Environment and Natural Resources Trust Fund (ENRTF) M.L. 2011 Project Abstract
For the Period Ending June 30, 2015

PROJECT TITLE: Determining Causes of Mortality in Moose Populations
PROJECT MANAGER: Michelle Carstensen
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 03f

APPROPRIATION AMOUNT: $600,000

Overall Project Outcomes and Results

Minnesota's moose (*Alces alces*) are dying at rates much higher than elsewhere in North America. Recent aerial surveys indicate the northeastern population has declined 50% since 2006. Previous research in MN reported a 21% average non-hunting mortality rate, much higher than the 8-12% reported for moose elsewhere in North America. In 2013, the Minnesota DNR launched a new study to determining cause-specific mortality by deploying Iridium GPS collars on moose in northeastern MN and investigated mortalities within 24 hours of death to identify proximate cause of mortality and to examine the influence of potential contributing factors. In the first 2.5 years of this multi-year study, 156 moose have been radiocollared and annual mortality rates were 19% and 12% in 2013 and 2014, respectively; 9% of collared moose have died in the first half of 2015. Overall, 41 moose have died and causes of mortality were health-related (61%), which included bacterial infections, winter ticks, brainworm, accident, multiple chronic health issues, and other undetermined health causes, and predator-related (39%), which included confirmed and likely wolf-kills. Predisposing health issues (e.g. brainworm, pneumonia, previous injury) likely contributed to at least 6 of the wolf-killed moose. Response times from initial mortality notification (e.g. text message or email) to a team in the field at the death site were ≤24 hours in 23 cases (59%), between 24 and 48 hours in 10 cases (26%), and >48 hours in 6 cases (15%). Mortality implant transmitters (MITs) were deployed in 61 moose to detect instantaneous death as well as internal body temperature. 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. This study has documented key mortality factors to improve our understanding of the moose decline in northeastern Minnesota.

Project Results Use and Dissemination

The moose project has received an enormous amount of media coverage, including international, national, regional, and local outlets. Minnesota DNR staff have provided presentations about this research project to international and national scientific meetings, regional meetings, and to local stakeholder groups. Links to some the highlighted media coverage and reports can be found on the project's website: http://www.dnr.state.mn.us/moose/index.html. Further, report on this project was published in the 2013 Summaries of Research Findings: http://www.dnr.state.mn.us/publications/wildlife/research2013.html

With the continuation of ENTRF project funding for "Moose Decline and Air Temperatures in Northeastern Minnesota", M.L. 2014, Chp. 226, Sec. 2, Subd. 5m, outreach and dissemination of this project is on-going. Peer-reviewed publication of the findings of cause-specific mortality for adult moose

in this study will be initated after the completion of the third full year of the project (December 2015). Other peer-reviewed publications have been initated, including a techniques paper documenting the methods used to respond to moose mortalities within 24 of death, and a collaborative analyses of serum chemistries from moose in Minnesota, New England states (Maine, New Hampshire, and New York), and western US (Colorado, Wyoming, and Montana).

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2011 Work Plan Final Report

Date of Status Update: 8/17/15
Date of Next Status Update: Final Report
Date of Work Plan Approval: 8/11/2011
Project Completion Date: 6/30/2015

Project Title: Determining Causes of Mortality in Moose Populations

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Location:

Counties Impacted: Cook, Lake, St. Louis

Ecological Section Impacted: Northern Superior Uplands (212L)

Total ENRTF Project Budget:	**ENRTF Appropriation $:**	600,000
	Amount Spent $:	599,977
	Balance $:	23

Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 03f

Appropriation Language:
$300,000 the first year and $300,000 the second year are from the trust fund to the commissioner of natural resources to determine specific causes of moose mortality and population decline in Minnesota and to develop specific management actions to prevent further population decline. This appropriation is available until June 30, 2015, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Determining causes of death in declining moose population

II. PROJECT SUMMARY: 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. A 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 communication satellite- linked 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.

III. PROJECT STATUS UPDATES:

Project Status as of December 2011: While moose captures will not occur until January-February of 2013, we will be receiving two prototype test collars from each of the three collar manufacturers. These collars will be rigorously tested in a variety of habitat types and weather conditions this winter. We continue to work with biologists and veterinarians nationally and internationally to ensure that we have a complete list of appropriate diagnostics.

Project Status as of June 2012: We received 2 prototype test collars from two vendors (the third was unable to complete their design of the Iridium collars). Both collar types were thoroughly tested and evaluated, and we are pleased with their capabilities. We have completed our specifications for the collar bid process and will be putting them out to bid in July. We are also working on getting the bid out for the moose captures that will be occurring in January-February of 2013. We continue to work with biologists and veterinarians nationally and internationally to ensure that we have a complete list of appropriate diagnostics.

Project Status as of December 2012: We put our collars out to bid and Vectronics (a collar company out of Germany) was awarded our contract. Our order for 100 GPS Iridium collars was placed and we have received all 100 collars from the manufacturer. All collars have been programmed and have undergone rigorous individual testing to be sure they function as specified. We purchased a base station modem, where all of the data the collars provide will be sent to and stored for analysis. We put our capture contract out to bid as well, and the bid was awarded to Quick Silver Aviation, and the capture process is slated to begin near the end of January, 2013. Capture planning efforts are well underway, and the logistics (fueling locations, lodging for the crews etc) have been worked out. We have placed an order for capture drugs, and have begun ordering/receiving veterinary supplies for the capture as well. Additionally, we have ordered and received 3 SPOT devices, which will be used to notify emergency personnel if immediate medical assistance is needed for our necropsy response field teams. All primary necropsy responders have underwent extensive necropsy training at the University of Minnesota Veterinary Diagnostic Laboratory and are ready to field necropsy moose. We have our field necropsy kits built, and ready for use. Necropsy response teams will be on call to respond to any mortalities as soon as the first moose is captured. We continue to work with biologists and veterinarians nationally and internationally to ensure that we have a complete list of appropriate diagnostics.

Project Status as of June 2013: From Jan 20 – Feb 7, 2013, 111 moose (84 females, 27 males) were captured and fitted with GPS collars (this includes 10 collars from a University of Minnesota researcher who is collaborating on the project, and one collar that was redeployed after a mortality). ENTRF funds were used to pay for the capture of 100 moose. Four moose (2 females, 2 males) died within 2 weeks of their capture date and were considered capture related mortalities and have been censored from analysis. Of the 100 collars purchased by the MN DNR, 26 have had mortality switch malfunctions, resulting in the collars being locked in mortality mode. To address this, we worked with the collar manufacturer to develop a localization program, which evaluates all the locations and generates a text message notification if the GPS fixes are within a 20 m radius. This program has actually increased our ability to recognize animals that are moribund, but are not actually dead, allowing us to euthanize the animal. This allows never before documented clinical signs to be observed and key samples (e.g., fresh blood) to be collected, which is vital when trying to determine cause of death. This program has also helped us identify wolf-kills faster, as wolves will feed under the collar and prevent it from going into mortality until they have left the carcass. As of 25 June, 2013, 15 of 107 (14%; 11 females, four males) collared moose have died. Causes of death are as follows: 5 wolf kills, 2 wolf-caused injuries with secondary lethal infections, one *P. tenuis* infection, 3 winter ticks, and 4 health-related mortalities with results pending. Two of the moose were found alive and euthanized, 4 carcasses were extracted intact and delivered to the UM VDL for a complete necropsy, and 11 were necropsied in the field. The causes of mortalities determined to-date have not been unexpected. Spring is the most stressful time of year for moose (i.e., lack of adequate forage, very little remaining fat reserves) and coupled with snow conditions that favored wolves and winter ticks, these types of mortalities are not unusual. The body condition score of each animal was evaluated when possible at capture. Ultrasound rump fat measurements were also performed. Biological samples collected at capture were evaluated for a variety of disease agents and evaluated for the health status of the animal. Snow urine collections began in January 2013. Random snow-urine samples and samples from known moose were collected through 24 March 2013. Presently, these samples are being analyzed in the laboratory for urea nitrogen and creatinine.

Project Status as of December 2013: As of 10-January, 2014, 22 of 107 (20.6%; 18 females, 4 males) collared moose have died. Causes of death are as follows: 8 wolf kills (3 of which had predisposing health conditions that likely contributed to their death), 2 wolf-caused injuries that led to secondary lethal bacterial infections, 10 health-related deaths (including 2 *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, and 4 unknowns with pending results), 1 trauma (compound fracture that led to septicemia), and 1 unknown (only collar recovered, no carcass was found). Whole carcasses were retrieved for 8 of these moose, with field necrospies preformed on the remainder. In 16 of 22 mortality responses (73%), our response time to the scene was ≤24 hours (4 of which were <6 hrs). Collar transmission failures and wolf-caused collar movements have delayed response times in the remainder of cases. Our ability to retrieve intact carcasses has been greatly enhanced by the use of chainsaw winches, powerful snow machines with a rubber sled specifically designed to drag moose, and an Argo (amphibious 6-wheeler). We have successfully trained 8 primary moose responders that are capable to lead field necropsy teams, and recruited 13 secondary and 18 tertiary responders to assist in mortality responses. Mortality response teams (2-3 people) are on-call 24 hours/day, everyday (including weekends and holidays). Further, the 26 collars with failed mortality functions are monitored daily through a localization program and staff checking transmissions to ensure adequate moose movements. An additional 8 collars have stopped transmitting entirely and those moose are currently censored from the study. The collar manufacturer, Vectronics Aerospace, has replaced all 34 malfunctioning collars (free of charge), under warranty. We will be using these new, replacement collars to capture an additional 30 adult moose (22 females, 8 males) this coming winter. Biological samples obtained during initial moose captures were analyzed and serologic evidence of exposure to West Nile Virus, malignant catarrhal fever, various serovars of *Leptospira interrogans*, and *Borreilia* was documented. Progesterone levels were screened for 75 females and 56 (75%) were pregnant. Fecal floatation was used to screen moose at capture for parasites, with 31 of 84 (36.9%) infections identified. These parasites included *Nematodirus* sp. (20 moose), Strongyle-type ova (6

moose), *Moniezia* sp. (1 moose), and coinfections in 4 moose. Aging of moose at capture has also been completed and mean age was 5.75 years (SE = 0.4, *n* = 84), with a range of 1 to 14 years.

During 23 January-25 March, 124 snow-urine samples of moose were collected randomly during 5, 2-week sampling intervals, and an additional 112 specimens were collected from 35 (31 females, 4 males) targeted, collared moose (collared moose were sampled during 1-3, 2-week sampling intervals). According to our random sampling, overall, the mean urea nitrogen:creatinine (UN:C) ratio for the entire winter was 3.7 mg:mg (SE = 0.4, *n* = 123), and the percentage of snow-urine specimens collected with UN:C ratios indicative of severe nutritional restriction (≥3.5 mg:mg) of moose was 32%. Mean urinary UN:C ratios indicated that nutritional restriction on average was "normal" or modest during late January, but was severe throughout February and early March, and still moderately severe during late March. Overall, about 41% of the UN:C values of total snow-urine specimens collected tracking target moose indicated moose were experiencing moderately severe (21.4%) to severe (20.0%) dietary restriction; the remaining 58.6% reflected normal or modest winter restriction. From late February through late March, the percentage of snow-urine specimens reflecting normal restriction was stable at about half (53.8-57.7%); however, the percentage of samples indicative of severe restriction doubled from late February (19.2%) to late March (38.5%), and those reflecting moderately severe restriction decreased from 28.0 to 7.7%. The random sampling approach involved specimens from a large number of moose during each 2-week sampling interval will be continued as part of the adult moose mortality study in winter 2014.

Ammendment Request (12/31/13): This amendment request proposing to move $17,000 currently allotted to cover diagnostic screening and testing of samples from dead moose (Activity 2: Determine specific causes of mortality of moose in NE Minnesota) to help offset increased costs for moose captures this coming winter (February 2014), which is also within budget Activity 2 budget. With only 30 moose being captured this coming winter, the costs per moose have increased to $1650/moose. DNR has additional project funding that can used to pay for diagnostic fees for dead moose. Moving these funds will assist us in covering the increased helicopter capture contract for the project. We also propose to move $12,660 currently allotted for our wildlife technician within Activity 3, to Activity 2; as seasonal volunteers and a University of Minnesota graduate student have been able to assist with winter snow urine collection, thus freeing up the wildlife technician to spend more time monitoring and responding to moose mortalities. Lastly, we request to move the remaining balance for capture drugs, $8,036, to offset fleet costs for project management staff. Additional DNR funds were utilized to pay for capture drug costs in FY13, and no additional drugs needs to be purchased in FY14 for winter 2014's captures. Moving of these funds does not impact our work plan. Lastly, Erika Butler is no longer an employee of the MN DNR; therefore, Michelle Carstensen is now the project manager for this study. Approved by the LCCMR 2/5/2014.

Project Status as of June 2014: The survival rate for adult moose in Year 1 (4 February, 2013 to 5 February, 2014) of this study was 79.9% (95%CI = 72.0 to 87.9%). A total of 21 collared moose (17 females, 4 males) have died. At the end of Year 1, we had 78 moose remaining with active collars, excluding censored animals (n=12). Causes of death are as follows: 11 predator-related mortalities (52%), which includes 6 wolf kills (3 of which had predisposing health conditions that likely contributed to their death), 3 likely wolf kills, and 2 wolf-caused injuries that led to secondary lethal bacterial infections; and 10 health-related mortalities (48%), which includes 2 *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, 1 trauma with associate septicemia, and 3 undetermined health issues. Whole carcasses were retrieved for 8 of these moose, with field necrospies performed on the remainder. A total of 12 collared moose were censored in Year 1 due to capture-related mortalities (n=4), slipped collar (n=1), and collars that stopped transmitting (n=7).

From February 6-11, 2014, 31 new moose (12 males, 19 females) and 5 female moose with failed collars (originally captured in 2013) were captured and recruited into the study. Sample size for the start of Year 2 was 104 collared moose. As of June 20, 2014, survival rate is 93.4%. A total of 7 collared moose (6 females, 1 male) have died. Causes of death are as follows: 4 predator-related mortalities

(57%), which includes 3 wolf kills and 1 wolf-caused injury that led to a secondary lethal bacterial infection; and 3 health-related mortalities (43%), which includes 1 *P. tenuis* infection, 1 accident (fell through the ice and drowned), and 1 undetermined health issue. Nine collared moose from Year 2 are censored thus far, which includes 3 capture-related mortalities, 1 slipped collar, and 5 collars that stopped transmitting. Progesterone levels from blood samples obtained during captures indicated a 77% pregnancy rate; similar to 75% from last winter. Winter mortalities (from capture to 30 April) of collared moose in Year 2 is 3x lower than Year 1 (3% vs 9.5%). It appears that winter survival was enhanced by the prolonged winter 2013, which may have suppressed winter tick numbers, as we have not reported any winter tick mortalities during winter 2014. Also, the historically severe winter of 2014 likely reduced deer numbers in our study area, which would lessen disease exposure risks of moose to *P. tenuis* and liver flukes.

Biological samples obtained at capture were analyzed and serologic evidence of exposure to West Nile Virus (8 of 34, 23.5%), malignant catarrhal fever (1 of 34, 2.9%), various serovars of *Leptospira interrogans* (6 of 34, 17.6%) and *Borreilia* (2 of 34, 5.9%) was documented. Progesterone levels were screened for 23 females and 19 (83%) were pregnant. Fecal floatation was used to screen moose at capture for parasites, and 3 of 28 (10.7%) were identified as having infections. These parasites included *Nematodirus* sp. (2 moose) and coinfections with Strongyle-type ova (1 moose). Mean age of captured moose was 5.3 years (n=23, range 1 to 13). The body condition score of each moose was evaluated and recorded whenever possible; 6 were classified as thin (16.7%), 21 as normal (58.3%), and 9 as fat (25%). None of the animals were classified as very thin.

Efforts continued during winter 2014 to assess severe nutritional restriction of moose throughout the study area by examining UN:C ratios from snow urine samples. Following the pilot year (winter 2013), a more aggressive effort was launched during the severe winter of 2014. From 9 January to 26 March, 313 fresh snow urine samples were collected during 6, 2-week sampling intervals. Sample sizes ranged from 33 to 79 specimens per interval and spatial coverage throughout the study area was extensive. Chemistry results and assessments are pending.

Ammendment Request (06/30/14): This amendment request is proposing to move a total of $1,855 of remaining unspent balances in diagnostic screening ($955), medical/lab supplies ($530), field equipment ($35), spotter plane ($230), (all Activity 2: Determine specific causes of mortality of moose in NE Minnesota), and seasonal volunteers ($105; Activity 3) to Iridium satellite download costs. This would increase the remaining funds available to cover the cost of data transmissions from our collared moose to $5,984. As this project is continuing, with an average of 90-100 moose on the air monthly, download fees are about $5,000/month. This amendment would enable us to spend monies in the high priority areas of the project, leaving DNR funding to cover other shortages. Moving of these funds does not impact our work plan. Approved by the LCCMR 6/26/2014.

Project Status as of December 2014:

Moose survival throughout the second year of this study has markedly improved, with only an 11% mortality rate (compared to 20% during the first year). From February-December 2014, 11 collared moose have died. Six (55%) of these deaths were predator-related, including 4 wolf kills, 1 likely wolf kill, and 1 wolf-caused injury with a secondary lethal infection. Five (45%) deaths were health-related, including 1 *P. tenuis* infection, 1 likely *P. tenuis* infection, 1 accident (fell through the ice), and 2 with multiple, chronic issues (e.g., kidney disease, cachexia, internal bleeding, bacterial infection, and liver flukes). This enhanced survival may be at least partially attributed to less of a winter tick burden, as two consecutive severe winters likely reduced tick numbers. Further, wolves may have shifted a greater portion of their prey base in late winter through early spring to deer, as winter severity impacted deer survival.

A total of 39 collared moose have died since this study began, which included 7 capture-related mortalities that will be censored from subsequent survival analyses. Overall causes of death are as

follows: 7 capture myopathy or associated capture-related issues (18%); 17 predator-related mortalities (53%), which includes 11 wolf kills, 3 likely wolf kills, and 3 wolf-caused injuries that led to secondary lethal bacterial infections; and 15 health-related mortalities (47%), which includes 3 *P. tenuis* infections, 1 likely *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, 1 trauma with associate septicemia, 1 accident, 2 with multiple/chronic health issues, and 3 undetermined health issues. Whole carcasses were retrieved for 14 of these moose, with field necrospies performed on remaining 25 moose. Response times from initial mortality notification (e.g. text message or email) to a team in the field at the death site were ≤24 hours in 23 cases (59%), between 24 and 48 hours in 10 cases (26%), and >48 hours in 6 cases (15%). Delays in mortality responses > 24 hours have been due to collar failures and wolves actively feeding on the moose carcass and preventing the collar from sending a mortality alert. There are currently 94 remaining moose in the study, but 18 of these have collars that are experiencing transmission failures and we are not certain of their status; thus, 76 moose are actively transmitting data. Plans are underway to capture 26 new moose in winter 2015 (funded by LCCMR: Moose decline and air temperature in Minnesota and MN DNR), to return the sample size to >100 collared moose; each moose will receive an MIT.

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 successfully 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–July 2015, 9 collared moose died and were investigated. Six moose died from health-related causes (1 *P. tenuis* infection, 2 bacterial infections, and 3 undetermined), 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.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Purchase and thoroughly field test 100 communication satellite-linked Global Positioning System (GPS) collars

Description: One hundred GPS collars utilizing the Iridium communication satellite technology will be purchased in spring of 2012. The collars will notify the research team when a moose has died by way of a motion-sensitive switch in the collar and subsequently sending a text message with the moose's location. This technology will be thoroughly field tested in a variety of habitat types and weather conditions prior to deployment on moose. Prototypes of the collars will be requested from the various manufacturers for more rigorous testing in the winter of 2011-2012.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 256,721
Amount Spent: $ 256,721

Balance: $0

Activity Completion Date:

Outcome	Completion Date	Budget
1. Field test prototype collars provided by vendors.	3/31/2012	$0
2. Purchase 100 GPS collars	5/30/2012	$ 256,721
3. Thoroughly field test collars and their mortality notification function	11/30/2012	$0

Activity Status as of December 2011: Two Iridium GPS collar prototypes have been requested from each of the three manufacturers of collars. The manufacturers agreed to provide the collars to us at no cost. Collars will be delivered by the end of December, after which they will be thoroughly field tested in a variety of habitat types and weather conditions. Their remote programming capabilities will also be tested.

Activity Status as of June 2012: We received 2 prototype test collars from two vendors (the third was unable to complete their design of the Iridium collars). Both collar types were thoroughly tested and evaluated, and we are pleased with their capabilities. We have completed our specifications for the collar bid process and will be putting them out to bid in July. We plan on receiving the 100 GPS collars by November of 2012.

Activity Status as of December 2012: We received 100 GPS Iridium collars from Vectronics (a collar company in Germany). All collars have been programmed and undergone rigorous individual testing to ensure they function as desired. We purchased a base station modem, which is where all the data will be sent and stored for analysis.

Activity Status as of June 2013: Of the 100 collars purchased by the MN DNR, 26 have had mortality switch malfunctions resulting in the collars being locked in mortality mode. To address this, we worked with the collar manufacturer to develop a localization program, which evaluates all the locations and generates a text message notification if the GPS fixes are within a 20 m radius. This program is currently functioning on both our locked-in-mortality collars (notification generated if fixes from the past 12 hours are within a 20 m area) and our properly functioning collars (notification generated if the fixes from the past 24 hours are within a 20 m area). This program has actually increased our ability to recognize animals that are moribund, but are not actually dead, allowing us to euthanize the animal. This allows never before documented clinical signs to be observed and key samples (e.g., fresh blood) to be collected, which is vital when trying to determine cause of death. This program has also helped us identify wolf-kills faster, as wolves will feed under the collar and prevent it from going into mortality until they have left the carcass.

Activity Status as of December 2013: Of the 100 collars originally purchased by MN DNR, 34 have been replaced under warranty for failed mortality switches (n = 26) or total loss of transmission (n = 8). In addition to localization program, which alerts the moose response teams via text message if a moose has not move >20m in a defined time period, our staff also check moose transmissions daily to ensure adequate movement. Given the 34 collar replacements, no additional collars need to be purchased for the upcoming capture of 30 moose in February 2014.

Activity Status as of June 2014: Replacement collars, provided by the manufacturer at no charge under warranty, were used to collar all new moose in February 2014. An additional 7 collars have failed this winter and are in the process of being replaced under warranty as well. One collar failed outside the 1-year warranty period and will not be replaced.

Activity Status as of December 2014: We have received the 7 replacement collars, provided at no cost by the manufacturer, referenced in the June 2014 status update. Another 8 collars stopped

transmitting in the field and have been replaced as well. Therefore, no new collars are needed to be purchased for winter 2015 captures, as we have enough replacement collars on-hand to collar 26 moose.

Activity Status as of June 2015: No additional collars were purchased, but 1 additional replacement collar was received as a warranty replacement due to a collar failure.

Final Report Summary: August 2015
After our original purchase of collars (*n*=100) at the start of this study, we never had to purchase any additional collars to maintain our sample size of collared moose. This is because we had 49 collars replaced under warranty for various failure issues (e.g. locked in mortality mode, stopped transmitting, intermittent transmissions). While collar failures were a constant issue in this study, we developed other methods of monitoring (i.e. localization program, adjusting frequency of fixes to allow for increased tracking on certain individuals, etc.) to overcome many of these challenges. Unfortunately, approximately 25 moose have had collars fail to the extent that we were unable to monitor them at all. Throughout this project, the collar manufacturer has provided excellent customer service and warrantied their products as expected under the terms of the contract.

ACTIVITY 2: Determine specific causes of mortality of moose in NE MN

Description: Global Positioning System (GPS) collars will initially be deployed on 100 adult moose (approximately 75 females and 25 males) in January-February of 2013. A second capture event will occur in January-February of 2014 to maintain sample size at 100 animals; refurbished GPS collars will be deployed on these animals. 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 responders 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, a trained biologist or veterinarian will perform a thorough field examination (necropsy). Diagnostic screening for more than 30 diseases, toxicities and deficiencies will occur by Board-certified veterinary pathologists.

Summary Budget Information for Activity 2:

ENRTF Budget:	**$ 336,665**
Amount Spent:	**$ 336,642**
Balance:	**$ 23**

Activity Completion Date:

Outcome	Completion Date	Budget
1. Determine specific causes of death of moose that die during the study period.	6/30/2015	$ 322,597
2. Refurbish GPS collars (approximately 20) to maintain sample size at 100 animals	11/30/2013	$0
3. Quantifying rate of exposure to diseases and toxicity and deficiency levels	6/30/2015	$ 14,045
4. Preliminary data analyses and final LCCMR report	6/30/2015	$ 0
5. Descriptive reports/articles in peer-reviewed publications addressing findings	6/30/2016	$ 0

Activity Status as of December 2011: While collaring of moose will not occur until January-February of 2013, we continue to work with biologists and veterinarians nationally and internationally to ensure that we have developed a complete list of diseases, toxicities, and deficiencies to screen for.

Activity Status as of June 2012: While collaring of moose will not occur until January-February of 2013, we continue to work with biologists and veterinarians nationally and internationally to ensure that we have developed a complete list of diseases, toxicities, and deficiencies to screen for.

Activity Status as of December 2012: Our capture bid has been awarded to Quick Silver Aviation and capture efforts are slated to begin in the end of January, 2013. Capture efforts will likely take 2-3 weeks to complete. Capture planning and logistics (such as helicopter fueling sites, target numbers of moose to be captured throughout the study area, lodging for capture crews, etc) are well underway. We have begun to pay fees for satellite data acquisition as we test collars. We have ordered and received 3 SPOT devices, which will be used to notify emergency personnel if immediate medical assistance is needed for our necropsy response field team and have ordered/received veterinary and laboratory supplies needed for captures and biological sampling.

Activity Status as of June 2013: As of 25 June, 2013, 15 of 107 (14%; 11 females, four males) collared moose have died. Causes of death are as follows: 5 wolf kills, 2 wolf-caused injuries with secondary lethal infections, one *P. tenuis* infection, 3 winter ticks, and 4 health-related mortalities with results pending. Two of the moose were found alive and euthanized (the *P. tenuis* case and one of the wolf-caused injuries with a secondary bacterial infection), 4 carcasses were extracted intact and delivered to the UM VDL for a complete necropsy, and 11 were necropsied in the field. The causes of mortalities determined to-date have not been unexpected. Response time has varied, though the majority of responses (53%) have occurred within 24 hours of mortality notification, 4 (27%) were within 32 hours and 3 (20%) ranged from 33-96 hours. Three of the wolf-killed moose had a delayed response time (31, 46, and 60 hours) because the wolf activity at the death site prevented the collar from going into mortality mode (thereby, no notification was generated) until they left the carcass remains. The new localization program will hopefully minimize this lag affect in the future. The moose with a 96 hour response time had sent a localization notification, but no mortality notification. While viewing the GPS location data for this moose, the moose response team believed it was alive and making small- movements; clearly, this was not the case and we have altered our response strategy accordingly.

Activity Status as of December 2013: As of 10-January, 2014, 22 of 107 (20.6%; 18 females, 4 males) collared moose have died. Causes of death are as follows: 8 wolf kills (3 of which had predisposing health conditions that likely contributed to their death), 2 wolf-caused injuries that led to secondary lethal bacterial infections, 10 health-related deaths (including 2 *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, and 4 unknowns with pending results), 1 trauma (compound fracture that led to septicemia), and 1 unknown (only collar recovered, no carcass was found). Whole carcasses were retrieved for 8 of these moose, with field necrospies preformed on the remainder. In 16 of 22 mortality responses (73%), our response time to the scene was ≤24 hours (4 of which were <6 hrs). Collar transmission failures and wolf-caused collar movements have delayed response times in the remainder of cases. Our ability to retrieve intact carcasses has been greatly enhanced by the use of chainsaw winches, powerful snow machines with a rubber sled specifically designed to drag moose, and an Argo (amphibious 6-wheeler). We have successfully trained 8 primary moose responders that are capable to lead field necropsy teams, and recruited 13 secondary and 18 tertiary responders to assist in mortality responses. Mortality response teams (2-3 people) are on-call 24 hours/day, everyday (including weekends and holidays). Further, the 26 collars with failed mortality functions are monitored daily through a localization program and staff checking transmissions to ensure adequate moose movements. An additional 8 collars have stopped transmitting entirely and those moose are currently censored from the study. The collar manufacturer, Vectronics Aerospace, has replaced all 34 malfunctioning collars (free of charge), under warranty. We will be using these new, replacement collars to capture an additional 30 adult moose (22 females, 8 males) this coming winter.

Activity Status as of June 2014: A total of 35 collared moose have died since this study began, which included 7 capture-related mortalities that will be censored from subsequent survival analyses. Overall causes of death are as follows: 7 capture myopathy or associated capture-related issues (20%); 15 predator-related mortalities (43%), which includes 9 wolf kills , 3 likely wolf kills, and 3 wolf-caused

injuries that led to secondary lethal bacterial infections; and 13 health-related mortalities (37%), which includes 3 *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, 1 trauma with associate septicemia, 1 accident, and 4 undetermined health issues. Whole carcasses were retrieved for 12 of these moose, with field necrospies performed on remaining 23 moose. Response times from initial mortality notification (e.g. text message or email) to a team in the field at the death site were ≤24 hours in 20 cases (57%), between 24 and 48 hours in 9 cases (26%), and >48 hours in 6 cases (17%). Delays in mortality responses > 24 hours have been due to collar failures and wolves actively feeding on the moose carcass and preventing the collar from sending a mortality alert.

Activity Status as of December 2014: A total of 39 collared moose have died since this study began, which included 7 capture-related mortalities that will be censored from subsequent survival analyses. Overall causes of death are as follows: 7 capture myopathy or associated capture-related issues (18%); 17 predator-related mortalities (53%), which includes 11 wolf kills, 3 likely wolf kills, and 3 wolf-caused injuries that led to secondary lethal bacterial infections; and 15 health-related mortalities (47%), which includes 3 *P. tenuis* infections, 1 likely *P. tenuis* infection, 3 winter ticks, 1 liver fluke infection with secondary bacterial infection, 1 trauma with associate septicemia, 1 accident, 2 with multiple/chronic health issues, and 3 undetermined health issues. Whole carcasses were retrieved for 14 of these moose, with field necrospies performed on remaining 25 moose. Response times from initial mortality notification (e.g. text message or email) to a team in the field at the death site were ≤24 hours in 23 cases (59%), between 24 and 48 hours in 10 cases (26%), and >48 hours in 6 cases (15%). Delays in mortality responses > 24 hours have been due to collar failures and wolves actively feeding on the moose carcass and preventing the collar from sending a mortality alert. There are currently 94 remaining moose in the study, but 18 of these have collars that are experiencing transmission failures and we are not certain of their status; thus, 76 moose are actively transmitting data.

Activity Status as of June 2015: A total of 53 collared moose have died since this study began, which included 12 capture-related mortalities that will be censored from subsequent survival analyses, as these individuals died within 2 weeks post-capture and were not recruited into the study cohort. Overall proximate causes of death for the 41 collared moose in the study were as follows: 16 confirmed and likely wolf kills (39%), 8 bacterial infections (20%), 5 confirmed and likely *P. tenuis* infections (12%), 4 multiple, chronic health issues (10%), 3 winter tick infestations (7%), 1 accident (2%), and 4 undetermined health issues (10%). Whole carcasses were retrieved for 13 (32%) of the study cohort, with field necropsies preformed on the remaining 28 (68%) moose. Response times from initial mortality notification (e.g. text message or email) to a team in the field at the death site were ≤24 hours in 25 cases (61%), between 24 and 48 hours in 11 cases (27%), and >48 hours in 5 cases (12%). Delays in mortality responses > 24 hours have been due to collar failures and wolves actively feeding on the moose carcass and preventing the collar from sending a mortality alert. There are currently 109 remaining moose in the study, but 21 of these have collars that are experiencing significant transmission failures and we are not certain of their status; thus, 88 moose are actively transmitting data.

Final Report Summary: August 2015

This aggressive study has demonstrated that it is possible to respond to moose mortalities in a timely manner and obtain valuable diagnostic information to help illuminate the many causes of death for this species. The use of satellite-GPS technology was instrumental in allowing us to identify mortality events; however, we had to overcome some significant challenges in collar functionality. Previous studies in MN have pointed to health impacts as a potential driver in population declines; yet, many of those deaths lacked diagnostic data to assign causation. In this study, we not only obtained diagnostic evidence of parasites and pathogens, we also identified predisposing conditions that may be contributing to proximate causes of mortality (e.g., a brainworm infection moose is then killed by wolves). Another example is the documentation of 4 cases of initial wolf-induced injuries that did not result in immediate deaths, rather the moose lived for several days to weeks after before succumbing to bacterial infection from that initial attack. It is likely that this type of mortality has been largely undiscovered or underestimated in previous study, given the often lengthy time delays in getting to

carcasses to obtain needed evidence. Further, 61% of all proximate mortalities in this study were health-related and 39% were predator-related. Teasing apart some of the ultimate causes (e.g. toxicities, pathogens, parasites, and climate change) will require more data over a longer time-span, as we are only 2.5 years into this current study. With the continuation of ENTRF project funding for "Moose Decline and Air Temperatures in Northeastern Minnesota", M.L. 2014, Chp. 226, Sec. 2, Subd. 5m, we will continue to monitor these collared moose from this study for several years.

ACTIVITY 3: Determine the influence of nutritional stress as a contributing factor to the specific causes of deaths.

Description:
Biological samples (blood, feces, and urine) will be collected from all moose at capture and fat measurements will be made by ultrasound. Baseline (early winter) data from blood and urine specimens and fat measurements will be used to assess body condition, nutritional status, and overall health of moose. Snow-urine samples will be collected each winter throughout the study area, and then chemically analyzed to determine the degree of winter nutritional stress experienced by the broader moose population. Value of this latter technique has been demonstrated with moose on Isle Royale and with elk and bison in Yellowstone National Park.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 6,614
Amount Spent: $ 6,614
Balance: $ 0

Activity Completion Date:

Outcome	Completion Date	Budget
1. Assess the nutritional condition, health, and overall well-being of moose at the start of winter.	6/30/2015	$ 0
2. Determine how progressive winter nutritional stress and poor condition of moose contributed to specific causes of death.	6/30/2015	$ 6,614
3. Preliminary data analyses and final LCCMR report	6/30/2015	$ 0

Activity Status as of December 2011: To date, no work has been completed on this activity.

Activity Status as of June 2012: To date, no work has been completed on this activity.

Activity Status as of December 2012: The snow-urine sampling protocol has been developed and random sampling of moose snow-urine will begin in early January, 2013.

Activity Status as of June 2013 The body condition score of each animal was evaluated and recorded whenever possible. Nearly 1/3 of the 103 moose assessed were classified as either very thin (4, 3.8%) or thin (30, 29.1%). Sixty-seven were categorized as normal (65%) and 2 (1.9%) were identified as being fat. Ultrasound rump fat measurements were also performed, and these results have yet to be analyzed. Blood samples collected at capture were evaluated for evidence of exposure to West Nile Virus, eastern equine encephalitis, malignant catarrhal fever, Lyme Disease, and 6 serovars of Leptospira interrogans. Full serum chemistry profiles and complete blood counts were completed. Samples were also screened for microfilarial infections and tick-borne illnesses. Fecal floatations were performed to evaluate parasite load. Snow urine collections began on 23 January 2013. A team of 2-3 field techs collected fresh, random snow-urine samples from moose throughout the study area, and beginning on 13 February, a week after adult capture operations were completed, we began sampling "known" GPS-collared moose as well. In total, 124 random snow-urine samples and 71 samples from

33 known moose were collected through 24 March 2013. Presently, these samples are being analyzed in the laboratory for urea nitrogen and creatinine.

Activity Status as of December 2013: Biological samples obtained during initial moose captures were analyzed and serologic evidence of exposure to West Nile Virus, malignant catarrhal fever, various serovars of *Leptospira interrogans*, and *Borreilia* was documented. Progesterone levels were screened for 75 females and 56 (75%) were pregnant. Fecal floatation was used to screen moose at capture for parasites, with 31 of 84 (36.9%) infections identified. These parasites included *Nematodirus* sp. (20 moose), Strongyle-type ova (6 moose), *Moniezia* sp. (1 moose), and coinfections in 4 moose. Aging of moose at capture has also been completed and mean age was 5.75 years (SE = 0.4, *n* = 84), with a range of 1 to 14 years. During 23 January-25 March, 124 snow-urine samples of moose were collected randomly during 5, 2-week sampling intervals, and an additional 112 specimens were collected from 35 (31 females, 4 males) targeted, collared moose (collared moose were sampled during 1-3, 2-week sampling intervals). According to our random sampling, overall, the mean urea nitrogen:creatinine (UN:C) ratio for the entire winter was 3.7 mg:mg (SE = 0.4, *n* = 123), and the percentage of snow-urine specimens collected with UN:C ratios indicative of severe nutritional restriction (≥3.5 mg:mg) of moose was 32%. Mean urinary UN:C ratios indicated that nutritional restriction on average was "normal" or modest during late January, but was severe throughout February and early March, and still moderately severe during late March. Overall, about 41% of the UN:C values of total snow-urine specimens collected tracking target moose indicated moose were experiencing moderately severe (21.4%) to severe (20.0%) dietary restriction; the remaining 58.6% reflected normal or modest winter restriction. From late February through late March, the percentage of snow-urine specimens reflecting normal restriction was stable at about half (53.8-57.7%); however, the percentage of samples indicative of severe restriction doubled from late February (19.2%) to late March (38.5%), and those reflecting moderately severe restriction decreased from 28.0 to 7.7%. The random sampling approach involved specimens from a large number of moose during each 2-week sampling interval will be continued as part of the adult moose mortality study in winter 2014.

Activity Status as of June 2014: Monitoring the nutritional status of free-ranging moose long-term at the population level should facilitate a better understanding of important relationships to other aspects of their ecology, including movements, habitat use, survival, cause-specific mortality and population performance. Urea nitrogen:creatinine (UN:C) ratios of urine voided in snow (snow-urine) have exhibited significant potential as a metric of winter nutritional status and have been associated with long-term changes in the moose population on Isle Royale. During our pilot study (winter 2012-13) in northeastern Minnesota 124 snow-urine samples of moose were serially collected throughout the study area from 23 January to 25 March. The percentage of snow-urine specimens with UN:C ratios indicative of severe nutritional restriction (≥3.5 mg:mg) was 32% and this level of nutritional restriction was apparent from February through early March; during late March restriction was still moderately severe. Following the pilot study, a more aggressive effort was launched during the severe winter of 2013-14. From 9 January to 26 March, 313 fresh specimens were collected during 6, 2-week sampling intervals. Sample sizes ranged from 33 to 79 specimens per interval and spatial coverage throughout the study area was extensive. Chemistry results and assessments are pending.

Activity Status as of December 2014: Analyses of snow urine chemistries, including urea nitrogen:creatinine (UN:C) ratios, from the 313 samples collected during winter 2014 have been completed. Mean UN:C ratios per interval were well below the 3.5 mg:mg threshold indicative of severe nutritional restriction throughout this winter; percentage of samples indicative of severe nutritional restriction ranged from only 12% to 27% per interval, and were associated with markedly lower winter mortality of moose. As a reminder, during winter 2013, 124 samples were collected and percentage of snow-urine specimens with UN:C ratios indicative of severe nutritional restriction from late January to late March ranged from 21% to 67% of the specimens, which correlated with high winter

mortality of moose that year. To date, these data are indicating that winter nutritional restriction of moose is playing a key role in population performance, although additional winters of data are needed to understand annual variation.

Activity Status as of June 2015:
Moose at capture (*n*=32) were generally in good condition (44% normal, 53% thin, and 3% very thin). Ultrasonic rump fat measurements were obtained from 25 moose, and maximum rump fat averaged 1.05cm (SE = 0.17cm). There was minimal hair loss noted from winter ticks. Pregnancy rate, determined by progesterone values in 18 blood samples, was 89%; higher than 2013 (83%) and 2014 (77%). Biological samples (*n*= 26 blood samples) obtained during initial moose captures were analyzed and serologic evidence of exposure to West Nile Virus (*n*=7, 33%), various serovars of *Leptospira interrogans(n*=6, 23%), and *Borreilia* (*n*=2, 8%) was documented. Fecal floatation was used to screen moose at capture for parasites, with 10 of 31 (32%) infections identified. These parasites included *Nematodirus* sp. (6 moose), Strongyle-type ova (2 moose), and *Moniezia* sp. (2 moose). Aging of moose at capture is pending.

Final Report Summary: August 2015
Overall, nutritional condition in moose at capture was the poorest in 2013, but average to good in 2014 and 2015, as evidenced by body condition scores, ultrasonic rump fat measurements, and snow urine chemistries. Overall exposure to West Nile Virus (29/158, 18%), Eastern Equine Encephalitis (0/158, 0%), various serovars of *Leptospira interrogans(*23/158, 15%), malignant catarrhal fever (51/158, 32%), and *Borreilia* (27/158, 17%) were reported. While blood evidence indicated exposure to these various diseases (with the exception of EEE), clinical evidence of infection was not observed either during capture or at death in some cases. Little is still known about these disease may impact moose or contributed to reduced survival or productivity. Further analyses of serum chemistries are pending.

V. DISSEMINATION:

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

Activity Status as of December 2011: To date, no information has been disseminated.

Activity Status as of June 2012: To date, no information has been disseminated.

Activity Status as of December 2012: The MN DNR adult moose mortality project (funded by ENTRF) will be highlighted at the MN DNR's Roundtable press conference on January 4th, 2013. Additionally, we have done numerous radio interviews (KFAN, MPR, Brainerd Outdoors, etc) and been contacted for multiple newspaper stories. We have given presentations about the project at the University of Minnesota College of Veterinary Medicine multiple times. We have also been contacted by various reporters hoping to cover our capture in detail.

Activity Status as of June 2013: The project has received a substantial amount of local, national, and international press. Conservatively, a couple hundred stories have been run by various media outlets, including USA Today, ABC News, the Star Tribune, Pioneer Press, National Wildlife Federation, The Nature Conservancy, Outdoor News, Minnesota Public Radio, the Duluth News Tribune, the Cook County Herald, the Bismarck Tribune, the Pittsburgh Post Gazette, the Spokesman Review, to name a few . Research team members have been asked to present preliminary data at numerous conferences, including the Wildlife Disease Association, the North American Moose Conference, Foreign Animal Disease Workshop, the national chapter of the Wildlife Society, and multiple others.

Activity Status as of December 2013: The project continues to receive local, national, and international press. In September, a story about our adult moose project was featured in the New York

Times. This sparked increased attention on Minnesota's moose decline and many spin-off articles and radio interview this past fall. Attached is a list of media activity during this reporting period:

June

Mesabi Daily News (Researching Moose Mystery)
Northland News Center – Superior WI (Moose Calves In DNR Study Die Quickly)
St. Cloud Times.com –video (Moose Study: Declining Population)

July

TAKEPART.com (Warning: Effects of Climate Change In Moose of MN)
On Earth Magazine (What's Killing MN Moose?)
Salon.com (MN Moose Mystery)

August

Aspen Public Radio (Referenced MPR Feb '13 article)
Outdoor News (Sweet Retreat R Johnson Donation Project)
KARE 11 (MN moose study examines declining populations)

September

U of M Alumni Magazine (Adult & Calf Moose Studies)
Washington Post – Health & Science (MN Adult Project)
KARE 11 News (MN Moose Study Examines Population Declines)
The Day – NH National News (Reference MN Moose Study as model)
TNC Magazine (Moose and a Resilient Forest)
KARE 11 News (DNR Begins Phase 2 of Moose Study)
The Telegraph - NH News Paper (Mortality TEXTs MN Moose Project)
Smithsonian Magazine (MN Moose Are Missing and Nobody Really Knows Why)
StarTrib (MN Moose Die: Wolves, Ticks, Abandonment, and Disease)
Associated Press (MN Sees Steep Decline In Young Moose Population)
NBC Nightly News (Where Have All the Moose Gone?)
Duluth News Tribune (More Bad News for Moose)

October

Post Bulletin – Rochester (Moose Study Imperfect but Necessary)
Cook County News Herald (Moose Calves Dying At Higher Rate Than Expected)
Bangor News –Out There (National Moose Population Concerns – Complex, Kantar discussion)
Audubon Magazine (Mysterious Moose Die-Offs – compilation of many articles/interviews)
Christian Science Monitor (Moose Die-off Massive and Mystery to Scientists)
The New York Times editorial (The Disappearing Moose)
Mail OnLine (Why Are Moose Dying out in the US? – rewrite of NYT)
NYT (Moose Die-Off Alarms Scientists)
YaHoo News (NA Moose population Continues to Decline – NYT spin-off)
New York Public Radio (radio interview on MN's moose decline)
Wisconsin Public Radio (radio interview on MN's moose decline)

November

The Globe and Mail (B.C. Study to Probe Mystery of Dying Moose – MN Study Design)
German Press Agency (The Dying Giants: Mysterious Death of Moose in North America)
StarTrib – (…Climate Change Threatens Big Game … ref NWF paper, w/Leslie McInenly)
The Japan Time News (What's happening to Moose? -- rendition of Washington Post Story)
SmartNews – Smithsonian Mag Blog (MN Moose Are Missing -- reprint of NBC Feb 13 story)
MPR News (To Help Moose – Wildlife Group Sets Climate Change Agenda)

Moose Project Presentations by staff:

- Tait Lake Association: Moose Project Presentation, July 2013
- Duluth Izak Walton League: Moose Project Presentation with Mike Schrage, October 2013

- Finnish Conservation Staff Visitors: Moose Project Presentation, October 2013
- Wood Lake Nature Center: Moose Project Presentation, November 2013
- International Wolf Center: Minnesota Moose Research Update, October 2013
- North Star Museum, Girl & Boy Scouting, Open House (Club Bruce), October 2013
- 20th Annual Conference of the Wildlife Society, Milwaukee, WI: Determining Causes of Death in Minnesota's Declining Moose Population, October 2013
- Regional Disease Meeting (Minnesota, North Dakota, Ontario, Manitoba, and Saskatchewan), Special Session on Moose Management and Research, International Fall, MN, September 2013
- Minnesota Moose Research and Management Conference, Cloquet, MN, December 2013

Lastly, a report on this project was published in the 2012 Summaries of Research Findings: http://www.dnr.state.mn.us/publications/wildlife/research2012.html

Activity Status as of June 2014: There was great interest from national and international media to attend our moose capture operation in early February. News teams from French TV1, Al-Jazeera America, CBS News- New York, New Your Times, and BBC-Canada interviewed moose project staff and aired stories; some are still available as links on our moose project webpage: http://www.dnr.state.mn.us/moose/index.html

The coverage from these media outlets led to increase interest at local levels as well. The following is a list of radio shows that featured moose project staff:

- MPR Daily Circuit (March 3, 2014)
- Angler Hunter Radio (February 28, 2014)
- KFAN Outdoors Radio (February 20, 2014)
- WPR Larry Meiller Show (March 12, 2014)

Moose Project Presentations by staff:

- Minnesota Veterinary Medicine Association Annual Meeting, Minneapolis, MN : Determining cause-specific mortality in Minnesota's declining moose population, February 2014
- Minnesota Interagency Fire Commission Meeting, Helitak Training Session, Camp Ripley, MN: Update on the adult moose mortality study, February 2014
- Midwest Fish and Wildlife Health Committee Meeting, Columbia, MO: Determining cause-specific mortality in Minnesota's declining moose population, April 2014
- Science Museum's "Take you kid to work day", moose project display and Q&A, April 2014
- North Star Museum, Girl & Boy Scouting, (Club Bruce), May 2014
- 48th North American Moose Conference and Workshop, Girdwood, AK: Determining cause-specific mortality in Minnesota's declining moose population, May 2014

Media coverage for the project

- Star Tribune: Round Table, Unraveling the moose mystery, January 2014
- Portland Press Herald: Minnesota moose study begins, January 2014
- MPR News: Minnesota moose decline gets closer look by DNR, January 2014
- Mesabi Daily News: Researchers to collar moose in study, February 2014
- Associated Press: Researchers to collar 52 adult moose in northeast Minnesota, February 2014
- Hibbing Daily Tribune: Moose hunt up for debate by legislature, February 2014
- The Bemidji Pioneer: Minnesota's moose hold their own for one more year, mortality among adults and calves still too high to sustain population, February 2014
- Duluth News Tribune: Aerial survey shows Minnesota moose holding their own in the past year, February 2014
- St. Cloud Times: Surveys and studies continue on what can be done with the state's moose population, February 2014
- East Grand Forks Herald: Minnesota moose population trend shows no significant change, February 2014

- MPR News: Numbers improve, but Minnesota moose not out of the wood, February 2014
- Durango Herald: Why are Minnesota moose dying so fast, March 2014
- Post Bulletin: Are Minnesota's moose on the way out?, March 2014
- Alaska Dispatch: A moose mystery, March 2014
- New York Times: Minnesota Mystery, What's killing the moose, March 2014
- Indian Country: Minnesota moose deaths still confound scientists, March 2014
- Mesabi Daily News: Opinion, Don't let moose by sacrificed, April 2014
- Scientific American: Rapid climate change turns northwoods into moose graveyard, May 2014
- Carleton College Voice: The mystery of the disappearing moose, June 2014

Activity Status as of December 2014: The following is a list of presentations, media interviews, and articles that have involved this study from July 1 through December 31, 2014:

Moose Project Presentations:

- 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. October 2014.
- Chapter K PEO (Women's Club), St Paul, MN: Determining cause-specific mortality in Minnesota's declining moose population, November, 2014
- Dodge Nature Center, Bloomington, MN. Determining cause of moose mortality in Minnesota, December 2014.
- Forestry Employees Association Annual meeting, Crosby, MN: Determining cause-specific mortality in Minnesota's declining moose population, December, 2014

Radio Shows:

- Brainerd Outdoor Radio with Brian Moon, aired July 12, 13, and 14, 2014.
- Angler Hunter Radio, live interview December 31, 2014.

Media coverage for the adult moose mortality project:

- Rick Kupchella's Bring Me The News: DNR launching two-pronged campaign to help Minnesota's moose, August 2014
- CBS Boston: Parasite decreases moose population, impacting New England hunting season, September 2014
- Missoulian: Moose populations down as winter ticks cull herds, September 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
- Reading Eagle: 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

Lastly, a report on this project was published in the 2013 Summaries of Research Findings: http://www.dnr.state.mn.us/publications/wildlife/research2013.html

Activity Status as of June 2015:

Radio Shows:

- 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:

- 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.

Final Report Summary: August 2015

The moose project has received an enormous amount of media coverage, including international, national, regional, and local outlets. DNR staff have provided presentations about this research project to international and national scientific meetings, regional meetings, and to local stakeholder groups. Links to some the highlighted media coverage and reports can be found on the project's website: http://www.dnr.state.mn.us/moose/index.html

With the continuation of ENTRF project funding for "Moose Decline and Air Temperatures in Northeastern Minnesota", M.L. 2014, Chp. 226, Sec. 2, Subd. 5m, outreach and dissemination of this project is on-going. Peer-reviewed publication of the findings of cause-specific mortality for adult moose in this study will be initated after the completion of the third full year of the project (December 2015). Other peer-reviewed publications have been initated, including a techniques paper documenting the methods used to respond to moose mortalities within 24 of death, and a collaborative analyses of serum chemistries from moose in Minnesota, New England states (Maine, New Hampshire, and New York), and western US (Colorado, Wyoming, and Montana). We will be continuing to report to LCCMR on the outcomes of this study through subsequently funded study.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	$ Amount	Explanation
Personnel:	$ 24,993	1 Wildlife Technician (unclassified), 50% effort , field data collection and analysis, field necropsies, and outreach; 2 seasonal volunteers, 100% effort, field data collections (room and board only)
Professional/Technical Contracts:	$ 14,045	Nationally certified laboratory in Minnesota (to be determined), disease and health screening for dead moose (screening for over 30 diseases, various toxicities, and nutritional deficiencies)
Service Contracts	$ 219,495	Helicopter for wildlife capture (to be determined), Year 2: initial moose capture and handling, Year 3: additional moose capture to maintain sample size; Iridium satellite data acquisition (company undetermined), downloading location data and location fixes
Equipment/Tools/Supplies:	$ 280,780	GPS collars (120) will provide notification and location of death; capture drugs for chemical immobilization of moose; supplies for necropsy kits used to collect samples from dead moose; field equipment (GPS units, camera, etc) used for mortality investigation
Travel Expenses in MN:	$ 36,917	Mileage to/from study area by project managers and technician and volunteers
Other:	$ 23,770	DNR spotter plane to be used during capture/recapture events
TOTAL ENRTF BUDGET:	**$ 600,000**	

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

Explanation of Capital Expenditures Greater Than $3,500: NA

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 0.5 FTE

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Minnesota Deer Hunter's Association	$ 5,000	$0	Transport of carcasses
State			

Other DNR funds (general funds, game and fish funds, etc)	$ 221,500	$525,000	Shared services, fish and wildlife division support, project management, field necropsies, MIT calibration study, collaborative parasitology studies, snow urine analysis, habitat analysis and mapping, data analysis, writing, and outreach
TOTAL OTHER FUNDS:	**$ 226,500**	**$525,000**	

VII. PROJECT STRATEGY:

A. Project Partners:
Dr. Michelle Carstensen, MN DNR, project leader
Dr. Glenn DelGiudice, MN DNR, co-investigator
Dr. Ulrike Munderloh, University of MN Dept. of Entomology, collaborator
Dr. Ron Moen, NRRI-UMD, collaborator;
Mark Johnson, MDHA, collaborator
Mike Schrage, Fond du Lac Resource Management Division, collaborator
Dr. Arno Wuenschmann, Veterinary Diagnostic Laboratory, collaborator
Dr. Anibal Armien, Veterinary Diagnostic Laboratory, collaborator

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 quantify rates of exposure to diseases, pregnancy rates, and assist with assessment of overall health and physiological status of moose. Seasonal and annual survival and cause-specific mortality rates will be assessed.

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.

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.

C. Spending History:

Funding Source	M.L. 2005 or FY 2006-07	M.L. 2007 or FY 2008	M.L. 2008 or FY 2009	M.L. 2009 or FY 2010	M.L. 2010 or FY 2011
Not applicable, see Budget Detail for more information.					

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. MAP(S): N/A

X. RESEARCH ADDENDUM: See Research Addendum

XI. REPORTING REQUIREMENTS:

Periodic Work Plan status update reports will be submitted not later than January 2012, July 2012, January 2013, July 2013, January 2014, July 2014, January 2015, and July 2015. A final report and associated products will be submitted between June 30 and August 1, 2015 as requested by the LCCMR.

Final Attachment A: Budget Detail for M.L. 2011 (FY 2012-13) Environment and Natural Resources Trust Fund Projects

Project Title: Determining Causes of Mortality in Moose Populations
Legal Citation: M.L. 2001, First Special Session, Chp. 2, Art. 3, Sec 2, Subd. 03f
Project Manager: Michelle Carstensen
M.L. 2011 (FY 2012-13) ENRTF Appropriation: $ 600,000
Project Length and Completion Date: 6/30/15
Date of Update: 8/17/15

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Balance	Activity 2 Budget	Amount Spent	Balance	Activity 3 Budget	Amount Spent	Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Purchase and thoroughly field test 100 communication satellite-linked Global Positioning System (GPS) Collars***			***Determine specific causes of mortality of moose in NE MN***			***Determine the influence of nutriontal stress as a contributing factor to the specific causes of death***				
Personnel (Wages and Benefits)											
Wildlife Techinician: 1- 50% FTE (80% salary, 20% benefits), field data collection and analysis, field necropsies, and outreach (Sept 2013- June 2015)				20,479	20,456	23				20,479	23
Seasonal Volunteers: 2- 100% effort (room and board only), field data collections (January- April 2013-2014)							4,514	4,514	0	4,514	0
Professional/Technical Contracts											
Nationally Certified Laboratory in Minnesota (yet undetermined) ; disease and health screening for dead moose (screening for over 30 diseases, various toxicities, and nutritional deficiencies)				14,045	14,045	0				14,045	0
Service contracts											
Helicopter for moose capture (QuickSilver Aviation): 2013: Initial moose capture and handling; 2014: Additional moose capture to maintain sample size				152,000	152,000	0				152,000	0
Iridium satellite data acquistion (Vectronics): dowloading of location data and costs for location fixes.				67,495	67,495	0				67,495	0
Equipment/Tools/Supplies											
GPS collars: provide notification and location of death	256,721	256,721	0							256,721	0
Capture drugs ($228/moose)				19,324	19,324	0				19,324	0
Medical and laboratory supplies and field necropsy kits				2,770	2,770	0				2,770	0
Field equipment (handheld GPS, camera, antenae, etc)				1,965	1,965	0				1,965	0
Capital equipment over $3,500											
Fee Title Acquisition											
Easement Acquisition											
Professional Services for Acquisition											
Printing											
Travel expenses in Minnesota											
Travel to study area by project management staff (fleet @ $0.55/mi, 20,000 miles)				19,036	19,036	0				19,036	0
Travel to study area by technician and seasonals (fleet @ $0.55/mi, 20,000 miles)				15,781	15,781	0	2,100	2,100	0	17,881	0
Other											
Spotter plane during capture/recapture efforts (120 hours @$200/hour)				23,770	23,770	0				23,770	0
COLUMN TOTAL	**$256,721**	**$256,721**	**$0**	**$336,665**	**$336,642**	**$23**	**$6,614**	**$6,614**	**$0**	**$600,000**	**$23**

Determining Cause-Specific Mortality in Minnesota Declining Moose Population

Dr. Michelle Carstensen

Erik Hildebrand

David Pauly

Margaret Dexter

Dawn Plattner

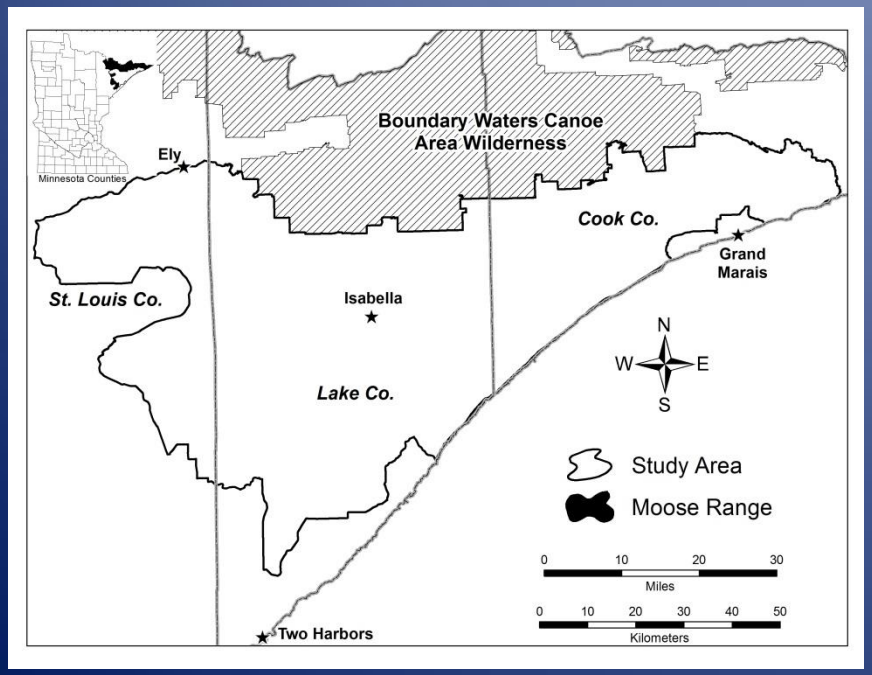
Dr. Chris Jennelle

Dr. Veronique St. Louis

Minnesota Department of Natural Resources

Wildlife Health Program

Northeast Minnesota Adult Moose Mortality Project



- **Goal is to understand and quantify cause-specific, non-hunting mortality**
- $2M project
- Maintain sample size of 100 radiocollared moose for ≥3 yrs, 2013-2015 (collars will last 4-5 yrs),
- Respond <24 hrs of death
  - Extract whole carcass
  - Preform field necrospy

How is all this going to work?

- Vectronics Aerospace GPS-Iridium collars, Berlin, Germany
- All trained, primary responders on the moose mort teams will have state-issued smart phone
- Alerts will be texted for mortality and localization events
- Smart phone can access full data record for individual moose w/mapping
- Initial assessment of field logistic can be done in the palm of your hand!

*A mortality team will be on-call 24/7, 365 day/year!

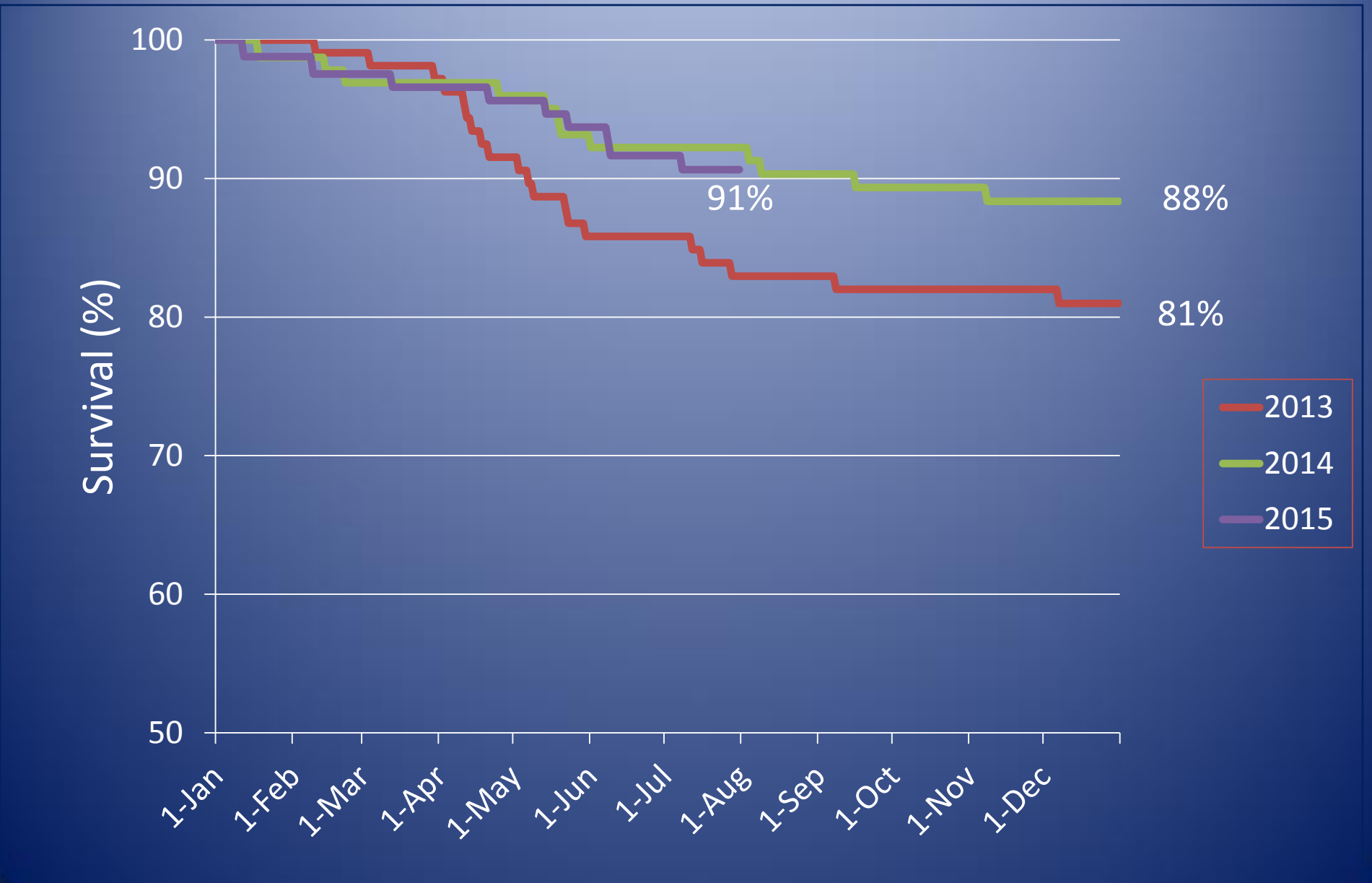
Mortality Implant Transmitters

- Record internal body temperature and internal “activity” (not true heart rate)
- Send instant text message notification of death (versus waiting 6hr for collar notification)
- Help us understand a moose’s physiological response to ambient temperature

Moose at Capture

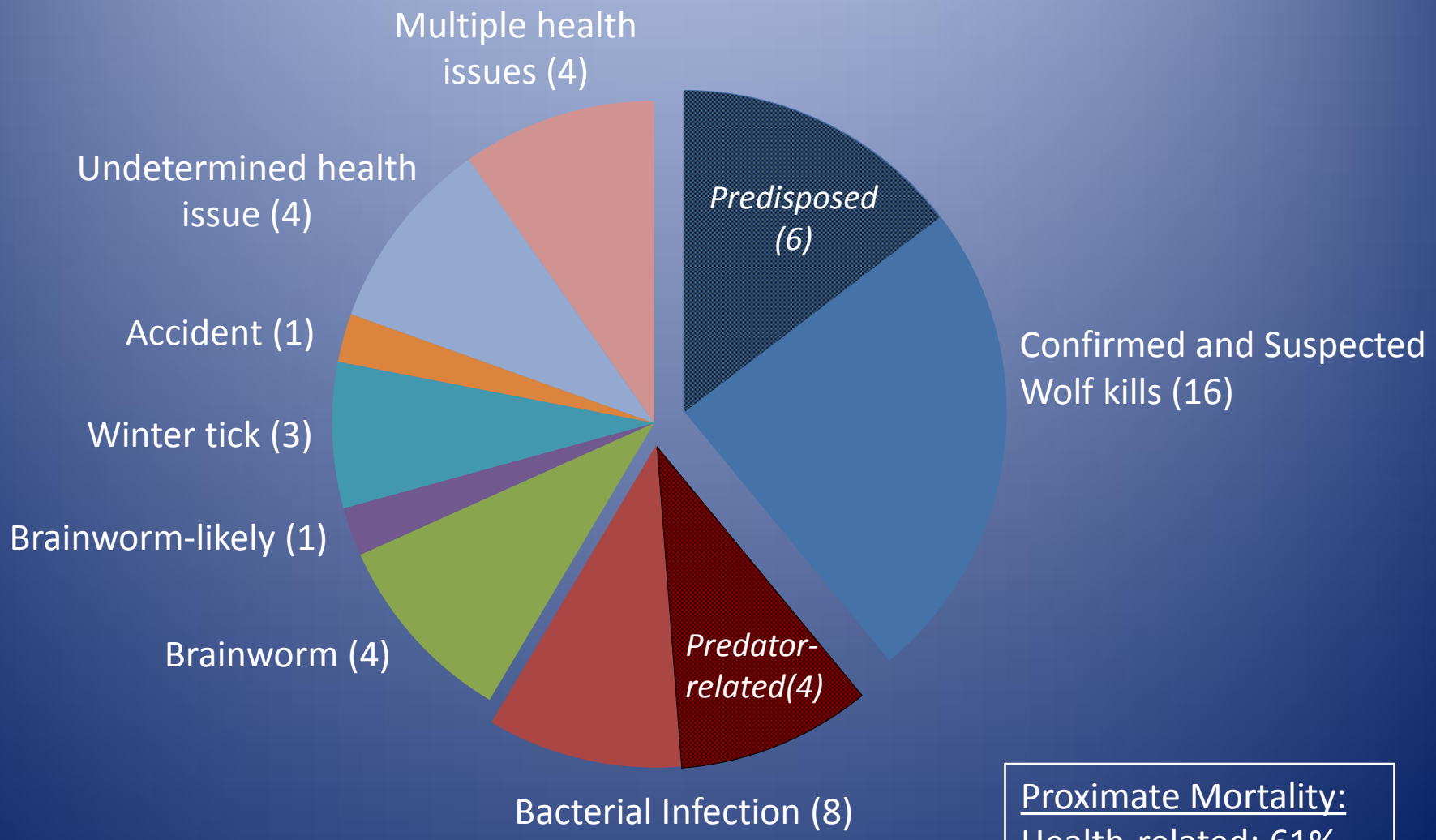
- Year 1 (2013): 111 captured (84F, 27M)
  - 4 capture-related mortalities (3.6%)
  - Mean age = 5.8 yrs (n=96)
  - 83% pregnancy rate
  - 28 MITs deployed; 5 spit out
- Year 2 (2014): 36 captured (24F, 12M)
  - Includes 5 recaptured moose with bad collars
  - 3 capture-related mortalities (8.1%)
  - Mean age = 5.6yrs (n=30)
  - 77% pregnancy rate
  - 30 MITs deployed; 12 spit out
- Year 3 (2015): 32 captured (20F, 12M)
  - Includes 1 recaptured moose with bad collar
  - 5 captured-related mortalities (15.6%)
  - 89% pregnancy rate
  - 23 MITs deployed; 3 spit out
- Total unique individuals in study = 168
- Total MITs successfully deployed = 61

Annual survival rates of adult moose, 2013-2015



Causes of Adult Moose Mortalities

Feb 2013-July 2015, *n=41*

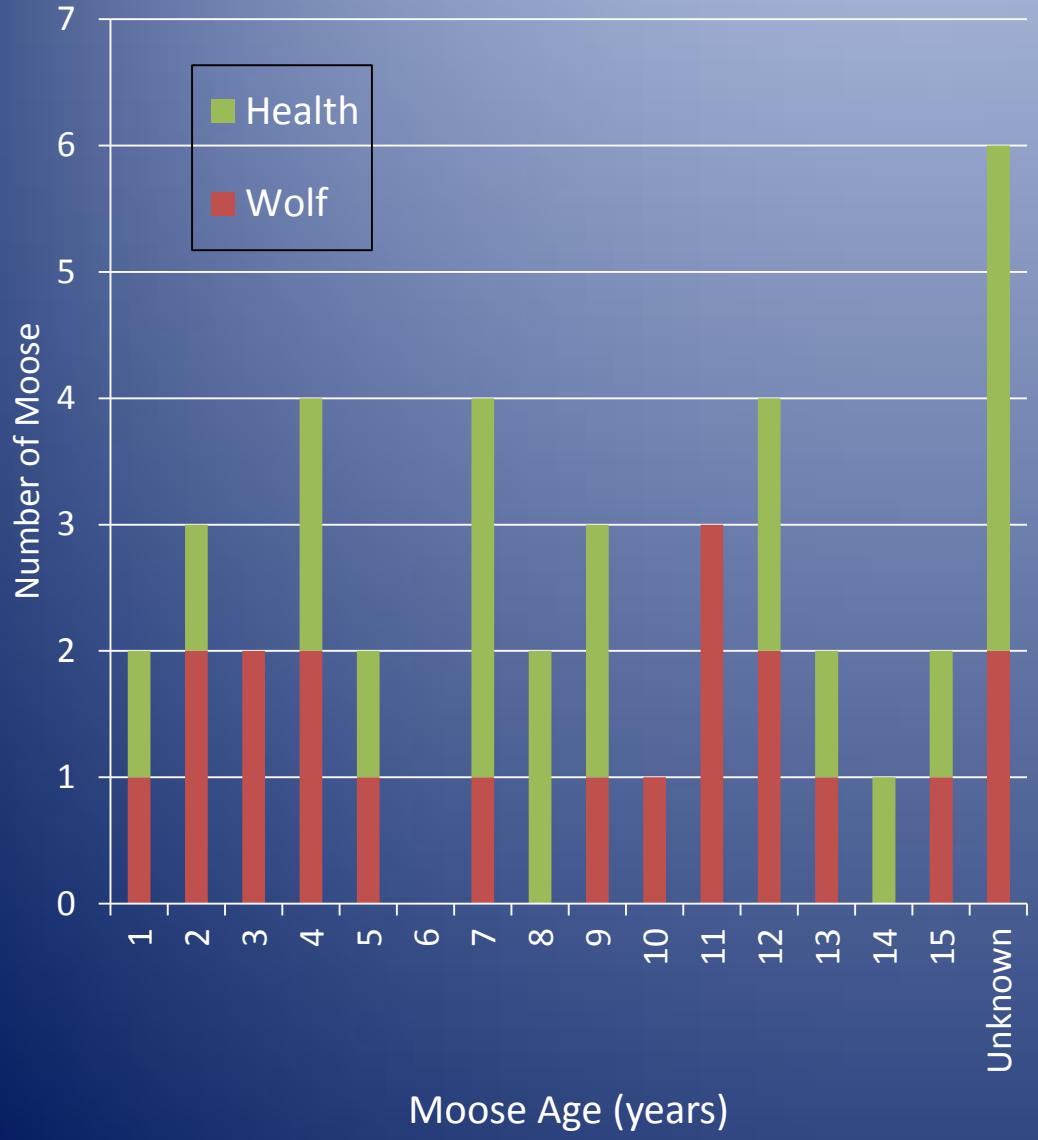


Proximate Mortality:
Health-related: 61%
Predator-related: 39%

Wolf-kills, confirmed and likely (*n* = 16)

- 6 moose had health conditions that could have predisposed them to predation
  - Encephalitis and meningitis in brain, emaciated, pneumonia in lungs
  - Observed with head tilt at capture, circling (*n*=2), presumed to be P. Tenuis infection
  - Confirmed P. Tenuis infection (*n*=2)
  - Observed alive with previous injuries
- 5 moose were totally scavenged, unable to collect much for diagnostics
- 5 moose were partially scavenged, samples did not point to any clear underlying health condition or incidental findings that we're unsure if important

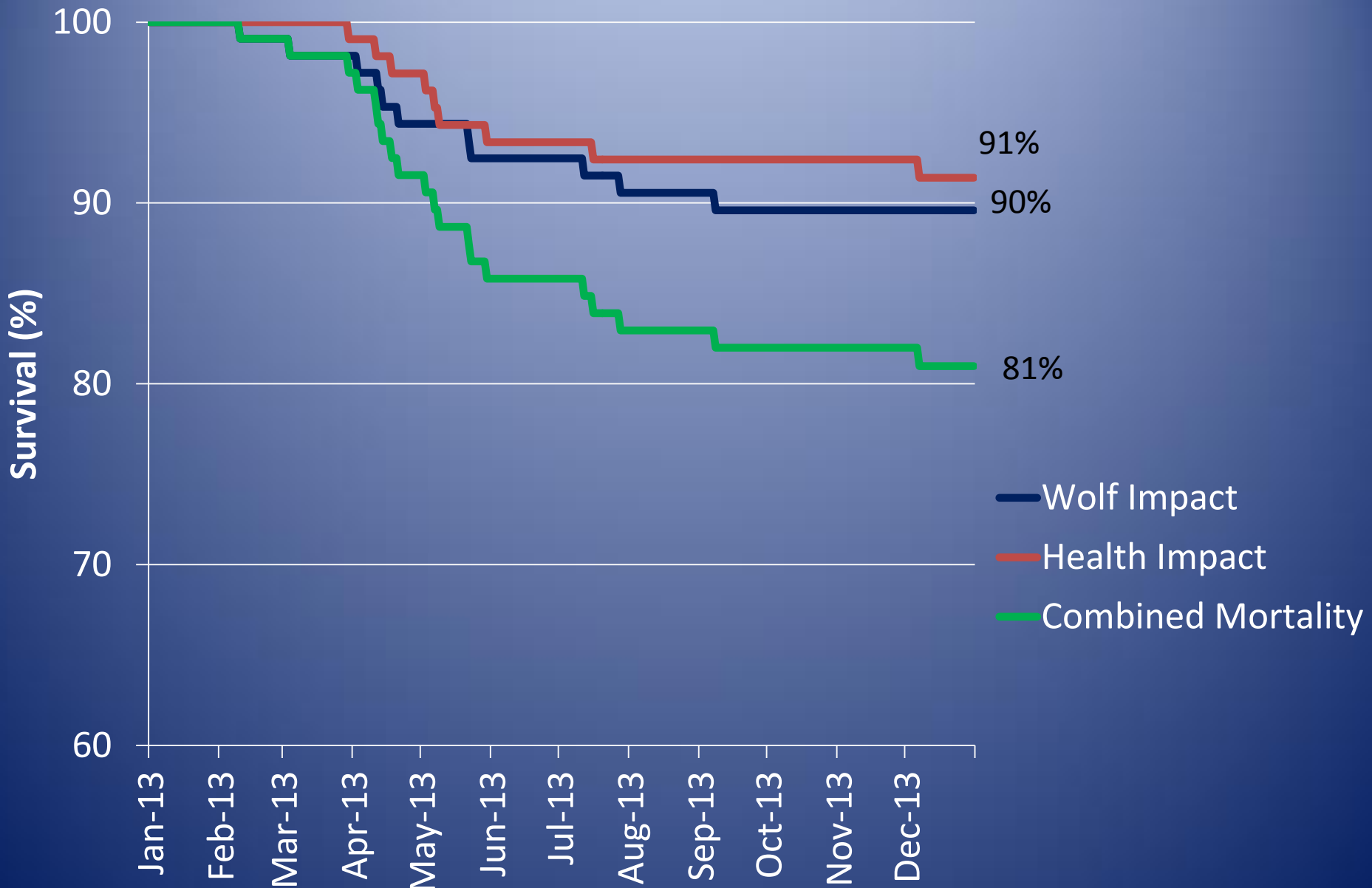
Ages of Moose at Death



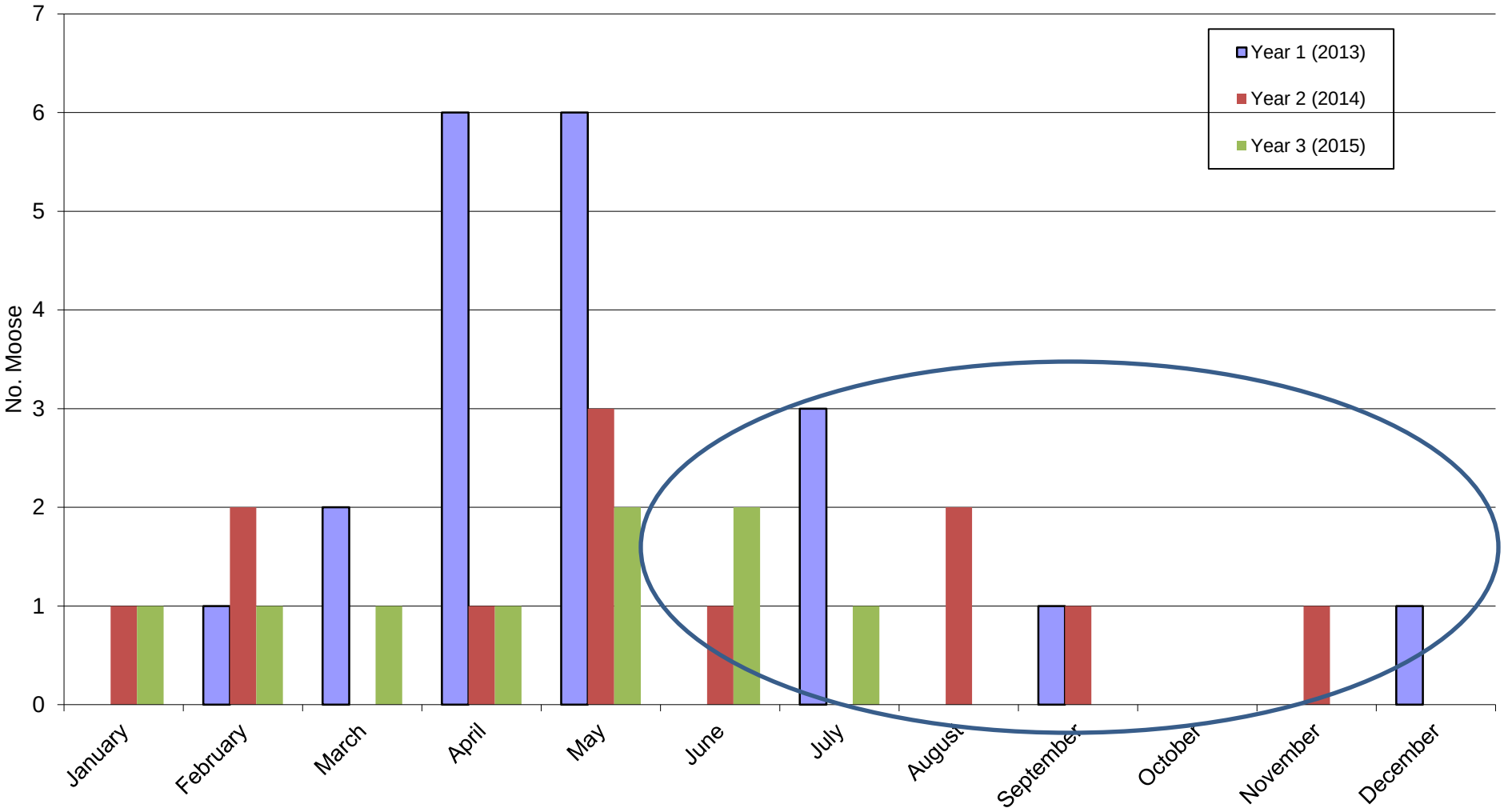
- Overall age of all moose at death = 7.8 yrs (±0.7), n = 35, 6 moose have pending ages
- Mean age of health-related deaths: 8.1 yrs (±1.0), n = 17, missing 4 ages
- Mean age of wolf-related deaths: 7.5 yrs (±1.1), n = 18, missing 2 ages

- Young Moose (≤3): 7 (5W, 2H)
- Prime Moose (4-8): 12 (4W, 8H)
- Old Moose (≥8): 16 (9W, 7H)

Impacts of Wolves and Health on Adult Moose, 2013



Timing of Adult Moose Mortalities (*n* = 41; Feb 2013 - July 2015)



Getting the Moose Out

Whole Carcass Extraction, n=13 (32%)

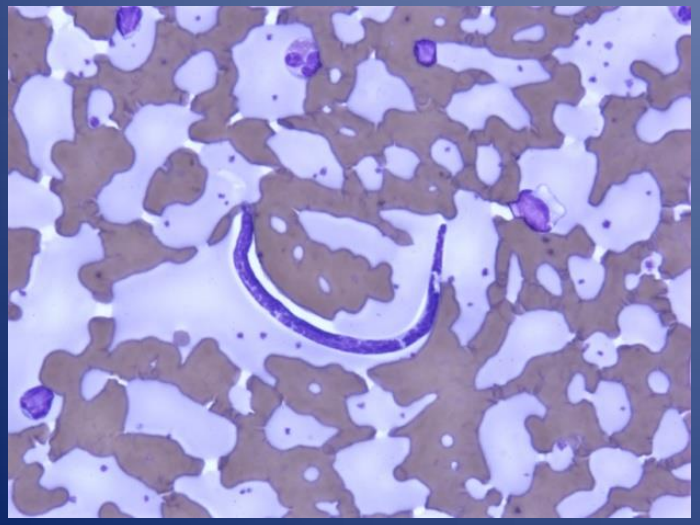
Response Times:

<24 hours: 61%

25-48 hours: 27%

>48 hours: 12%

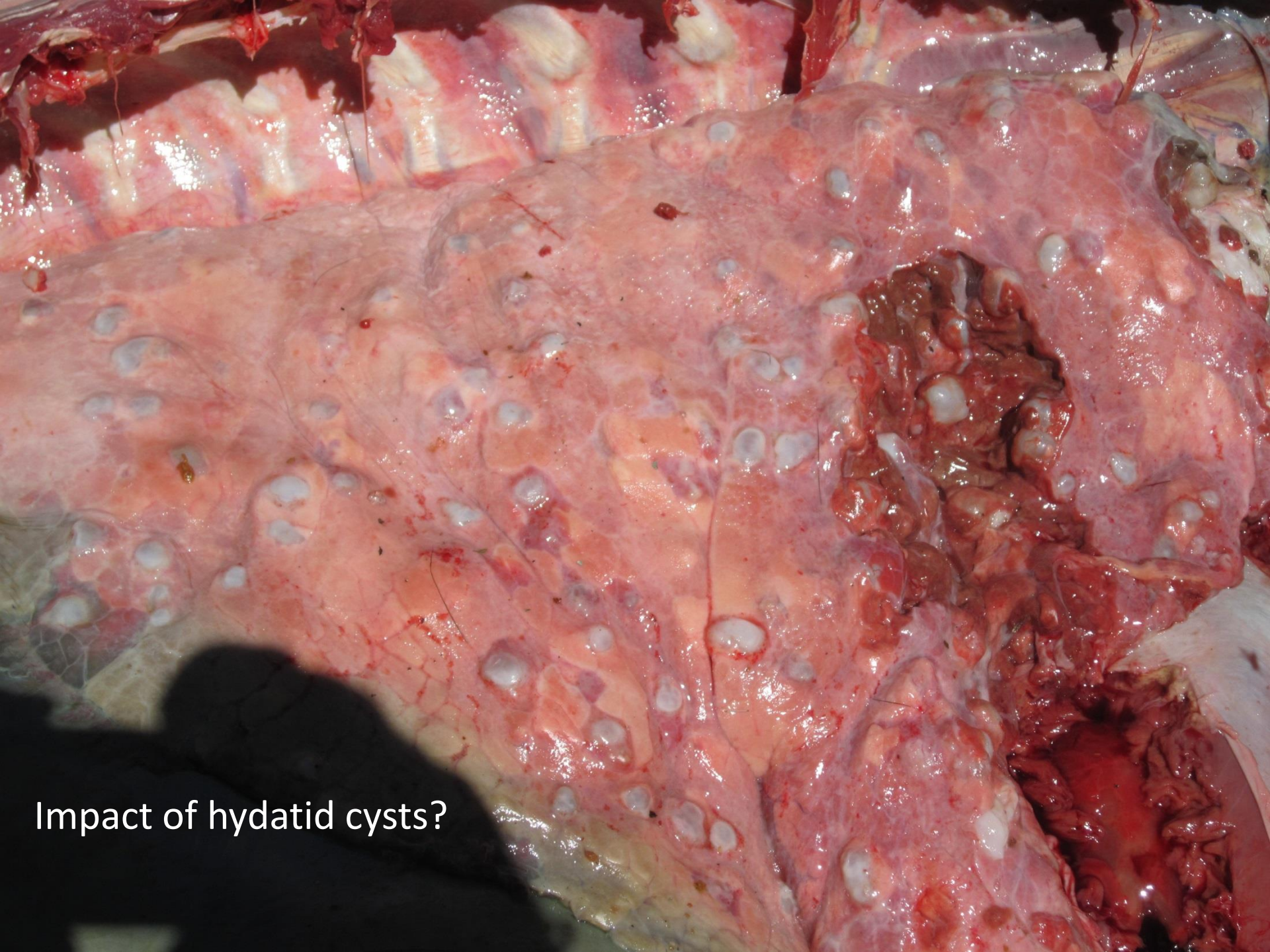
Whole Moose to Diagnostic Lab



- Full necropsies at UM-VDL by board-certified pathologists
- Screen for wide array of diseases
- Parasite testing (Univ of Tennesee and USDA-ARS, North Carolina)
- Tick borne illnesses (Univ of MN)
- Nutrition and diet studies (Ohio State Univ and Univ of UM)
- Collected metagenomics samples on “unknown deaths” (UC-Davis)
- Banking nearly every sample we can justify!

Field Necropsies, n=28 (68%)

Unknowns remain……


Impact of hydatid cysts?


Impact of liver flukes?

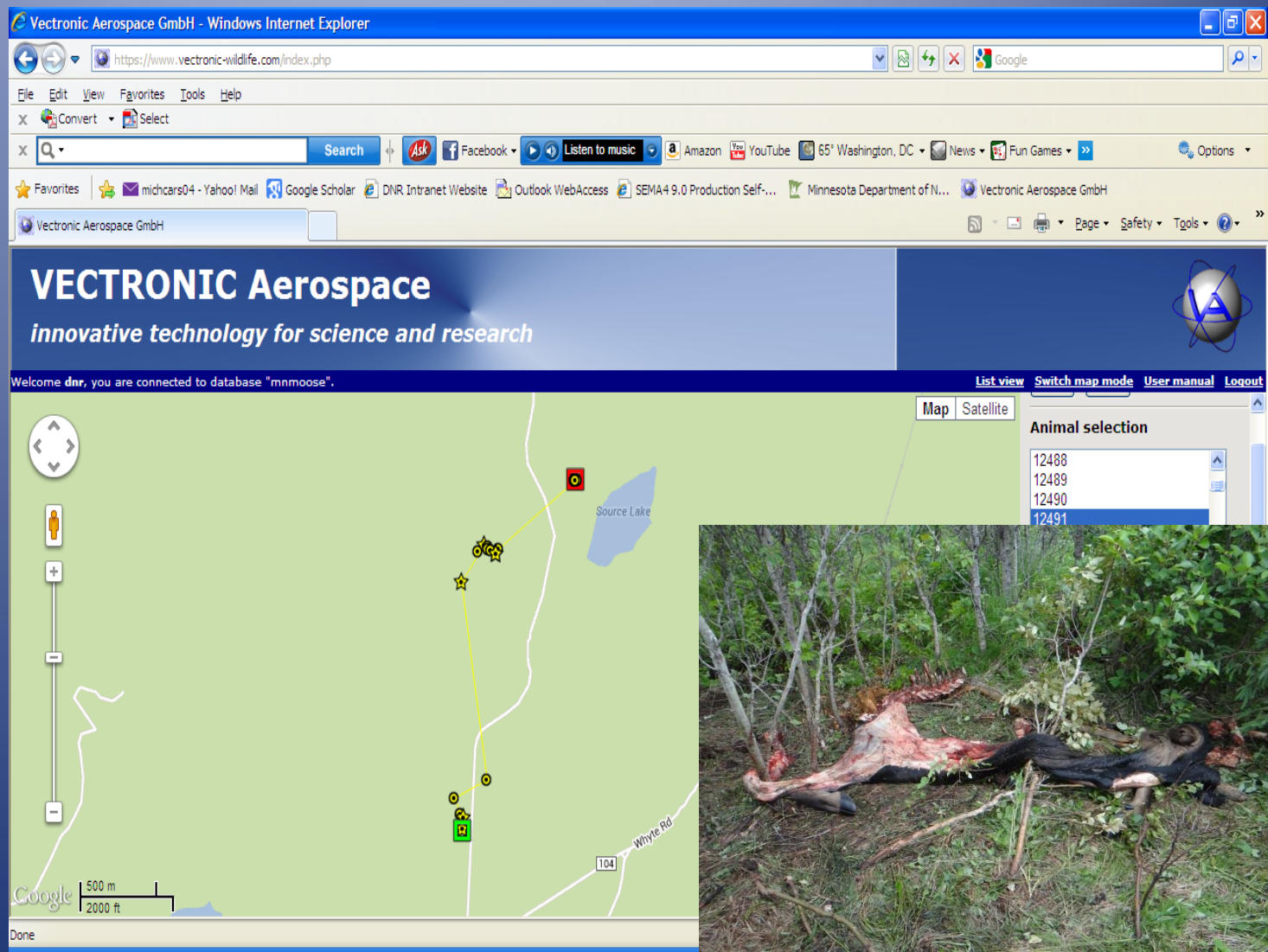
MITs enable analyses of physiological responses during mortality event

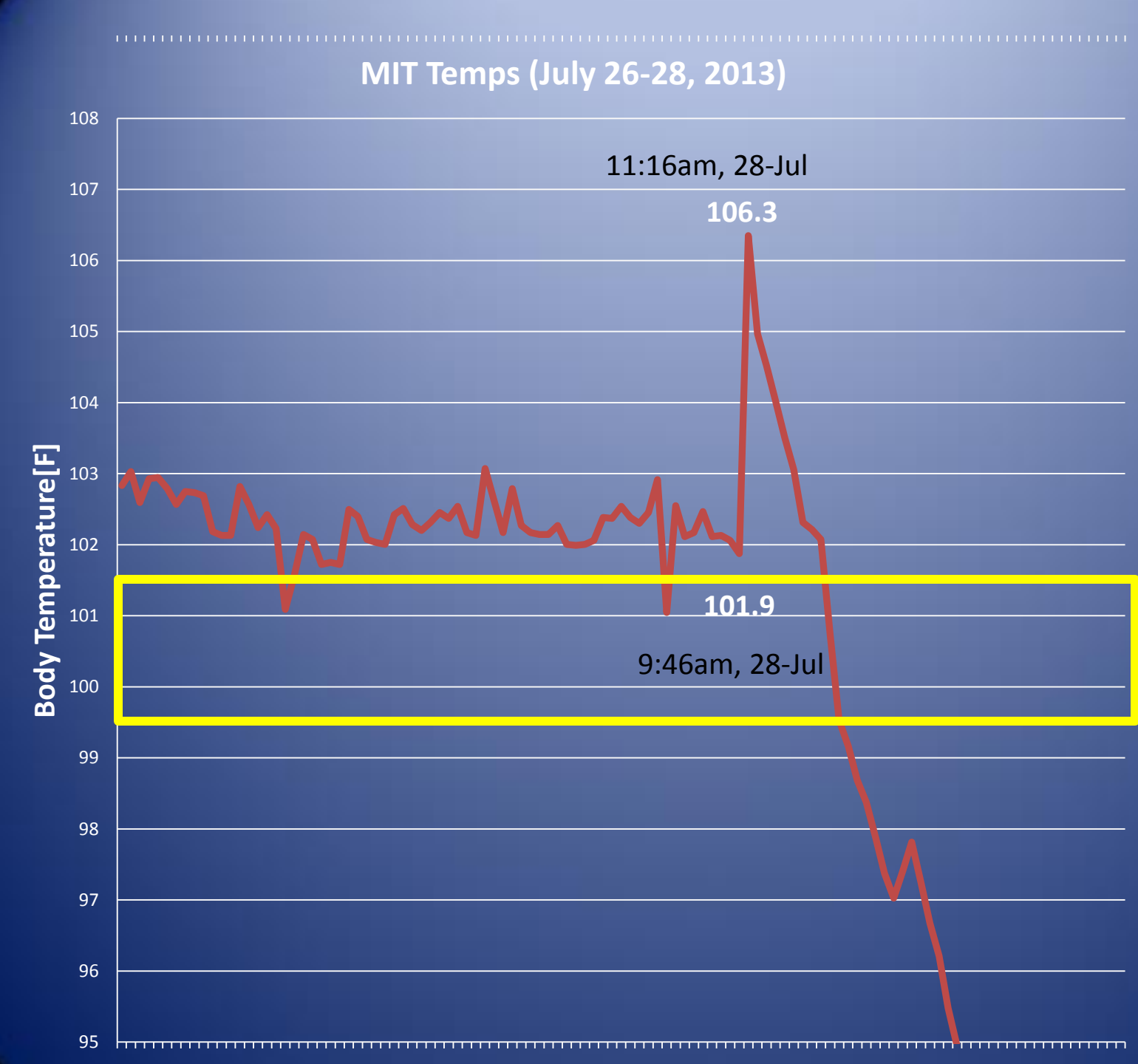
Movement activity from 7-26 to 7-28.

618m run to northeast between 7:30am and 11:45am on 28-July

Mort site is indicated by red square.

Moose was killed by wolves.

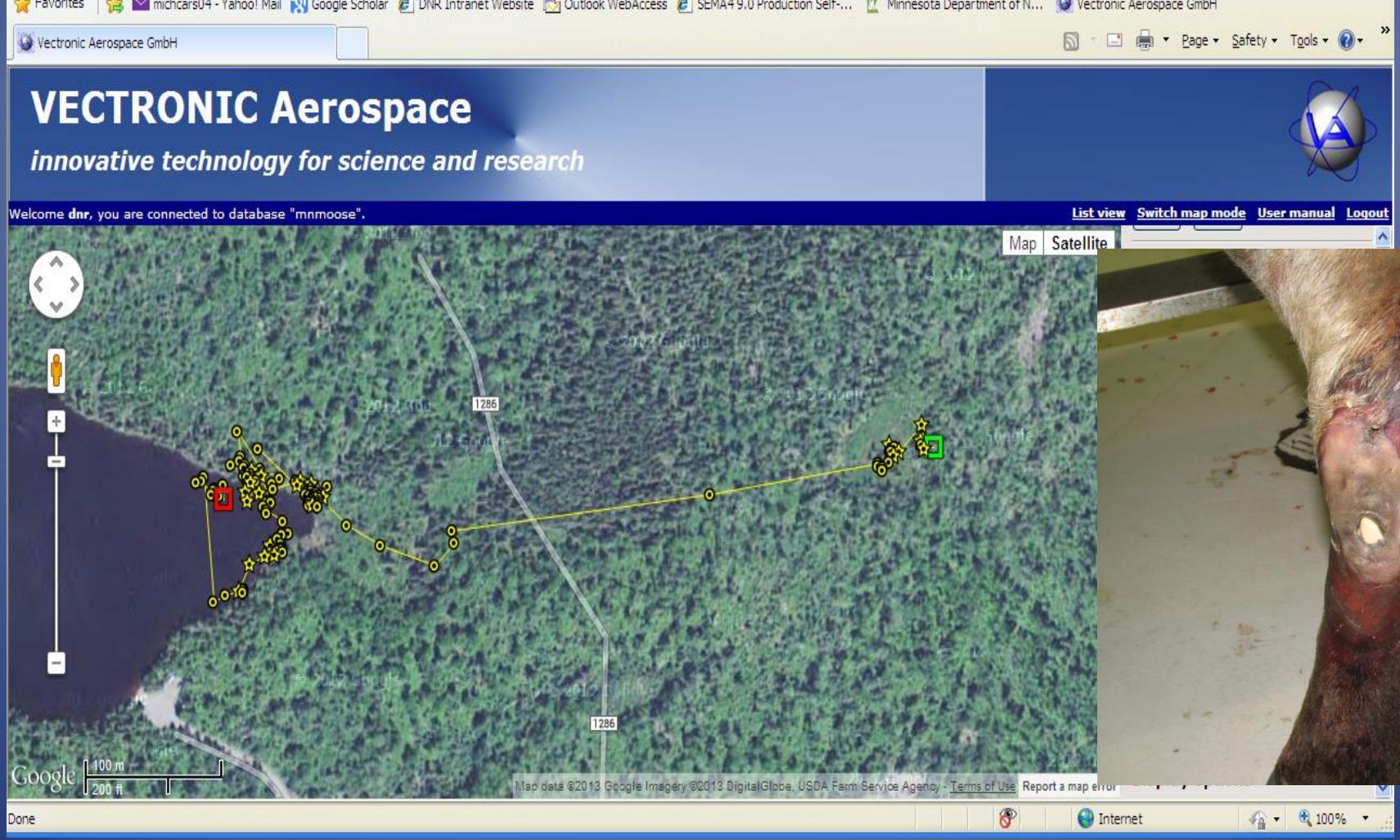




MIT data indicated a sharp elevation in body temperature from 9:46am to 11:16am,

Same time period the moose was being chased by wolves.

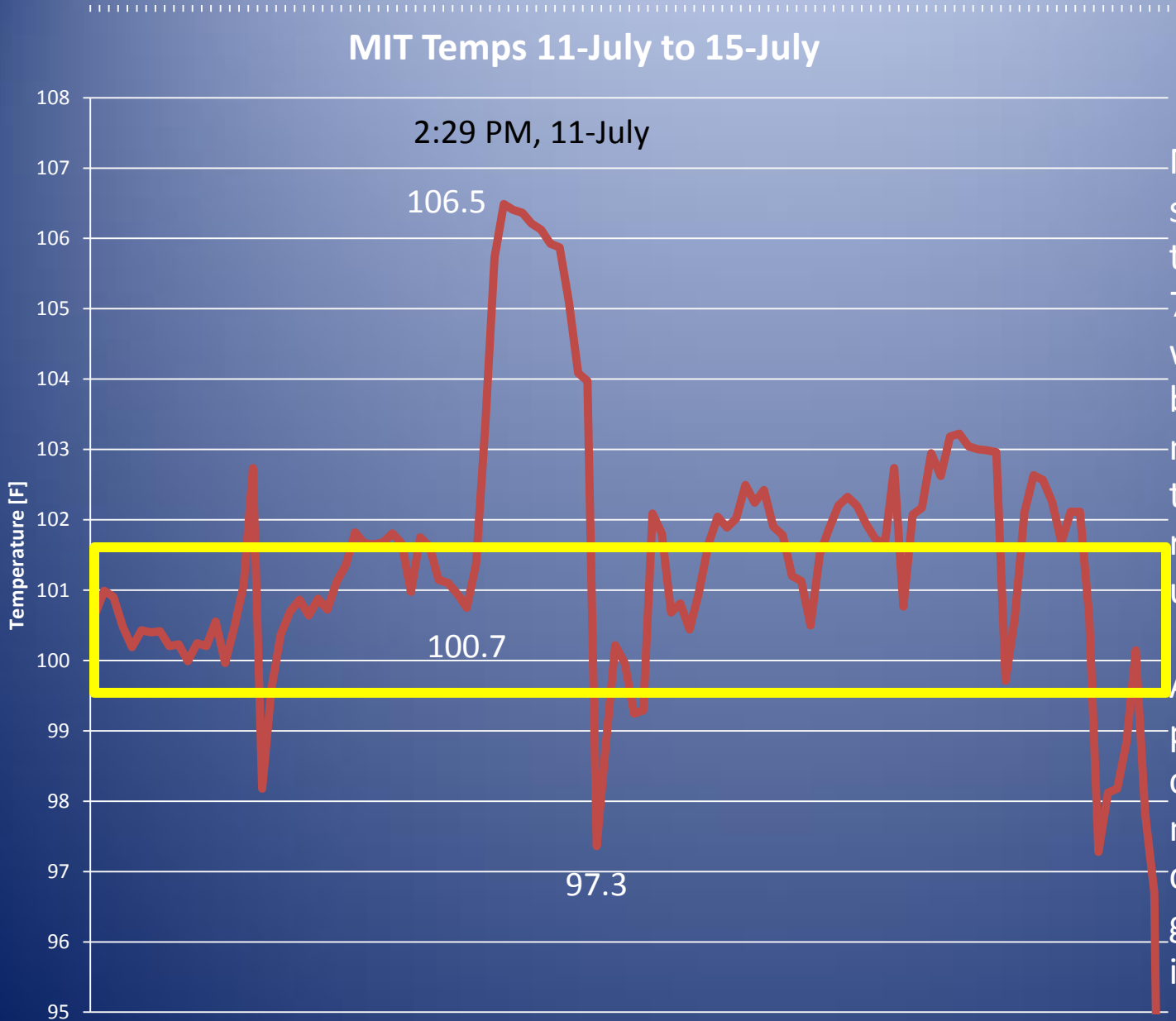
At time of mort notification, body temperature was 102.2F (1:32 PM) and declining.



Movement activity just prior to death; 11-July to 15-July.

Note the >400m movement from the interior on 11-July towards the lake on 15-July.

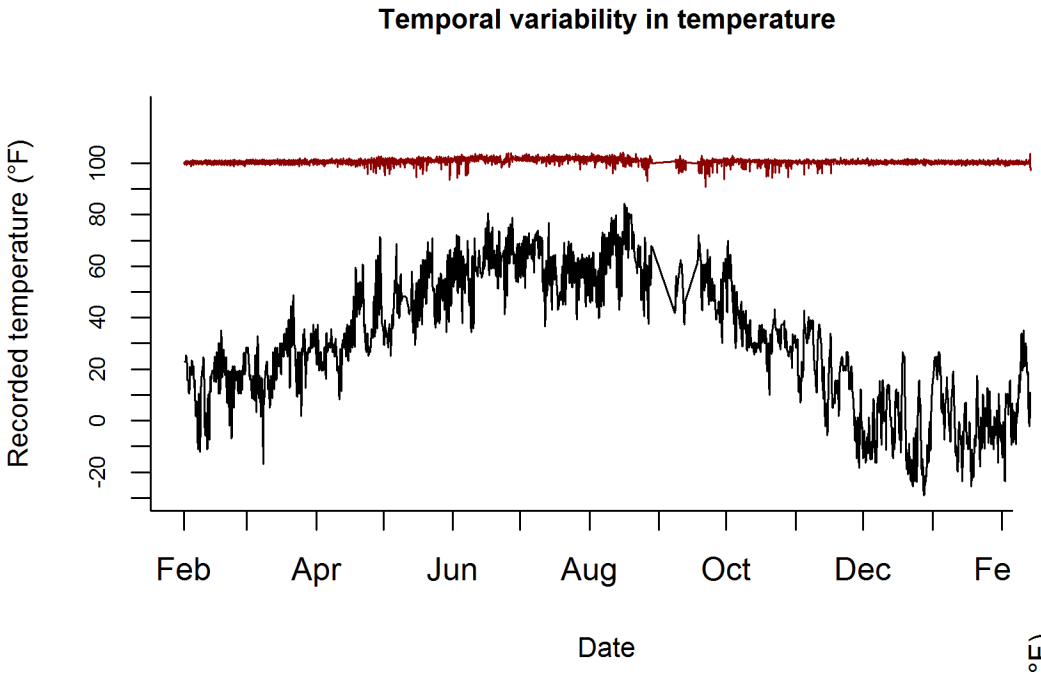
Mort site is indicated by red square. She was found dead, floating. Trauma-induced infection, septicemia.



MIT data indicated a sharp elevation in body temperature from 1-7pm on 11-July, which would suggest this may be the reason the moose began moving towards the water and remained in the lake until she died.

At necropsy, pathologist speculated compound fracture may have occurred 3-4 days prior to death, given the state of the infection.

A year in the life of a moose's rumen



Our first moose with an MIT for 1 year was killed by wolves in Feb 2014.

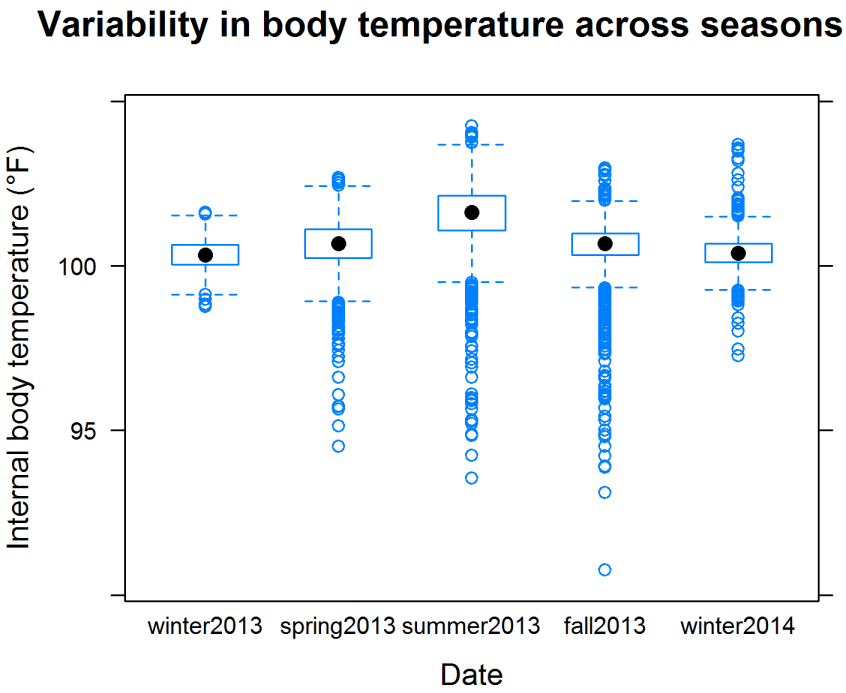
We are beginning to look at body temp responses to increased ambient temps

Why the temp drops below 99°F? Water intake?

- 1.3% of annual readings <99°F?

5% of annual readings were 102-104°F, most of these were in June, July and August

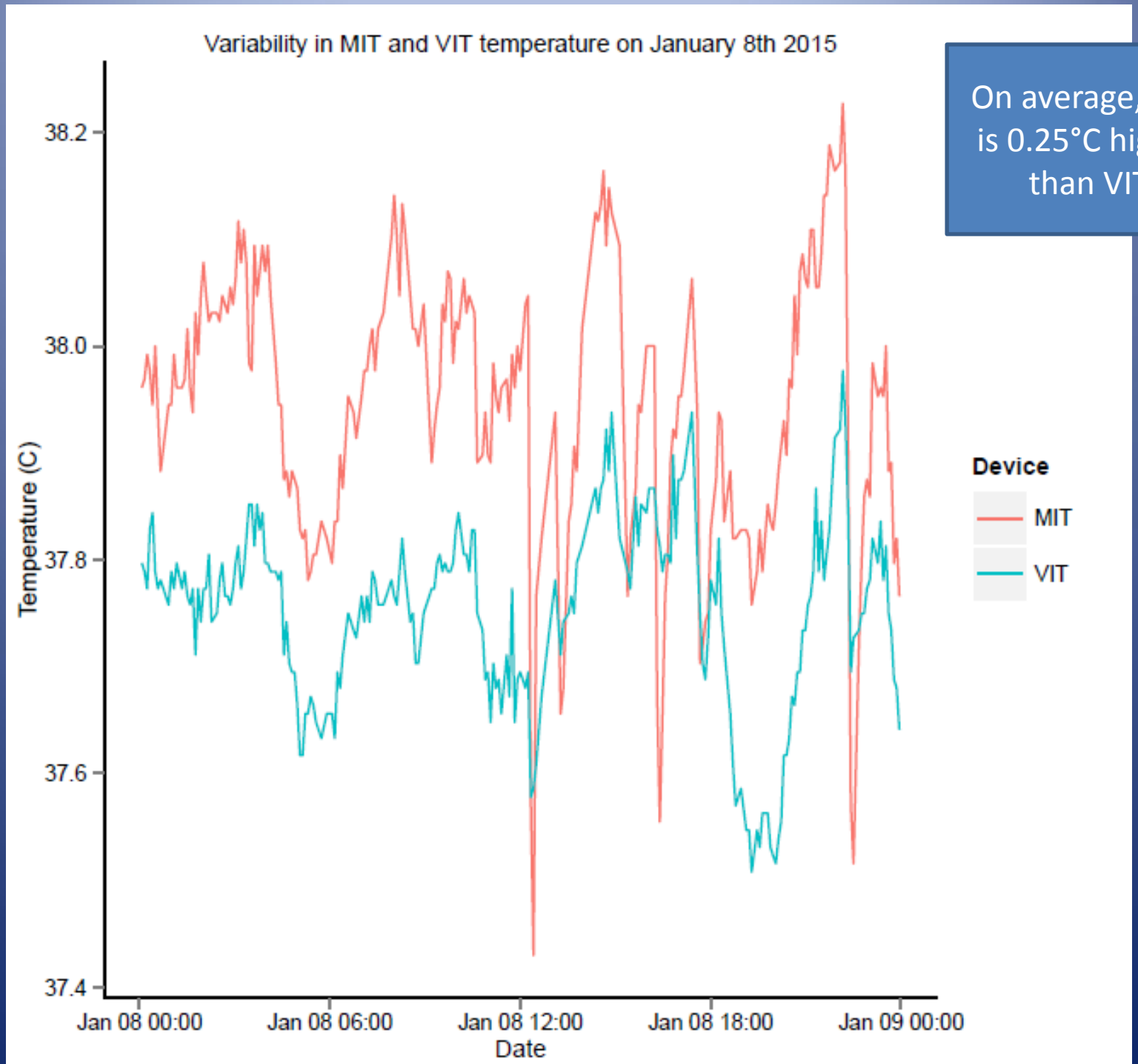
- How are they mitigating this excessive heat?



Calibration of the MITs in Alaska

Andrew Herberg, MS student, UMN
Dr. Michelle Carstensen, MNDNR
Dr. Veronique St-Louis, MNDNR
John Crouse, AG&F
Dan Thompson, AG&F
Dr. Larissa Minicucci, UMN
Dr. John Fieberg, UMN

- 10 moose were fitted with both the rumen bolus (MIT) and vaginal implant transmitter (VIT) with temperature sensor
- Observational study of 8 captive, adult females at the Moose Research Center, Alaska
- Record moose behaviors at 2-week intervals each season for 1 year
- Correlate changes in MIT and VIT readings to moose behavior; develop correction factor.
- Extrapolate findings to free-ranging moose in MN with MITs
- Began in Dec 2014; expected to be complete by fall 2015



On average, MIT is 0.25°C higher than VIT

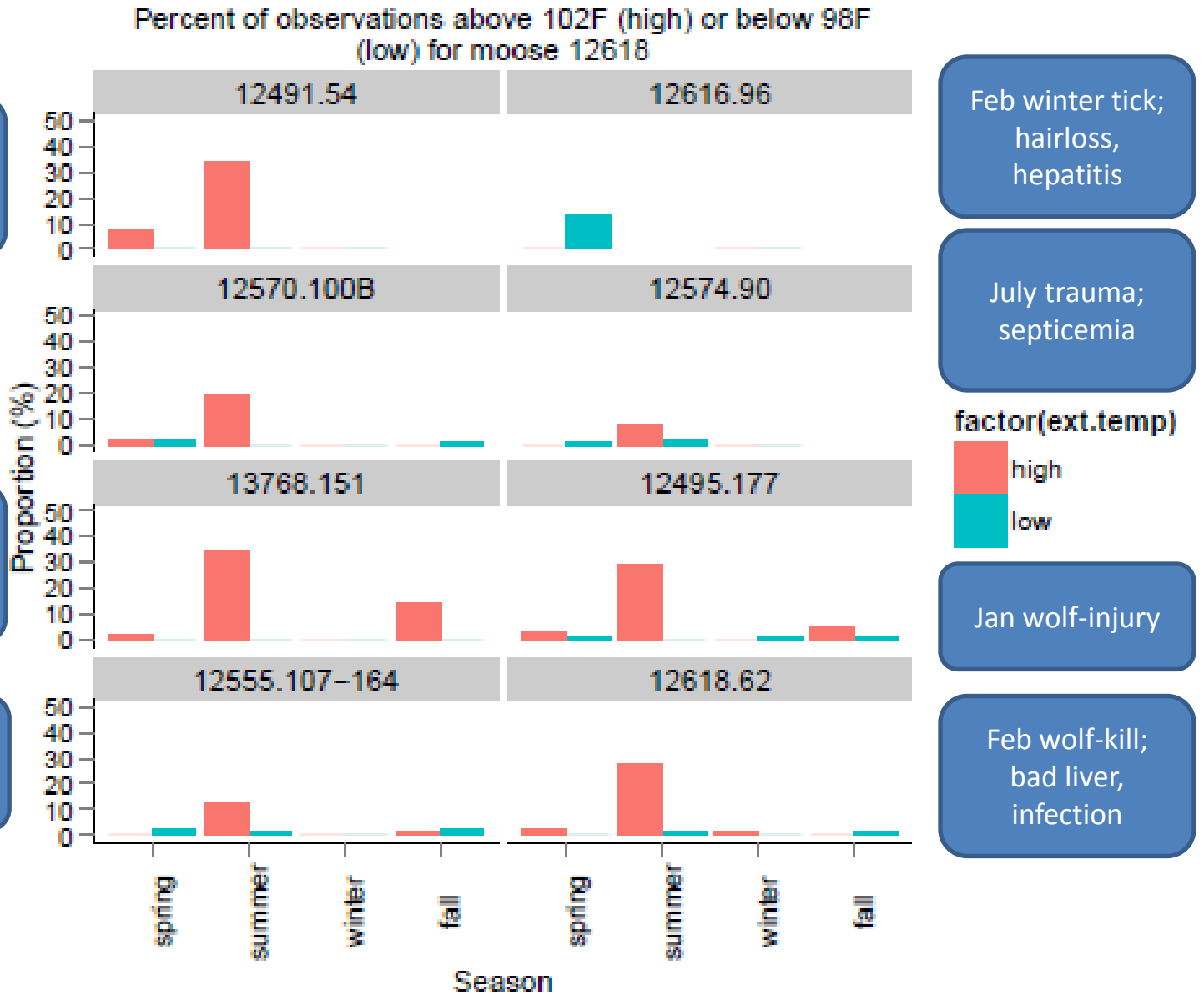
A closer look at extreme highs and extreme lows

July wolf-kill; pituitary lesion

Aug wolf-kill; not much left

Sept euthanz; hematoma, liver

Alive!



Feb winter tick; hairloss, hepatitis

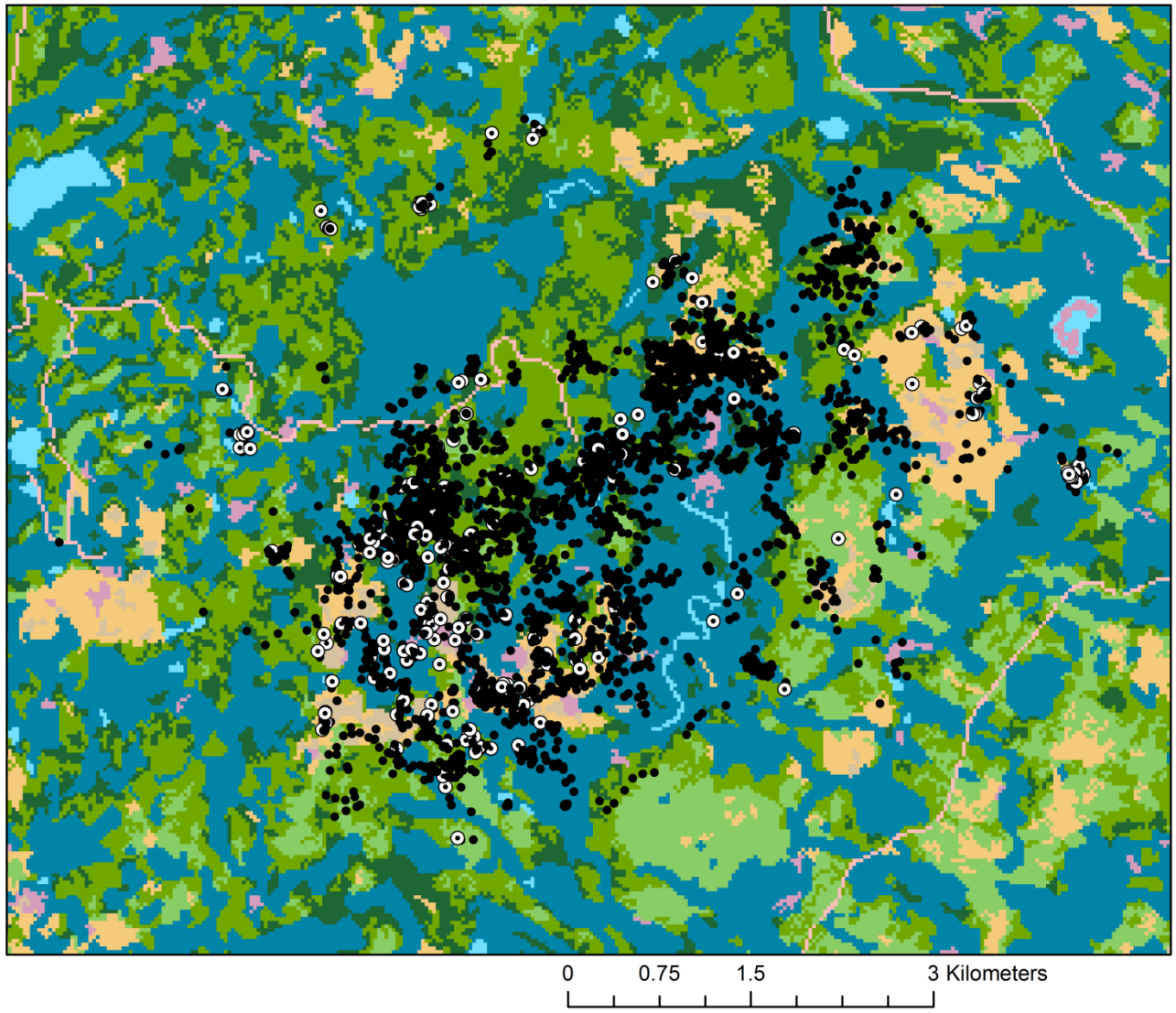
July trauma; septicemia

Jan wolf-injury

Feb wolf-kill; bad liver, infection

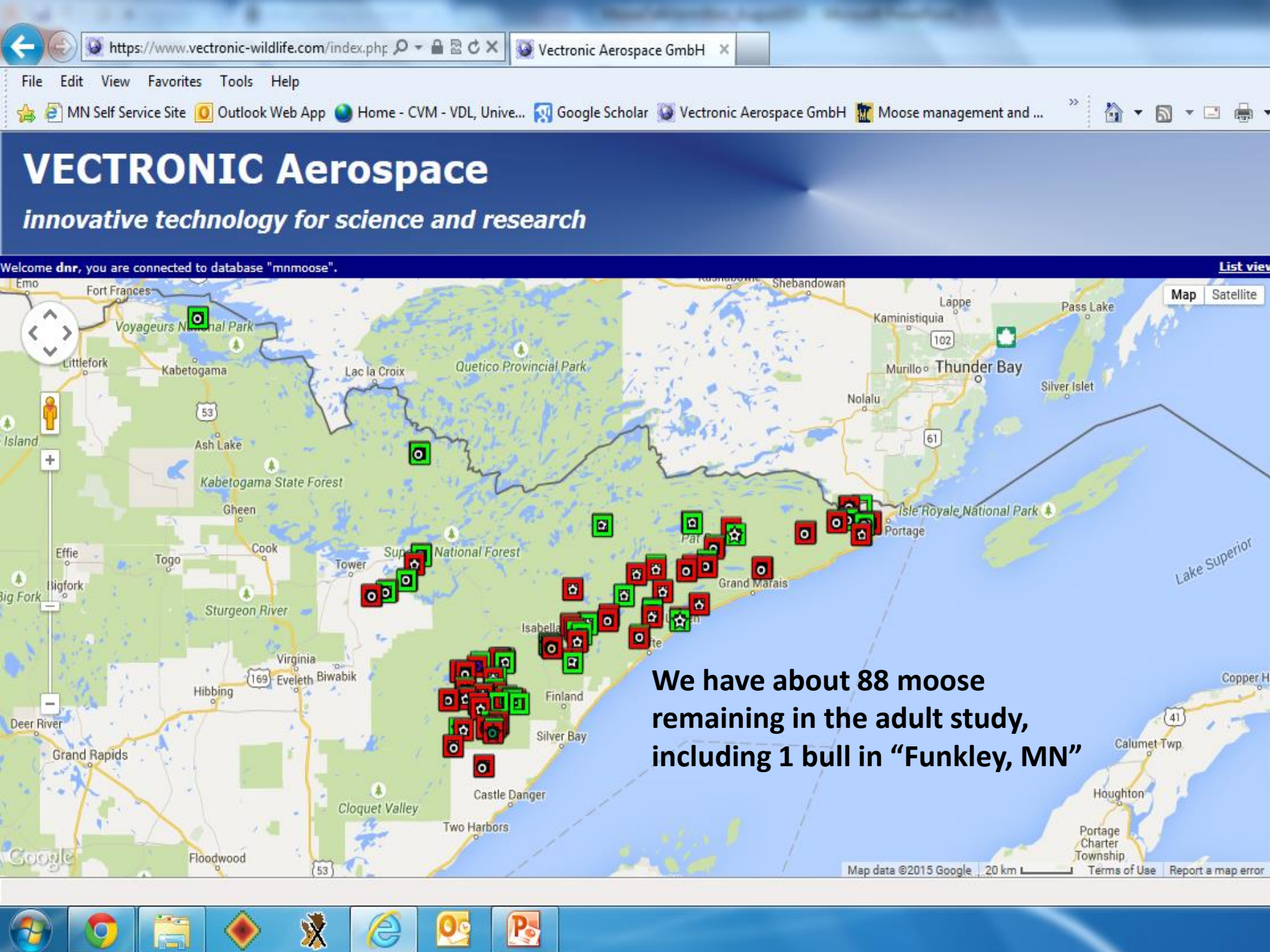
Where do moose go when they are hot?

Observations for moose 12570 that were above or below 102 Fahrenheit



Moose Health Collaborations

- Microfilarial testing and P. tenuis PCR (Rick Gerhold, Univ of TN)
- Tick borne illnesses (Uli Mundeloh, UMN)
- Neospora & Toxoplasmosis testing (JP Dubey, USDA-ARS)
- Diet & nutrient requirements (James Forester, UMN)
- Gut metagenomics (Kelly Wrighton, Ohio State Univ)
- Fecal microbiome (Amy Kingsley, UMN)
- EEE vectors (Amy Kingsley, UMN)
- Thiamine deficiency (Dr. Don Tillitt, USGS)
- Hair cortisol and long term stress (Tiffany Wolf, MN Zoo)
- Moose genetics (Jared Strasburg, UMD)
- Moose virome (Kevin Keel, UC-Davis)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Vectronic Aerospace GmbH
File Edit View Favorites Tools Help
MN Self Service Site
Outlook Web App
Home - CVM - VDL, Unive...
Google Scholar
Vectronic Aerospace GmbH
Moose management and ...
VECTRONIC Aerospace
innovative technology for science and research
Welcome dnr, you are connected to database "mnmoose".
List view
Map
Satellite
Fort Frances
Voyageurs National Park
Littlefork
Kabetogama
Lac la Croix
Quetico Provincial Park
Ash Lake
Kabetogama State Forest
Gheen
Effie
Togo
Cook
Tower
Sturgeon River
Virginia
Eveleth
Biwabik
Hibbing
Deer River
Grand Rapids
Cloquet Valley
Floodwood
Finland
Silver Bay
Castle Danger
Two Harbors
Grand Marais
Isabella
Lake Superior
Isle Royale National Park
Portage
Shebandowan
Kaministiquia
Lappe
Pass Lake
Murillo
Thunder Bay
Silver Islet
Nolalu
Calumet Twp
Houghton
Portage Charter Township
Copper H
Map data ©2015 Google
20 km
Terms of Use
Report a map error
We have about 88 moose remaining in the adult study, including 1 bull in “Funkley, MN”

What are the management options?

- Management happening now:
  - Ended hunting (State and Tribal)
  - Targeted moose habitat management/restoration
- Possible other management options:
  - Decrease deer numbers?
  - Predator control? Difficult now that wolves are re-listed.
  - Targeted habitat management related to disease vectors? Is that possible?
  - Do nothing?
- Which are supported?
  - How much do we value moose?
  - How much do we value other wildlife that may be positively or negatively affected by managing the landscape for moose?
- Governor's Executive Order (April 2015) ended all state-permitted moose collaring due to capture-related deaths

Acknowledgments


Photo: Veronique St-Louis, MRC Alaska

- Environmental and Natural Resource Trust Fund and Minnesota DNR, Division of Wildlife
- Glenn DelGiudice, Bob Wright, Dave Ingebrigtsen, Nancy Hansen, John Guidice, MN DNR
- Arno Wuenschmann, Anibal Armien, Roger Moon, Uli Munderloh, Bill Severud, Larissa Minicucci, University of MN
- John Crouse and Dan Thompson, MRC
- Mike Schrage, Lance Overland, Fond du Lac Resource Management Division
- Andy Edwards and Nick Boygo, 1854 Treaty Authority
- Rick Gerhold and Caroline Grunenwald, University of TN
- Ron Moen and Amanda McGraw, University of MN –Duluth
- Steve Windels, Bryce Olson, Voyageur's National Park
- Erika Butler, DVM
- Minnesota Deer Hunters Association
- North Star Museum of Boy and Girl Scouting

NORTH STAR MUSEUM OF BOY SCOUTING & GIRL SCOUTING

UNIVERSITY OF MINNESOTA DULUTH NATURAL RESOURCES RESEARCH INSTITUTE

UNIVERSITY OF MINNESOTA

1854 TREATY AUTHORITY GRAND PORTAGE · BOIS FORTE

MINNESOTA DEER HUNTERS ASSOCIATION HUNTING HABITAT EDUCATION LEGISLATION

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

NAH-GAH-CHI-WA-NONG FOND DU LAC RESERVATION

Minnesota DEPARTMENT OF NATURAL RESOURCES