### **Mortality Investigation:**

A team of highly trained responders (e.g., biologists and veterinarians) will be stationed throughout NE MN. An on-call schedule will be developed with a minimum of 3 responders per moose mortality notification; these responders will investigate mortalities within 24 hours of receiving the mortality text message. We will make every effort to remove the entire carcass intact and submit it to the Veterinary Diagnostic Laboratory (VDL) at the University of Minnesota, where it will be thoroughly examined by board-certified veterinary pathologists. When carcasses cannot be removed intact, we will perform a complete field necropsy. Tissue samples from all of the major organs (including the eyes and the entire brain) will be collected and samples will be split between preservation methods (formalin and chilling) and submitted to the VDL as soon as possible for a full diagnostic work-up.

### **Population Level Assessment of Winter Nutritional Restriction**

We will collect snow-urine samples within 24-48 hours of a recent snowfall at least 3-4 times during each winter throughout the study area. Samples will be chemically analyzed for UN, C, and K. Actual values, changes, and trends of UN:C and K:C ratios will allow us to assess and make temporal and spatial comparisons of nutritional restriction of moose, while physiological modeling will further permit us to assess body condition over space and time at the individual and population levels (DelGiudice et al. 1997, 2001; Moen and DelGiudice 1997).

### **Statistical Analysis**

Cause-specific mortality rates will be estimated using cumulative incidence functions (CIFs) to account for left-truncation (DelGiudice et al. 2002, Heisey and Peterson 2006).

Cox Proportional Hazard Models will be used to examine if covariates measured at the time of capture (including body mass, blood and urine constituents, and rump fat) are associated with survival. Moose with slipped collars or lost signals will be censored from analyses. Linear regression will be used to characterize the relationship between female age and estimated body mass and to model blood and urine characteristics as a function of age and body mass. Lastly,

we will apply the same methods as Lenarz et al. (2009, 2010) to estimate annual survival rates, non-anthropogenic mortality rates, and to test the predictions outlined in the Background section regarding relationships between age and ambient temperature versus annual and seasonal survival rates.

## **RESULTS AND DELIVERABLES**

The results of serological screening for diseases; serum analyses for pregnancy testing, chemistry profiles, and metabolic hormones; and complete and differential blood cell counts will quantify rates of exposure to diseases, pregnancy rates, and assist with assessment of overall health and physiological status. We will assess these results relative to seasonal and annual survival and cause-specific mortality rates.

Specific causes of death of collared moose that die during the study period will be determined, contributing to our understanding of the role health-related mortalities are playing in the overall decline of the NE MN moose population. Once the specific causes of mortality and major influential factors (i.e., nutritional condition, seasonal weather conditions) are identified, appropriate management actions may be taken to address the population's decline. For example, if parasites such as liver flukes and brainworm are responsible for the moose decline, steps (e.g., reducing deer population, prescribed burns) may be taken to mitigate the life cycle of these parasites.

Nutritional status and overall health of collared animals and the moose population at large will be assessed as winters progress. Conclusions will be formulated about the nutritional condition, health, and overall well-being of moose at the start of winter, as well as how progressive winter nutritional stress and poor condition of moose may be contributing to specific causes of death. If nutritional status is identified as a contributing factor to moose mortality and population decline, then management efforts can be focused on enhancing forage quantity and quality.

The primary goal of our 3-year study is to thoroughly investigate the causes of non-anthropogenic mortality of adult moose in northeastern Minnesota by an unprecedented field approach and comprehensive data collection methods. However, our study design also will allow us to re-examine and extend survival relationships reported by Lenarz et al. (2009, 2010). After a 6-year study of adult moose in NE Minnesota, Lenarz et al. (2009) documented lower annual survival rates (relative to non-anthropogenic sources of mortality) of moose compared to populations ranging farther North. They also reported several significant inverse relationships between annual and certain seasonal survival rates and increasing ambient temperatures, and they observed higher mortality rates than expected during non-winter months. By way of these findings, climate change has been implicated as a potentially significant factor influencing the decline of Minnesota's NE moose population (Lenarz et al. 2009, 2010). The additional survival data generated from our study and re-examinations of survival-ambient temperature relationships, coupled with the behavioral data and habitat needs identified by the current moose study of Moen (2009), will provide insight into whether the statistical relationships previously reported are real and ecologically significant, or erroneous, perhaps attributable to limited sample sizes and data collection over a relatively brief period of time. Coupling our improved understanding of how climate, diseases, and parasites may be influencing the population performance of this large, popular native megafauna with findings of moose behavior and habitat research conducted by the Natural Resources Research Institute (and previously funded by the LCCMR) will be key to the development of future population and habitat management strategies. Sharing what we conclude from these expanded data analyses and the information synthesized at professional meetings and through publication in peer-reviewed,

scientific journals will likely expand the value of the study to other geographic regions, as well as to the scientific study and management of other species.

#### **TIMETABLE**

February 2012- Capture 75 female moose and 25 male moose.

February 2013- Capture moose to maintain sample size at 100.

February 2014- Capture moose to maintain sample size at 100.

March 21, 2015- Formulate conclusions about the nutritional condition, health, and overall well-being of moose at the start of winter.

June 30, 2015- Determine specific causes of death of moose that die during the study period; quantify rate of exposure to disease and toxicity and deficiency levels; formulate conclusions about how progressive winter nutritional stress and poor condition of moose contributed to specific causes of death.

February 2017-Recover remaining collars and summarize cause-specific mortality of animals that remained on the air beyond 2015.

#### **DISSEMINATION AND USE**

Annual research summaries addressing accomplishments to date will be written and available on the DNR website. Descriptive reports/articles will be written and submitted for publication in peer-reviewed publications, such as the Journal of Wildlife Diseases.

## BUDGET

<b>Determining Causes of Death in Declining Moose Populations Project Budget</b>		
<b>IV. TOTAL TRUST FUND REQUEST BUDGET (3 years)</b>		
<b>BUDGET ITEM</b>	<b>AMOUNT</b>	
<b>Personnel:</b>		
Wildlife Technician, 1 PTE, field data collection, analyze, field necropsies, outreach; 36 mos; 50% effort (\$42,200/yr @ 75% salary & 25% fringe)	\$	63,300
2 seasonal interns, field data collections (work for room & board only)	\$	12,000
<b>Contracts:</b>		
Wildlife Helicopter Capture Company (yet undetermined): Year 1: Initial moose capture and handling (100 moose @ \$1,000 ea); Year 2: Additional moose capture to maintain sample (20 moose @ \$1000 ea); Year 3: Additional moose capture to maintain sample (20 moose @ \$1000 ea)	\$	140,000
University of Minnesota, Veterinary Diagnostic Laboratory: disease and health screening for dead moose (screening for over 30 diseases, various toxicities and nutritional deficiencies) (est. 60 moose @ \$450 ea)	\$	27,000
University of Minnesota, Department of Entomology, diagnostic services (screening for 4 tick borne diseases)	\$	5,000
<b>Equipment/Tools/Supplies:</b>		
GPS collars (Year 1: 100@\$2,300, new) (Year 2: 20@\$1,000, refurbished; Year 3: 20@1,000 refurbished)	\$	270,000
Capture drugs (\$228/moose for immobilization and reversal)	\$	31,900
Medical & laboratory supplies and field necropsy kits (syringes, needles, sawzall, blood tubes, whirlpaks, etc)	\$	3,300
Field equipment (handheld GPS, camera, antennae, receiver, etc)	\$	2,000
<b>Acquisition:</b>		N/A
<b>Travel:</b>		
Travel to study area by project management staff (fleet@\$0.55/mi, 20,000 miles)	\$	11,000
Travel to study area by technician and interns (fleet@\$0.55/mi, 20,000)	\$	10,500
<b>Additional Budget Items:</b>		
Spotter plane during capture/recapture efforts (120 hrs @\$200/hr)	\$	24,000
<b>TOTAL ENVIRONMENT &amp; NATURAL RESOURCES TRUST FUND \$ REQUEST</b>	<b>\$</b>	<b>600,000</b>
<b>V. OTHER FUNDS</b>		
<b>SOURCE OF FUNDS</b>	<b>AMOUNT</b>	<b>Status</b>
<b>Other Non-State \$ Being Applied to Project During Project Period:</b>		
Minnesota Deer Hunter's Association	\$ 5,000	Secured
<b>Other State \$ Being Applied to Project During Project Period:</b>		
DNR Shared Services	\$ 19,430	Secured
FAW Division Support	\$ 25,820	Secured
<b>In-kind Services During Project Period:</b>		
MNDNR Wildlife Health Program: Wildlife Veterinarian, project management, field necropsies,	\$ 52,500	Secured
MNDNR Wildlife Health Program: Wildlife Health Program Coordinator, project management, field necropsies, analyze, write, outreach; 36 mos, 25% effort	\$ 45,000	Secured
MNDNR Wildlife Research: Research Scientist, project management, analyze, write, outreach; 36 mos, 10% effort	\$ 21,000	Secured
MNDNR Wildlife Health Program: Wildlife Health Specialist, field data collection, field necropsies, outreach; 36 mos, 15% effort	\$ 15,750	Secured
MNDNR Wildlife Research: Animal Health Technician, snow urine analysis	\$ 5,000	Secured
MNDNR Wildlife Research GIS: Wildlife GIS Specialist, habitat analysis and mapping	\$ 5,000	Secured
MNDNR Wildlife Health Program: University of Minnesota, Veterinary Diagnostic Laboratory, disease and health screening for live moose at capture (screening for over 30 diseases, various	\$ 32,000	Secured
University of Minnesota, Veterinary Diagnostic Laboratory, disease and health screening for dead moose (pathologist time, operational costs, bacteriology, molecular diagnostics, histopathology) (\$1,340/moose)	\$ 120,600	Secured
Fond du Lac Resource Management Division, field support	\$ 80,000	Secured
<b>Remaining \$ From Current ENRTF Appropriation</b>	N/A	N/A
<b>Funding History</b>	N/A	N/A
<b>TOTAL OTHER FUNDS</b>	<b>\$</b>	<b>427,100</b>

## CREDENTIALS

### Erika Butler, DVM

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#### Education

**D.V.M.** (2006) University of Minnesota, College of Veterinary Medicine, Saint Paul, MN.

- Interdisciplinary Track with a focus on wildlife disease detection, surveillance, and investigation.

**B.S.** Fisheries and Wildlife Biology (2002) University of North Dakota, Grand Forks, ND. Summa Cum Laude

- Honor's Thesis Title: Dynamics of Continuing Expansion by Wild Pigs in California.

#### Publications

Butler, E.A., W.F. Jensen, R.E. Johnson and J.M. Scott. 2008. Grain overload and secondary effects as potential mortality factors of moose in North Dakota. *Alces* 44:73-79.

Butler, E., M. Carstensen, M. Schrage, D. Pauly, M. Lenarz, and L. Cornicelli. 2008. Preliminary results from the 2007-2008 moose herd health assessment project. Summaries of wildlife research findings 2008, Division of Fish and Wildlife, MN DNR, St. Paul, MN [www.dnr.state.mn.us/publications/wildlife/research2008.html](http://www.dnr.state.mn.us/publications/wildlife/research2008.html)

Carstensen, M., E. Butler, M. DonCarlos, and L. Cornicelli. 2008. Managing bovine tuberculosis in northwestern Minnesota; a 2008 progress report. Summaries of wildlife research findings 2008, Division of Fish and Wildlife, MN DNR, St. Paul, MN [www.dnr.state.mn.us/publications/wildlife.html](http://www.dnr.state.mn.us/publications/wildlife.html)

Carstensen, M., E. Butler, D. Pauly, M. Schrage, and L. Cornicelli. 2007. Preliminary results from the 2007 moose herd health assessment project. Summaries of wildlife research findings 2007, Division of Fish and Wildlife, MN DNR, St. Paul, MN [www.dnr.state.mn.us/publications/wildlife/research2007.html](http://www.dnr.state.mn.us/publications/wildlife/research2007.html)

Carstensen, M., L. Cornicelli, M. DonCarlos, and E. Butler. 2006. Minnesota Department of Natural Resources Chronic Wasting Disease Surveillance Program 2006. Summaries of wildlife research findings 2007, Division of Fish and Wildlife, MN DNR, St. Paul, MN [www.dnr.state.mn.us/publications/wildlife/research2006.html](http://www.dnr.state.mn.us/publications/wildlife/research2006.html)

Grund, M. D., L. Cornicelli, L. T. Carlson, and E. A. Butler. 2010. Bullet fragmentation and lead deposition in white-tailed deer and domestic sheep. *Human-Wildlife Interactions* 4:43-50.

#### Related Experience

**Wildlife Veterinarian with the MN Department of Natural Resources (MNDNR),** (July 2009-present)  
Carlos Avery Wildlife Management Area, MN

- Provide technical direction, development, and implementation of Department programs to detect and manage wildlife diseases
- Assist and advise other Wildlife Management Section personnel in activities including radio telemetry, chemical immobilization, and research study design
- Recommend and develop professional working agreements with other agencies to enhance the Department's efforts to address wildlife diseases and obtain diagnostic and other professional services
- Represent the Department at both technical and policy levels regarding wildlife health issues
- Design, conduct, and supervise wildlife disease research projects
- Maintain an up to date knowledge of wildlife disease, emerging animal disease, scientific research, advancements in wild animal handling, sampling, necropsy, and euthanasia techniques by representing the department at seminars, conferences, and training

**Wildlife Veterinarian with the ND Game and Fish Department (NDGF), (Feb 2007-July 2009) Bismarck, ND**

- Monitor the health and status of wild mammal, bird, and fish populations in ND by developing and implementing disease surveillance programs, responding to morbidity and mortality events, and conducting necropsies and examinations
- Act as a liaison with other state, federal, and tribal wildlife professionals, maintain the department's Animal Health Emergency Preparedness Plan
- Provide wildlife disease information, protocols, scientific analysis, and "in the field" support and assistance to department staff, the media, and the general public
- Direct department personnel in the safe handling and sampling of wildlife, provide risk management protocols for dealing with sick and injured wildlife, recommend and provide drugs for wildlife captures, and assist with chemical immobilization of wildlife
- Train and supervise seasonal staff involved in disease surveillance projects
- Assist state and federal law enforcement personnel with wildlife mortality and potential criminal investigations
- Act as the department representative on feral swine eradication efforts
- Maintain the current wildlife disease laboratory and mobile lab and assist with designing the new laboratory facility

**Wildlife Health Specialist with the MN DNR, (July 2006-Jan 2007) Carlos Avery Wildlife Management Area, MN**

- Assisted with the coordination and collection of tissue samples for disease screening, with a focus on bovine tuberculosis and CWD surveillance in white-tailed deer
- Organized, analyzed, and interpreted data
- Provided statewide training on the safe and correct procedures for tissue collection
- Ensured proper sample handling and submission and maintain our disease database and frozen back-up samples

**Externship with U.S. Fish and Wildlife Kenai National Wildlife Refuge, (Feb –May 2006) Soldotna, AK**

- Organized and interpreted necropsy reports dating from the 1970's-present and created an Access database of necropsy results and collection data.
- Generated a written report entitled Diseases Found on the Kenai National Wildlife Refuge with Recommendations for Screening and Investigations.
- Performed multiple necropsies on various species, trained staff in necropsy technique and sample collection.
- Assisted Alaska Department of Fish and Game with moose immobilization and blood collection, caribou immobilization, blood collection, physical exams, and vaccinations.
- Captured injured eagles and stabilized them prior to shipping them to a rehabilitation center.

**Externship with Minnesota Department of Natural Resources, (Feb 2006) Madelia, MN.**

- Coordinated and conducted tuberculosis surveillance efforts in free-ranging deer shot on positive farms.
- Collaborated with shooters and area staff to coordinate sample collection, carcass confiscation, and sample submission.
- Trained area staff in proper sample collection technique, recognition of tuberculosis-like lesions, and identification of carcasses to be confiscated.

**Externship with Southeastern Cooperative of Wildlife Disease Study (SCWDS), (Nov 2005) University of Georgia, Athens, GA.**

- One month externship which focused on wildlife disease surveillance, necropsy, and histopathology.
- Co-authored an article entitled "Bovine TB in a Minnesota Deer" in SCWDS Briefs, Jan 2006, Volume 21 (4).

**Volunteer Wildlife Technician, (Sep 2005, Sep and Nov 2004) Minnesota Department of Natural Resources, Madelia, MN.**

- Collected tissue samples from hunter-harvested elk to determine which diseases, parasites, and deficiencies occur in Minnesota's wild elk herd.
- Assisted with the training of MN DNR employees in the proper technique of identifying and collecting retropharyngeal lymph node samples from deer for CWD testing.

**West Nile Virus (WNV) Research Assistant**, (May 2004 - Sep 2004 & May 2003 - Sep 2003) University of Minnesota, Saint Paul, MN.

- Part of a research team aimed at understanding the likely vectors for WNV and characterizing the changing mosquito fauna (season and area) throughout Minnesota.
- Conducted mammal abundance surveys.

**Animal Health Technician**, (Nov 2004, Nov 2003, and Nov 2002) Minnesota Department of Natural Resources, Madelia, MN.

- Worked as part of the rapid response team, collecting obex samples (2002) and retropharyngeal lymph nodes (2004, 2003) from hunter harvested deer for chronic wasting disease testing.

**Volunteer Wildlife Technician**, (Oct 2003) Minnesota Department of Natural Resources, Madelia, MN.

- Assisted the MN DNR wildlife veterinarian in a West Nile Virus study investigating the possible effects of WNV in ruffed grouse and American woodcock.

### **Awards and Honors**

- **Special Project Award**, MN Department of Natural Resources, 2007
- **Summa Cum Lauda Honors Graduate**, University of North Dakota, 2002
- **Clifford Thomas Presidential Scholarship**, 2001 – 2002
- **Jerome and Katharine Dunlevy High Achiever Scholarship**, 2000 – 2001
- **W. Ken Hyslop Scholarship**, 1999 – 2000
- **Perrott High Achiever Scholarship**, 1998 – 1999
- **Presidential Scholarship**, 1998 – 1999
- **Dean's List**, spring 2000, fall 2000, and spring 2001
- **President's Honor Roll**, spring 2002, fall 2001, spring 2001, fall 2000, spring 2000, and fall 1999

### **Memberships/Affiliations**

- Wildlife Disease Association (WDA) member (2005-present)
- Bovine Tuberculosis Committee member and Wildlife Health Committee member, United States Animal Health Association (USAHA), (2006-present)
- Midwest Fish and Wildlife Health Committee member (2007-present)

**EDUCATION**

**University of Minnesota**, Ph.D. Wildlife Conservation, December 2004.  
**University of Minnesota**, M.S. Wildlife Conservation, January 2002.  
**Cornell University**, B.S. Animal Science, January 1996.  
*Academic Honors* : Cornell Tradition Fellow, Dean’s List

**SUMMARY OF EXPERIENCE**

**Minnesota Department of Natural Resources, Wildlife Health Program Coordinator** .....2006-Present  
Coordinated the state's wildlife health program to address diseases threatening the state's game species including Chronic Wasting Disease (CWD), bovine tuberculosis (TB), and highly pathogenic avian influenza (HPAI). Design and coordinate studies on moose and wolf health. Designed surveillance protocols for disease detection and trend analysis. Provided expertise on wildlife disease issues. Trained agency personnel, veterinary students, and volunteers on tissue extraction and the proper handling of biological samples. Supervised program staff. Organized spending plans and managed the program budget for both state and federal grants. Designed the state's bovine tuberculosis management program for white-tailed deer and coordinated activities with state and federal partners. Represented the state agency at local, state and national meetings regarding disease surveillance. Designed the state's response plan for an outbreak of HPAI in wild birds and worked with state and federal partners on emergency preparedness.

**Minnesota Department of Natural Resources, Natural Resource Specialist-Wildlife Diseases** ..... 2004-2006  
Coordinated the state's Chronic Wasting Disease (CWD) surveillance program and provided expertise on wildlife disease issues. Trained agency personnel, veterinary students, and volunteers on tissue extraction and the proper handling of biological samples. Organized equipment, work schedules and field logistics. Created and maintained a database of statewide CWD samples collected from hunter-killed white-tailed deer and tracked test results to provide the public with accurate and timely reports. Analyzed spatial distribution of sampling data and applied statistical tests to ensure an accurate probability of disease detection. Collaborated with wildlife professionals on epidemiological modeling of CWD. Refined the state's CWD contingency plan. Designed the state's bovine tuberculosis surveillance program for white-tailed deer and coordinated sample collections following an outbreak in domestic cattle. Represented the state agency at public meeting and planning session regarding tuberculosis surveillance. Presented disease surveillance findings at regional scientific meetings.

**University of Minnesota, Graduate Research Assistant**..... 1999-2004  
Participated in a Minnesota Department of Natural Resources study investigating the effects of winter severity and deer nutrition on fawning characteristics. Worked closely with state agency personnel, and trained and supervised interns and volunteers. Gained experience in large animal capture and handling techniques, immobilizing drugs, *in vivo* body composition determination using isotope dilution, blood and urine sampling, tooth extraction, and ultrasonography. Experienced in radio-tracking animals from the ground and fixed wing aircraft. Interpreted spatial data using a variety of software programs including XY-Log, LOAS, and ArcView GIS. Experienced in aerial photo interpretation. Performed extensive laboratory analyses including blood lyophilization; fat, nitrogen, and ash extraction of carcass samples; and infrared spectroscopy. Presented research findings at national meetings of wildlife professionals and local meetings of funding organizations. Submitted research findings for national publication to peer-reviewed journals.

**Institute for Local Self-Reliance, Research Associate/Program Manager** ..... 1996-2000  
Investigated and promoted the use of value-added agricultural products as substitutes for petroleum-based industrial products as a pollution prevention strategy. Provided technical assistance to industrial manufacturers, state agencies, environmental groups, and community organizations through workshops, personal consultations and written materials. Managed program budget and gained experience in grant writing and reporting to funding organizations. Researched and published a series of pollution prevention fact sheets, industry reports, and articles for national trade magazines and peer-reviewed, environmental journals. Organized and coordinated planned events. Gave presentations at local, regional and national meetings and served as an invited speaker at numerous events. Consulted farmer-owned cooperatives on business plan development. Created and managed program website. Served as a judge for the Governor's Award for Pollution Prevention. Appointed to the Listed Metals Advisory Council, created to oversee the state's mandate on reducing the use of heavy metals in specified products.

### PROFESSIONAL MEMBERSHIPS

Wildlife Disease Association, member of Wildlife Disease Committee; The Wildlife Society; Vice-Chair of the Midwest Fish & Wildlife Health Committee; member of Dean's Advisory Council, UM-College of Veterinary Medicine; member of Advisory Council for the UM-Veterinary Diagnostic Laboratory

### SELECTED PUBLICATIONS

Carstensen, M. D. J. O'Brien and S. M. Schmitt. 2010. Public acceptance as a determinant of management strategies for bovine tuberculosis in free-ranging U.S. wildlife. *Veterinary Microbiology: in press*.

Carstensen M., G. D. DelGiudice, B. A. Sampson, and D. W. Kuehn. 2009. Survival, birth characteristics, and cause-specific mortality of white-tailed deer neonates. *Journal of Wildlife Management* 173(2): 175–183.

Dubey, J. P, M. C. Jenkins, O.C.H. Kwok, R. L. Zink, M. L. Michalski, V. Ulrich, J. Jill, M. Carstensen, and P. Thulliez. 2009. Seroprevalence of *Neospora caninum* and *Toxoplasma gondii* antibodies in white-tailed deer (*Odocoileus virginianus*) from Iowa and Minnesota using four serologic tests. *Veterinary Parasitology* 161: 330–334.

Dubey J. P, G. V. Velmurugan, V. Ulrich, J. Gill, M. Carstensen, N. Sundar, O. C. H. Kwok, P. Thulliez, D. Majumdar, and C. Su. 2008. Transplacental toxoplasmosis in naturally-infected white-tailed deer: isolation and genetic characterization of *Toxoplasma gondii* from fetuses of different gestational ages. *International Journal of Parasitology* 38: 1057–1063.

DelGiudice, G. D., M. S. Lenarz, and M. Carstensen Powell. 2007. Age-specific fertility and fecundity in northern free-ranging white-tailed deer: evidence for reproductive senescence? *Journal of Mammalogy* 88 (2): 427–435.

DelGiudice, G. D., J. Fieberg, M. R. Riggs, M. Carstensen Powell, and W. Pan. 2006. Long term age-specific survival analysis of female white-tailed deer. *Journal of Wildlife Management*: 70(6): 1556–1568.

Carstensen Powell, M., G. D. DelGiudice, and B. A. Sampson. 2005. Low risk of marking-induced abandonment in free-ranging white-tailed neonates. *Wildlife Society Bulletin* 33 (2): 643–655.

DelGiudice, G. D., B. A. Sampson, D. W. Kuehn, M. Carstensen Powell and J. Fieberg. 2005. Understanding margins of safe capture, chemical immobilization, and handling of free-ranging white-tailed deer. *Wildlife Society Bulletin* 33(2): 677–687.

Carstensen Powell, M. 2005. Fawn survival and cause-specific mortality in Minnesota's forest zone. Midwest Wolf Stewards Meeting, April 27-28, 2005, Hinckley, MN.

Carstensen Powell, M. and G. D. DelGiudice. 2005. Birth, morphological and blood characteristics of free-ranging white-tailed deer neonates. *Journal of Wildlife Diseases* 41: 171-183.

Carstensen, M. and G. D. DelGiudice. 2003. Using doe behavior and vaginal implant transmitters to capture neonate white-tailed deer in north central Minnesota. *The Wildlife Society Bulletin* 31: 634–641.

**Curriculum Vitae  
of  
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**CURRENT  
STATUS:**

**Deer Project Leader**, Forest Wildlife Populations and Research Group, Minnesota Department of Natural Resources, currently conducting long-term studies examining experimentally the relationship of winter severity and habitat to the winter distribution, movements, and survival of white-tailed deer at the population level in north-central Minnesota.

**Adjunct Associate Professor** and member of the graduate faculty, Wildlife Conservation Program, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, since 1992.

**RESEARCH  
INTERESTS:**

Examination of the relationships of natural and human-induced environmental variation and impacts with the distribution, habitat use, nutrition and demographic events of animal populations.

**EDUCATION:**

**Sep 1983-  
June 1988** University of Minnesota, College of Natural Resources, St. Paul, MN 55108  
Major: Wildlife Biology  
Ph.D. in Wildlife Biology

**Jan 1980-  
May 1982** University of Arizona, College of Agriculture, Tucson, AZ 85721  
Major: Wildlife Conservation  
Master of Science in Renewable Natural Resources

**Sep 1975-  
May 1977** Cornell University, College of Agriculture, Ithaca, NY 14853  
Major: Natural Resources  
Minor: Biology  
Bachelor of Science in Natural Resources

**Sep 1973-  
May 1975** Nassua Community College, Garden City, NY  
Major: Biology

**EXPERIENCE**

**Research:**

**1990-Present** Principal investigator examining experimentally the impact of winter severity and diminishing conifer cover on the winter movements, distribution, habitat use, food habits, nutritional condition, age-specific survival, cause-specific mortality, and reproductive success of white-tailed deer in north central Minnesota.

**2003-2005** Study assessing winter nutritional condition of free-ranging moose in northeastern Minnesota to establish reference values and accumulate baseline information relative to biological and environmental factors.

- 1999-2002** Principal investigator examining the relationship of winter severity and undernutrition on the importance of the jack pine cover type as thermal cover for white-tailed deer in Minnesota's Transition Zone.
- 1988-2001** Principal investigator in a study examining winter food habits, undernutrition, and population condition of elk and bison in Yellowstone National Park, WY, for the U.S. National Park Service; a primary focus was the effects of the fires of 1988 (Wildlife Monographs No. 147, October 2001).
- 1988-1997** Collaborating with Dr. Rolf O. Peterson, Michigan Technological University, in a 9-year study of winter nutrition of free-ranging moose related to winter severity, habitat differences, and winter tick infestation in Isle Royale National Park.

### **RESEARCH PUBLICATIONS:**

- Sampson, B. A., and **G. D. DelGiudice**. 2010. Performance of Global Positioning System collars on white-tailed deer: is it vegetation or behavior? *Journal of Wildlife Management*. *Submitted*.
- DelGiudice, G. D.**, B. A. Sampson, M. S. Lenarz, M. W. Schrage, and A. J. Edwards. 2010. Winter body condition of moose (*Alces alces*) in a declining population in northeastern Minnesota. *J. Wildl. Dis.* *Accepted*.
- Fieberg, J., and **G. D. DelGiudice**. 2009. Estimating age-specific hazards from wildlife telemetry data. *Environmental and Ecological Statistics*. DOI 10.1007/s10651-009-0128-x (On-line).
- Kochanny, C. O., **G. D. DelGiudice**, and J. Fieberg. 2009. Comparing Global Positioning System and Very High Frequency telemetry home ranges of white-tailed deer. *J. Wildl. Manage.* 73: 779-787.
- Carstensen, M., **G. D. DelGiudice**, B. A. Sampson, and D. W. Kuehn. 2009. Survival, birth characteristics, and cause-specific mortality of white-tailed deer neonates. *J. Wildl. Manage.* 73: 175-183.
- Fieberg, J., and **G. D. DelGiudice**. 2009. What time is it? Importance of time origin and scale in applications of extended proportional hazards models. *Ecology* 90: 1687-1697.
- Fieberg, J., and **G. D. DelGiudice**. 2008. Exploring migration data using interval-censored time-to-event models. *J. Wildl. Manage.* 72: 1211-1219.
- Fieberg, J., D. W. Kuehn, and **G. D. DelGiudice**. 2008. Understanding variations in autumn migration of northern white-tailed deer by long-term study. *J. Mammal.* 89: 1529-1539.
- Maurer, L. E., L. A. Schelling, A. J. Solliday, N. Burkhart, W. J. Paul, **G. D. DelGiudice**, J. A. Frick, and R. G. Harper. 2008. Organochlorine pesticide in gray wolves (*Canis lupus*) and northern white cedar (*Thuja occidentalis*) from Minnesota. *Science of the Total Environment*. *Submitted*.
- Barrett, M., S. Morano, **G. D. DelGiudice**, and J. Fieberg. 2008. Translating bait preference to capture success of northern white-tailed deer. *J. Wildl. Manage.* 72:555-560.
- DelGiudice, G. D.**, M. S. Lenarz, and M. Carstensen Powell. 2007. Age-specific fertility and fecundity in northern free-ranging white-tailed deer: evidence for reproductive senescence? *J. Mammal.* 88:427-435.
- Sampson, B. A., and **G. D. DelGiudice**. 2006. Tracking the rapid pace of GIS-related capabilities and their accessibility. *Wildl. Soc. Bull.* 34:1446-1454.
- DelGiudice, G. D.**, J. Fieberg, M. R. Riggs, M. Carstensen Powell, and W. Pan. 2006. A long-term age-specific survival analysis of female white-tailed deer. *J. Wildl. Manage.* 70:1556-1568.
- Raizman, E. A., S. J. Wells, P. A. Jordan, **G. D. DelGiudice**, and R. R. Bey. 2005. *Mycobacterium avium* subsp. paratuberculosis from free-ranging deer and rabbits surrounding Minnesota dairy herds. *Can. J. Vet. Res.* 69:32-38.
- DelGiudice, G. D.**, B. A. Sampson, D. W. Kuehn, M. Carstensen Powell, and J. Fieberg. 2005. Understanding margins of safe capture, chemical immobilization, and handling of free-ranging white-tailed deer. *Wildl. Soc. Bull.* 33:677-687.
- Carstensen Powell, M., **G. D. DelGiudice**, and B. A. Sampson. 2005. Low risk of marking-induced abandonment in free-ranging white-tailed deer neonates. *Wildl. Soc. Bull.* 33:643-655.
- Carstensen Powell, M., and **G. D. DelGiudice**. 2005. Birth, morphological, and blood characteristics of free-ranging white-tailed deer neonates. *J. Wildl. Dis.* 41:171-183.
- Carstensen, M., **G. D. DelGiudice**, and B. A. Sampson. 2003. Using doe behavior and vaginal implant transmitters to capture neonate white-tailed deer in north central Minnesota. *Wildl. Soc. Bull.* 31: 634-641.

- DelGiudice, G. D.**, M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival and cause-specific mortality of female white-tailed deer in north central Minnesota. *J. Wildl. Manage.* 66:698-717.
- DelGiudice, G. D.**, B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer. *Wildl. Soc. Bull.* 29:1147-1157.
- DelGiudice, G. D.**, R. Moen, F. J. Singer, and M. R. Riggs. 2001. Physiological responses of Yellowstone elk and bison to winter nutritional restriction and simulated body condition before and after the fires of 1988. *Wildlife Monographs No. 147.* 60pp.
- DelGiudice, G. D.**, K. D. Kerr, L. D. Mech, M. R. Riggs, and U. S. Seal. 1998. Urinary 3-methylhistidine and progressive winter undernutrition in white-tailed deer. *Can. J. Zool.* 76:2090-2095.
- DelGiudice, G. D.** 1998. Surplus killing of white-tailed deer by wolves in northcentral Minnesota. *J. Mammal.* 79:227-235.
- Doenier, P. B., **G. D. DelGiudice**, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. *Wildl. Soc. Bull.* 25:235-243.
- Kreeger, T. J., **G. D. DelGiudice**, and L. D. Mech. 1997. Effects of fasting and refeeding on body composition of captive gray wolves (*Canis lupus*). *Can. J. Zool.* 75:1549-1552.
- Moen, R., and **G. D. DelGiudice**. 1997. Simulating nitrogen metabolism and urinary urea nitrogen: creatinine ratios in ruminants. *J. Wildl. Manage.* 61:881-894.
- DelGiudice, G. D.**, R. O. Peterson, and W. M. Samuel. 1997. Trends of winter nutritional restriction, ticks, and numbers of moose of Isle Royale. *J. Wildl. Manage.* 61:895-903.
- DelGiudice, G. D.**, and M. R. Riggs. 1996. Long-term research of the white-tailed deer-conifer thermal cover relationship: aligning expectations with reality. *Trans. of North Am. Wildl. and Nat. Resour. Conf.* 61:416-428.
- DelGiudice, G. D.**, M. A. Asleson, L. W. Varner, E. C. Hellgren, and M. R. Riggs. 1996. Creatinine ratios in random sampled and 24-hour urines of white-tailed deer. *J. Wildl. Manage.* 60:381-387.
- DelGiudice, G. D.**, M. R. Riggs, L. D. Mech, and U. S. Seal. 1995. Assessing animal condition, nutrition, and stress from urine in snow - response. *Wildl. Soc. Bull.* 23:698-704.
- DelGiudice, G. D.** 1995. Assessing winter nutritional restriction of northern deer with urine in snow: considerations, potential and limitations. *Wildl. Soc. Bull.* 23:687-693.
- DelGiudice, G. D.**, M. A. Asleson, L. W. Varner, and E. C. Hellgren. 1995. Twenty-four-hour urinary creatinine and urea nitrogen excretion in male white-tailed deer. *Can. J. Zool.* 73:493-501.
- DelGiudice, G. D.**, L. D. Mech, and U. S. Seal. 1994. Nutritional restriction and acid-base balance in white-tailed deer. *J. Wildl. Dis.* 30:247-253.
- Rodiek, J. E. and **G. D. DelGiudice**. 1994. *Wildlife Habitat Conservation: Its Relationship to Biological Diversity and Landscape Sustainability: A National Symposium.* *Landscape and Urban Planning* (28):1-3.
- DelGiudice, G. D.**, L. D. Mech, and U. S. Seal. 1994. Winter undernutrition and serum and urinary urea nitrogen of white-tailed deer. *J. Wildl. Manage.* 58:430-436.
- DelGiudice, G. D.**, F. J. Singer, U. S. Seal, and G. Bowser. 1994. Physiological responses of Yellowstone bison to winter nutritional deprivation. *J. Wildl. Manage.* 58:24-34.
- Parker, K. L., **G. D. DelGiudice**, and M. P. Gillingham. 1993. Do urinary urea nitrogen and cortisol ratios of creatinine reflect body fat reserves in black-tailed deer? *Can. J. Zool.* 71:1841-1848.
- DelGiudice, G. D.**, L. D. Mech, K. E. Kunkel, E. M. Gese, and U. S. Seal. 1992. Seasonal patterns of weight, hematology, and serum characteristics of female white-tailed deer in Minnesota. *Can. J. Zool.* 70:974-983.
- Rawson, R. E., **G. D. DelGiudice**, H. E. Dziuk, and L. D. Mech. 1992. Energy metabolism and physiology of white-tailed deer fawns. *J. Wildl. Dis.* 28:91-94.
- DelGiudice, G. D.**, M. E. Nelson, and L. D. Mech. 1991. White-tailed deer nutrition, population and ecology in the central Superior National Forest. *U.S.D.A. For. Serv., Gen. Tech. Rep. NC-147.* 16pp.
- DelGiudice, G. D.**, F. J. Singer, and U. S. Seal. 1991. Physiological assessment of winter nutritional deprivation in elk of Yellowstone National Park. *J. Wildl. Manage.* 55:653-664.
- DelGiudice, G. D.**, U. S. Seal, and L. D. Mech. 1991. Indicators of severe undernutrition in urine of free-ranging elk during winter. *Wildl. Soc. Bull.* 19:106-110.
- DelGiudice, G. D.**, R. O. Peterson, and U. S. Seal. 1991. Differences in urinary chemistry profiles of moose on Isle Royale during winter. *J. Wildl. Dis.* 27:407-416.
- DelGiudice, G. D.**, L. S. Duquette, U. S. Seal, and L. D. Mech. 1991. Validation of estimating food intake in gray wolves by Na<sup>22</sup> turnover. *J. Wildl. Manage.* 55:59-71.

- DelGiudice, G. D.,** K. E. Kunkel, L. D. Mech, and U. S. Seal. 1990. Minimizing capture-related stress on white-tailed deer with a capture collar. *J. Wildl. Manage.* 54:299-303.
- DelGiudice, G. D.,** L. D. Mech, and U. S. Seal. 1990. Effects of winter undernutrition on body composition and physiological profiles of white-tailed deer. *J. Wildl. Manage.* 54:539-550.
- DelGiudice, G. D.,** P. R. Krausman, E. S. Bellantoni, M. C. Wallace, R. C. Etchberger, and U. S. Seal. 1990. Blood and urinary profiles of free-ranging desert mule deer in Arizona. *J. Wildl. Dis.* 26:83-89.
- DelGiudice, G. D.,** L. D. Mech, and U. S. Seal. 1989. Browse diversity and the physiological status of white-tailed deer during winter. *Trans. North Am. Wildl. and Nat. Resour. Conf.* 54:134-145.
- DelGiudice, G. D.,** P. R. Krausman, E. S. Bellantoni, R. C. Etchberger, and U. S. Seal. 1989. Reversal of xylazine hydrochloride-ketamine hydrochloride immobilizations of free-ranging desert mule deer with tolazoline hydrochloride. *J. Wildl. Dis.* 25:96-111.
- DelGiudice, G. D.,** L. D. Mech, and U. S. Seal. 1989. Physiological assessment of deer populations by analysis of urine in snow. *J. Wildl. Manage.* 53:284-291.
- DelGiudice, G. D.,** U. S. Seal, and T. J. Kreeger. 1988. Xylazine hydrochloride-induced glycosuria in white-tailed deer. *J. Wildl. Dis.* 24:317-321.
- DelGiudice, G. D.,** L. D. Mech, and U. S. Seal. 1988. Chemical analyses of deer bladder urine and urine collected from snow. *Wildl. Soc. Bull.* 16:324-326.
- DelGiudice, G. D.,** and U. S. Seal. 1988. Classifying winter undernutrition in deer via serum and urinary urea nitrogen. *Wildl. Soc. Bull.* 16:27-32.
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- Mech, L. D., U. S. Seal, and **G. D. DelGiudice.** 1987. Use of urine in snow to indicate condition of wolves. *J. Wildl. Manage.* 51:10-13.
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- DelGiudice, G. D.,** L. D. Mech, U. S. Seal, and P. D. Karns. 1987. Winter fasting and refeeding effects on urine characteristics in white-tailed deer. *J. Wildl. Manage.* 51:860-864.
- DelGiudice, G. D.,** L. D. Mech, W. J. Paul, and P. D. Karns. 1986. Effects on fawn survival of multiple immobilizations of captive, pregnant white-tailed deer. *J. Wildl. Dis.* 22:245-248.
- Kreeger, T. J., **G. D. DelGiudice,** U. S. Seal, and P. D. Karns. 1986. Immobilization of white-tailed deer with xylazine hydrochloride and ketamine hydrochloride and antagonism by tolazoline hydrochloride. *J. Wildl. Dis.* 22:407-412.
- Kreeger, T. J., **G. D. DelGiudice,** and U. S. Seal. 1986. Urethral diverticulum prevents catheterization in male white-tailed deer (*Odocoileus virginianus* Zimmermann). *J. Wildl. Dis.* 22:131-133.
- Kreeger, T. J., **G. D. DelGiudice,** U. S. Seal, and P. D. Karns. 1986. Methods of urine collection for male white-tailed deer. *J. Wildl. Dis.* 22:442-445.
- Mech, L. D., **G. D. DelGiudice,** P. D. Karns, and U. S. Seal. 1985. Yohimbine hydrochloride as an antagonist to xylazine hydrochloride-ketamine hydrochloride immobilizations of white-tailed deer. *J. Wildl. Dis.* 21:405-410.
- Mech, L. D., and **G. D. DelGiudice.** 1985. Limitations of the marrow-fat technique as an indicator of body condition. *Wildl. Soc. Bull.* 13:204-206.
- DelGiudice, G. D.,** and J. E. Rodiek. 1984. Do elk need free water in Arizona? *Wildl. Soc. Bull.* 12:140-146.
- DelGiudice, G. D.,** and J. E. Rodiek. 1983. A habitat analysis of spring-summer elk range on the Apache-Sitgreaves National Forest. Pages 69-96, *in Proc. of the Western States Elk Workshop, February 22-24, 1982.* Arizona Dep. Game and Fish, Phoenix, Arizona.
- Rodiek, J. E., and **G. D. DelGiudice.** 1983. Coordinating timber management activities for elk habitat requirements on the Apache-Sitgreaves National Forest. Pages 57-68, *in Proc. of the Western States Elk Workshop, February 22-24, 1982.* Arizona Dep. Game and Fish., Phoenix, Arizona.
- Rodiek, J. E., and **G. D. DelGiudice.** 1983. Designing for habitat in managed forests. *Landscape J.* 2:134-144.

#### **BOOK CHAPTERS:**

- DelGiudice, G. D.,** K. R. McCaffery, D. E. Beyer, Jr., and M. E. Nelson. 2009. Prey of wolves in the Great Lakes

region. Pages 155-173 in A. P. Wydeven, T. R. Van Deelen, and E. J. Heske, editors. Recovery of gray wolves in the Great Lakes Region of the United States: an endangered species success story. Springer. New York, New York.

**DelGiudice, G. D.**, U. S. Seal, and L. D. Mech. 1992. Nutritional indices of wild mammals: a new direction for wildlife and habitat management systems. Pages 541-546 in B. B. Bobek, K. Perzanowski, and W. L. Regelin, editors. Global Trends in Wildlife Management, Vol. II, 18<sup>th</sup> IUGB Congress (1987), Jagiellonian University, Swiat Press, Krakow, Poland.

**DelGiudice, G. D.**, J. Stone, L. D. Mech, and U. S. Seal. 1992. Sampling considerations involved with monitoring the nutritional status of gray wolves (*Canis lupus*) via biochemical analysis of snow-urine. Pages 35-38 in B. B. Bobek, K. Perzanowski, and W. L. Regelin, editors. Global Trends in Wildlife Management, Vol. II, 18<sup>th</sup> IUGB Congress (1987), Jagiellonian University, Swiat Press, Krakow, Poland.

**DelGiudice, G. D.**, L. D. Mech, and U. S. Seal. 1991. Browse diversity and the physiological status of white-tailed deer during winter. Pages 77-93 in J. E. Rodiek and E. Bolen, editors. Wildlife Habitats in Managed Landscapes. Island Press, Washington, D.C. (Reprinted from the Trans. North Am. Wildl. and Nat. Resour. Conf. 54:134-145).

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**Education**

College: DVM, College of Veterinary Medicine, Munich, Germany, 1975  
University: Ph.D., College of Veterinary Medicine, Munich, tropical veterinary medicine  
1977

**Selected Publications:**

- Baldrige GD, Burkhardt NY, Labruna MB, Pacheco RC, Paddock CD, Williamson PC, Billingsley PM, Felsheim RF, Kurtti TJ, Munderloh UG. Low Copy Number Plasmids are Widely Dispersed in *Rickettsia* Species Associated with Blood-feeding Arthropods and may have Multiple Origins. *Appl Environ Microbiol.* 2010 Jan 22. [Epub ahead of print]
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- Felsheim RF, Oliva Chávez AS, Palmer GH, Crosby L, Barbet AF, Kurtti TJ, Munderloh UG. 2009. Transformation of *Anaplasma marginale*. *Vet. Parasitol.* Sept. 20. Epub ahead of print.
- Billeter SA, V.P. Diniz PP, Battisti JM, Munderloh UG, Breitschwerdt EB, Levy MG. 2009. Infection and Replication of *Bartonella* Species Within A Tick Cell Line. *Experimental and Applied Acarology.* 49(3):193-208. Epub Feb. 26.
- Baldrige GD, Scoles GA, Burkhardt NY, Schroeder B, Kurtti TJ, Munderloh UG. 2009. Transovarial transmission of *Francisella*-like Endosymbionts and *Anaplasma phagocytophilum* in *Dermacentor albipictus* (Acari:Ixodidae). *J Med Ent* 46:625-32.
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**Education:**

Ph.D., 1995. University of Minnesota, Wildlife Conservation. M.S., 1988. University of Minnesota, Wildlife. Plant Physiology Minor. B.S., 1984. Cornell University, Division of Biological Sciences.

**Professional Experience:**

Research Associate, Natural Resources Research Institute, University of Minnesota, 1998 to present.  
Graduate Faculty, Integrated Biological Science, Univ. of Minnesota-Duluth. Fall 2004 to present.  
Graduate Faculty, Conservation Biology, Univ. of Minnesota-Twin Cities. Fall 2005 to present.  
Instructor/Assistant Professor, Biology Dept., Univ. of Minnesota-Duluth. 2000 to present

**Refereed Publications (Most recent only, 4 of 31 total):**

McGraw, A.M., R. Moen, et al. *In press*. An advisory committee process to plan for moose in Minnesota. *Alces* 00:000-000.  
Moen, R., J.M. Rasmussen, C.L. Burdett, and K.M. Pelican. 2010. Hematology, serum chemistry, and body mass of free-ranging and captive Canada lynx in Minnesota. *Journal of Wildlife Diseases* 46:13-22.  
Moen, R.A., C.L. Burdett, and G.J. Niemi. 2008. Predicting suitable denning habitat for Canada lynx based on past reproduction. *Journal of Wildlife Management* 72:1507:1513.  
McCann, N.P., R.A. Moen, and G.J. Niemi. 2008. Using pellet counts to estimate snowshoe hare numbers in Minnesota. *Journal of Wildlife Management* 72:955:958.  
Burdett, C.L., R.A. Moen, G.J. Niemi, and L.D. Mech. 2007. Defining Canada lynx space use and movements with GPS telemetry. *Journal of Mammalogy* 88:457-467.

**Technical Reports (Most recent only, these and others available from [www.nrri.umn.edu/lynx](http://www.nrri.umn.edu/lynx)):**

Moen, R. et al. 2010. Habitat and road use by Canada lynx making long-distance movements. NRRI/TR 2010/02.  
Moen, R. 2009. Canada lynx in the Great Lakes region. 2009 Annual Report. NRRI/TR-2009/40.  
Moen, R. 2009. Lynx habitat suitability in and near Voyageurs National Park. NRRI/TR-2009/19.  
Moen, R. 2009. Den sites of radiocollared Canada Lynx in Minnesota 2004-2007. NRRI/TR-2009/07.  
Moen, R. 2009. Canada lynx in the Great Lakes region. 2008 Annual Report. NRRI/TR-2009/06.  
Moen, R. and R.J. Baker. 2008. Canada lynx on the border. NRRI/TR-2008/16.  
Hanson, K. and R. Moen. 2008. Diet of Canada lynx in Minnesota. NRRI/TR-2008/13.

**Proposals and Contracts (recent):**

2010. Legislative Citizen Committee on Minnesota Resources. Identifying Critical Habitats for Moose in Northeastern Minnesota. R. Moen, M. Lenarz, M. Schrage, A. Edwards, and M. Johnson. \$507,000.  
2010. National Park Service BRMD. Climate change adaptation planning for boreal forest ecosystems in Voyageurs National Park. S. Windels, R. Moen, and L. Frelich. \$200,000. *Pending Preproposal*.  
2009. USGS POBS. Thermal infrared imaging for moose and deer in Voyageurs National Park. M. Nelson, R. Moen, and S. Windels. \$75,000. *Pending*.  
2010. Tribal Wildlife Grants Program. Mooz (Moose) Habitat Use in a Changing Climate. S. Moore, A. Edwards, and R. Moen. \$199,999.  
2009. Lake Superior Coastal Zone Program. Bats and wind along the North Shore of Lake Superior. \$20,000.  
2008. Grand Portage National Monument. Beaver Populations in Grand Portage National Monument and the Grand Portage Indian Reservation. R. Moen and S. Moore. \$18,985.

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B.S. Wildlife Resources, University of Idaho 1990  
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Mike has been the wildlife biologist for the Fond du Lac Band since 1995. He has been involved in moose habitat management, hunting issues and population surveys since 1996. He has helped lead moose population research since 2002 in northeast Minnesota. He served on the Moose Advisory Committee which made recommendations to the Minnesota DNR for writing their moose management plan. In 2010 he received the Distinguished Moose Biologist Award for his contributions to the field of moose management.

Lenarz, M.S., M.E. Nelson, M.W. Schrage, and A. J. Edwards. 2009. Temperature mediated moose survival in northeastern Minnesota. *Journal of Wildlife Management* 73:503-510.

Lenarz, M.S., J. Fieberg, M.W. Schrage, and A.J. Edwards. 2010. Living on the edge: viability of moose in northeastern Minnesota. *Journal of Wildlife Management* 74:1013-1023.

**Arno Wuenschmann** is an associate professor at the College of Veterinary Medicine (Department of Population Medicine and Minnesota Veterinary Diagnostic Laboratory) at the University of Minnesota. He is a veterinary pathologist, certified by the American College of Veterinary Pathologists. The focus of his work is pathology of free-ranging animals (“wildlife”) and zoo and exotic animals.

Dr. Wuenschmann has worked with moose since he began working at the Minnesota veterinary Diagnostic Laboratory in 2000. He has authored or co-authored various papers addressing diseases in free-ranging animals including a survey of morbidity and mortality factors in harbor porpoises from German waters.

1. **Wüenschmann A**, Siebert U, Frese K (1999): Thymic cysts in harbor porpoises (*Phocoena phocoena*). *Vet Pathol* 36: 391-396
2. Van Bresse MF, Van Waerebeek K, Siebert U, **Wüenschmann A**, Chávez-Lisambart L, Reyes JC (2000): Genital diseases in Peruvian dusky dolphins (*Lagenorhynchus obscurus*). *J Comp Pathol* 122: 266-277
3. Siebert U, **Wüenschmann A**, Weiss R, Frank H, Benke H, Frese K: Post-mortem findings in harbour porpoises (*Phocoena phocoena*) from the German North and Baltic Seas. *J Comp Pathol* 124 (2001): 102-114
4. Guo J, Rasmussen J, **Wüenschmann A**, de la Concha-Bermejillo A: Genetic characterization of orf viruses isolated from various ruminant species of a zoo. *Vet Microbiol* 99 (2004): 81-92.
5. **Wüenschmann A**, Shivers J, Carroll L, Bender J: Pathological and immunohistochemical findings in American crows (*Corvus brachyrhynchos*) naturally infected with West Nile virus. *J Vet Diagn Invest* 16 (2004): 329-333.
6. **Wüenschmann A**, Shivers J, Bender J, Carroll L, Fuller S, Saggese M, van Wettere A, Redig P: Pathologic findings in red tailed hawks (*Buteo jamaicensis*) and Cooper’s hawks (*Accipiter cooperi*) naturally infected with West Nile virus. *Avian Dis* 48 (2004): 570-580.
7. **Wüenschmann A**, Shivers J, Bender J, Carroll L, Fuller S, Saggese M, van Wettere A, Redig P: Pathologic and immunohistochemical findings in goshawks (*Accipiter gentilis*) and great horned owls (*Bubo virginianus*) naturally infected with West Nile virus. *Avian Dis* 49 (2005): 252 - 259.
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9. Dean J, Latimer KS, Oaks, JL, Schrenzel M, Redig, P, **Wüenschmann A**: Falcon adenovirus infection breeding Taita falcons (*Falco fasciinucha*). *J Vet Diagn Invest* 18 (2006): 282-286.
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11. Olson E, **Wüenschmann A**, Dubey JP: Sarcocystis sp.-associated meningoencephalitis in a bald eagle (*Haliaeetus leucocephalus*). *J. Vet. Diagn. Invest.* 19 (2007): 564-568.
12. Pauli AM, Cruz-Martinez LA, Ponder J, Redig PT, Glaser A, Klauss G, Schoster JV, **Wüenschmann A**: Ophthalmologic and oculopathologic findings in red-tailed hawks (*Buteo jamaicensis*) and Cooper’s hawks (*Accipiter cooperi*) with naturally acquired West Nile virus infection. *J Am Vet Med Assoc* 231 (2007): 1240-1249.
13. **Wüenschmann A**, Rejmanek D, Cruz-Martinez L, Barr BC. *Sarcocystis falcatula*-associated encephalitis in a free ranging Great-Horned Owl (*Bubo virginianus*), Order: Strigiformes. *J Vet Diagn Invest* 21 (2009): 283-287.
14. Ruder MG, Feldman SH, **Wüenschmann A**, McRuer DL. Association of *Mycoplasma corogypsi* and polyarthritis in a black vulture (*Coragyps atratus*) in Virginia. *J Wildl Dis* 45 (2009): 809-816.
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## Curriculum Vitae

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- II. BUSINESS ADDRESS:** Veterinary Population Medicine  
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MSc. 1992, Universidade Federal Fluminense, Rio de  
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- IV. BOAR CERTIFICATION** Diplomate of the  
American College of Veterinary Pathologists. 2006
- V. PROFESSIONAL POSITIONS:**
- 1986-1988 **Student Laboratory Technician** Regional Animal Laboratory (LARA),  
Agricultural Ministry, Pernambuco, Brazil.
- 1988-1989 **Veterinary Medical Officer.** National Veterinary Diagnostic and Research  
Laboratory *Dr. Gerardino Medina H.*, Ministry of Agricultural Development,  
Panama.
- 1991-1994 **Research Associate.** Animal Health Project, EMBRAPA/Universidade  
Federal Rural de Rio de Janeiro, Brazil.
- 1994-1995 **Head Pathologist** at the National Laboratory of Veterinary Diagnostic and Research  
*Dr. Gerardino Medina H.*, Panama, Ministry of Agricultural Development, Panama.
- 1996-1999 **Veterinary Pathology Resident.** Institute of Veterinary Pathology of the Justus-  
Liebig-Universität Gießen, Germany.
- 2000- 2001 **National Livestock Research Director.** Panamanian Agriculture and Livestock  
Research Institute of Panamá (IDIAP), Ministry of Agricultural Development,  
Panama.
- 2000- 2001 **Associate Professor of Veterinary Pathology.** University of Panama, Panama City,  
Panama.
- 2001- 2005 **Veterinary Pathologist** at the Department of Surgery, Medical School, University of  
Minnesota, Minneapolis, Minnesota, USA.
- 2005 – 2006 **Clinical Assistant Professor of Veterinary Pathology** at the Department of  
Pathobiological Sciences, School of Veterinary Medicine, University of Wisconsin-  
Madison, Madison, Wisconsin, USA
- 2006-Present **Assistant Clinical Professor of Veterinary Pathology** at the Minnesota Veterinary  
Diagnostic Laboratory, Department of Population Medicine, College of Veterinary  
Medicine, University of Minnesota, Minnesota, USA.
- VI. CURRENT RESEARCH SUPPORT:**

Neural Stem cell Response to Viral Encephalitis. The major goal of this research project is to investigate the role of neuroinflammation on key neural stem functions during herpes encephalitis. NHI **Co-Investigator**  
Investigation of the multiple-malformation syndrome in Alpacas and Llamas associated with choanal atresia. Morris Animal Foundation: \$ 62 816; 2008-2010, **Principal Investigator**

Estudio de mamíferos silvestres y domésticos, sus ectoparásitos y agentes patógenos en el Parque Nacional Isla Coiba. Secretaria Nacional de Ciencia Tecnología e Innovación de Panamá (SENACIT), Ciudad del Saber, **Panamá**: \$ 49 550; 2010-2011, **Co-Investigator**

Using the Smithsonian Institution Global Earth Observatories to investigate the effect of anthropogenic climate change on the ecology of zoonotic and vector-borne diseases. USA Center for Disease Control and Prevention: \$ 199 394; 2009-2010, **Co-Investigator**

## XXVI. PUBLICATIONS:

### *Journals (Refereed)*

1. **Armién AG**, Peixoto PV, Tokarnia CH. Experimental poisoning of sheep by *Baccharis megapotamica* var. *megapogotamica* and var. *weirii* (Compositae). *Pesq. Vet. Bras.*, 13(1/2): 5-20, 1993.
2. Tokarnia CH, Costa ER, Barbosa JD, **Armién AG**, Peixoto PV. Experimental poisoning of horses by *Palicourea marcgravii* (Rubiaceae). *Pesq. Vet. Bras.* 13(3/4):67-72, 1993.
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4. **Armién AG**, Peixoto PV, Barbosa JD, Tokarnia CH. Experimental poisoning of sheep by *Nerium oleander* (Apocinaceae). *Pesq. Vet. Bras.* 14(2/3):85-93, 1994.
5. **Armién AG**, Tokarnia CH. Experiments on the toxicity of some ornamentals plants toxicity in sheep. *Pesq. Vet. Bras.* 14 (2/3): 69-73. 1994.
6. Barbosa JD, **Armién AG**, Tokarnia CH. Experimental poisoning of goats by *Baccharis megapotamica* var. *weirii* (Compositae). *Pesq. Vet. Bras.* 14(1):5-13. 1994.
7. Brito MF, **Armién AG**, Tokarnia CH. Experimental poisoning by the pods of *Stryphnodendron coriaceum* (Leg. Mimosoideae) in goats. *Pesq. Vet. Bras.* 15(4): 111-116, 1995.
8. **Armién AG**, Peixoto PV, Döbereiner J, Tokarnia CH. Experimental poisoning by *Holcalyx glaziovii* (Leg. Mimosoideae) in bovines. *Pesq. Vet. Bras.* 15(4): 89-92, 1995
9. Tokarnia CH, Peixoto PV, **Armién AG**, Diemeier D, Barbosa JD. Experimental poisoning in horses by *Pseudocalymma elegans* (Bignoniaceae). *Pesq. Vet. Bras.* 15(1): 35-39. 1995
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11. **Armién AG**, Peixoto PV, Barbosa JD, Tokarnia CH. (1995). Experimental poisoning by *Rhododendron ledifolium* (Ericaceae) in sheep. *Pesq. Vet. Bras.* 15(1): 1-9. 1995.
12. **Armién AG**, D'angelis FH, Tokarnia CH. Experimental poisoning by *Ricinus communis* seeds (Euphorbiaceae) in sheep. *Pesq. Vet. Bras.* 16(4): 99-106. 1996.
13. Brito MF, **Armién AG**, Tokarnia CH. Experimental poisoning by *Abrus precatorius* seeds (Leg. Papilionoidea) in sheep. *Pesq. Vet. Bras.* 16(2/3): 59-66, 1996.
14. Tokarnia CH, **Armién AG**, Peixoto PV, Barbosa JD, Brito MF, Döbereiner J. Experiments on the toxicity of some ornamental plants in cattle. *Pesq. Vet. Bras.* 16(1): 5-20, 1996
15. **Armién AG**, Peixoto PV, Döbereiner J, Tokarnia CH. An outbreak of narasine poisoning in swine. *Pesq. Vet. Bras.* 17(2): 63-68, 1997.
16. Tokarnia CH, **Armién AG**, Barros SS, Peixoto PV, Döbereiner J. Complementary studies on the toxicity of *Lantana camara* (Verbenaceae) in cattle. *Pesq. Vet. Bras.* 19(3/4): 128-132, 1999.
17. Kümper H, König M, Thiel HJ, **Armién AG**. Atypische ZNS – Veränderungen infolge diaplazentärer BVD – Virusinfektion. *Tierärztl Prax (German)*. 28: 74-9, 2000.

18. Kipar A, Hetzel U, **Armién AG**, Baumgärtner W. Bilateral focal cerebral angiomas associated with nervous signs in felines. *Vet. Pathol.* 38: 350-353, 2001.
19. Schmitz G, **Armién, AG**, Fonfara S, Teifke JP and Burkhard E. Induction of apoptosis by canine natural killer cells. *Journal of Veterinary Medicine, Series A*, Vol. 50 (3) 156-159, 2003.
20. Gonzales MV., Armien B, **Armién A**, and Salazar-Bravo J. *Liomys adpersus*. Mammalian species No. 759: 1-3, 2004.
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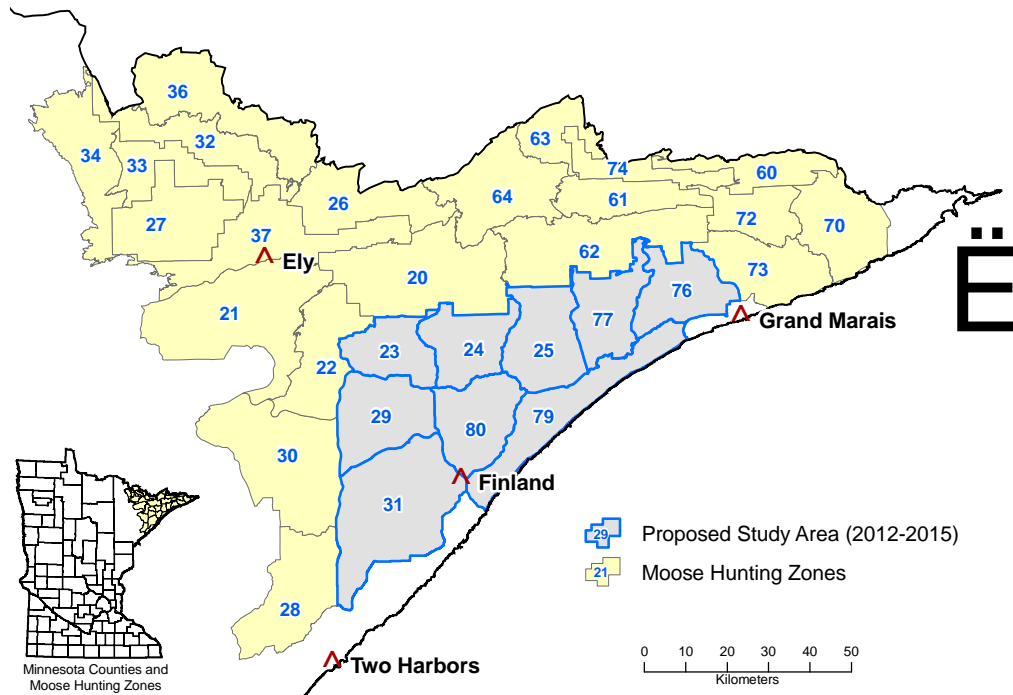
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Diseases
Brucella
Bluetongue
Epizootic hemorrhagic disease
Infectious bovine rhinotracheitis
Bovine viral diarrhea virus 1 and 2
Leptospira (6 serovars)
M. paratuberculosis
Malignant catarrhal fever
Bovine parainfluenza virus 3
Borrelia
Neospora
Anaplasma
West Nile Virus
Eastern equine encephalitis
P. tenuis

**Table 1.** Diseases screened for at time of capture using moose serum.



**Figure 1.** Study area for 2012-2015 LCCMR project for determining causes of death in declining moose population, northeastern Minnesota.