

DETERMINING CAUSE-SPECIFIC MORTALITY IN MINNESOTA DECLINING MOOSE POPULATION



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Moose (*Alces alces*)

- 4 subspecies in North America
 - Western Moose

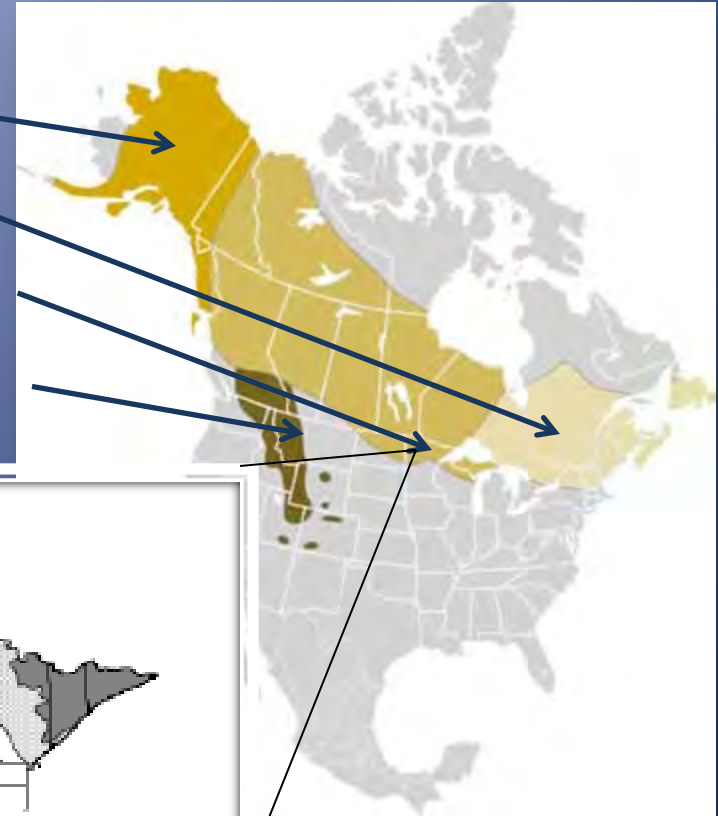


A. a. gigas

A. a. americana

A. a. andersoni

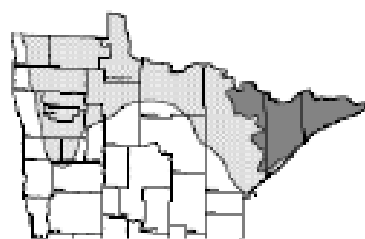
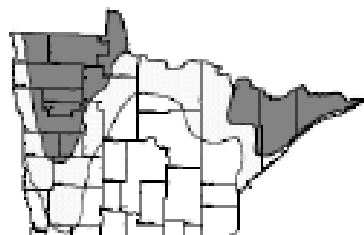
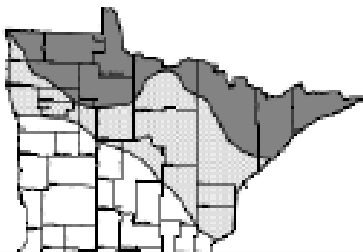
A. a. shirasi



1965

1986

2009



Moose Predators

- Predators:
 - Grizzly bears



- Black bears



- Wolves



Moose Diseases

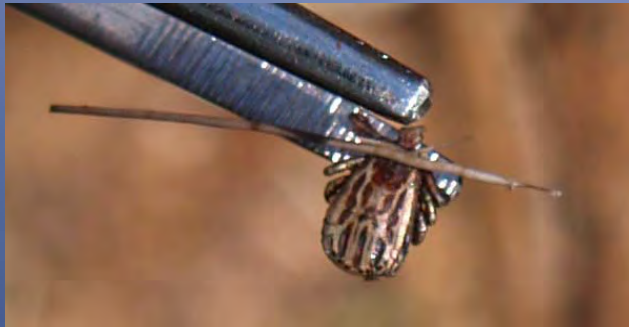
Brainworm

*Parelaphostrongylus
tenuis*



Winter tick

Dermacentor albipictus



Liver fluke

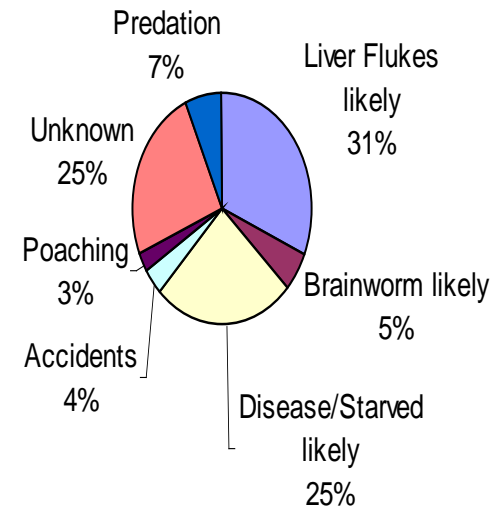
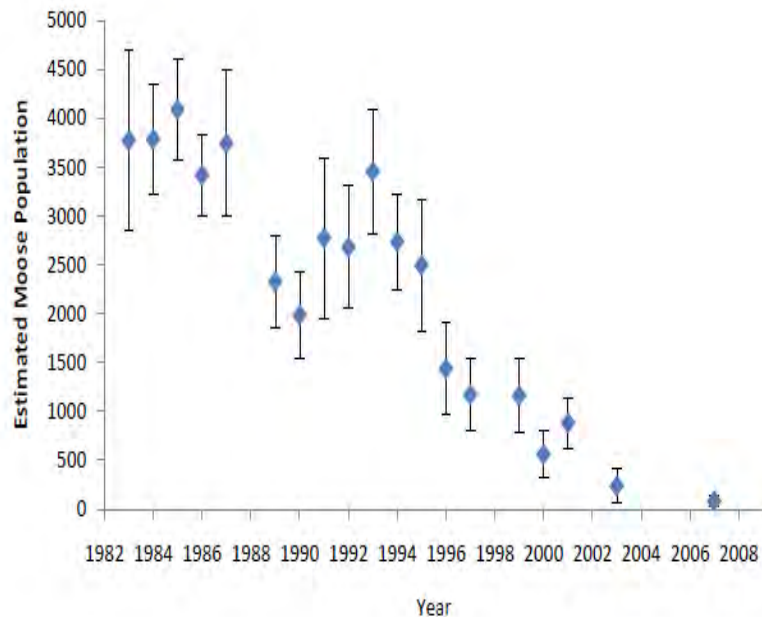
Fascioloides magna



Northwest MN Moose Population

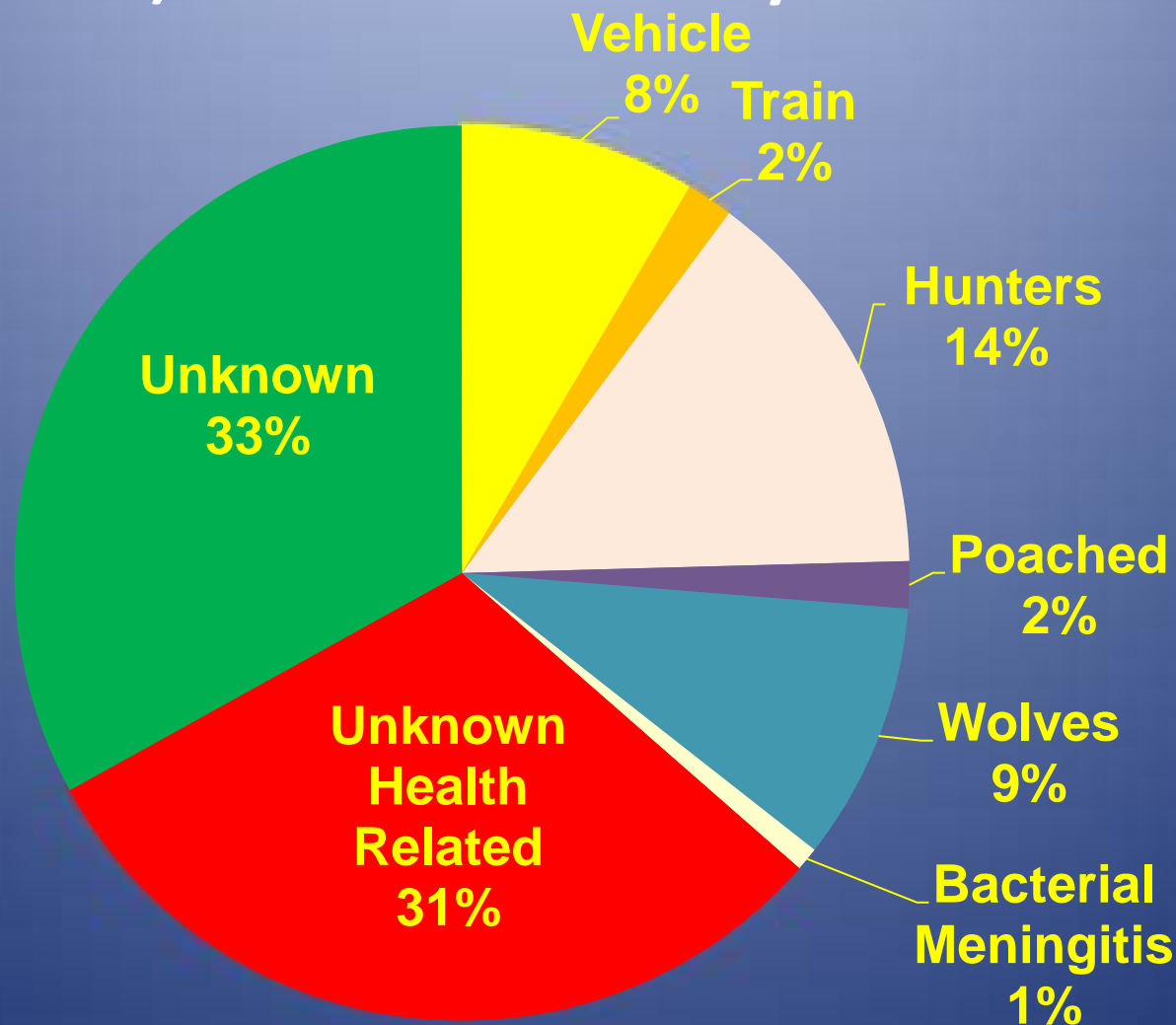
Population crash – we used to have >4,000 moose in the 1980's, but by the 1990's, things started to change.....

- Stopped hunting in 1997
- Habitat management efforts
- Radiocollared (VHF) adult mortality study, 1995-2000
 - Climate change correlation
 - Health related (liver flukes and brainworm)





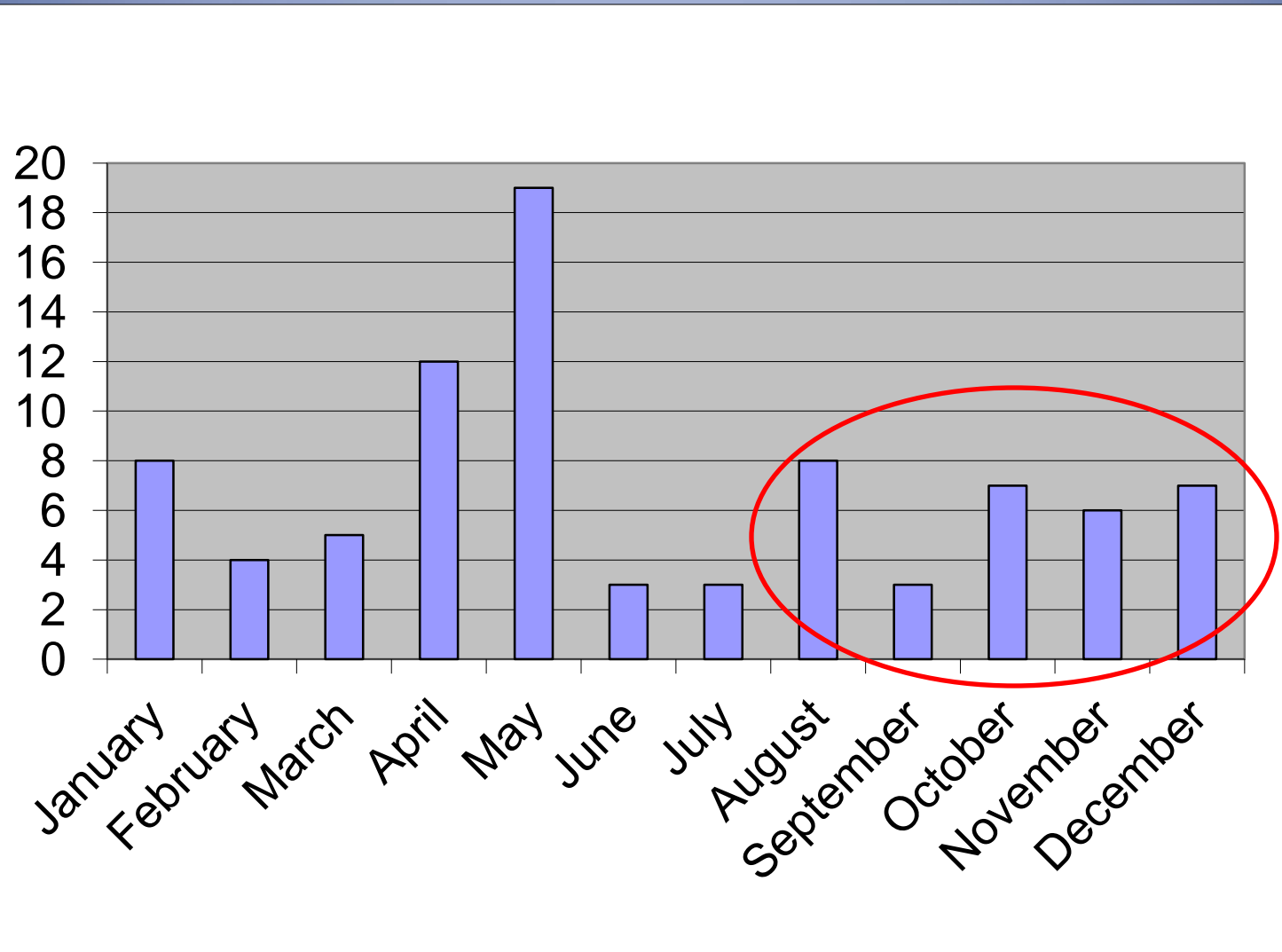
2002-2008 Northeast Radiocollared (VHF) Moose Study Results



Many moose that looked like this, tipped-over dead



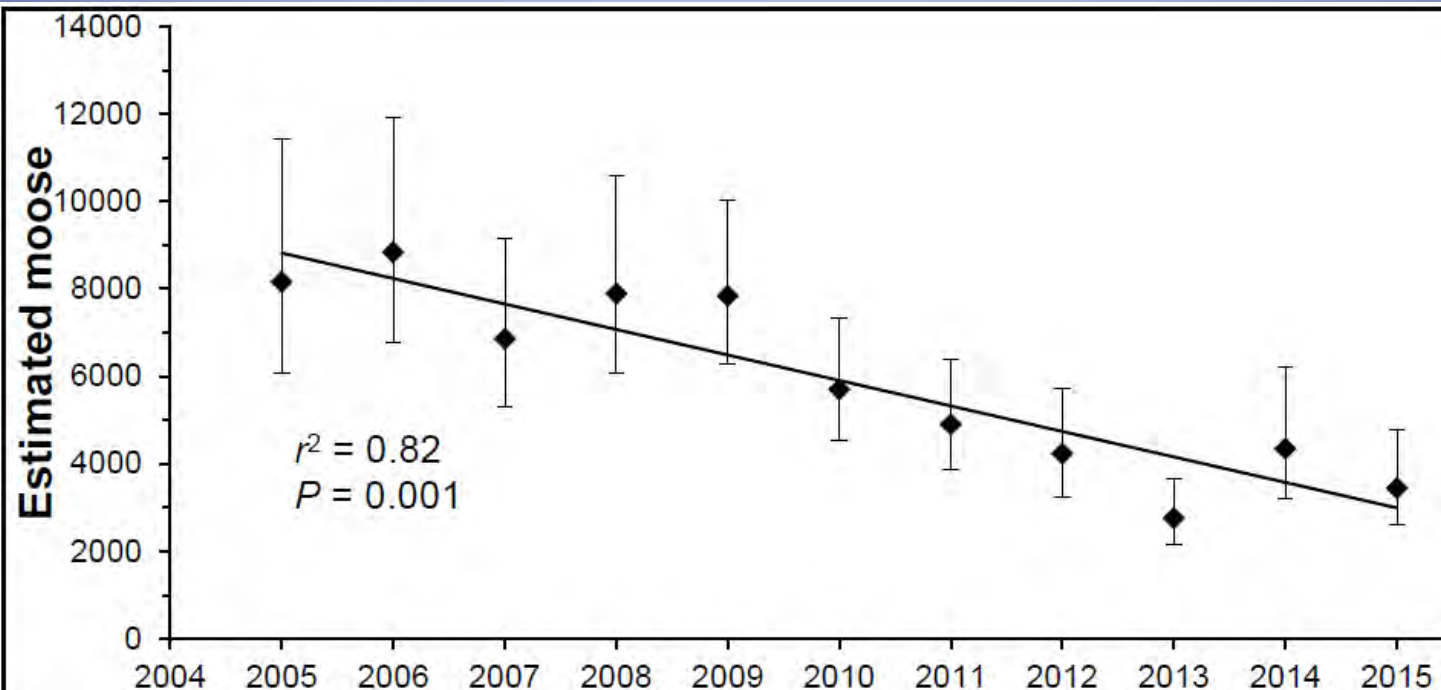
...At the wrong time of year



	Average Adult Non-Hunting Mortality
Alaska & Canada	8 – 12%
Northwestern Minnesota	21% (16–26%) (1995-2000)
Northeastern Minnesota	21% (5–35%) (2002-2008)



Northeast MN Population Trend



Survey	Estimate	90% Confidence Interval	Calf: Cow	% Calves	% Cows w/ twins	Bull: Cow
2005	8,160	6,090 – 11,410	0.52	19	9	1.04
2006	8,840	6,790 – 11,910	0.34	13	5	1.09
2007	6,860	5,320 – 9,100	0.29	13	3	0.89
2008	7,890	6,080 – 10,600	0.36	17	2	0.77
2009	7,840	6,270 – 10,040	0.32	14	2	0.94
2010	5,700	4,540 – 7,350	0.28	13	3	0.83
2011	4,900	3,870 – 6,380	0.24	13	1	0.64
2012	4,230	3,250 – 5,710	0.36	15	6	1.08
2013	2,760	2,160 – 3,650	0.33	13	3	1.23
2014	4,350	3,220 – 6,210	0.44	15	3	1.24
2015	3,450	2,610 – 4,770	0.29	13	3	0.99

Possible contributing factors in the decline



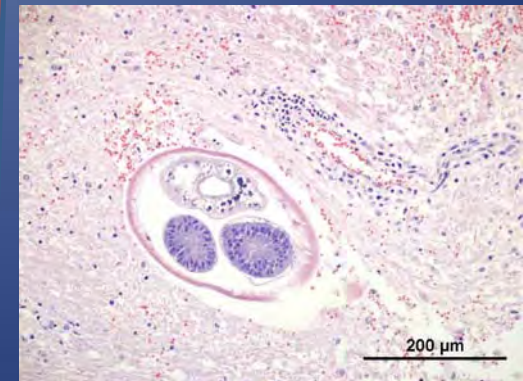
Nutritional Restriction?



Predator Pressure?



Climate Change?



Disease and Parasites?

**Big Questions:
Why now?
What has changed?**

Current Research on MN's Moose Decline

- Adult and calf cause-specific mortality studies – MN DNR
- Habitat use and restoration studies – UMD-NRRI, Voyageurs National Park, Grand Portage Indian Reservation
- Moose-wolf interaction study – MN Zoo, UMD-NRRI
- Moose-deer habitat use and disease interaction study – MN Zoo, UMD-NRRI, MN DNR



Why do we care? So what if the moose disappear.....
Truth is, moose are not only a Minnesota icon in peril,
but other states/provinces are losing moose, too.

Minn. sees steep decline in young moose population
September 27, 2013

Disappearing North American Moose Alarm Scientists

The New York Times **Environment**

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPA

ENVIRONMENT SPA

Moose Die-Off Alarms Scientists

Thanks To Parasites, Moose Are Looking More Like Ghosts

by FRED BEVER
November 05, 2013 4:33 PM

Climate change, ticks claiming moose in New Hampshire

VPR News

5:00 PM FRI OCTOBER 18, 2013

Vermont Steps Up Moose Monitoring

MN moose population continues to decline

October 15, 2013

Is Climate Change to Blame for Moose Decline?

The Bismarck Tribune

EDITORIAL
The Disappearing Moose

By THE EDITORIAL BOARD
Published: October 16, 2013

US moose decline not mirrored in Ontario or Quebec

But decline in population in Outaouais leads Quebec to limit tags as hunting season begins

CBC News Posted: Oct 16, 2013 5:00 AM ET | Last Updated: Oct 16, 2013 7:27 AM ET

States Initiating Research on Moose Declines; Minnesota Halts Hunt

'Moose die-off' not seen in Yukon, where populations stable

Multiple moose populations declining across U.S.

13 7:40 PM CT | Last Updated: Oct 16, 2013 7:58 PM CT

Montana, Wyoming investigate plummeting moose populations

Minn. moose study examines declining populations

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The 'prairie moose phenomona'



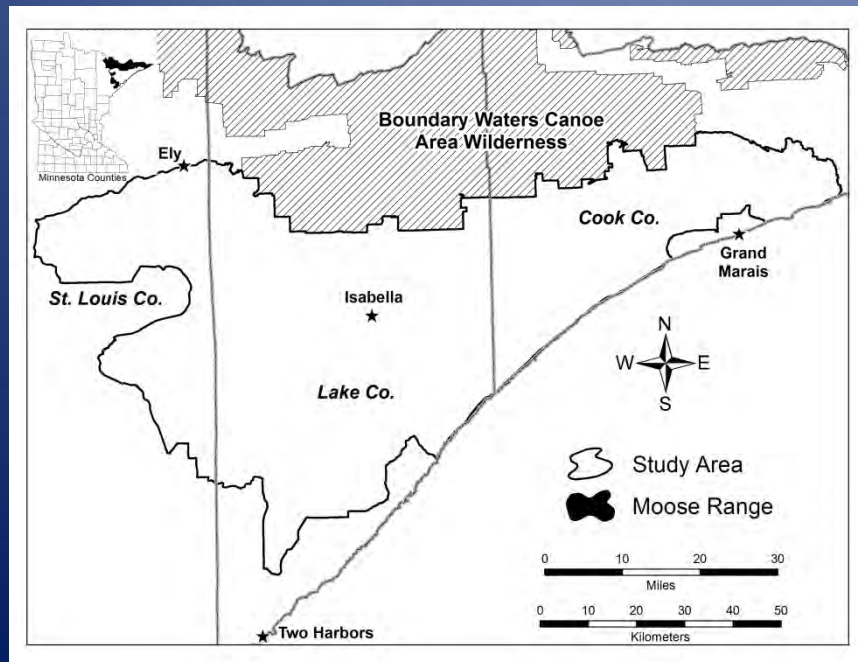
Minnesota's Disappearing Moose, Recent Media Coverage



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
 - Perform field necropsy



How is all this going to work?



- Vectronics Aerospace GPS-Iridium collars
- 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



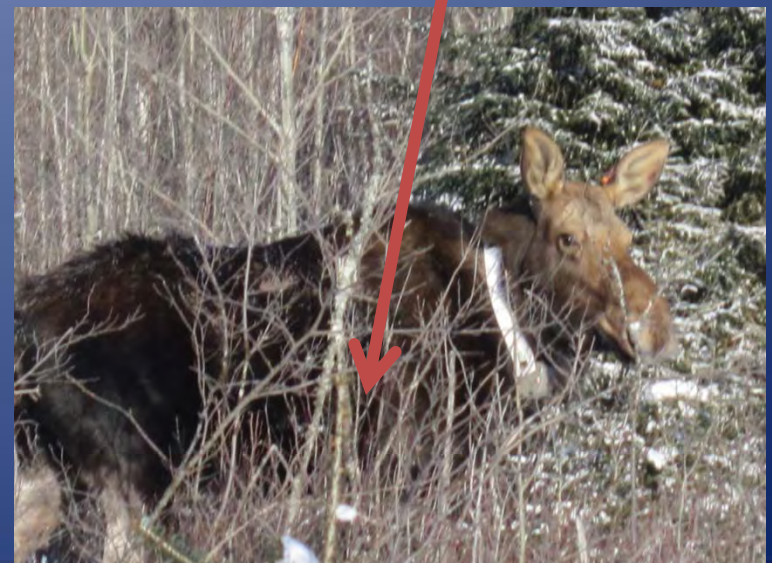
How cool is this????

A guy at his computer in Berlin,
Germany.....



Sends a message to a satellite.....

That talks to the MIT in the moose's
stomach!



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

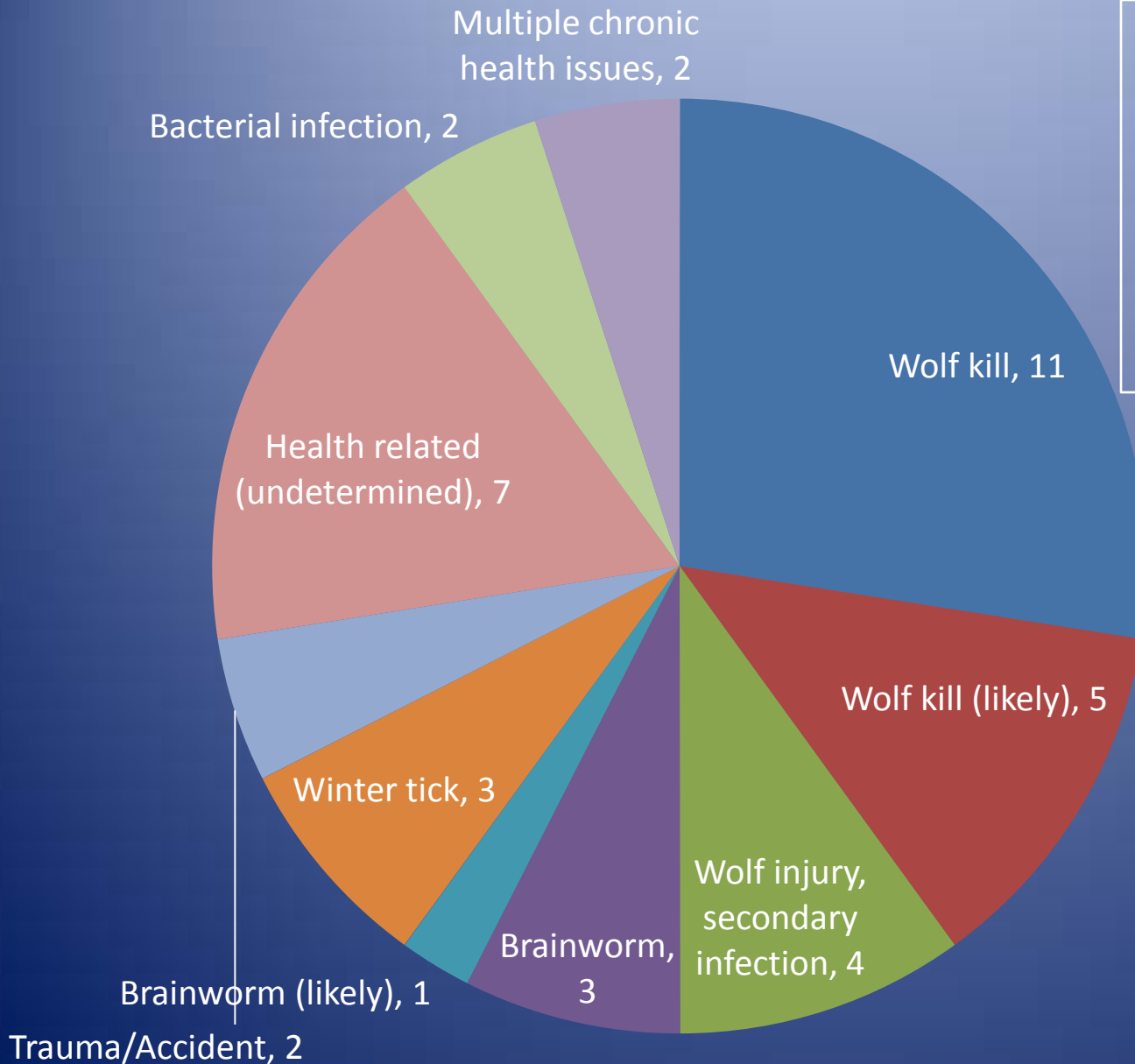


Annual survival rates of adult moose, 2013-2015



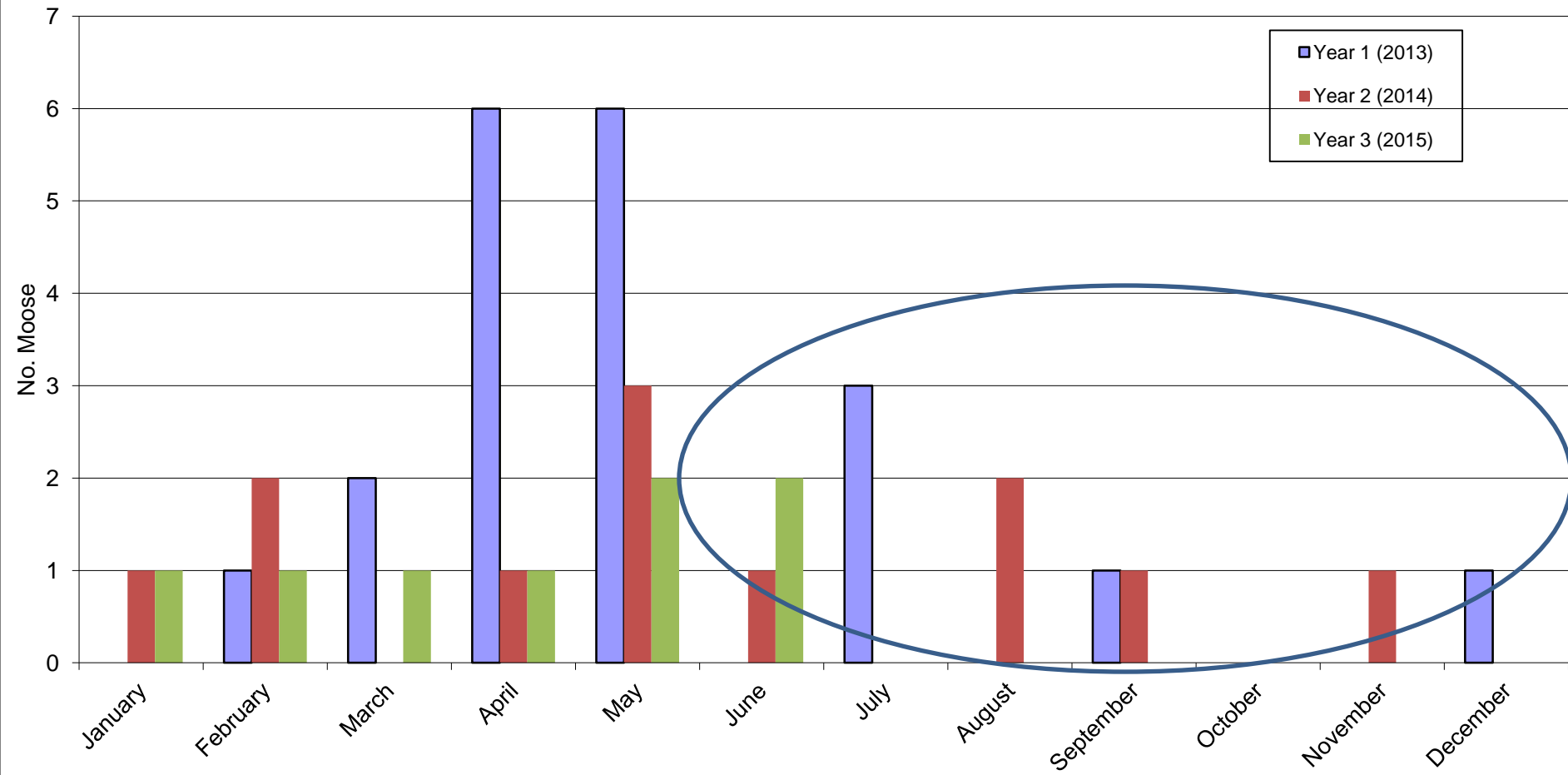
Adult Moose Mortalities (n=40, Feb 2013- June 2015)

2013: 20 deaths
-11 predator; 9 health
2014: 12 deaths
-6 predator, 6 health
2015: 8 deaths
-3 predator, 5 health



Timing of Adult Moose Mortalities

($n = 40$; Feb 2013 - June 2015)

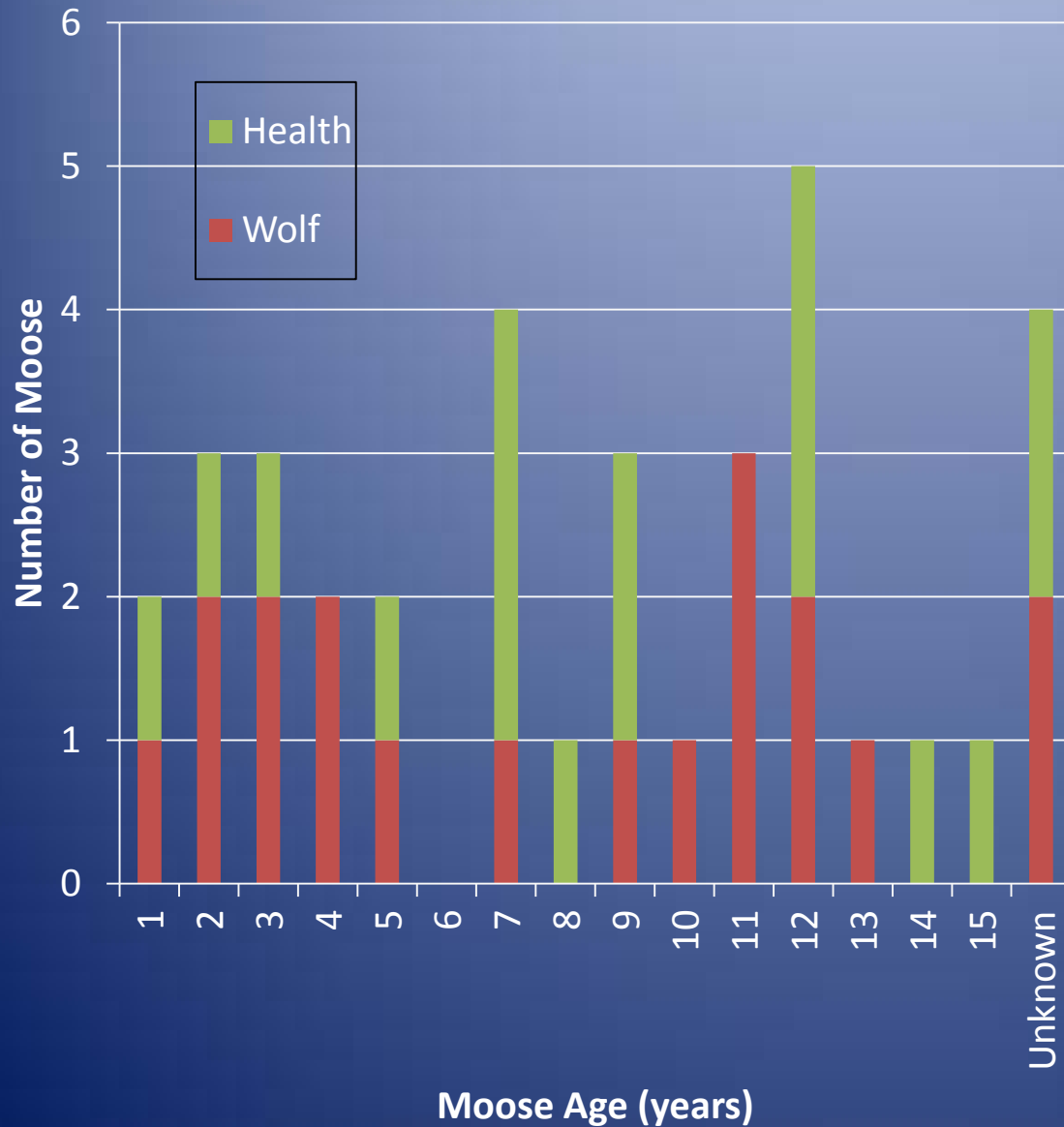


Wolf-kills, confirmed and likely ($n = 16$)

- 5 moose had health conditions that could have predisposed them to predation
 - Brain lesion with mild encephalitis
 - Observed with head tilt, circling ($n=2$), presumed to be *P. Tenuis* infection
 - Confirmed *P. Tenuis* infection
 - Leg injury and wounds on rump
- 4 moose were totally scavenged, unable to collect much for diagnostics
- 7 moose were partially scavenged, samples did not point to any clear underlying health condition or results are still pending



Ages of Moose at Death



- Overall age of all moose at death = 7.6 yrs (± 0.7), $n = 32$, 4 moose have pending ages
- Mean age of health-related deaths: 8.2 yrs (± 1.1), $n = 15$, missing 2 ages
- Mean age of wolf-related deaths: 7.1 yrs (± 1.0), $n = 17$, missing 2 ages
- Young Moose (≤ 3): 8 (5W, 3H)
- Prime Moose (4-7): 8 (4W, 4H)
- Old Moose (≥ 8): 16 (8W, 8H)

Whole Carcass Extraction



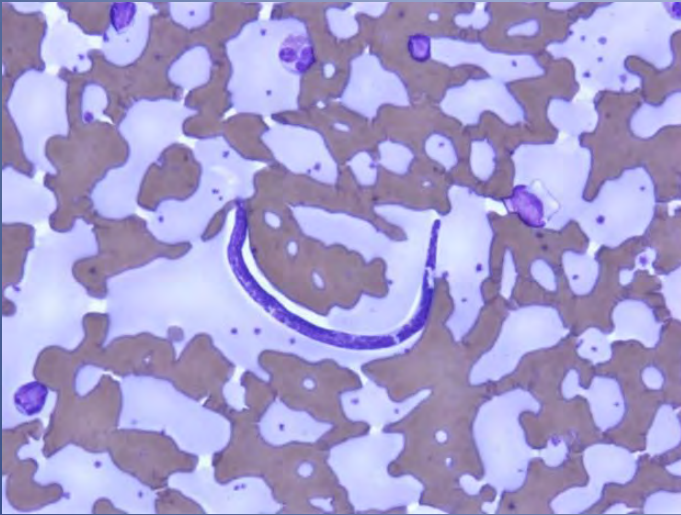


ARGO and MOOSE TACO

Field Necropsies



Disease Screening at Necropsy

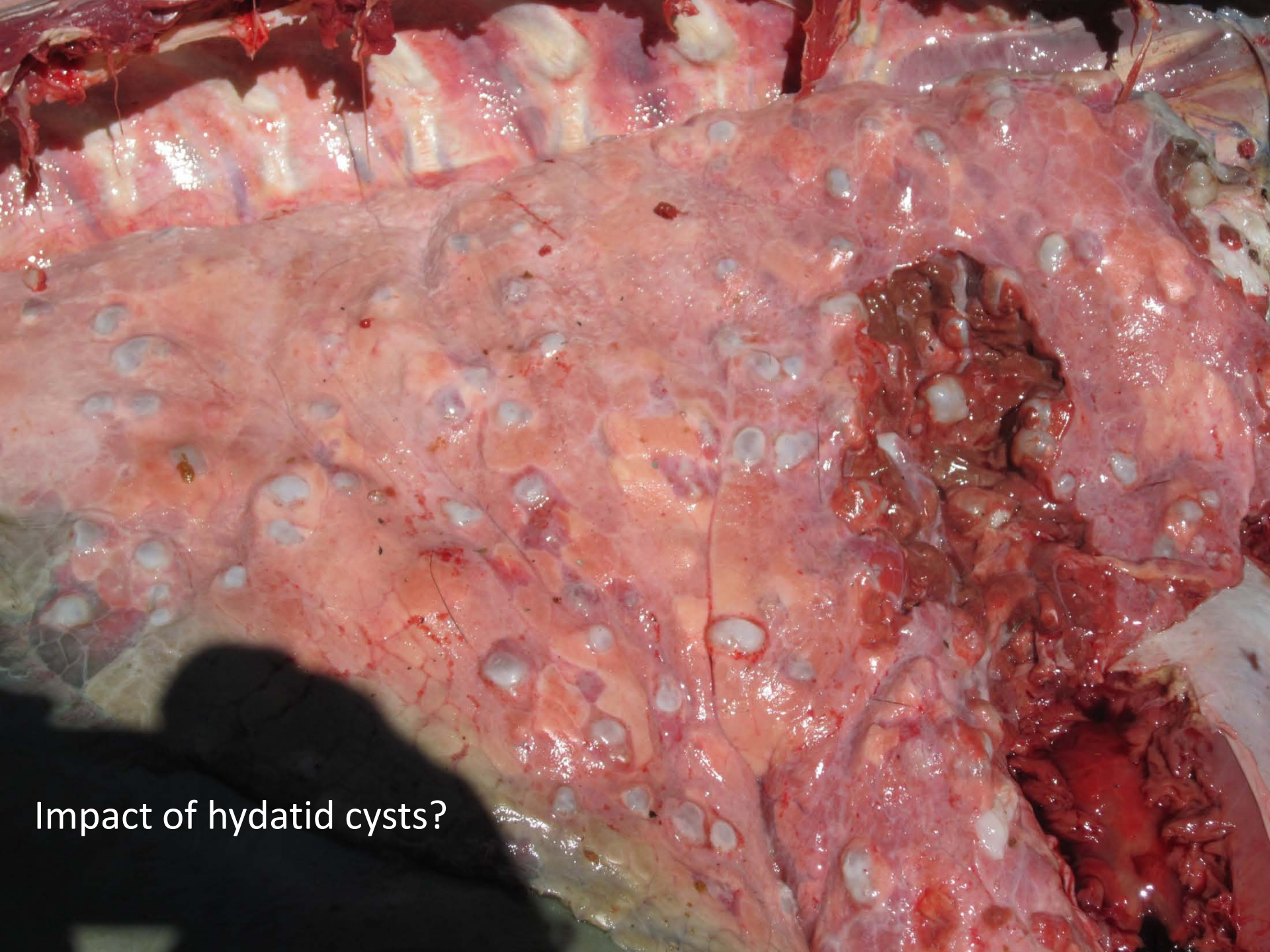


- Full necropsies at UM-VDL by board-certified pathologists
- If serum collected, screen for wide array of diseases
- Microfilarial testing (Univ of TN collaboration)
- Tick borne illness screening (Univ of MN collaboration)
- Neospora testing (USDA-ARS collaboration)
- WNV, EEE, WEE, and MCF PCR
- Collected metagenomics samples on “unknown deaths”
- Banking nearly every sample we can justify!



Unknowns remain.....





Impact of hydatid cysts?



Impact of liver flukes?

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)

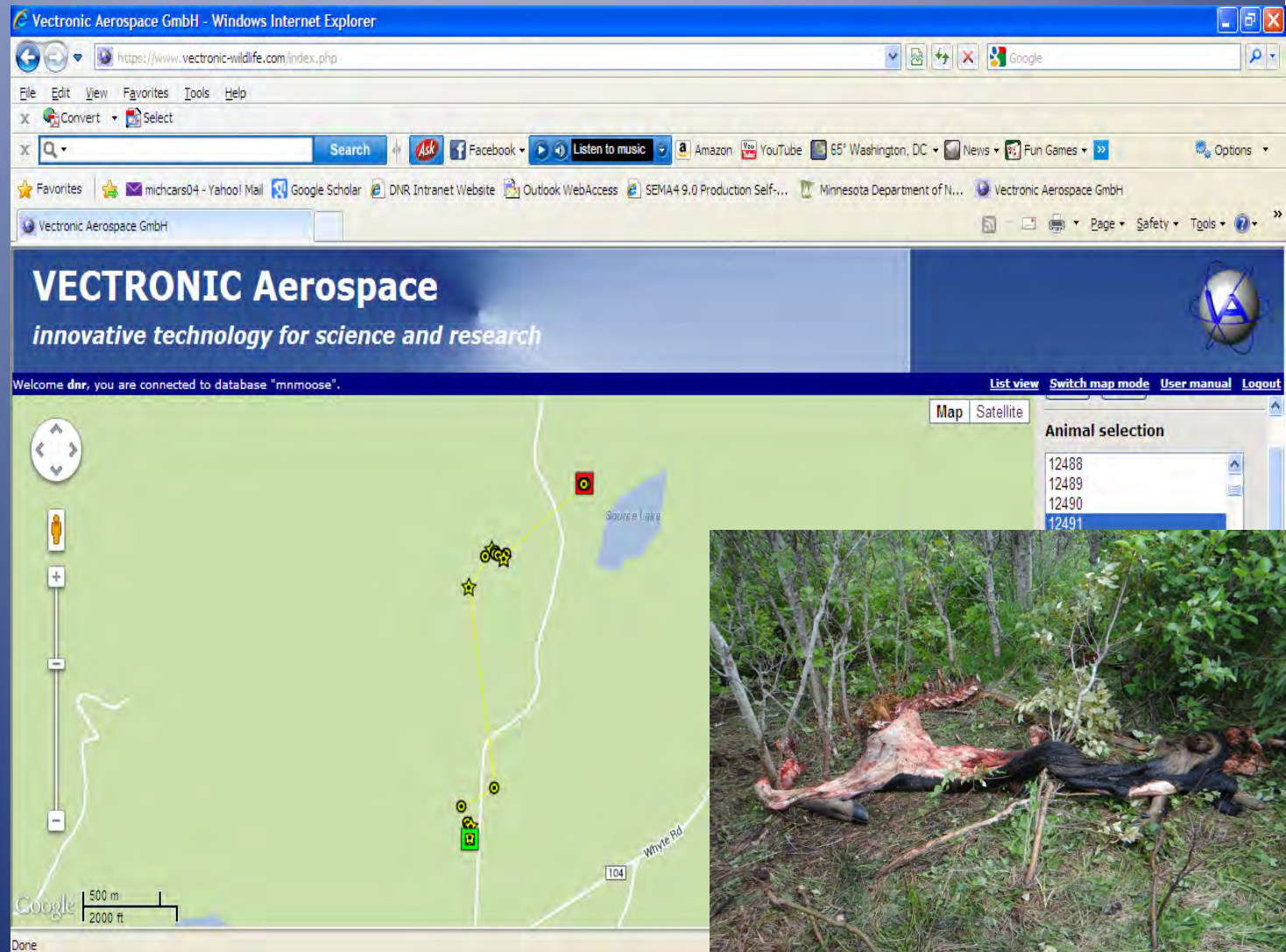
MITs: Enhanced mortality notifications AND SO MUCH MORE!

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.



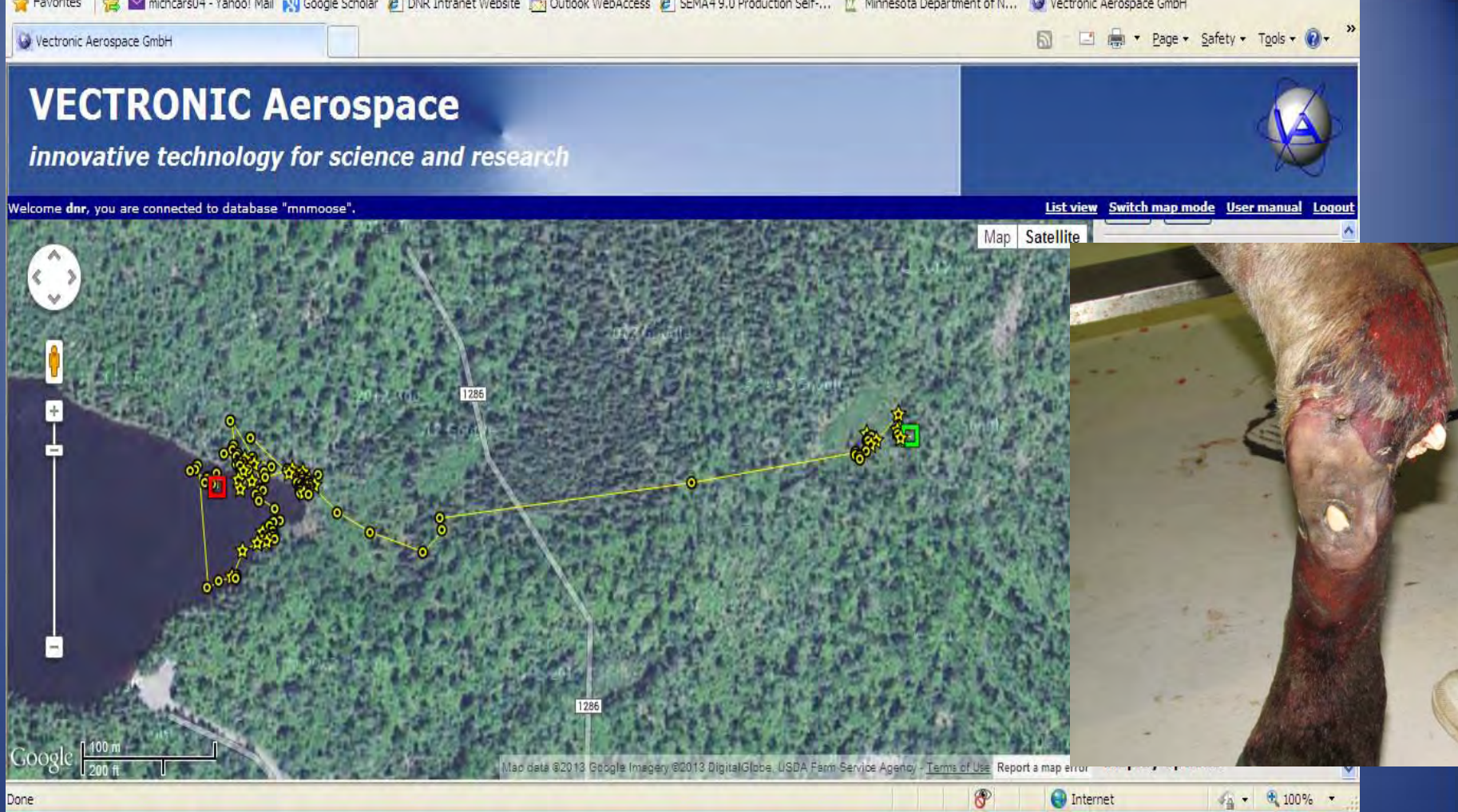
MIT Temps (July 26-28, 2013)



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.



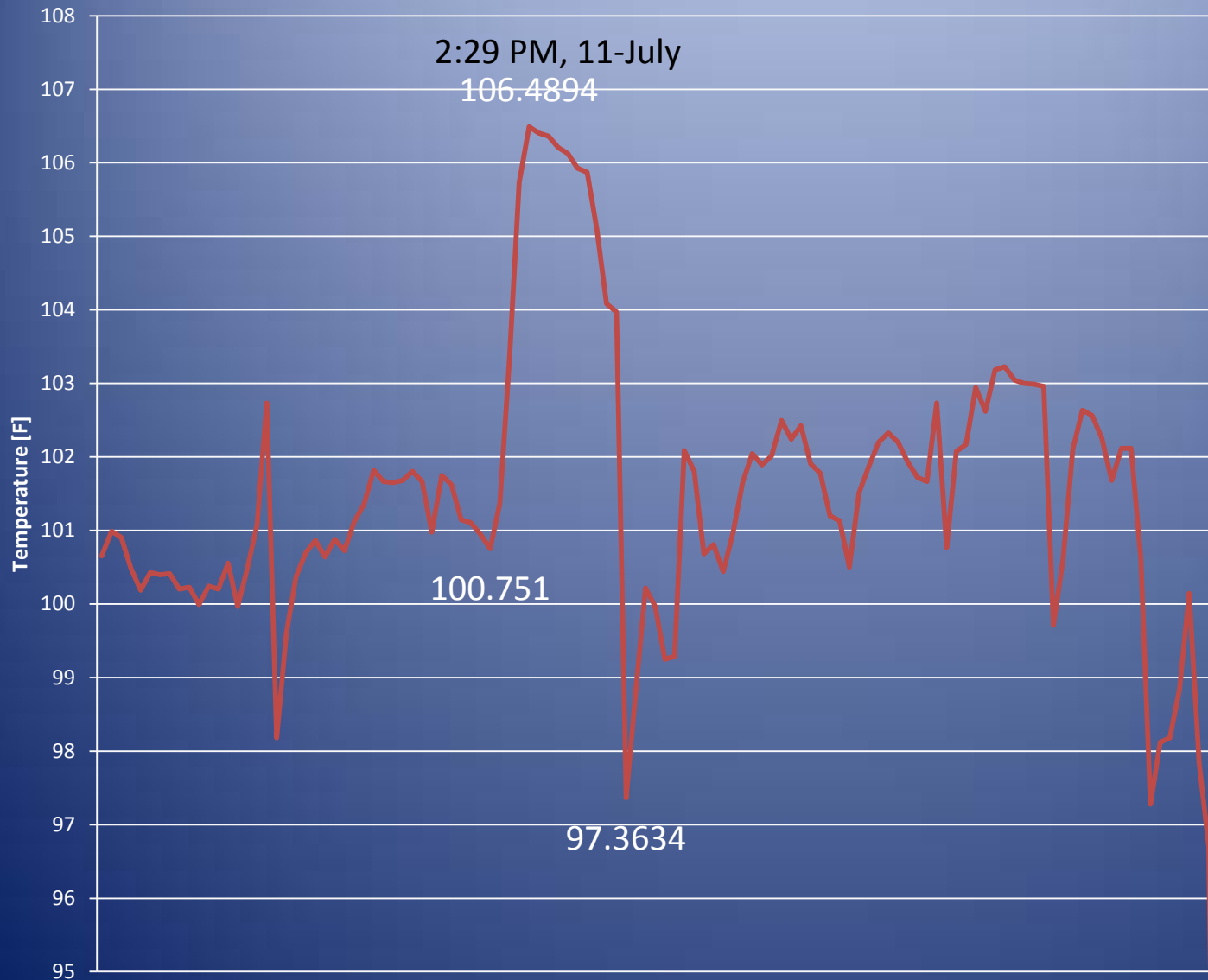
Movement activity just prior to death; 11-July to 15-July.

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 Temps 11-July to 15-July

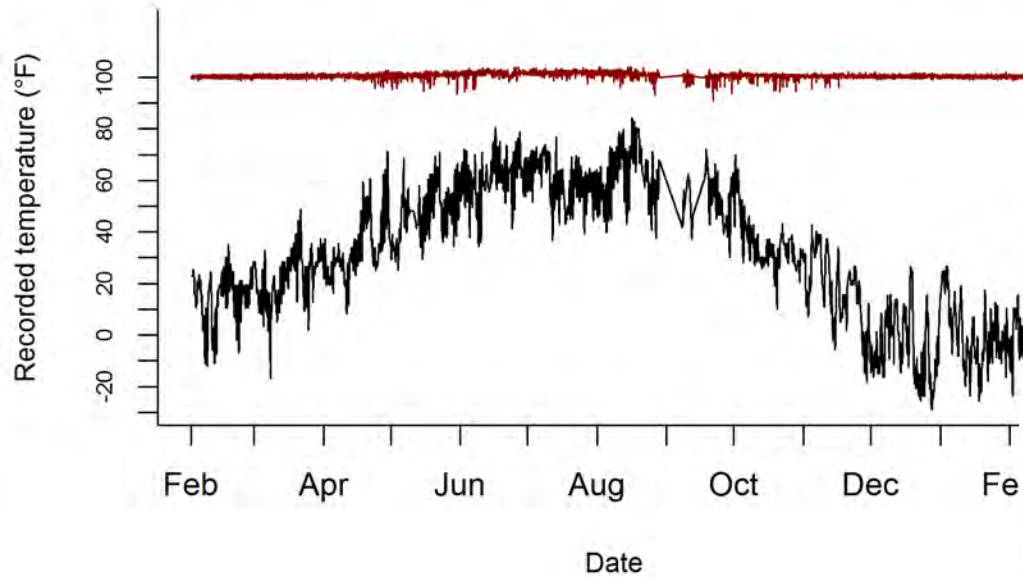


MIT data indicated a sharp elevation in body temperature from 1-7pm on 11-July, which would suggest this may be the reason the moose began moving towards the water and remained in the lake until she died.

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

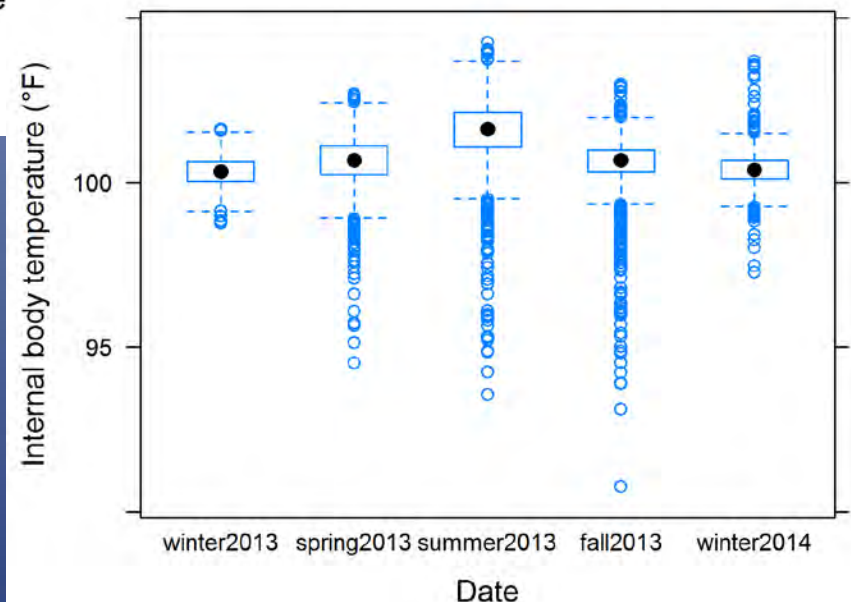
Temporal variability in temperature



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

Variability in body temperature across seasons



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

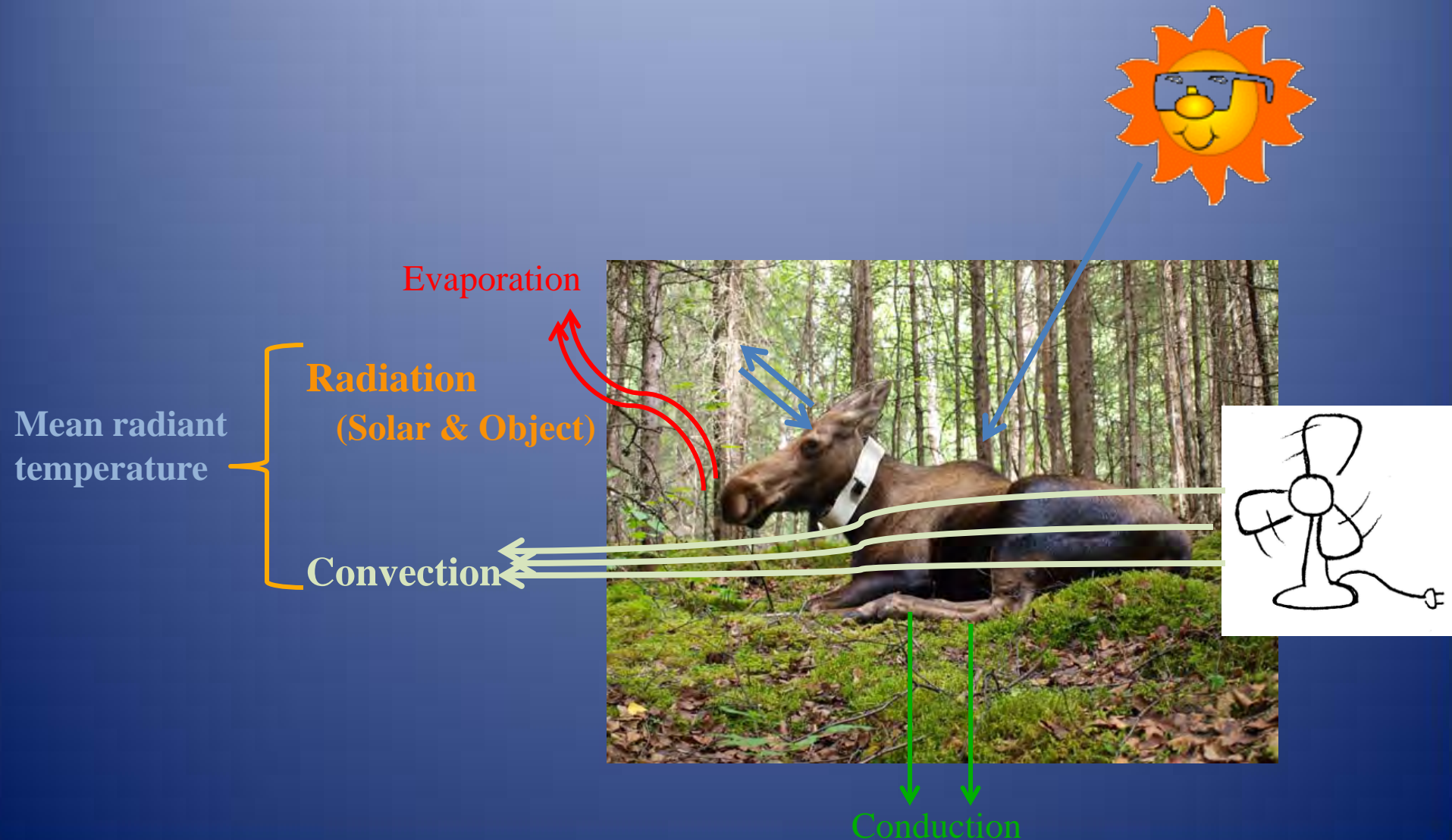
- How are they mitigating this excessive heat?

Moose and temperature in MN

- ❑ Moose in MN are at the southern edge of their range
- Increasing summer temperatures in NE MN may cause thermal cover to become increasingly important for moose
 - Normal average July temperature in northeast Minnesota is 17.5°C
 - Average daily temperature maximum during July is 24.4°C



If you are a hot moose, what can you do?



Wouldn't this be nice???



Moose Decline and Air Temperatures in NE MN



- \$600k in LCCMR funding (2015-17)
- Allows continuation (Year 3) of both adult and calf moose mortality studies with expanded use of MITs to obtain internal body temps
- Goal is to relate ambient temperatures to the physiology (internal body temp), behavior (habitat use, activity), and fitness (survival and reproduction) of moose
 - First time to examine these relationships with the inclusion of internal body temperatures

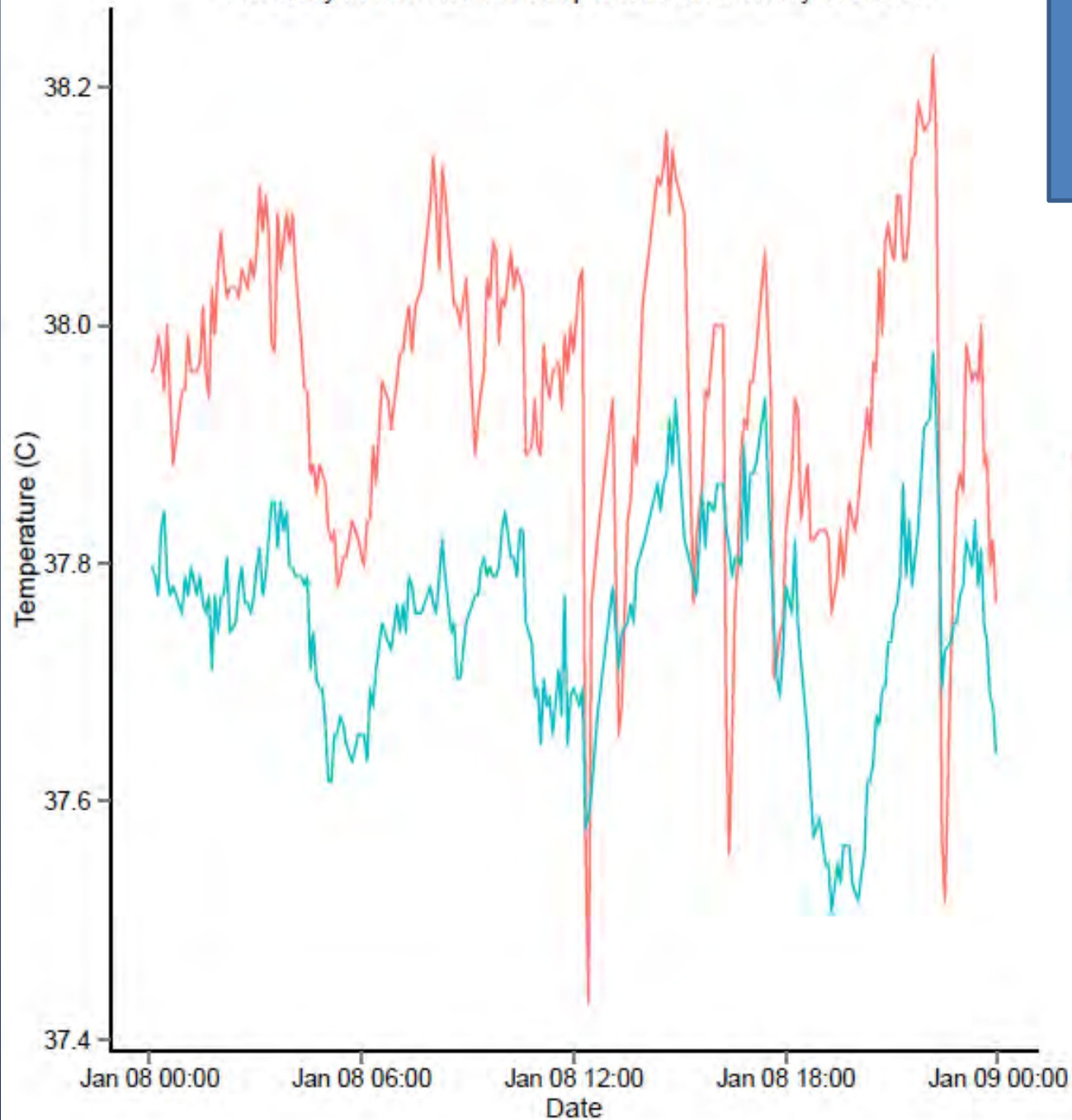
Calibration of the MITs

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



- Observational study of 8 captive, adult females at the Moose Research Center, Alaska
- Moose were fitted with both the rumen bolus (MIT) and vaginal implant transmitter (VIT) with temperature sensor
- 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

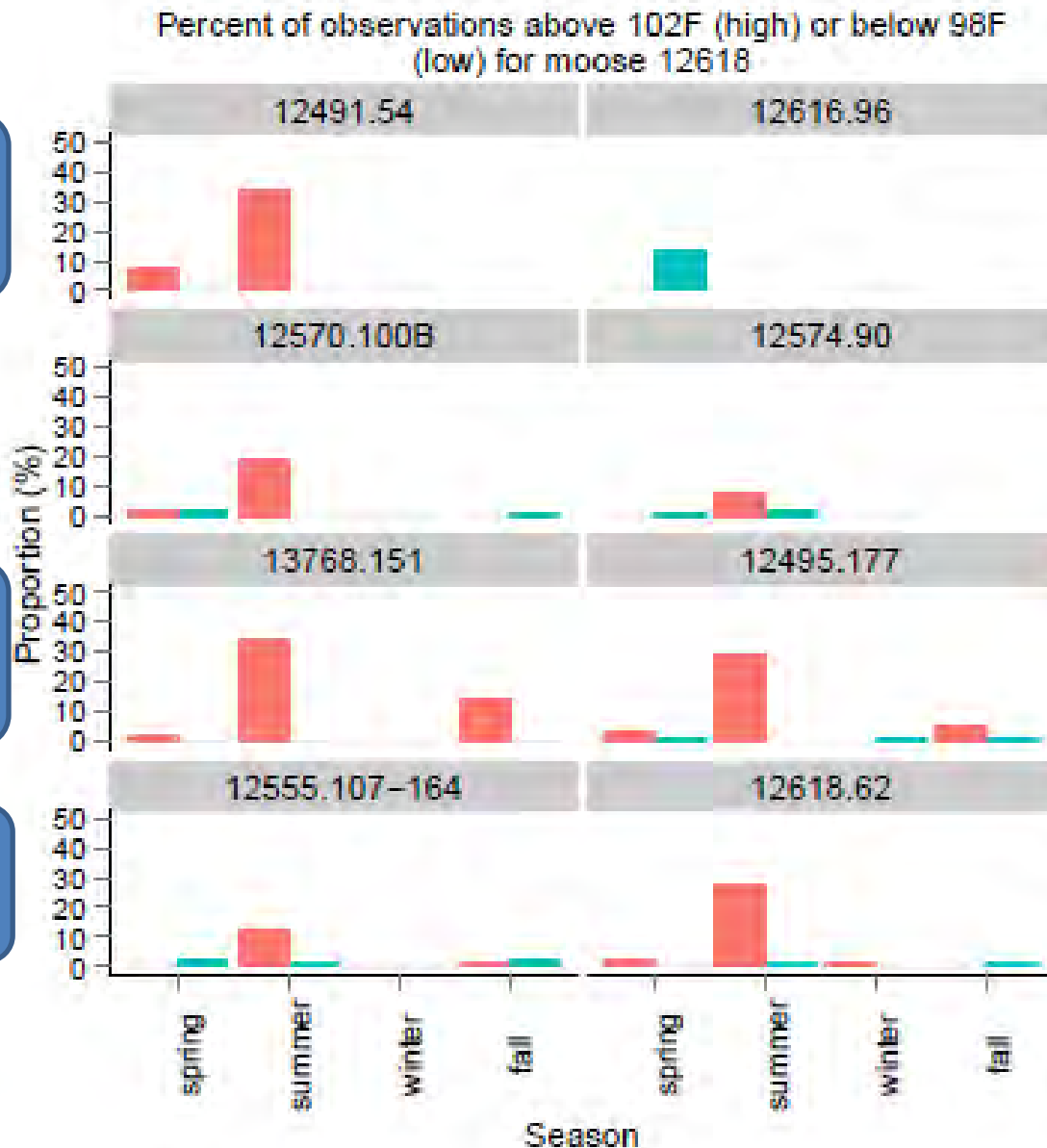
Variability in MIT and VIT temperature on January 8th 2015



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



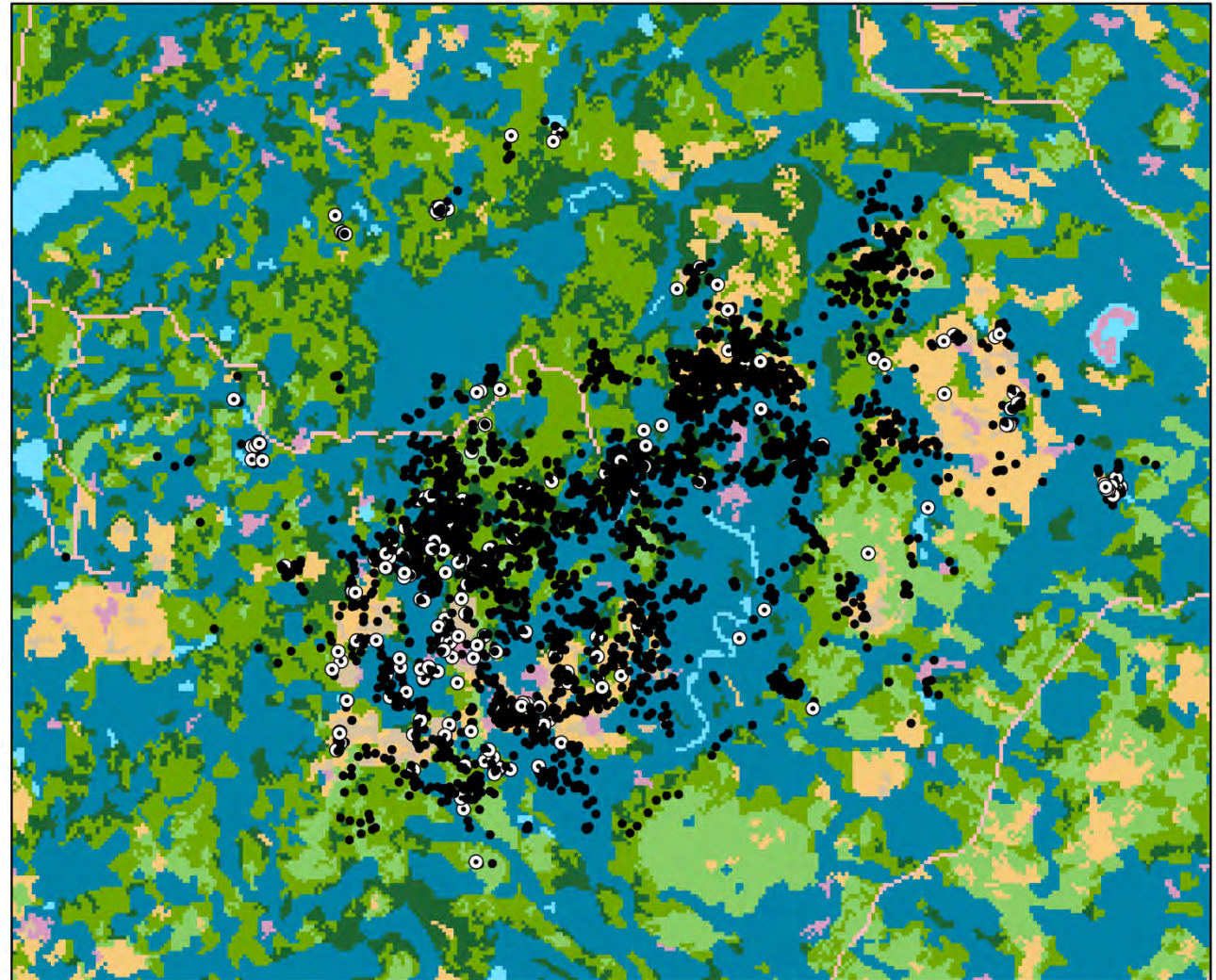
Moose locations

- Below 102
- ⊙ Above 102

NLCD 2011 - Land Cover

Land Cover Class

- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land (Rock/Sand/Clay)
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands



0 0.75 1.5 3 Kilometers



Studying Moose Calf Survival in a Declining Population on the Cutting-edge of Technology: *Overcoming the Inevitable Challenges before Reaching that “Sweet Spot”*

Glenn DelGiudice,^{1,2} William J. Severud,² and T. R. Obermoller,¹

¹Forest Wildlife Populations and Research Group, MN DNR

²Department of Fisheries, Wildlife, and Conservation Biology, UMN-St. Paul



25 Collar 12567 U

Last location: 2015-05-15 01:05:44

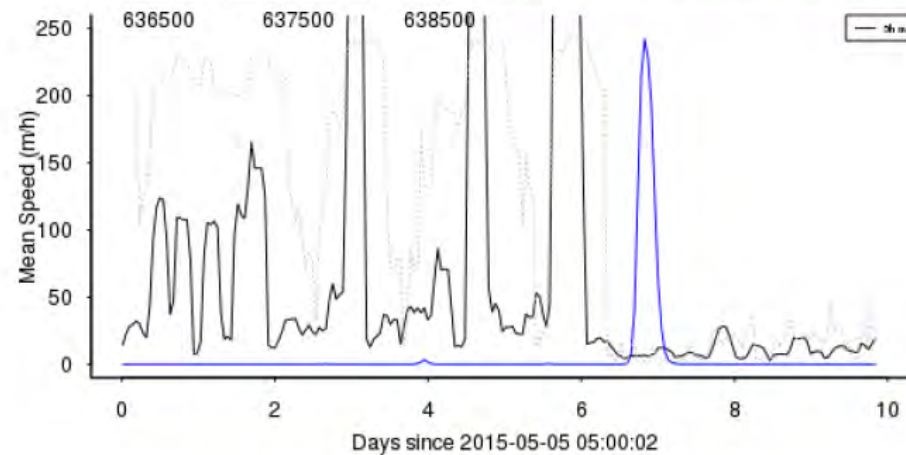
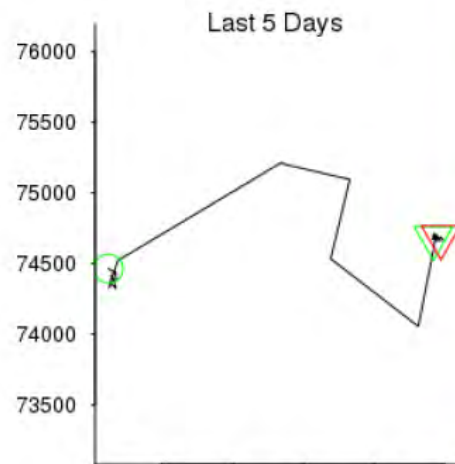
Max 3-h Avg. Speed (24h) = 19.9 m/h

Collar Temp = 14°C // Mortality Status = -7: Mortality, outside fence

UTM.X = 638479, UTM.Y = 5274688

Longitude = -91.15739, Latitude = 47.61079

Stat	T2h	T24h	T48h	Total
Disp.	2	53	30	758
Path	104	290	547	370777
Speed	20	12	11	65





some dnr, you are connected to database "mnmoose".

[List view](#) [Switch map mode](#) [User manual](#) [Logout](#)



Work space

[Load](#) [Save](#)

Animal selection

12562
12563
12564
12565
12566
12567
12568
12569
12570
12571
12572

Data selection

☐ Recent positions
☐ Positions by month / year
☒ Time span

Start date: 2015-05-10
End date: 2015-05-26

[Select](#) [Clear](#)

Display options

General options:

☒ Animate

Data layers:

☒ = day location
☒ = night location
☒ 12567 (384 pos.)

☒ Show fixes
☒ Show track

Map overlay options

KML/KMZ address

Display name

[Add overlay](#)
[Clear overlays](#)

google

Map data ©2015 Google Imagery ©2015 Chas/Spot Image, DigitalGlobe, USDA Farm Service Agency 100 m [Terms of Use](#) [Report a map error](#)





Percentage of all calf mortalities (n=40), 2013 and 2014

0% 20% 40% 60% 80% 100%

Wolf Predation

68%

Bear Predation

16%

Natural Abandonment

6%

Drowning

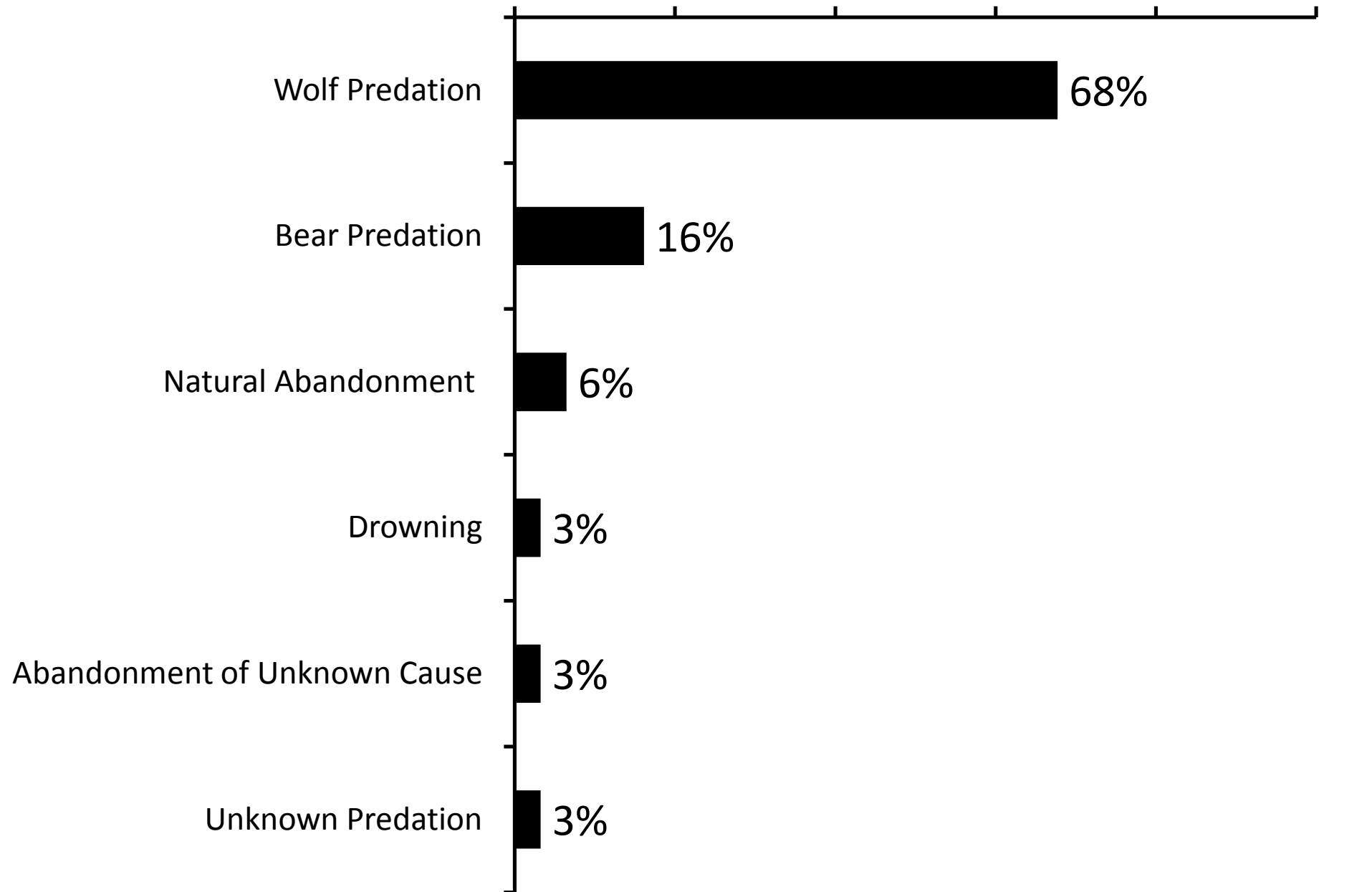
3%

Abandonment of Unknown Cause

3%

Unknown Predation

3%





Welcome dmr, you are connected to database "minmoose".

[List view](#) [Switch map mode](#) [User manual](#) [Logout](#)



Map Satellite

Work space

[Load](#) [Save](#)

Animal selection

- 13776
- 13777
- 13778
- 13779
- 13780
- 13781
- 13782
- 13783
- 13784
- 13785

Data selection

- ☐ Recent positions
- ☐ Positions by month / year
- ☒ Time span

Start date: 2015-05-02
End date: 2015-05-07

[Select](#)

[Clear](#)

Display options

General options:

☐ Animate

Data layers:

- ☐ day location
- ☐ night location

☒ 13778 (184 pos.)

- ☒ Show fixes
- ☒ Show track

Map overlay options

KML/KMZ address

Display name

[Add overlay](#)

[Clear overlays](#)

Calving/mortality site

Google

Map data ©2015 Google Imagery ©2015 Ches/Spot Image, DigitalGlobe, USDA Farm Service Agency 200 m Terms of Use Report a map error









15°C (06/14/2015 11:12PM CAMERA19



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
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- 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



Questions?



Image taken by A. Burcar

Moose Mortalities, Year 1: Feb 2013 - Dec 2013

- Year 1 total = 20/107 (19%)



- 11 predator-related mortalities (55%)
 - 6 wolf kills
 - 3 wolf kill, likely
 - 2 wolf injuries with secondary lethal infection
- 9 health-related mortalities (45%)
 - 1 brainworm
 - 3 winter tick
 - 1 liver fluke infection with secondary bacterial infection
 - 1 trauma with secondary infection/septicemia
 - 3 undetermined health issues
- 7 carcasses were removed intact, including 2 moose that were euthanized by team
- 11 censored moose (collar failures, slipped collars, etc.)

Moose Mortalities, Year 2: Jan 2014 - Dec 2014

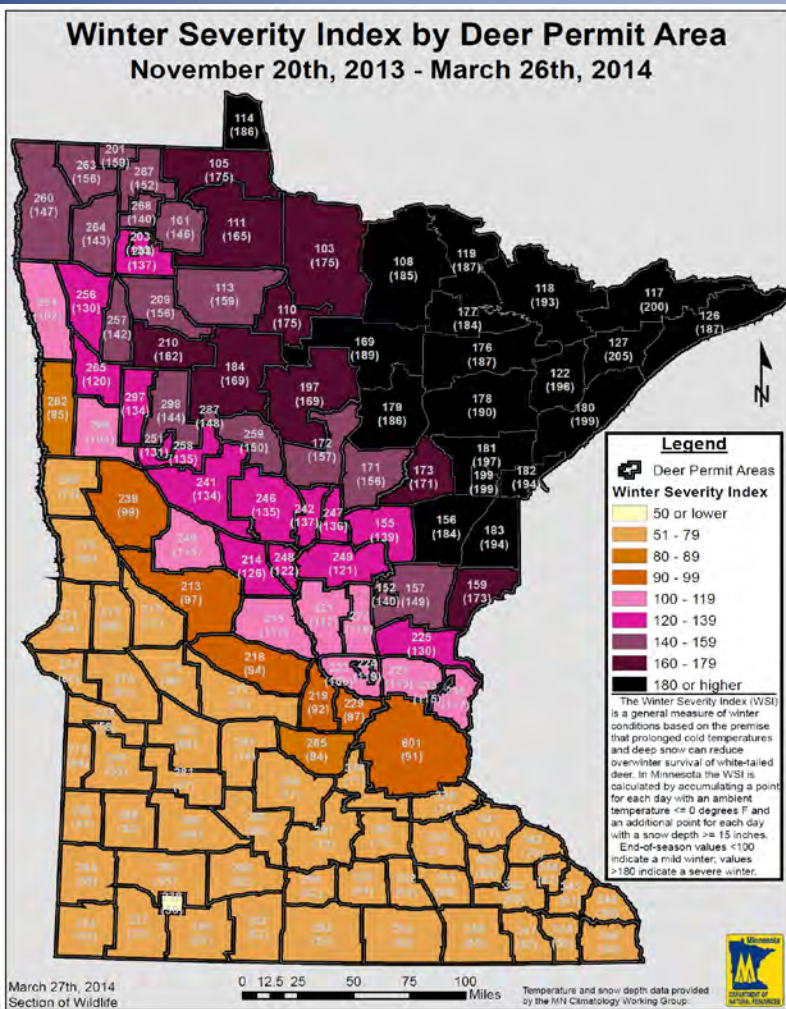


• Year 2 total = 12/104 (12%)

- 6 predator-related mortalities (50%)
 - 4 wolf kills
 - 1 wolf kill, likely
 - 1 wolf injury with secondary lethal infection
- 6 health-related mortalities (50%)
 - 2 brainworm
 - 1 brainworm (likely)
 - 1 accident (fell through the ice)
 - 2 multiple chronic health issues
- 4 carcass were removed intact, and 4 moose were euthanized by team
- 17 censored moose (collar failures, slipped collars, etc.)

Winter 2014, Historically Severe

Winter Severity Index by Deer Permit Area
November 20th, 2013 - March 26th, 2014



- Winter/spring moose mortalities in 2014 were only HALF of what we observed in 2013 (7 vs 15 deaths)
- Bad winter good for moose?
 - Less winter tick burden from long previous winter 2013
 - Wolves shifting prey base to weakened deer
 - Lower deer numbers

Moose Mortalities, Year 3: Jan 2015 – June 2015



- Year 3 total = 8/101 (8%)
 - 3 predator-related mortalities (37%)
 - 1 wolf kill
 - 1 wolf kill likely
 - 1 wolf injury with secondary lethal infection
 - 5 health-related mortalities (63%)
 - 5 undetermined health issues, pending results
 - 11 censored moose (collar failures, slipped collars, etc.)
 - Currently, 94 moose remaining in the study with active collars.
 - With expected collar life of 4-5 years, we'll be monitoring collared moose in this study until 2020.