



Environment and Natural Resources Trust Fund (ENRTF) M.L. 2014 Work Plan

Date of Report: June 4, 2015
Date of Next Status Update Report: December 2015
Date of Work Plan Approval: June 4, 2014
Project Completion Date: June 30, 2017
Does this submission include an amendment request? Yes

PROJECT TITLE: Moose Decline and Air Temperatures in Northeastern Minnesota

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Location: Work will take place in St. Louis, Lake, and Cook Counties.

Total ENRTF Project Budget:	ENRTF Appropriation:	\$600,000
	Amount Spent:	\$217,609
	Balance:	\$382,391

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 5m

Appropriation Language:

\$600,000 the second year is from the trust fund to the commissioner of natural resources in cooperation with the University of Minnesota to study the physiology and behavior of adult moose and effects of female condition on calf production and survival to determine the impact of air temperature on moose population performance and decline. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Moose Decline and Air Temperatures in Northeastern Minnesota

II. PROJECT STATEMENT:

Until recently, 2 geographically distinct moose (*Alces alces*) populations occurred in Minnesota (MN), one in the northwestern (NW) and the other in the northeastern (NE) part of the state. Since the mid-1980s the NW population has decreased from an estimated 4,000 to less than 100 moose, and since 2006 the NE population has declined 69% from an estimated 8,840 to 2,760 moose. Mean annual mortality rates of adults have been similarly high (21%) in both regions. Climate change has been implicated as an underlying factor in both population declines. There were inverse relationships between warming ambient temperatures and decreasing survival of adult moose. Unlike in the NW region, however, in the NE little is known about other potentially important factors contributing to the natural mortality of moose (e.g., predation, disease, parasites, undernutrition). Two aggressive companion studies are presently investigating specific causes of mortality and survival rates of adults and calves, and their quantitative impacts on performance (survival and reproduction) of the NE population.

Trends in temperature and precipitation patterns are likely to increase in intensity over the next century. If moose are unable to sufficiently thermoregulate above certain ambient temperature thresholds, we might expect to see increased body temperatures and energy expenditures required to stay cool, which over time could have negative consequences for body condition, reproduction, and survival. Currently, no data exist to support the direct adverse effects of ambient temperature on the physiology, survival, or reproduction of free-ranging moose.

The primary goal of our 3-year study is to thoroughly investigate how ambient temperatures relate to moose productivity, reproductive success, and survival in NE MN by applying an unprecedented field approach and comprehensive data collection methods. Recently, a minimally invasive telemetry system for ruminants, called a mortality implant transmitter (MIT), has been developed to allow nearly continuous monitoring of body temperature with a battery lifetime of ≥ 2 years. Using these MITs and global positioning system (GPS) collars on adult moose in this study will allow us to correlate ambient temperature with adult female physiology, behavior (habitat use and activity), and fitness (survival and reproduction). We will estimate the seasonal survival of 30 implanted moose, determine specific causes of mortality, and assess calf production. We also will estimate survival and determine the causes of mortality of calves of by GPS-collared mothers ~~40 newborns~~. Presently, less is known about calf productivity, survival, and mortality factors than for adult moose in northern Minnesota.

This study will be the first to examine these relationships in a way that includes monitoring body temperature. The results of this study will be critical to an improved understanding of if, when, and how moose are able to successfully modulate their internal body temperature. In particular, we aim to determine if moose modify their activity and use available habitat in response to ambient temperatures, and to evaluate population performance. Such an understanding should prove valuable in the formulation of future population and habitat management strategies and activities.

III. PROJECT STATUS UPDATES:

Project Status as of December 2014:

On July 1, 2014, we had 94 collared adult moose remaining from the previous study that was funded by LCCMR “Determining causes of mortality in moose populations.” Since then we have investigated mortalities of 4 collared adult moose, and 14 collars have stopped transmitting location information. We plan to capture 24–26 new adult moose during January–February 2015 to return the sample size to >100 collared adults. Each captured adult moose will receive an MIT.

We placed ambient temperature loggers (black globes and white funnels) in 7 open habitat sites throughout the study area. Data from the temperature loggers will be used with data from 12 official weather stations in

northeastern Minnesota to determine the best ambient temperature predictor for moose with MITs in this study. Further, an MIT calibration study was initiated in December 2014 using captive moose at the Moose Research Center in Alaska. This calibration study, which is being funded by MN DNR, will determine the best methods for interpretation of MIT data generated in wild moose in Minnesota.

We monitored the movements and survival of moose calves that had been GPS-collared during spring 2014. We investigated the mortalities of collared moose calves that died. We measured habitat characteristics at 88 pre-calving, calving, and mortality sites of calves GPS-collared during spring 2013 and 2014. We also conducted a controlled study of new GPS calf collars to determine the effects of physical disturbance and weather conditions on the durability and proper functioning of the collars.

Amendment Request (12/21/2014): This amendment will extend the completion date for capturing adult moose—Outcome 1 of Activity 1—from 6/30/2015 to 6/30/16, allowing us to capture 24–30 moose each of the next 2 winters. Increased survival of collared adult moose during 2014, free replacement collars for January–February 2015, and reduced capture costs have made it possible to utilize funding from this grant to add new individuals (24–30 each winter) into the study over 2 years. This greatly enhances our ability to capture environmental variation among years and extends the life of the study. Further, along with matching funds from DNR, more MITs can be placed in captured moose in January–February 2016, which will provide a larger sample of physiological data for this study. Extending this timeline and maintaining a viable sample size of collared adult moose (>100) through 2016 will not otherwise impact our work plan and will enable us to spend funds in the high priority areas of the project. **Amendment approved by the LCCMR (12/30/2014).**

Project Status as of June 2015:

From February 16 until February 22, 2015, we captured 32 adult moose (20 females, 12 males). Unfortunately, 5 of those moose died shortly after capture and were censored from the study. Given the elevated rate of capture-related mortality, we decided to discontinue captures and not deploy additional collars for Dr. Ron Moen (not using ENRTF funding) as we had intended. We deployed 27 new collars and 23 MITs, which returned our study sample to 101 moose. Moose at capture were generally in good condition (44% normal, 53% thin, and 3% very thin). There was minimal hair loss noted from winter ticks. Pregnancy rate, determined by progesterone values in blood samples, was 89%; higher than 2013 (83%) and 2014 (77%).

During January–June 2015 6 collared moose died and were investigated. Three moose died from health-related causes (1 undetermined and 2 with diagnostic results still pending), and 3 moose died from predator-related causes (1 wolf kill, 1 likely wolf kill, and 1 injury caused by wolves that led to a secondary infection that was lethal).

Our MIT calibration project with Alaska Game & Fish, which began in December 2014 and is funded by DNR, has shown the MIT to be a highly accurate measurement of internal body temperature in moose. On average, the MIT was only 0.25°C higher than body temperature determined by vaginal implant transmitters. Further, preliminary analyses of data from MITs recovered from moose that have died in Minnesota ($n = 8$) indicated prolonged elevated temperatures (>102°F) for 10–30% of readings during the summer months.

We are monitoring the current calving activity of 60 adult female moose with functioning GPS collars. So far they have produced 46–61 calves, depending upon the assumed rate of having twins (0–32%). We have investigated 17 possible calf mortality sites and found direct evidence of a calf mortality at 8 of them. Whether or not the mother returns to the site after fleeing has been a reliable indicator of actual calf mortality. We are collecting habitat data at the calving and mortality sites.

Amendment Request (06/04/2015): This amendment, prompted by Executive Order 15-10 issued on April 28, 2015, directing the Minnesota Department of Natural Resources to discontinue placing radio collars on moose, will eliminate Outcome 1 of Activity 2, alter the methods for Outcomes 2 and 3 of Activity 2, and reallocate some of the funds related to capturing and collaring moose so we will be able to achieve the main Outcomes for

Activity 2 using alternative methods and to track and investigate the mortalities of already-collared adult moose for a longer period of time than was initially proposed.

Budget requests:

- Increase Personnel for Activity 1 from \$74,000 to \$111,000 to add a 3rd year of partial support for a Wildlife Health Specialist to investigate the mortalities of adult moose
- Reduce Wildlife helicopter capture costs from \$48,000 to the actual amount spent of \$31,770
- Reduce Univ. of Minnesota Veterinary Diagnostic Lab for Activity 2 from \$5,000 to \$4,000 because we will be submitting fewer whole calf carcasses and tissue samples for analysis
- Increase Satellite data acquisition for Activity 1 from \$35,000 to \$60,000 to add a 2nd and 3rd year of data acquisition for adult moose and increase the duration of time we collect hourly locations of adult female moose to enable us to identify possible sites of calf mortality events
- Reduce Satellite data acquisition for Activity 2 from \$15,000 to \$3,000 because we are not deploying collars on moose calves during 2015
- Reduce GPS collar costs for Activity 1 from \$75,000 to \$0 because the adult moose collars we deployed during 2015 were left over from previous years of the study and no new collars were purchased
- Reduce GPS collar costs for Activity 2 from \$55,000 to \$0 because we were able to cancel the order for calf moose collars that were no longer needed
- Reduce Mortality implant transmitters and Pharmaceuticals from a total of \$33,000 to the actual amount spent of \$31,677
- Reduce Air temperature loggers from \$4,500 to \$0 because we used other funds to purchase them
- Increase Travel expenses for Activity 1 from \$29,030 to \$59,029 because fleet expenses are greater than we projected
- Reduce Travel expenses for Activity 2 from \$35,409 to \$26,009 because lodging and fleet expenses are less than we projected
- Increase Airplane flights for Activity 1 from \$10,500 to \$23,554 because in addition to the spotter plane used during capture operations we will need to track down missing moose and eventually remotely trigger the release (i.e., removal) of the adult moose collars
- Add \$50,400 for Aerial surveys for Activity 2 because we will need to observe adult female moose and their remaining calves during late-fall and winter to estimate calf survival without collared calves

Project Status as of December 2015:

Project Status as of June 2016:

Project Status as of December 2016:

Project Status as of June 2017:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Determine the physiological and behavioral impacts that ambient temperatures have on adult moose and determine specific causes of mortality.

Description: Global Positioning System (GPS) collars and mortality implant transmitters (MITs) will be deployed on 30 adult moose (approximately 22 females and 8 males) in January–February of 2015 ~~and 2016~~. Additionally, external ambient temperature loggers will be placed on each collar. The collars will notify the research team when a moose has died by way of a motion-sensitive switch in the collar and a subsequent text message. A network of strategically stationed response teams will reach moose within the critical 24 hours after

death, ensuring the carcass and tissue samples are suitable for diagnostics. When possible, carcasses will be transported intact to a nationally-certified laboratory in Minnesota for a full diagnostic workup. Otherwise, trained field biologists will perform a thorough field examination (necropsy). Diagnostic screening for more than 30 diseases, toxicities and deficiencies will occur by Board-certified veterinary pathologists. Further, internal body temperature data will be compared to ambient temperatures to determine if moose alter their use of specific habitat types depending on ambient temperatures or their current physiological state.

Summary Budget Information for Activity 1:

ENRTF Budget: ~~\$ 338,721~~
\$ 346,721
Amount Spent: \$ 149,218
Balance: \$ 197,503

Activity Completion Date: 6/30/2017

Outcome	Completion Date	Budget
1. Capture, collar, and implant 30 adult moose in the study area	6/30/2016	\$ 177,436 89,930*
2. Determine behavioral impacts of ambient temperature on moose	6/30/2017	\$ 103,189 163,747*
3. Continue to determine specific causes of mortality of moose that die during the study period	6/30/2017	\$ 58,096 93,044*
4. Quantifying rate of exposure to diseases and toxicity and nutritional deficiencies	6/30/2017	\$ 0**
5. Preliminary data analyses and final LCCMR report	6/30/2017	\$ 0**
6. Descriptive reports/articles in peer-reviewed publications addressing findings	6/30/2017	\$ 0**

* Of the ~~\$338,721~~\$346,721 for Activity 1, \$11,291 is for Direct & Necessary services to support the appropriation.

** Analyses and reports for Outcomes 4–6 will be completed through in-kind contributions of the lead investigators and others.

Activity Status as of December 2014:

Plans are underway to capture 24–26 moose during January–February 2015 to rebuild the sample size to >100 collared adult moose. Fortunately, warranty collar replacements have arrived and no additional new collars need to be purchased at this time; 30 MITs and external temperature loggers have been ordered. Seven ambient temperature loggers were placed in open habitat types in the study area and are downloaded monthly. In addition, ambient temperature data from NOAA and RAWs stations within the study area have been downloaded each month. An MIT calibration study (not funded by LCCMR) was initiated with captive moose in Alaska to improve our understanding of the MIT data and to develop methods for data analyses for moose with MITs for this LCCMR-funded study. Four collared adult moose have died since this project began in July 2014. Through investigations of those mortalities we determined that the causes of mortality included wolf predation (1 confirmed wolf kill, 1 likely wolf kill) and health conditions (1 likely brainworm, 1 multiple health issues).

Activity Status as of June 2015:

From February 16 until February 22, 2015, we captured 32 adult moose (20 females, 12 males). Unfortunately, 5 of those moose died shortly after capture and were censored from the study. Capture myopathy was the cause of death in 4 moose; the fifth moose had a seizure during handling that may have been attributable to a tumor on its adrenal gland. Given the elevated rate of capture-related mortality, we decided to discontinue captures and not deploy additional collars for Dr. Ron Moen (not using ENRTF funding) as we had intended. We deployed 27 new collars and 23 MITs, which returned our study sample to 101 moose. Since this project began in 2013, we have collared 168 unique moose and successfully deployed 61 MITs.

Moose at capture were generally in good condition, as body condition scores at capture were 44% normal, 53% thin, and 3% very thin. There was minimal hair loss noted from winter ticks. Pregnancy rate, determined by

progesterone values in blood samples, was 89%; higher than 2013 (83%) and 2014 (77%). Biological samples collected at capture are being evaluated for a variety of disease agents, and results are pending.

During January–June 2015 6 collared moose died and were investigated. Three moose died from health-related causes (1 undetermined and 2 with diagnostic results still pending). Three moose died from predator-related causes (1 wolf kill, 1 likely wolf kill, and 1 injury caused by wolves that led to a secondary infection that was lethal). Thus far in the 3rd year of this study, 6% of the collared moose have died. For the same period during Years 1 and 2 mortality rates were 19% and 12%, respectively.

Our MIT calibration project with Alaska Game & Fish, which began in December 2014 and is funded by DNR, has shown the MIT to be a highly accurate measurement of internal body temperature in moose. On average, the MIT was only 0.25°C higher than body temperature determined by vaginal implant transmitters. Further, preliminary analyses of data from MITs recovered from moose that have died in Minnesota ($n = 8$) indicated prolonged elevated temperatures (>102°F) for 10-30% of readings during the summer months. Continued work on this calibration study will shed new light on the proper interpretation of MIT data from moose in this ENRTF-funded study and assist with our understanding of potential effects of ambient temperature on moose survival, habitat use, and production of calves.

Activity Status as of December 2015:

Activity Status as of June 2016:

Activity Status as of December 2016:

Activity Status as of June 2017:

Final Report Summary:

ACTIVITY 2: Determine the potential effects of the condition and behavior of adult female moose on calf productivity and survival.

Description: Calving behavior and activity (i.e., movements) of all adult GPS-collared female moose will be intensely monitored in near real-time by several proven computer methods during May to early-June 2015 to determine pregnancy and, using twinning rates determined during previous years of this study, overall calf production. ~~GPS collars programmed to collect one location per hour will be deployed on 40 captured newborn (< 4 days old) moose calves (~20 females, 20 males) of GPS-collared dams also fitted with MITs. The twinning rate of the collared calves of dams will be used to estimate overall calf production. The GPS calf collars send a text message and email to our research response team within 6 hours of a calf mortality, allowing the team to initiate a field investigation within 12-24 hours.~~ We will continue to monitor hourly locations of females with calves throughout the summer, using rapid movements of more than 400m to identify possible calf mortality sites. As with the adults, intact fresh carcasses of calves or remaining tissue samples will be transported to the Veterinary Diagnostic Laboratory at the University of Minnesota for diagnostic workup, or detailed necropsies will be conducted in the field. We will use aerial surveys of collared mothers during late-fall, mid-winter, and late-winter to observe remaining calves and estimate seasonal and annual survival rates of calves. Prolonged physiological stress and behavioral responses to increased temperatures can have debilitating effects on the nutritional condition and overall health of adult moose, which can compromise their ability to become pregnant, fetal development, and survival of calves throughout their first year. Seasonal and annual survival and specific causes of mortality of the ~~GPS-collared calves~~ of collared adults will be determined during their first year and relationships with ambient temperature, physiological status (i.e., body temperatures) and behavior (e.g., habitat use) of the dams will be examined.

Summary Budget Information for Activity 2:

ENRTF Budget: ~~\$ 261,279~~
\$ 253,279*
 Amount Spent: \$ 68,391
 Balance: \$ 184,888

Activity Completion Date: 6/30/2017

Outcome	Completion Date	Budget
1. Capture & collar 40 moose calves	6/30/2015	\$ 101,652*
2. Determine the relationship between physiological & behavioral responses of females and the production and survival of calves	6/30/2017	\$ 112,480 153,666**
3. Continue to determine specific causes of mortality of calves during their first year	6/30/2017	\$ 47,147* 80,613**

* The ENRTF budget for Activity 2 includes \$19,000 that is unallocated, so the budgets for the two Outcomes sums to \$234,279, not \$253,279.

** Of the ~~\$261,279~~\$253,279 for Activity 2, \$10,475 is for Direct & Necessary services to support the appropriation.

Activity Status as of December 2014:

We monitored the movements and survival of moose calves that had been GPS-collared during spring 2014. We investigated the mortalities of collared moose calves that died. We measured habitat characteristics at 88 pre-calving, calving, and mortality sites of calves GPS-collared during spring 2013 and 2014. We also conducted a controlled study of new GPS calf collars to determine the effects of physical disturbance and weather conditions on the durability and proper functioning of the collars.

Activity Status as of June 2015:

We are monitoring the current calving activity of 60 adult female moose with functioning GPS collars. As of May 25th 46 of 60 adult females (76.7%) had calved, as determined from remotely tracking female movements. This means that minimum calf production of the study cohort is at least 46 calves (assuming all singletons) and may be as high as 61 calves (assuming a 32% twinning rate as in 2014). Based on cumulative data and winter pregnancy-testing by serum progesterone concentrations at adult capture, we expect a minimum of 53 females (88.9%) to calve and a study cohort of 53–70 calves. We have investigated 17 possible calf mortality sites and found direct evidence of a calf mortality at 8 of them. Whether or not the mother returns to the site after fleeing has been a reliable indicator of actual calf mortality. During investigative visits to the calving sites (approached only after the mother and calves have moved away) and mortality sites we are conducting extensive habitat analyses to assess each site for escape or hiding cover and forage availability and quality. Estimated calf mortality through May was 11–28%.

Activity Status as of December 2015:**Activity Status as of June 2016:****Activity Status as of December 2016:****Activity Status as of June 2017:****Final Report Summary:****V. DISSEMINATION:**

Description: Annual research summaries addressing accomplishments to date will be written and available on the MNDNR website. Descriptive reports and articles will be written and submitted for publication in peer-reviewed journals.

Status as of December 2014:

Annual research summaries for the adult and calf components of this project for state fiscal year 2014, which preceded funding under this appropriation but are directly relevant, are available on the MN DNR website (<http://www.dnr.state.mn.us/publications/wildlife/index.html>).

Glenn DelGiudice provided interviews about the moose calf survival study to reporters from

- Outdoor News (Minnesota and Wisconsin editions),
- Minneapolis Star Tribune,
- Duluth News Tribune,
- St. Cloud Times,
- Cook County Herald,
- Outdoor Life magazine, and
- Minnesota Public Radio.
- Brainerd Outdoor Radio with Brian Moon, aired July 2014.

He also gave presentations at

- 2 meetings of professional wildlife managers and researchers

and public audiences at

- Bear Head Lake State Park,
- the International Wolf Center, and
- Normandale Community College.

Michelle Carstensen gave presentations about the adult moose study at

- Bear Head Lake State Park, Ely, MN: Determining cause-specific mortality in Minnesota's declining moose population, July 2014
- Grand Rapids Public Library, Grand Rapids, MN: Determining cause-specific mortality in Minnesota's declining moose population, August 2014.
- Vermilion Community College (VCC), Student Chapter of The Wildlife Society, Ely, MN: NE MN adult moose mortality – VCC Volunteers, September 2014
- Mind Trekkers Festival, Virginia, MN: Moose project display and Q&A, October 2014
- International Wolf Center, Ely, MN: What is the status of northeastern Minnesota's moose population and what are we learning, October 2014.
- North Star Museum of Boy and Girl Scouting, St. Paul, MN. Display on moose project. November 2014.
- Dodge Nature Center, Bloomington, MN. Determining cause of moose mortality in Minnesota, December 2014.
- Forestry Association Employees, Brainerd, MN. Determining cause of moose mortality in Minnesota, December 2014.

Media coverage for the adult moose mortality project also included the following:

- Brainerd Outdoor Radio with Brian Moon, aired July 12, 13, and 14, 2014.
- The Spokesman-Review: Wild moose chase: Researchers tracking 25 collared moose in NE Washington, October 2014
- Care2: How a tiny brain worm is killing moose across North America, October 2014
- The Spokesman-Review: Study: Wolf impact significant on Minnesota moose, November 2014
- Minneapolis Star Tribune: Are wolves to blame for fewer Minnesota moose, November 2014
- Rick Kupchella's Bring Me The News: Federal officials ask for help to solve illegal killing in NW Minnesota, November 2014
- Ithaca Journal: Cornell on lookout for Adirondack moose, December 2014
- Science Recorder: New York State to launch three-year study of moose, December 2014

- Bennington Banner: Biologists study moose after die-offs, December 2014
- Hamodia: Researchers assess NY moose after die-offs, December 2014
- New Hampshire Voice: Researchers look into moose die-offs in Minnesota, December 2014
- Mankato Free Press: Mankato Area Lifelong Learns hosts class on Minnesota moose, December 2014
- Mankato Free Press: Mankato group talks Minnesota moose population decline, December 2014
- First for Wildlife: Studies show relationship between wolves and Minnesota moose population decline, December 2014
- The Barre Montpelier Times Argus: Researchers assess Adirondack moose after die-offs, December 2014
- Concord Monitor: Researchers assess Adirondack moose after die-offs, December 2014

Status as of June 2015:

Peer-reviewed publications from previous years of the moose calf research

- Severud, W. J., G. D. DelGiudice, T. R. Obermoller, T. A. Enright, R. G. Wright, and J. D. Forester. 2015. Using GPS collars to determine parturition and cause-specific mortality of moose calves. *Wildlife Society Bulletin*. In Press.
- DelGiudice, G. D., W. J. Severud, T. R. Obermoller, R. G. Wright, T. A. Enright, and V. St-Louis. 2015. Monitoring movement behavior enhances recognition and understanding of capture-induced abandonment of moose neonates. *Journal of Mammalogy*. In Press.

Glenn DelGiudice provided interviews about the moose calf survival study to reporters from

- OUTDOORS, April 2015, Joseph Friedrichs
- The Wall Street Journal, May 2015, Joe Barrett
- Minneapolis StarTribune, April 2015, Josephine Marcotty
- Pioneer Press, February 2015, John Myers
- Duluth News Tribune, February 2015, John Myers

Glenn DelGiudice and Ph.D. graduate student, Bill Severud, also gave presentations at

- DelGiudice, G. D., W. J. Severud, and T. R. Obermoller. Studying moose calf survival in a declining population on the cutting-edge of technology: overcoming the inevitable challenges before reaching that "Sweet Spot." 49th North American Moose Conference and Workshop, Granby, CO. 28 April 2015.
- DelGiudice, G. D. Status and trends of Minnesota's moose populations. 49th North American Moose Conference and Workshop, Granby, CO. 28 April 2015.
- DelGiudice, G. D. Status, trends, and research of Minnesota's moose populations. Cottonwood County Game and Fish Protective League, Spring Forum. 26 March 2015.
- DelGiudice, G. D., W. J. Severud, T. R. Obermoller, and R. G. Wright. 2015. Determining an effective approach for capturing moose neonates and minimizing capture-related abandonment in northeastern Minnesota. 2015 Joint Annual Meeting of Minnesota & Wisconsin Chapters of The Wildlife Society, Duluth, MN. 19 February 2015.
- Severud, Bill and Glenn DelGiudice. Cause-specific mortality of moose calves: an update from northeastern Minnesota. 49th North American Moose Conference and Workshop, Granby, CO. 28 April 2015.
- Severud, Bill. Cause-specific mortality of moose calves in northeastern Minnesota, 2013 and 2014. 3rd Annual Natural Resources Association of Graduate Students Research Symposium, St. Paul, MN. 22 April 2015.
- Severud, Bill and Glenn DelGiudice. Cause-specific mortality of moose calves in northeastern Minnesota, 2013 and 2014. 2015 Joint Annual Meeting of Minnesota & Wisconsin Chapters of The Wildlife Society, Duluth, MN. 19 February 2015.

- Severud, Bill and Glenn DelGiudice. Cause-specific mortality of moose calves in northeastern Minnesota, 2013 and 2014. Conservation Biology Lunch Seminar, University of Minnesota, St. Paul, MN. 10 February 2015.
- Severud, Bill and Glenn DelGiudice. What is the status of northeastern Minnesota's moose population and what are we learning? Normandale Community College Slice of Life Lecture Series, Bloomington, MN. 3 February 2015.

Radio Shows About the Adult Moose Project:

- The Ticket FM, Angler Hunter Radio, live interview, 14 January 2015.
- Minnesota Public Radio: Moose and climate change, February 2015.
- The Ticket FM, Angler Hunter Radio, topic coverage on our captures, 25 February 2015.
- WTIP, Environment: Dr. Seth Moore on the state of moose and moose research, 25 March 2015.
- WTIP, Lake Superior Project: The Role of Collaring in Moose Research, 26 March 2015.
- The Ticket FM, Angler Hunter Radio, update on moose mortalities and moose collaring, 13 May 2015.

Presentations About the Adult Moose Project:

- Silver Bay Veterans Center, January 2015.
- Minnesota Veterinary Medical Association, February 2015.
- Retired Vets: Determining Cause specific mortality in Minnesota declining moose population, 6 February 2015.
- Dordt College Field Trip/Presentation, 6 February 2015.
- Kanabec Adult Hunter Ed Program, February 2015.
- MIFC, Annual Aviation Workshop, Grand Rapids; interagency cooperation on slinging moose, 25 February 2015.
- Mora Adult Hunter Education Class, 26 February 2015.
- Wood Lake Nature Center, March 2015.
- School of Environmental Studies, April 2015.
- North American Moose Conference, April 2015.
- NE Regional Managers Meeting, Moose Project Update, 13 April 2015.
- Iron Range Science and Engineering Festival, 21-23 April 2015.
- Minnesota Pollution Control Agency, 3 June 2015.
- Bear Head Lake State Park, Tower/Soudan K-6 Field Day, 27 May 2015.
- Two Harbors High School, 27 May 2015.

Media Coverage of the Adult Moose Project:

- Star Tribune: Landwehr, What's gone right in the first four years, 3 January 2015.
- Alexandria Echo Press: Updated, Moose spotted near Brandon, 6 January 2015.
- CBS Local: Walleyes, deer, wolves and moose among topics of DNR event, 16 January 2015.
- Austin Daily Herald: Walleyes, deer, wolves and moose among topics of DNR event, 17 January 2015.
- Pioneer Press: DNR's 'Roundtable' hits on pines, potatoes, deer stands and more, 24 January 2015.
- Rick Kupchella's Bring Me The News: Moose that wandered to southern Minnesota had a brain worm, DNR says, 30 January 2015.
- Star Tribune: Sleepy Eye moose died from brain worm infection, 30 January 2015.
- Minnesota Public Radio News: What climate change means for Minnesota moose, 3 February 2015.
- OutdoorHub: Minnesota's Famous Wandering Moose Was Killed by Brain Worms, 6 February 2015.
- Duluth News Tribune: Winter survey shows Minnesota moose numbers still low, 17 February 2015.
- Minnesota Public Radio News: DNR, moose count confirms continuing decline, 17 February 2015.
- Minnesota Outdoor News: Minnesota's moose population remains at low levels, 17 February 2015.
- INFORUM: Annual Minnesota winter moose survey shows big drop from last year, 17 February 2015.

- Alexandria Echo Press: DNR aerial survey indicates more low numbers for Minnesota's moose population, 17 February 2015.
- KDAL: Minnesota moose population remains low, 17 February 2015.
- WDSM: Minnesota moose population remains low, 17 February 2015.
- Rick Kupchella's Bring Me The News: New numbers show MN's moose population is down to just a few thousand, 18 February 2015.
- KTTC: DNR, moose count confirms continuing decline, 18 February 2015.
- WDAZ: Minnesota moose population still down, 18 February 2015.
- Minnesota Outdoor News: No end to declining trend in northeast moose herd, 19 February 2015.
- Hometown Focus: Minnesota's moose population remains at low levels, 20 February 2015.
- SW News Media: Minnesota DNR, Moose population stays at low levels, 20 February 2015.
- Brainerd Daily Dispatch: Outdoor Notes, 20 February 2015.
- St. Cloud Times: Moose researchers fear they are running out of time, 21 February 2015.
- Crow River Media: State's moose population remains at low levels, 26 February 2015.
- Star Tribune: Minnesota's moose numbers drop again; DNR says 'decline will likely continue', 19 April 2015.
- Tower Timberjay News: DNR suspends adult moose captures early, 22 April 2015.
- Minnesota Outdoor News: Moose collaring in state is over, but not research, 28 May 2015.

Status as of December 2015:

Status as of June 2016:

Status as of December 2016:

Status as of June 2017:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	\$ Amount	Explanation
Personnel:	\$ 121,000 <u>158,000</u>	1 Wildlife Health Specialist (\$74,000) – 43% FTE for 23 years to do field work for adult component, analyze data, & do outreach. 3 Field technicians (\$47,000) – 46% FTE each for 1 year to do field work for calf component.
Professional/Technical/Service Contracts:	\$ 214,795 <u>210,565</u>	Moose capture – Capture & handling 30 adult moose (\$48,000 <u>\$31,770</u>). Univ. of Minnesota – Field work & analysis for calf component (\$80,000), statistical consulting (\$26,795) & diagnostic lab analyses for adult and calf components (\$10,000 <u>\$9,000</u>). Satellite data acquisition – transmission of location, temperature, heart rate, & mortality data from adult moose (\$35,000 <u>\$60,000</u>) and calves (\$15,000 <u>\$3,000</u>). \$175/month plus a per-transmission fee.

Equipment/Tools/Supplies:	\$ 167,500 <u>31,677</u>	GPS collars for adult moose (\$75,000) & calves (\$55,000) — Collect moose location data; transmit temperature & heart rate data; competitive bid process to select vendor. Mortality implant transmitters (\$27,000 <u>25,856</u>) — Record body temperature & heart activity data from 30 adult moose. Air temperature loggers (\$4,500) — Record ambient air temperatures on 30 adult moose collars. Pharmaceuticals (\$6,000 <u>5,821</u>) — Drugs for immobilization of captured moose & reversal.
Travel Expenses in MN:	\$ 64,439 <u>85,038</u>	Fleet, mileage, lodging, & meals for project managers & field staff (\$56,939 <u>81,938</u>). Room & board for volunteer technician to do field work for calf component (\$7,500 <u>3,100</u>).
Other: Spotter plane <u>Aircraft services</u>	\$ 10,500 <u>73,954</u>	DNR aircraft (52 hours @ \$205/hour) for moose capture operations and tracking (\$23,554) and fall-winter aerial surveys (\$50,400).
Other: Direct & Necessary costs	\$ 21,766**	DNR Direct & Necessary services to support this appropriation (*see footnote).
Other: <u>Unallocated (added 06/04/2015)</u>	\$ 19,000	<u>Unallocated portion of ENRTF appropriation</u>
TOTAL ENRTF BUDGET:	\$ 600,000	

* Direct and Necessary expenses include both Department Support Services (Human Resources \$2,480**, IT Support \$2,750**, Safety \$613**, Financial Support \$5,999**, Communications Support \$1,141**, Planning Support \$704**, and Procurement Support \$235**) and Division Support Services (\$7,844**). Department Support Services are described in the agency Service Level Agreement, and is billed internally to divisions based on rates that have been developed for each area of service. These services are directly related to and necessary for the appropriation. Department leadership services (Commissioner's Office and Regional Directors) are not assessed. Division Support Services include costs associated with Division business offices and clerical support. Those elements of individual projects that put little or no demand on support services such as large single-source contracts, large land acquisitions, and funds that are passed-thru to other entities are not assessed Direct and Necessary costs for those activities. For this work plan, activities contracted to the University of Minnesota with associated costs of \$116,795 have not been assessed Direct and Necessary costs.

** Direct and Necessary expenses will be recalculated and revised based upon the 6/4/2015 budget amendment, if approved, and pending DNR accounting review.

Explanation of Use of Classified Staff: Funds will not be used to pay for classified staff.

Explanation of Capital Expenditures Greater Than \$5,000: NA

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2.25 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.7 FTE

B. Other Funds:

Source of Funds	\$ Amount Proposed	\$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota, Veterinary Diagnostic Laboratory;(pathologists at 0.09 FTE for 2 yrs)	\$ 48,800	\$ 16,000	disease and health screening for dead moose
1854 Treaty Authority	\$ 25,000	\$ 8,000	capture & field necropsy support, supplies, equipment, spotter plane costs
Fond du Lac Resource Management Division	\$ 20,000	\$ 5,000	capture support, field necropsy support
Natural Resources Research Institute: Ron Moen	\$ 10,000	\$ 2,500	field necropsy support, data analyses
State			
MNDNR Wildlife Health Program: Michelle Carstensen; 24 mos, 50% effort	\$ 75,450	\$ 42,103	project management, field necropsies, analyze, write, outreach
MNDNR Forest Wildlife Populations & Research Group: Glenn D. DelGiudice; 24 mos, 50% effort	\$ 95,250	\$ 34,341	project management, fieldwork, data analysis, writing, outreach
MNDNR Wildlife Health Program: Erik Hildebrand; 24 mos, 25% effort	\$ 25,990	\$ 21,052	field data collection, field necropsies, outreach
MNDNR Wildlife Health Program: David Pauly/Dawn Plattner; 24 mos, 57% effort	\$ 87,730	\$ 37,982	field data collection, field necropsies, outreach
MNDNR Wildlife Health Program: Other	\$ 0	\$ 72,365	Staff time, travel, supplies, etc. in support of Activity 1
MNDNR Forest Wildlife Populations & Research Group: Other	\$ 0	\$ 24,820	Staff time, travel, supplies, etc. in support of Activity 2
TOTAL OTHER FUNDS:	\$ 388,220	\$264,163	

VII. PROJECT STRATEGY:**A. Project Partners:**

Lead investigators—Dr. Michelle Carstensen (adult component, \$0 from the ENRTF appropriation) and Dr. Glenn D. DelGiudice (calf component, \$0), MN DNR.

Co-investigators—Natural Resources Research Institute (\$0) and University of Minnesota Department of Fisheries, Wildlife, & Conservation Biology (\$106,795).

Collaborators—Fond du Lac Resource Management Division (\$0), University of Minnesota Veterinary Diagnostic Laboratory (\$10,000), 1854 Treaty Authority (\$0), Minnesota Deer Hunters Association (\$0).

B. Project Impact and Long-term Strategy:

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 contribute to quantifying 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 (adults and calves) that die during the study period will be determined, contributing to our understanding of the specific role health-related factors and other mortality forces (e.g., undernutrition, predation) are playing in the overall decline of the NE moose population. Once the specific causes of mortality and major influential factors (i.e., nutritional condition, seasonal weather conditions) are identified, appropriate population and habitat management actions may be taken to address the population's decline.

The primary goal of our 3-year study is to thoroughly investigate how ambient temperatures relate to moose productivity, reproductive success, and survival in NE MN by applying an unprecedented field approach and

comprehensive data collection methods. No other study has documented a relationship between ambient temperature, body temperature (measured in free-ranging moose), and other variables which may influence this relationship (e.g., activity, habitat use). 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 MN, 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 seasonal survival rates and increasing ambient temperatures, and they observed higher mortality rates than expected during non-winter months. Those findings implicated climate change 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, increased study period, and re-examinations of relationships between survival and ambient temperatures, 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 spurious, perhaps attributable to limited sample sizes and data collection over a relatively brief period of time. Improved understanding of how climate, diseases, parasites, nutrition, and habitat needs may be influencing the population performance of moose 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.

C. Spending History:

Funding Source	M.L. 2008 or FY09	M.L. 2009 or FY10	M.L. 2010 or FY11	M.L. 2011 or FY12-13	M.L. 2013 or FY14
M.L. 2011 ENTRF funding for "Determining causes of death in declining moose population"				\$ 600,000	
MNDNR, Wildlife Health Program for Adult Mortality Study				\$ 163,141	\$ 58,359
MN DNR, Section of Wildlife for Calf Mortality Study				\$ 220,000	\$ 221,397
TOTAL SPENDING HISTORY:				\$ 983,141	\$ 279,756

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See attached map.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: See attached Research Addendum.

XII. REPORTING REQUIREMENTS:

Periodic Work Plan status update reports will be submitted not later than December 2014, June 2015, December 2015, June 2016, December 2016, and June 2017. A final report and associated products will be submitted between June 30 and August 15, 2017 as requested by the LCCMR.



Environment and Natural Resources Trust Fund											
M.L. 2014 Project Budget											
Project Title: Moose Decline and Air Temperatures in Northeastern Minnesota											
Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 5m											
Project Manager: Michael A. Larson											
Organization: Minnesota Department of Natural Resources											
M.L. 2014 ENRTF Appropriation: \$600,000											
Project Length and Completion Date: 3 Years, June 30, 2017											
Date of Report: June 4, 2015											
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Revised Activity 1 Budget 06/04/2015	Amount Spent	Activity 1 Balance	Activity 2 Budget	Revised Activity 2 Budget 06/04/2015	Amount Spent	Activity 2 Balance	TOTAL BUDGET	TOTAL BUDGET 06-04-2015	TOTAL BALANCE
BUDGET ITEM	Determine effects of temperatures on adult moose.				Determine effects of female condition & behavior on calf moose.						
Personnel (Wages and Benefits)											
Wildlife Health Specialist (\$74,000) - 1 person, 0.43 FTE year-round for 23 years, 75% salary & 25% benefits; Field technicians (\$47,000) - 2 people for 180 days (0.69 FTE each) during spring/summer 2015, 1 person for 240 days (0.92 FTE) during fall 2015	\$74,000	\$111,000	\$22,553	\$88,447	\$47,000	\$47,000	\$19,833	\$27,167	\$421,000	\$158,000	\$115,614
Professional/Technical/Service Contracts											
Wildlife helicopter capture company to capture & handle 30 adult moose, competitive bid	\$48,000	\$31,770	\$31,770	\$0					\$48,000	\$31,770	\$0
Univ. of Minnesota for graduate student (0.5 FTE for 2 years) to lead field work & analyses for calf component					\$80,000	\$80,000	\$25,030	\$54,970	\$80,000	\$80,000	\$54,970
Univ. of Minnesota for statistical consultant (0.21 FTE, 83% salary & 17% benefits, spread across 3 years) for data analysis and modeling	\$13,400	\$13,400	\$2,831	\$10,569	\$13,395	\$13,395	\$2,830	\$10,565	\$26,795	\$26,795	\$21,134
Univ. of Minnesota Veterinary Diagnostic Lab for analyses of samples from captured and dead moose.	\$5,000	\$5,000	\$3,709	\$1,291	\$5,000	\$4,000	\$0	\$4,000	\$10,000	\$9,000	\$5,291
Satellite data acquisition for locations, heart rates, temperatures, & mortalities of adult moose; competitive bid	\$35,000	\$60,000	\$18,445	\$41,555					\$35,000	\$60,000	\$41,555
Satellite data acquisition for locations & mortalities of calf moose, competitive bid					\$15,000	\$3,000	\$1,725	\$1,275	\$15,000	\$3,000	\$1,275
Equipment/Tools/Supplies											
30 GPS collars for adult moose (had sufficient unused collars from previous years to deploy in 2015)	\$75,000	\$0	\$0	\$0					\$75,000	\$0	\$0
40 GPS collars for calf moose (no collaring in 2015)					\$55,000	\$0	\$0	\$0	\$55,000	\$0	\$0
30 Mortality implant transmitters to record heart activity & body temperatures of adult moose	\$27,000	\$25,856	\$25,856	\$0					\$27,000	\$25,856	\$0
30 Air temperature loggers to record ambient air temperatures (purchased these with non-ENRTF funds)	\$4,500	\$0	\$0	\$0					\$4,500	\$0	\$0
Pharmaceuticals for immobilization of captured moose	\$6,000	\$5,821	\$5,821	\$0					\$6,000	\$5,821	\$0
Travel expenses in Minnesota											
Fleet, mileage, lodging, & meals for project managers and field staff	\$29,030	\$59,029	\$25,916	\$33,113	\$27,909	\$22,909	\$13,481	\$9,428	\$56,939	\$81,938	\$42,541
Lodging & meals for 2 volunteer technicians					\$7,500	\$3,100	\$2,000	\$1,100	\$7,500	\$3,100	\$1,100
Other											
Aerial surveys for calves (added 06/04/2015)					\$0	\$50,400	\$0	\$50,400		\$50,400	\$50,400
Airplane flights for moose captures & tracking	\$10,500	\$23,554	\$8,554	\$15,000					\$40,500	\$23,554	\$15,000
Direct & necessary services to support this appropriation	\$11,291	\$11,291	\$3,763	\$7,528	\$10,475	\$10,475	\$3,492	\$6,983	\$21,766	\$21,766	\$14,511
Unallocated (added 06/04/2015)					\$0	\$19,000	\$0	\$19,000	\$0	\$19,000	\$19,000
COLUMN TOTAL	\$338,721	\$346,721	\$149,218	\$197,503	\$261,279	\$253,279	\$68,391	\$184,888	\$600,000	\$600,000	\$382,391



LCCMR Briefing on June 11, 2015

Moose Decline and Air Temperatures in Northeastern Minnesota

M.L. 2014, Chp. 226, Sec. 2, Subd. 5m

Table 1. ENRTF Moose Research Projects Timeline

ENRTF approp.	Manager	Organization	Collaring	Description
M.L. 2010 Subd. 3k	Moen	UMD	Yes	Identified habitat use to guide site enhancement or protection
M.L. 2011 Subd. 3f	Carstensen	DNR	Yes	Identified causes of mortality of adult moose
M.L. 2013 Subd. 4g	Moen	UMD	No	Evaluating habitat management for moose
M.L. 2014 Subd. 5m	Larson	DNR	Yes	Adult and calf moose mortality and adult physiology
M.L. 2014 Subd. 5l	Forester	Univ. of MN	No	Impacts of forest quality on moose food and cover

Table 2. DNR Moose Research Projects Summary and Funding

Calendar year	Adults		Calves	
	Winter collaring	Funding	Spring collaring	Funding
2013	111 captured 4 capture-related deaths	ENRTF M.L. 2011	49 captured 9 abandoned 11 capture-related deaths	Game & Fish Fund
2014	36 captured 3 capture-related deaths	ENRTF M.L. 2011	25 captured 9 abandoned 2 capture-related deaths	Game & Fish Fund
2015	32 captured 5 capture-related deaths	ENRTF M.L. 2014	No captures; tracking calving activity and mortality via GPS-collared mothers	ENRTF M.L. 2014

Table 3. DNR Moose Calf Capture Summary

Dates	Approach method	Handling time (minutes)	Number of calves			Disposition of abandoned calves
			Captured	Abandoned	Died	
May 8–17, 2013	Helicopter	10–15	49	9	11	9 died in the field
May 8–15, 2014	Ground	3–5	12	7	1	6 at MN Zoo 1 died in the field
May 21– June 19, 2014	Ground	Less than 1	13	2 ^a	1	1 at licensed facility; 1 died in the field

^a Last capture; late-born twins.

Peer Review of DNR Moose Calf Research

The initial moose calf research proposal was developed during 2012 with extensive consultation of the peer-reviewed scientific literature and with numerous researchers from outside Minnesota with experience capturing moose calves. This proposal was reviewed by DNR supervisors and managers with knowledge of and experience with capturing and handling wildlife for research.

A version of the proposal also was reviewed by the University of Minnesota's Institutional Animal Care and Use Committee (IACUC, Protocol ID: 1302-30328A) because the project included a university graduate student. As part of the IACUC process, annual status reports describing progress, challenges, and study responses to these challenges are submitted by the principal investigator and are reviewed by the IACUC before the project is approved to continue.

Annual progress reports also have been presented to and discussed with moose research colleagues within and outside Minnesota and other professional wildlife audiences. Specifically, Drs. Glenn DelGiudice and Ron Moen organize an annual moose research symposium, and during the one in fall 2013 a group comprising moose scientists from Minnesota, Ontario, and Sweden met in a special session to review the first year of captures for MN DNR's moose calf research project.

As at least a 3rd form of external scientific review, our LCCMR Research Addendum received rigorous peer review during winter 2013–2014.

Proposal to study moose calves without collaring them

In lieu of collaring moose calves to track their movements and study their mortality, we propose to monitor moose calves first by intensively but remotely tracking the movements and behavior of their mothers and subsequently with 3 aerial surveys during the leaf-off period of fall and winter.

Calving

As we did during 2013 and 2014, we continue to use several methods of computer-based monitoring of adult, GPS-collared females. The collars collect a location once every hour, and our team accesses and analyzes the locations several times each day. Since 2013 we have learned that pregnant moose make a characteristic, relatively long-distance “calving movement” and then localize to give birth. We use this information to determine which individuals are calving, the time of calving, and the specific location of calving.

We will use the twinning rates (i.e., proportions of calving females producing twins rather than singletons) that we observed during calving in 2013 and 2014 to estimate calf production with reasonable confidence. Calving females and their calves typically stay at their calving site for 7–10 days. After the mother’s GPS locations indicate that they have left the calving area we will locate the site on the ground and conduct extensive habitat analyses to assess habitat requirements for calving (e.g., attributes affording quality forage, hiding cover from predators, and thermal cover) and how these may be affected by various environmental factors (e.g., ambient temperature).

Calf survival and cause-specific mortality

Using data from 2013 and 2014 when we had samples of collared calves and their collared mothers we determined that females whose calves were killed by wolves or bears fled approximately 400–800 m from the calf mortality sites, whereas females moved only up to 70 m during the same amount of time when a calf mortality event did not occur. We will continue throughout the summer acquiring hourly locations of females that calved, whereas in previous years we reduced the frequency of adult collar locations to once every 4 hours after the calving period. Tracking hourly female movements will allow us to determine with reasonable confidence the temporal and spatial distribution of calf mortalities, at least during the first 2 months of age when natural causes of mortality, such as predation, have their most concentrated impact on calf survival. After mothers who fled are given an opportunity to return to the suspected calf mortality site and leave again, a behavior we documented previously, we will locate and investigate on the ground suspected calf mortality sites to verify if a mortality occurred and to document remaining evidence of the cause of death using the same field and lab methods as before.

Without GPS collars on calves we do not know if we will be able to detect mortality events throughout their entire first year of life. Therefore we will use a series of aerial surveys of GPS-collared mothers to determine if they still have calves with them. We propose 3 surveys—1 after leaf-off in the fall, 1 during mid-winter, and 1 during late-winter. We will use survey observations to verify tentative determinations of calf survival and mortality from the summer and to estimate seasonal survival, annual recruitment, and the impacts of calf recruitment on the overall moose population trajectory.

We will also continue detailed habitat analyses of calf mortality sites, both on the ground in the field and using geographic information systems (GIS) to identify potential habitat factors or deficiencies which may contribute to the vulnerability of calves to various sources of mortality and to improve our understanding of forest management activities that best meet the requirements of moose for reproductive success and survival.