THE 55th NORTH AMERICAN MOOSE CONFERENCE & WORKSHOP

Hosted by the Grand Portage Band

of Lake Superior Chippewa

Gichi-onigamiing

WELCOME

Welcome to the 55th North American Moose Conference and Workshop!

Boozhoo gakina awiya naanimidana-ashi naanan daso-biboon Moozoog-nakweshkodaadiwin!

A lot has happened in the World since we were last physically together at the 53rd Meeting in Maine nearly 4 years ago this month. Taylor Swift has produced four new albums, for starters! What is now the 55th Meeting was supposed to be held here in Grand Portage in May 2021, but a global pandemic and other global circumstances postponed our gathering. We are thankful the stars have finally aligned to allow us to meet in person once again, to share our knowledge about the science and management of moose, to relish the company of friends new and old, and to celebrate the unrivaled beauty of Lake Superior and Minnesota's North Shore here in Grand Portage.

We received an excellent slate of abstracts for this conference, with 36 oral presentations scheduled for all day Tuesday and Thursday afternoon. There are 16 posters for viewing during the formal poster session during the Monday Welcome Social (and they will be left up for the rest of the week as well). The 2022 recipient of the Distinguished Moose Biologist Award, Tuire Nygren, will be giving her keynote address on Tuesday morning, titled "Working And Living With Moose In Finland - A Narrative".

Traditionally, the North American Moose Conference and Workshop has offered one or more focused sessions (or workshops) on topics of interest. This year, the workshop is titled "Multinational and Indigenous Co-Stewardship of North American Moose", which will feature presentations on various stakeholder perspectives on ungulate management and facilitated discussions to map ways to understand and improve collaboration.

We have organized a series of evening events to help us connect and celebrate at this year's conference. There is a Welcome Social and Poster Session on Monday in the main conference room here at the Casino. We've arranged a "Moosic Night" on Tuesday on the shore of Lake Superior at the nearby Hollow Rocks Resort, where you'll all have a chance to perform with local musician Bump Blomberg via guitar, bass, piano, or your voice. We will be serving a traditional meal including locally harvested lake trout and moose meat. Wednesday evening is our traditional conference Awards Banquet held in the main conference room at the Casino, which includes a silent auction of moose paraphernalia and other outdoors-related items as a fundraiser for the Journal Alces and future North American Moose Conferences.

Those of us from Minnesota gather this year with a heavy heart, with the recent loss of our dear friend and colleague Glenn DelGuidice, a highly productive and respected researcher on white-tailed deer and moose with the Minnesota Department of Natural Resources for more than 30 years. See the extended *In Memoriam* section elsewhere in this program for more information about Glenn and other special moosers we've lost this year.

We wrote the following section for the program of the 54th North American Moose Conference and Workshop – we are repeating it here because we feel it succinctly describes this group:

> "The North American Moose Conference and Workshop is a unique creature, as there is no governing body with elected officers charged with organizing a conference every year. Just a group of wildlife biologists, managers, and others across North America (and beyond!) dedicated to the conservation and management of *Alces* who want to ensure we can share the most-up-to-date information on all things related to moose. One would be hard-pressed to think of another group that can boast of this kind of sustained energy based purely on individuals in the various states and provinces where moose reside to dedicate themselves to hosting a meeting every year.
>
> Those who've been around our moose conferences would attest that the "Moosers", as we sometimes call ourselves, are more than just a collection of individual biologists and managers. We are that oddly close-knit family who really like each other, who revel in each other's company, and who strive to carry on treasured family traditions. We travel together before and after conferences. We celebrate birthdays and retirements together. And sometimes we mourn together when we've experienced a loss. We've even been known to share a glass of beer (or more). We hope that some of you attending this conference for the first (or even second) time decide you want to become part of our Mooser family!"

Miigwetch and Sincerely,

55th North American Moose Conference and Workshop Organizing Committee

Steve Windels (Co-Chair) – Voyageurs National Park
Seth Moore (Co-Chair) – Grand Portage Band of Lake Superior Chippewa

ABOUT THE CONFERENCE HOST

The Grand Portage Band of Lake Superior Chippewa, Gichi-onigamiing, is a federally recognized Native American Ojibwe tribe.

Federally recognized Native American Ojibwe tribes in Minnesota proudly exercise their rights to food sovereignty through subsistence hunting and fishing. The Grand Portage Band of Lake Superior Chippewa is hosting the 55th North American Moose Conference on tribal lands to support the perpetuation of vital subsistence lifeways. Conservation by the Anishinaabeg (people) of the region promotes the health of the indigenous people that rely on functional ecosystems.

The Grand Portage Reservation covers 75 square miles of rugged terrain on the shore of Lake Superior. Moose research by tribal biologists began in 2008.

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The conference logo was designed by artist Steven StandingCloud. Steven is an Ojibwe and Lakota artist enrolled with the Red Lake Band of Chippewa Indians in Northern Minnesota. Steven has been an artist for most of his life. He is a Northern Woodlands and Plains Artist, with his art forms inherent to the Ojibwe and Lakota people. The images that he creates, using AI, are spirits that are hidden away that are released by the artist for all to see. Learn more about Steven and his art at his website: www.standingcloudgraphics.com.

SCHEDULE
All times Central Standard Time

MONDAY, MAY 22, 2023

ISLE ROYALE FIELD TRIP (optional)

7:30	**TRANSPORTATION TO VOYAGEUR II MARINA**
8:00	**VOYAGEUR II DEPARTS MARINA**
10:00	**ARRIVE WINDIGO, ISLE ROYALE**
14:00	**DEPART WINDIGO, ISLE ROYALE**
16:00	**ARRIVE VOYAGEUR II MARINA**
16:30	**TRANSPORTATION BACK TO CASINO**

CONFERENCE REGISTRATION AND WELCOME RECEPTION

17:00	**REGISTRATION OPEN IN HOTEL LOBBY**
18:00	**WELCOME RECEPTION IN CONFERENCE ROOM** (food and beverage provided, see page 31 for details.)
19:00	**POSTER SESSION IN CONFERENCE ROOM**
20:00	**POSTER SESSION ENDS**
21:00	**KAROAKE**

TUESDAY, MAY 23, 2023

7:00 **BREAKFAST AVAILABLE** (Main Conference Room)

WELCOME – OPENING SESSION

8:00 **DRUM AND FLAG CEREMONIES**

WELCOME
April McCormick, Grand Portage Secretary Treasurer

8:20 **HOST WELCOME AND WORKSHOP PREPARATION**
Seth Moore

8:30 **WELCOME TO THE 55TH NAMCW / LOGISTICS / DMB**
Steve Windels

8:45 **WORKING AND LIVING WITH MOOSE IN FINLAND –**
Virtual **A NARRATIVE** 33
Tuire Nygren, DMB Presentation

SESSION 1 – HABITAT **Moderator: Mike Schrage**

9:25 In person	**MAPPING MOOSE FORAGE AVAILABILITY AND QUALITY ACROSS ITS RANGE IN NORTHERN MINNESOTA** John Hak, Deahn Donner, Amanda McGraw, Alejandro A. Royo, Brian Miranda, Barry (Ty) Wilson, Eric Margenau, Michelle Carstensen, and Véronique St-Louis	34
9:45 In person	**FORESTS, FORAGE, AND FIRE SHAPE MOVEMENT PATTERNS AND INFLUENCE WINTER SURVIVAL OF THE MINNESOTA MOOSE POPULATION** James D. Forester and John L. Berini	35
10:05 In person	**RISK OF PREDATION AND HUNTING DRIVES USE OF VERTICAL AND HORIZONTAL COVER BY MOOSE (ALCES ALCES)** Lisa Jeanne Koetke, Dexter P. Hodder, and Chris J. Johnson	36
10:25 In person	**BROWSE SELECTION BY MOOSE AND SILVICULTURAL IMPACTS ON BROWSE PRODUCTION AT GITCHI ONIGAMING (GRAND PORTAGE), MN AND MINONG (ISLE ROYALE), MI** Matt Petz Giguere, William J. Severud, Kim Teager, and Seth A. Moore	37
10:45	**COFFEE BREAK**	

SESSION 2 – HUMAN DIMENSIONS **Moderator: Barb Keller**

11:00 In person	**WORKING WITH NOVA SCOTIA'S MI'KMAQ PEOPLE TO BETTER UNDERSTAND OUR SHARED IMPACT ON MOOSE** Jason Airst, Jenna Priest, Clifford Paul, Anthony King, Alison Bernard, and Jason Power	38
11:20 In person	**MOOSE AS A COMMON SYMBOL: WHAT IS MISSING FROM ONTARIO LAW AND POLICY?** Sydney Belleau and Brian McLaren	39
11:40 Virtual	**AN EXPERT ELICITATION STUDY OF MOOSE POPULATION DECLINE IN NORTHEAST MINNESOTA** Adam C. Landon, Kyle Smith, and David C. Fulton	40
12:00	**LUNCH** (Main Conference Room)	
12:45	**ALCES BUSINESS MEETING** (concurrent with end of lunch)	

SESSION 3 - POPULATION 1 **Moderator: Bill Faber**
(CONCURRENT WITH SESSION 4)

SESSION 4 – BEHAVIOR **Moderator: Bill Severud**
(CONCURRENT WITH SESSION 3)

SESSION 5 – POPULATION II (CONCURRENT WITH SESSION 6) **Moderator: Todd Froberg**

15:30 In person	**FOREST AND WILDLIFE UNDER PRESSURE - SYSTEMS ANALYSIS FOR SUSTAINABLE SOLUTIONS** Christer Kalen, Oskar Franklin, and Barbara Zimmermann	51
15:50 In person	**SPACE USE AND HABITAT SELECTION OF MOOSE IN RESPONSE TO SHORT-TERM WEATHER CONDITIONS IN NORTHEASTERN MINNESOTA** Deahn Donner, Eric Margenau, Amanda McGraw, Michelle Carstensen, Véronique St-Louis, Alejandro A. Royo, John Hak, and Brian Miranda	52
16:10 In person	**EXAMINING THE CO-BENEFITS OF MOOSE HARVEST AS A CARIBOU RECOVERY LEVER** Mateen Hessami, Rob Serrouya, Adam Ford, Melanie Dickie, and Clayton Lamb	53
16:30 In person	**FACTORS AFFECTING MOOSE DECLINES IN BRITISH COLUMBIA: SUMMARY AND RECOMMENDATIONS, 2012-2022** Morgan Anderson, Chris Procter, Matthew Scheideman, Dexter Hodder, Heidi Schindler, Caeley Thacker, and Holger Bohm	54
16:50 In person	**LANDSCAPE FEATURE DETERMINANTS OF BRAINWORM TRANSMISSION IN NORTHEASTERN MINNESOTA** Tyler J. Garwood, Seth A. Moore, Nicholas M. Fountain-Jones, Peter A. Larsen, and Tiffany M. Wolf	55
17:10	**ADJOURN**	
17:30	**SHUTTLES TO HOLLOW ROCK RESORT START**	
18:00 to 21:00	**MOOSIC NIGHT, HOLLOW ROCK RESORT** (food and beverage provided, see page 29 for details.)	

SESSION 6 - DISEASE I **Moderator: Tiffany Wolf**
(CONCURRENT WITH SESSION 5)

15:30 In person	**CO-INFECTION OF ANAPLASMA AND WINTER TICK DECREASES MOOSE CALF SURVIVAL IN MAINE** Alaina C. Woods, Lee Kantar, James Elliott, Sandra De Urioste-Stone, and Pauline L. Kamath	56
15:50 In person	**SEROLOGICAL TESTING OF PARELAPHOSTRONGYLUS TENUIS INFECTION IN WILD MINNESOTA MOOSE (ALCES ALCES) AND ELK (CERVUS CANADENSIS) USING A NOVEL ENZYME-LINKED IMMUNOSORBENT ASSAY (ELISA)** Jessie Richards, Michelle Carstensen, Tiffany Wolf, Seth Moore, and Richard Gerhold	57
16:10 In person	**AN EFFECTIVE ACARICIDE TREATMENT TO EXPERIMENTALLY MANIPULATE WINTER TICK LOAD ON MOOSE** Florent Dėry, Julien H. Richard, Sandra Hamel, Steeve D. Côté, Christian Dussault, and Jean-Pierre Tremblay	58
16:30 In person	**MOOSE HEALTH ASSESSMENT INDICATES HIGH PARASITE EXPOSURE IN NEW YORK** Jennifer Grauer, Krysten Schuler, Jacqueline Frair, and Angela Fuller	59
16:50 In person	**AN EXPERIMENTAL STUDY OF THE IMPACT OF WINTER TICKS ON THE ECOLOGY AND SURVIVAL OF MOOSE IN EASTERN CANADA** Steeve D. Côté, Catherine Bajzak, Vincent Bonin-Palardy, Delphine DePierre, Florent Dėry, Christian Dussault, Jalila Filali, Sandra Hamel, Julien Hénault-Richard, Denis Laurendeau, Morgane Le Goff, Patrick Leighton, Douglas Munn, Joe Nocera, Catherine Pouchet, Christopher Fernandez Prada, and Jean-Pierre Tremblay	60
17:10	**ADJOURN**	
17:30	**SHUTTLES TO HOLLOW ROCK RESORT START**	
18:00 to 21:00	**MOOSIC NIGHT, HOLLOW ROCK RESORT** (food and beverage provided, see page 29 for details.)	

WEDNESDAY, MAY 24, 2023

GRAND PORTAGE RESERVATION/GRAND PORTAGE NATIONAL MONUMENT FIELD TRIP

7:00	**BREAKFAST** (Main Conference Room)
9:00	**DEPART CASINO AND WALK TO GRAND PORTAGE NATIONAL MONUMENT.** **SEE PAGE 30 FOR ADDITIONAL INFORMATION ABOUT FIELD TRIP.**
12:00 to 13:00	**BOX LUNCH** (provided)
16:00	**RETURN TO CASINO**
18:00 to 21:00	**BANQUET AND AUCTION** (meal provided, see page 31 for additional information about auction.)

THURSDAY, MAY 25, 2023

7:00 **BREAKFAST AVAILABLE** (Main Conference Room)

MULTINATIONAL AND INDIGENOUS CO-STEWARDSHIP OF NORTH AMERICAN MOOSE

FRAMING INCLUSIVE MOOSE MANAGEMENT AND RESEARCH

8:00	**INTRO/WORKSHOP GOALS** Seth Moore	
8:05	**WHY ARE WE HERE? - TREATY DEPENDENCE AND OBLIGATIONS** Joseph Bauerkemper	61
8:35	**MODERN RECOGNITION OF TREATIES, CO-MANAGEMENT RESPONSIBILITIES, A NEW ERA OF CO-STEWARDSHIP** Seth Moore	61
9:05	**MOOSE CO-MANAGEMENT AND RESEARCH: MN DNR PERSPECTIVE** Kelly Straka	
9:15	**HUNTER PERSPECTIVE ON MOOSE MANAGEMENT** John Kaplanis	
9:25	**HOW TO EFFECTIVELY INTEGRATE MOOSE MANAGEMENT AND RESEARCH AMONG FEDERAL ENTITIES, STATES, PROVINCES, ACADEMIA, AND INDIGENOUS SOVEREIGNS** Facilitated Discussion - Katey Pelican	
9:45	**BREAK**	
10:00 Virtual	**MOVING BEYOND MANAGEMENT: INDIGENOUS PERSPECTIVES ON MOOSE** Jesse Popp	61
10:30	**A STRATEGY FOR DEVELOPMENT OF A FRAMEWORK FOR MULTINATIONAL MOOSE RESTORATION** Facilitated Discussion - Katey Pelican	
11:15	**PART 1: RESTORATION NEEDS BASED ON CURRENT STATE OF KNOWLEDGE**	
11:35	**PART 2: RESEARCH NEEDS, CATEGORIZED AND PRIORITIZED**	
12:00	**LUNCH** (Main Conference Room)	

THURSDAY, MAY 25, 2023

SESSION 7 – DISEASE II **Moderator: Michelle Carstensen**

13:00 In person	**PREVALENCE AND MORTALITY OF MOOSE INFECTED WITH ARTERIAL WORMS (*ELAEOPHORA SCHNEIDERI*) IN MONTANA, USA** Collin Peterson, Nick DeCesare, Rich Harris, and Jennifer Ramsey	62
13:20 In person	**ADULT COW AND CALF SURVIVAL IN MAINE (2014-2020): A WINTER TICK DRIVEN SYSTEM** Lee Kantar	63
13:40 In person	**TRIBAL MONITORING OF PARASITE PREVALENCE IN NORTHEASTERN MINNESOTA** Morgan Swingen	64
14:00 In person	**CAUSE-SPECIFIC MORTALITY OF MOOSE IN GRAND PORTAGE AND VOYAGEURS NATIONAL PARK, MINNESOTA, OVER 12 YEARS: BRAINWORM'S CONTRIBUTION TO THE DECLINE AND INDICATIONS OF WOLF PREY SWITCHING** Tyler J. Garwood, William J. Severud, Steve K. Windels, Arno Wünschmann, Edmund J. Isaac, Seth A. Moore, and Tiffany M. Wolf	65
14:20	**COFFEE BREAK**	

SESSION 8 – TECHNIQUES **Moderator: Morgan Swingen**

14:40 In person	**EVALUATING AN UNPILOTED AERIAL SYSTEM FOR MONITORING UNMARKED MOOSE IN NEW HAMPSHIRE** Lily M. Hall, Franklin B. Sullivan, Sophia A. Burke, Henry Jones, Michael W. Palace, and Remington J. Moll	66
15:00 In person	**USING DISTANCE SAMPLING TO ESTIMATE THE ABUNDANCE OF ISLE ROYALE MOOSE** A.R. Sovie, K.F. Keller, M.C. Romanski, J. Bonessi, S.A. Moore, E.J. Issac, and J.L. Belant	67
15:20 In person	**USING A TRAINED CONSERVATION DETECTION DOG TEAM TO EVALUATE POTENTIAL PARTURITION AND MORTALITY SITES OF NEONATAL MOOSE AND THEIR FINDINGS** Anna Weesies, Todd M. Kautz, Seth A. Moore, Yvette M. Chenuax-Ibrahim, Gregory A. Davidson, Edmund J. Isaac, William J. Severud, Nathaniel H. Wehr, Tiffany M. Wolf, and Jerrold L. Belant	68
15:40 In person	**IS A NEW WAY BETTER? SAMPLING WINTER TICK DENSITIES ON TRIBAL LAND IN MAINE** Benjamin Simpson, Tammy L. Wilson, Juliana Berube, Alexej P.K. Siren	69
16:00 In person	**DRIVER- AND LANDSCAPE-RELATED FACTORS ASSOCIATED WITH WILDLIFE-VEHICLE COLLISIONS IN THUNDER BAY, ONTARIO** Nicole Carson, Matayo Masinde, and Brian McLaren	70
16:20 Virtual	**UNDERSTANDING HOW THE HEALTH OF MOOSE IN ISLE ROYALE NATIONAL PARK IS INFLUENCED BY WEATHER AND WOLF PREDATION** Sarah R. Hoy, John A. Vucetich, Leah M. Vucetich, and Rolf O. Peterson	701

16:40 ADJOURN

CONFERENCE SPONSORS

We appreciate the generous support for this conference from our Gold Sponsors!

- 1854 Treaty Authority
- Grand Portage Band of Lake Superior Chippewa
- Minnesota Chapter of The Wildlife Society
- Minnesota Department of Natural Resources
- National Parks Conservation Association
- National Parks of Lake Superior Foundation
- Sportsmen for the Boundary Waters
- University of Minnesota Duluth / Department of Biology
- University of Minnesota Duluth / Natural Resources Research Institute

And our Silver Sponsor!

- North Central Section of The Wildlife Society

POSTER SESSION – Conference Room

The official poster session for "In person" presenters will be from 7:00 to 8:00 Monday, May 22nd during the Welcome Reception. For virtual posters, contact the authors by email. Posters will be kept in place throughout the conference.

10 In person	**EXPANDING OUR UNDERSTANDING OF HOW MOOSE USE AVAILABLE FOREST RESOURCES IN NORTHEAST MINNESOTA** Véronique St-Louis, Eric Margenau, Michelle Carstensen, Deahn Donner, John Hak, Amanda McGraw, Brian Miranda, Alejandro Royo	81
11 In person	**MODELING FOREST CHANGE WITHIN MINNESOTA MOOSE RANGE UNDER DIFFERENT CLIMATE SCENARIOS** Brian R. Miranda, Deahn Donner, John Hak, Eric Margenau, Amanda McGraw, Alejandro Royo, Michelle Carstensen, and Véronique St-Louis	82
12 Virtual	**SEASONAL PLASTICITY OF RESOURCE SELECTION DIFFERS BETWEEN MAINLAND AND ISLAND MOOSE POPULATIONS** Nathaniel H. Wehr, Seth A. Moore, Mark C. Romanksi, Edmund J. Isaac, Todd M. Kautz, Kenneth F. Kellner, Joshua J. Millspaugh, and Jerrold L. Belant	83
13 Virtual	**ISOTOPE SPATIAL-ECOLOGY OF MOOSE FROM SWEDEN** Elena Armaroli, Federico Lugli, Anna Cipriani, Thomas Tütken	84
14 Virtual	**ARTICULATION AND 3D PHOTOGRAMMETRY OF A MOOSE NEONATE SKELETON** Holly M. McVea, Lena M. Richter, Rodney C. S. McLatchy, and Roy V. Rea	85
15 Virtual	**BEHAVIOURAL ECOLOGY OF MOOSE AT ROADSIDE MINERAL LICKS IN NORTH-CENTRAL BRITISH COLUMBIA** Candyce E. Huxter, Roy V. Rea, Ken A. Otter, Gayle Hesse	86
16 Virtual	**INTERPRETING CAMERA TRAP PHOTO DATA OF MOOSE USING ROADSIDE MINERAL LICKS: WHAT IS BIOLOGICALLY RELEVANT?** Nikki L. Beaudoin, Roy V. Rea, Sunny Yi-Chin Tseng, and Chris J. Johnson	87

IN MEMORIAM – Dr. Glenn DelGiudice

We lost a great friend and colleague in December 2022, Dr. Glenn DelGuidice. Glenn was 68 and a few weeks short of retirement.

Glenn was a research scientist for the Minnesota Department of Natural Resources (MNDNR), and an adjunct professor at the University of Minnesota. Born on Long Island, NY, Glenn earned his B.S. from Cornell University in 1977. At the University of Arizona he studied elk for his M.S. Then, he worked with L. David Mech and Ulysses Seal on wolves and deer at the University of Minnesota, earning his Ph.D. in Wildlife Biology and Conservation in 1988. His graduate work on nutritional condition of white-tailed deer was groundbreaking; the techniques are still used today. Glenn was a longtime member of The Wildlife Society at the national and state levels.

Glenn started as the Deer Project Leader for the MNDNR in 1990, initiating a 15-year study on the impact of winter severity and diminishing conifer cover on various aspects of deer ecology in north-central Minnesota. He trained ~145 student field technicians during that time. In 2011, he became the Moose Project Leader for the MN DNR and led several studies on the declining moose population in northeastern Minnesota. He also helped initiate the multi-agency moose research meetings held in Minnesota.

His first research on moose was on Isle Royale, measuring moose nutritional condition with snow-urine analyses. The last time the NAMCW held in Grand Portage (35th, 1999), he, Ron Moen, Robert Garrrott, and Rolf Peterson put on a workshop on using urinary metabolites for enhancing ecological interpretations of winter severity on ungulates.

Glenn began a study on moose calf survival, cause-specific mortality, space use, and behavior in 2012, while also collecting moose snow-urine samples across northeastern Minnesota. The calf project had an unintended consequence: abandonment of calves by their mothers following capture, handling, and collaring. This unfortunate result of the study vexed Glenn and he wanted to understand why it was happening and correct it. He published 3 peer-reviewed papers explaining the calf and mother characteristics and movement patterns. In the end, reducing handling time to ~45 seconds and slimming the handling crew to 2 people did the trick. He called this strategy “getting small.”

Glenn generously shared his wealth of knowledge and experience with mentees. He was always professional and enjoyed teaching students, field technicians, and early-career field biologists ethical ways to handle animals, collect biological data, and participate in the wildlife field in general. Glenn's character, personality, encouragement, and inquisitive nature made him naturally a remarkable mentor. As such, he was posthumously awarded the inaugural Excellence in Mentorship Award from the Minnesota Chapter of The Wildlife Society in 2023.

Glenn was a prodigious writer and orator. He published >100 peer-reviewed papers, several book chapters, and innumerable MNDNR reports and moose aerial survey results. He encouraged his students to publish their work so it could reach a wide audience and further the science of wildlife management and ecology. At local meetings, he was usually given the final presentation slot so he could fit in everything he wanted to share.

Glenn's work ethic was often rewarded. He was a National Conservation Leadership Institute Fellow and received multiple certificates of outstanding achievement from the MNDNR, Minnesota Deer Hunters Association, and the US Veterans Affairs Medical Center. He was also awarded for outstanding teamwork in response to chronic wasting disease by MNDNR.

In addition to his legacy of research, Glenn also contributed his service to the wildlife profession by teaching wildlife immobilization, habitat management, and ecophysiology courses at UMN. He was also a member of the Wildlife Disease Association, a member of the editorial panel for Wildlife Society Bulletin, and a frequent peer reviewer for numerous journals. He reviewed abstracts for TWS annual conferences and was awarded for Outstanding Contributions to the 9th Annual Conference of TWS in Bismarck, ND in 2002.

Glenn will be deeply missed by his three children, Caitlin, Mikaela, and Nick, as well as by all those whose lives he impacted, including many of us moosers.

IN MEMORIAM – Dr. Vic Van Ballengerghe[1]

Victor Van Ballenberghe was born in Bayshore, Long Island, New York and grew up on a dairy farm in upstate New York. He received a biology degree from State University of New York (SUNY) at Oneonta and then entered the University of Minnesota in 1967 where he earned MS and PhD degrees. Vic's PhD (1972) research focused on wolves as part of a larger moose study in northeastern Minnesota. His research occurred in the early days of radiotelemetry and was of the first to employ the pioneering technology.

Vic's first job was as an extension trapper at South Dakota State University. Two years later, he was hired by the Alaska Department of Fish & Game to investigate the effect of the trans-Alaska pipeline on moose migration. In 1980, he joined the research branch of the U.S. Forest Service and conducted moose and wolf research in Denali National Park and the Copper River Delta. He initiated long-term, well known investigations into moose biology and behavior that extended over 40 years. A truly unique aspect of this research was Vic's documentation of the ecology, breeding activity, and mortality across the lifespan of multiple bull moose. Although Vic retired in 2000, he continued these studies until Parkinson's disease limited his activity.

Vic was a "boots on the ground" field biologist and believed that one had to spend time in the field and patiently observe animals in their natural habitat to truly understand selection processes affecting behavior and survival. He was well known for his consummate field skills and knowledge of natural history. Vic was a collaborative researcher, advising and supervising numerous graduate students including those researching moose and wolves in the Copper River and Denali. Vic authored and co-authored over one hundred technical journal articles, book chapters, and symposium papers. He published many popular articles and wrote numerous newspaper opinion pieces on controversial wildlife management issues. He worked with multiple film crews including the BBC, National Geographic, and Animal Planet, while accommodating National Park Service naturalists, private photographers, and so many others seeking his expertise and commentary. His exemplary professional efforts and leadership were recognized by his receiving the

[1] Reprinted from Alces Journal: https://alcesjournal.org/index.php/alces/issue/view/93

Distinguished Moose Biologist Award (1996) from the International Alces Working Group.

Vic was appointed to the Alaska Board of Game by Governor Bill Sheffield in 1985, serving one full term and two subsequent partial terms in 1996 and 2002. He was a strong advocate of scientific, evidence-based wildlife management, including support for bears and wolves. Fittingly, his last publication in Alces addressed large carnivore management in Alaska, advocating for stronger scientific versus political approaches.

Vic was an avid and extremely skilled photographer. His beautiful book In the Company of Moose (2004) contains 120 photographs from Denali National Park and elsewhere, set to Vic's descriptive and passionate writing portraying the year-round ecology and behavior of moose. The final chapter "Death of a Warrior" won awards for creative nonfiction.

Vic is survived by his wife Linda Masterson, daughter Andrea Bradford, son Jonathan Van Ballenberghe, and several nieces and nephews. He was truly a pioneer and stalwart of the moose world, with a professional legacy for future moosers to recognize and appreciate.

IN MEMORIAM – Gerry Lynch[2]

The moose management and biology world lost another pioneer on June 21, 2022 with the passing of Gerry Lynch at the age of 81. Gerry died peacefully at his home near Raleigh, North Carolina with his family at bedside, having dealt valiantly with a serious heart condition for several years. For many years, Gerry was a highly regarded regional wildlife biologist with Alberta Fish and Wildlife in Edson, Alberta. Eventually, he became the provincial moose manager based at the Edmonton headquarters where his management skills flourished. As an "early" moose manager, Gerry was progressive and innovative, designing management initiatives and developing long-term data sets that were uncommon at the time, yet are now the basis of sound moose management in Alberta and elsewhere. His exemplary efforts and leadership were recognized by his receiving the Distinguished Moose Biologist Award (2000) from the International Alces Working Group. The current cohort of moose biologists and managers in Alberta continue to marvel about Gerry's dedication and productivity in the "early days" and the wisdom still evident in those 'old programs' - such good data and ideas remain valid and ageless.

Gerry was born and raised near Madison, Wisconsin. After completing his Bachelor of Applied Science Degree in Natural Resources and Conservation at University of Wisconsin – Stevens Point (1963), Gerry completed a MS in Wildlife, Fish and Wildland Science and Management at the University of Wisconsin – Madison (1965–1967). His MS research involved aspects of skunk predation on waterfowl in Manitoba, after which his studies, research experience, and motivation set the tone for a productive and highly respected career.

Gerry was the consummate professional – a hard-working, kind, and considerate man throughout his life. Much of his work took place in the rugged and bog-filled boreal forest of the Swan Hills where he used innovative techniques to trap and track moose. He also built innovative all-terrain vehicles to aid his efforts long

[2] Reprinted from Alces Journal: https://alcesjournal.org/index.php/alces/issue/view/93

before ATVs became common in fieldwork. Always willing to help others, he assisted Dr. Bill Samuel in his pioneering work with winter ticks and moose.

Gerry loved outdoor recreation, was an avid hunter, and true friend of many. Often described as “the best moose hunting partner ever”, he cherished the comradery of moose hunting with friends who considered him a great “mooser”.

Beyond his professional dedication, Gerry’s family and their spiritual lives were foremost in his daily thoughts and actions. He and Janet were married 59 years and raised three children. Unfortunately, yet again, the moose world loses another early leader in the short history of moose management.

With deep admiration and respect for our friend,

Bill Samuel and Margo Pybus

2005 in Whitefish, MT

Gerry Vic

2022 DISTINGUISHED MOOSE BIOLOGIST

Tuire Nygren, Natural Resources Institute Finland (Retired)

Tuire Nygrén is a dedicated and influential moose biologist in Finland, with influences in the global moose world, refining moose hunting legislation, publishing her scientific results for the scientific community and for her country´s hunters and nature- interested people. Tuire is very determined, and it is always entertaining to sit down with her and discuss matters, from moose research projects, practical management matters to strategic passages and purely private perspectives and reflections in the exhilarating academic world.

It is obvious that the moose as an animal as well as moose management and hunting life is Tuire's environment, where her full personality come to life and quickens. Moose scientists, managers and hunters value her still highly today. Tuire participated in the annual population surveys of Finnish moose between 1976 to 1980 and planned, executed and published results of surveys 1980 – 2000. Based on her efforts and knowledge in moose population dynamics, genetics, and impact of selective hunting, Finnish hunting legislation was developed after Tuire's findings to adjust hunting season start and duration for avoiding direct impacts on effective population and genetic variability of moose in different parts of Finland. Tuire received awards for her efforts in Finnish Game Management and Hunting from the Finnish Hunters Association in 1993 and from the Finnish Wildlife Agency in 2015. Tuire has written 49 international and scientific papers and of these at least 2 in Alces, 12 books/book chapters and 137 articles in hunters magazines, newspapers, and popular magazines. Tuire has passionately dedicated her whole scientific life (and personal life) to moose research and management, and still is after her retirement.

Tuire Nygrén lives in a self-built house with her husband Kaarlo Nygrén (DMB 2018) on the shores of lakes Koitajoki and Mekrijärvi, in Finland's easternmost municipality, Ilomantsi, where darkness reigns in winter, where wolverines visit the cabin and where bears and wolves are common. Ilomantsi one of the snowiest municipalities in Finland, with snow well over a meter in places.

As a young parent of two children, Tuire and her husband came to the Ilomantsi Wildlife and Fisheries Research Institute in 1978 for a test, when researchers were needed at the station. And the couple decided to stay in Ilomantsi and raise their children there. Tuire had a long career at the Game and Fisheries Research Institute, and Tuire received her doctorate there in 2009.

Since Tuire retired, she has saved meters of research information about the Eurasian moose, and in the Nygrén couple's home there are brown binders by the meter, with consecutive numbering on the binders' spines, which contain Finland's largest research material on moose, a gold mine.

Things could have gone very badly for Tuire in 2016 when she was on her way home from an expert lecture. The road was muddy and the car lost grip, flew off the road and crashed into a birch tree. Tuire herself says that she had time in her mind to say goodbye to her loved ones. The airbag in the old car saved her from the worst. The injury was so severe that Tuire was in the hospital for two months and spent another month recovering at home under the care of her husband. But Tuire has now recovered and is back on the court. And today, alongside her passion for moose research, she has a new passion object which is genealogy.

HISTORY OF DISTINGUISHED MOOSE BIOLOGIST AWARD

The Distinguished Moose Biologist Award was established in 1981 to honor, and bring to public attention, the outstanding contribution of an individual to our understanding and management of moose. The award is open to individuals from any country who have made an outstanding contribution to our understanding and management of moose.

PAST RECIPIENTS

2022 — Tuire Nygrén, Finnish Game and Fisheries Research Institute (Now Natural Resources Institute Finland), Ilomantsi, Finland
2021 — [Not presented]
2020 — [Not presented]
2019 — Lee Kantar, Maine Department of Inland Fisheries and Wildlife, Bangor, Maine, USA
2018 — Roy V. Rea, University of Northern British Columbia, Prince George, BC, Canada
2017 — Kaarlo Nygrén, Finnish Game and Fisheries Research Institute, Ilomantsi, Finland
2016 — Ronald A. Moen, University of Minnesota, Duluth, Minnesota, USA
2015 — Peter J. Pekins, University of New Hampshire, Durham, New Hampshire, USA
2014 — Edward M. Addison, Ministry of Natural Resources, Maple, Ontario, Canada
2013 — [Not presented]
2012 — [Not presented]
2011 — Kjell Danell, Swedish University of Agricultural Sciences, Uppsala, Sweden
2010 — Michael W. Schrage, Fond du Lac Band of Chippewa, Cloquet, Minnesota, USA
2009 — Kenneth N. Child, Ministry of Environment, Prince George, BC, Canada
2008 — [Not presented]
2007 — Kris J. Hundertmark, University of Alaska, Fairbanks, Alaska, USA
2006 — Kristine M. Rines, New Hampshire Fish and Game, New Hampton, New Hampshire, USA
2005 — Bill Samuel, University of Alberta, Edmonton, Alberta, Canada
2004 — W. Eugene Mercer, Wildlife Division, St. John's, Newfoundland, Canada
2003 — Arthur R. Rodgers, Ministry of Natural Resources, Thunder Bay, Ontario, Canada
2002 — Bernt-Erik Sæther, Norwegian University of Science and Technology, Trondheim, Norway
2001 — R. Terry Bowyer, University of Alaska, Fairbanks, Alaska, USA
2000 — Gerry M. Lynch, Environmental Protection, Edmonton, Alberta, Canada
1999 — William J. Peterson, Department of Natural Resources, Grand Marais, Minnesota, USA
1998 — Peter A. Jordan, University of Minnesota, St. Paul, Minnesota, USA
1997 — Margareta Stéen, Swedish University of Agricultural Sciences, Uppsala, Sweden
1996 — Vic Van Ballenberghe, U.S. Forest Service, Anchorage, Alaska, USA
1995 — [Not presented]

1994 — James M. Peek, University of Idaho, Moscow, Idaho, USA
1993 — Murray W. Lankester, Lakehead University, Thunder Bay, Ontario, Canada
1992 — [Not presented]
1991 — Charles C. Schwartz, Dept. of Fish and Game, Soldotna, Alaska, USA
1990 — Rolf Peterson, Michigan Technological University, Houghton, Michigan, USA
1989 — Warren B. Ballard, Dept. of Fish and Game, Nome, Alaska, USA
1988 — Vince F.J. Crichton, Dept.of Natural Resources, Winnipeg, Manitoba, Canada
and Michel Crête, Ministère du Loisir de la Chasse et de la Péche, Québec, PQ, Canada
1987 — W.C. Bill Gasaway, Dept. of Fish and Game, Fairbanks, Alaska, USA
1986 — H. R. (Tim) Timmermann, Ministry of Natural Resources, Thunder Bay, Ontario, Canada
1985 — Ralph Ritcey, Fish and Wildlife Branch, Kamloops, British Columbia, Canada
1984 — Edmund Telfer, Canadian Wildlife Service, Edmonton, Alberta, Canada
1983 — Albert W. Franzmann, Division of Fish and Game, Soldotna, Alaska, USA
1982 — A. (Tony) Bubenik, Ministry of Natural Resources, Maple, Ontario, Canada
1981 — Patrick D. Karns, Division of Fish and Wildlife, Grand Rapids, Minnesota, USA
and Al Elsey, Ministry of Natural Resources, Thunder Bay, Ontario, Canada
1974 — Prior to the establishment of the Distinguished Moose Biologist Award the group recognized the pioneering moose research of the late Laurits (Larry)Krefting, U. S. Fish and Wildlife Service, with an individual award

NEWCOMER'S TRAVEL AWARD

In an effort to encourage new attendees at the North American Moose Conference and Workshop who will report on recent studies of moose ecology and who will submit a manuscript for possible publication in the journal Alces, the North American Moose Group will provide up to $4,000.00 CDN to the local organizing committee to cover the costs associated with attendance at the annual meeting for young researchers. It is expected that employers or sponsors of the applicants will also assist with travel costs.

This year we have 2 recipients of the Newcomer's Award. Both are at the conference for the first time this year:

Rebecca Levine is pursuing a M.S. degree at the University of Wyoming and runs the Meeteetse Moose Project in collaboration with the Wyoming Game & Fish Department and her advisor Dr. Kevin Monteith.

Alaina Woods is a 3rd year Ph.D. candidate at the University of Maine's Wildlife Disease Genetics Lab.

PREVIOUS NAMCWs AND INTERNATIONAL MOOSE SYMPOSIA

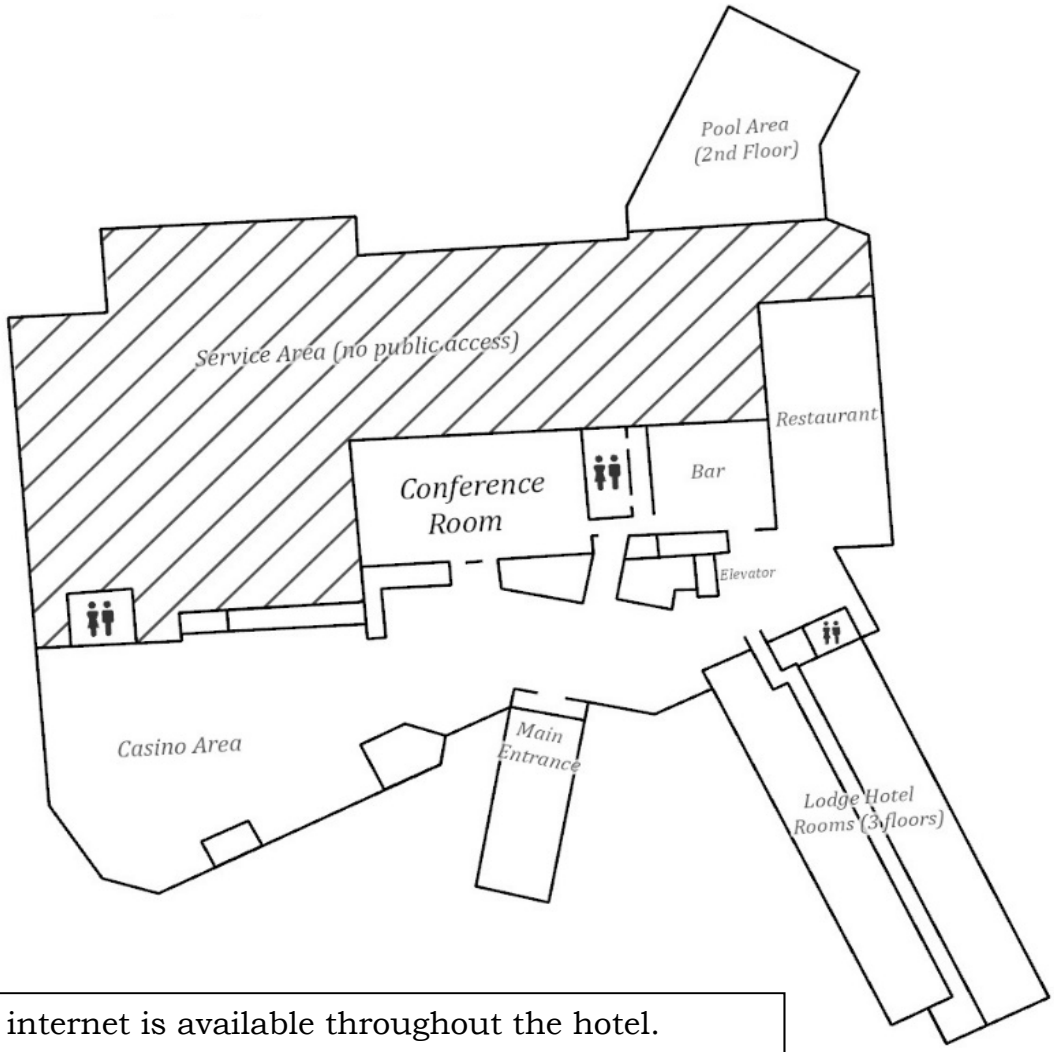
1963 – St. Paul, Minnesota
1964 – St. Paul, Minnesota
1966 – Winnipeg, Manitoba
1967 – Edmonton, Alberta
1968 – Kenai, Alaska
1970 – Kamloops, British Columbia
1971 – Saskatoon, Saskatchewan

8th 1972 – Thunder Bay, Ontario
9th 1973 – Québec City, Québec, in conjunction with the 1st International Moose Symposium
10th 1974 – Duluth, Minnesota
11th 1975 – Winnipeg, Manitoba
12th 1976 – St. John's, Newfoundland
13th 1977 – Jasper, Alberta
14th 1978 – Halifax, Nova Scotia
15th 1979 – Soldotna – Kenai, Alaska
16th 1980 – Prince Albert, Saskatchewan
17th 1981 – Thunder Bay, Ontario
18th 1982 – Whitehorse, Yukon Territory
19th 1983 – Prince George, British Columbia
20th 1984 – Québec City, Québec
1984 – Uppsala, Sweden, 2nd International Moose Symposium
21st 1985 – Jackson Hole, Wyoming
22nd 1986 – Fredericton, New Brunswick
23rd 1987 – Duluth, Minnesota
24th 1988 – Winnipeg, Manitoba
25th 1989 – St. John's, Newfoundland
26th 1990 – Regina and Ft. Qu'Apelle, Saskatchewan
1990 – Syktyvkar, Russia, 3rd International Moose Symposium
27th 1991 – Anchorage and Denali National Park, Alaska
28th 1992 – Algonquin Park, Ontario
29th 1993 – Bretton Woods, New Hampshire
30th 1994 – Idaho Falls, Idaho
31st 1995 – Fundy National Park, New Brunswick
32nd 1996 – Banff National Park, Alberta
33rd 1997 – Fairbanks, Alaska, in conjunction with the 4th International Moose Symposium
34th 1998 – Québec City, Québec
35th 1999 – Grand Portage, Minnesota
36th 2000 – Whitehorse, Yukon Territory
37th 2001 – Carrabassett Valley, Maine
38th 2002 – Hafjell, Norway, in conjunction with the 5th International Moose Symposium
39th 2003 – Jackson Hole, Wyoming
40th 2004 – Corner Brook, Newfoundland and Labrador
41st 2005 – Whitefish, Montana
42nd 2006 – Baddeck, Nova Scotia
43rd 2007 – Prince George, British Columbia
2008 – Yakutsk, Russia, 6th International Moose Symposium
44th 2009 – Pocatello, Idaho
45th 2010 – International Falls, Minnesota
46th 2011 – Jackson Hole, Wyoming
2012 – Bialowieza, Poland, 7th International Moose Symposium
47th 2013 – Whitefield, New Hampshire
48th 2014 – Girdwood, Alaska
49th 2015 – Middle Park, Colorado
50th 2016 – Brandon, Manitoba, in conjunction with the 8th International Moose Symposium
51st 2017 – Ingonish, Nova Scotia
52nd 2018 – Spokane, Washington
53rd 2019 – Carrabasset Valley, Maine
2020 – Cancelled (COVID-19 pandemic)
54th 2021 – Minnesota (virtual)
2022 – Cancelled (Covid / War). Joensuu, Finland, 9th International Moose Symposium
55th 2023 – Grand Portage, Minnesota

AREA INFORMATION AND MAP OF THE HOTEL

The Grand Portage Lodge & Casino is owned and operated by the Grand Portage Band of Lake Superior Chippewa, and sits on Grand Portage Bay on Lake Superior. The venue is located centrally within Gichi Onigaming (the Grand Portage Reservation), at the northeastern tip of Minnesota, bordering Canada. Learn more about the Grand Portage Anishinaabe and Gichi Onigaming on their website (www.grandportageband.com/).

Gichi Onigaming in the Ojibwe language means "the great carrying place," indicating the importance of the "Grand Portage" route used to travel between Lake Superior and interior waterways for centuries. The portage route is now a designated National Monument with a Heritage Center and historic depot located on the Grand Portage Bay. Learn more about the monument on the National Park Service's website (www.nps.gov/grpo/index.htm).



Wireless internet is available throughout the hotel.

Cellular coverage will depend on your carrier.

CONFERENCE ORGANIZING COMMITTEE

Thanks to all of our organizing committee members for volunteering to help put this meeting together!

Michell Carstensen	Minnesota Department of Natural Resources
William “Bill” Faber	Central Lakes College
Todd Froberg	Minnesota Department of Natural Resources
Nancy Hansen	Minnesota Department of Natural Resources
Jessica Holmes	Minnesota Department of Natural Resources
Tom Irvine	National Parks of Lake Superior Foundation
Barb Keller	Minnesota Department of Natural Resources
Martha Minchak	Retired
Ron Moen	University of Minnesota - Duluth
Seth Moore (Co-Chair)	Grand Portage Band of Lake Superior Chippewa
Roy Rea	University of Northern British Columbia
Art Rodgers	Ontario Ministry of Natural Resources and Forestry
Mark Romanski	Isle Royale National Park
Mike Schrage	Fond du Lac Band of Lake Superior Chippewa
William “Bill” Severud	South Dakota State University
Morgan Swingen	1854 Treaty Authority
Steve Windels (Co-Chair)	Voyageurs National Park
Tiffany Wolf	University of Minnesota – Twin Cities

CONFERENCE VENDORS

The following vendors will have representatives at the 55th North American Moose Conference and Workshop. Please consider visiting their booths in the Casino lobby during the Welcome Reception/Poster Session on Monday and during the conference!

- Advanced Telemetry Systems

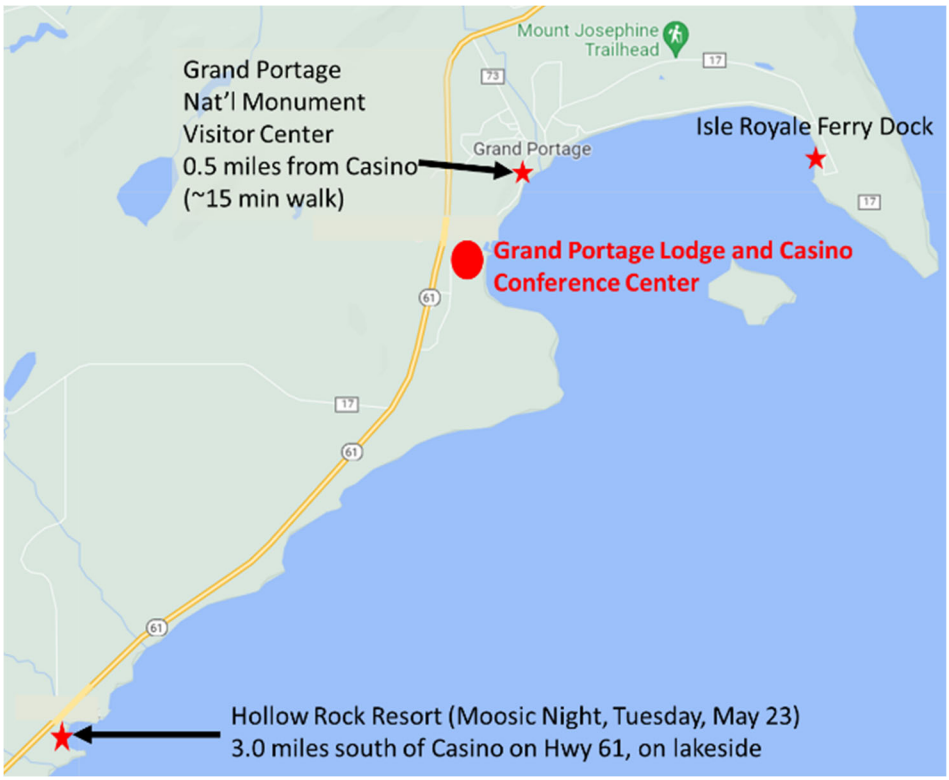
- Lotek Wireless

- Vectronic Aerospace

LOGISTICS FOR "MOOSIC" NIGHT (TUESDAY)

Join us for this fun evening at the nearby Hollow Rock Resort along the beautiful Lake Superior shoreline for music, food, drinks, and friendship! Local musician Bump Blomberg will be performing. And if you are at all moosically inclined, we will have guitars (acoustic, electric, bass), a keyboard, amps, microphones, etc. for you to jam out with Bump and anyone else who wants to join! Feel free to bring your own instruments too!

We will be serving a locally-sourced traditional meal of fried lake trout, moose meat stew, wild rice, and fry bread. Local craft beer, soft drinks, and other beverages provided.



The organizing committee has rented the 7 individual cabins at this small resort, and each is opened to guests on this night if you want to sit, get warm, use the restroom, etc. Just be sure to clean up after yourself and be considerate of the space!

Be prepared for spring weather ranging from 70F and sunny to 40F and windy. There will be several fire pits going throughout the grounds. We will have some chairs available outside for sitting but if you have any folding or camp-style chairs, please consider bring them to sit on.

We will be providing free shuttle service between the Casino and Hollow Rock (about 3 miles apart). Rides start in front of the Casino at 5:30 and continue at regular intervals as needed until the end of the night! There is limited parking at Hollow Rock so please plan to use the shuttle if you can.

LOGISTICS FOR FIELD TRIP (WEDNESDAY)

Everyone will meet in the Grand Portage National Monument (GRPO) Visitor Center between 9:00-9:30a. It's about a 15 minute (0.5 miles) walk from the casino. We will also have shuttles for those that want it. From there, we will divide you into two groups, with Group 1 starting the tour at the GRPO Visitor Center, and Group 2 starting on the shuttle tour of the Grand Portage Reservation Wildlife Program. We will provide a box lunch and refreshments and then the groups will switch for the afternoon.

Grand Portage National Monument Tour

We will start with a presentation by former GRPO Supt. and historian Tim Cochrane on the co-stewardship process and some history of moose, etc. in the region. We will then have an opportunity to watch the park film (which is really well done), view the visitor center's exhibits, and then get a "backstage tour" of GRPO's archives with Museum Technician Stephen Veit, with artifacts dating back as far as 10,000 years ago.

Grand Portage Reservation Wildlife Program

This shuttle bus tour will include visiting some recent moose habitat projects and a live demonstration of using trained dogs to find moose kill sites.

Schedule (subject to change)

Time	Activity	Location
7:30-9:00a	Breakfast	Grand Portage Lodge and Casino
9:00-9:30a	Walk/Shuttle to Grand Portage National Monument	Grand Portage National Monument
GROUP 1		
9:30-10:15a	Tim Cochrane Presentation (All Group 1)	Grand Portage National Monument
10:15-12:00p	Park Film/Exhibits/Archives Tour (Sub-Groups x2)	Grand Portage National Monument
12:00-1:00p	Box lunch	Grand Portage National Monument
1:00-3:30p	Grand Portage Wildlife Tour	Grand Portage Reservation Lands
3:30-4:00p	Walk/Shuttle back to Lodge Casino	Grand Portage Lodge and Casino
GROUP 2		
9:30-12:00p	Grand Portage Wildlife Tour	Grand Portage Reservation Lands
12:00-1:00p	Box lunch	Grand Portage Reservation Lands
1:00-1:45p	Tim Cochrane Presentation (All Group 2)	Grand Portage National Monument
1:45-3:30p	Park Film/Exhibits/Archives Tour (Sub-Groups x2)	Grand Portage National Monument
3:30-4:00p	Walk/Shuttle back to Lodge Casino	Grand Portage Lodge and Casino

LOGISTICS FOR WELCOME RECEPTION AND BANQUET

MONDAY NIGHT, MAY 22, WELCOME RECEPTION AND POSTER SESSION

Join us in the main conference room at Grand Portage Lodge and Casino for our Welcome Social and Poster Session from 6:00-9:00p. Buffet-style dinner, complimentary local craft beer, and a cash bar will be served in this room.

Poster presenters will be available to answer questions on Monday from 7:00 to 8:00p, but posters will be left up all week for continued viewing. Make sure to check out the vendors in the Lobby as well!

And for any budding singers out there, we will have Karaoke set-up in this room starting at 9:00p.

WEDNESDAY NIGHT, MAY 24, AWARDS BANQUET AND SILENT AUCTION

Join us again in the main conference room at Grand Portage Lodge and Casino for our Awards Banquet and Silent Auction from 6:00-9:00p. Buffet-style dinner, complimentary local craft beer, and a cash bar will be served in this room.

A silent auction will offer donated items from conference attendees and other sponsors. There are usually some very interesting moose or other wildlife related items up for bid. This auction is a fundraiser for the Journal Alces and for future North American Moose Conferences. Please consider donating items from your locale or from your travels in Moose Country – see Martha Minchak if you have items to donate.

LOGISTICS FOR FOOD AND REFRESHMENTS

- All meals from Monday evening through Thursday lunch are provided as part of in-person registration.

- Isle Royale Field Trip participants on 5/22 get a box lunch, but breakfast is on your own.

- *Meals on Sunday, Monday breakfast/lunch, Thursday dinner, and all day Friday are on your own.*

Monday, May 22	• Monday Welcome Social/Poster Session in Conference Room from 6:00-900p. Buffet style dinner, complimentary beer, cash bar.
Tuesday, May 23	• Breakfast served buffet style in Conference Room from 7:00-8:00a. • Coffee breaks in Conference and Lobby • Lunch served buffet style in Conference Room from 12:00-1:30p. • "Moosic Night" at Hollow Rock Resort with buffet style dinner, beer, and other beverages from 6:00-9:00p. Shuttle service to/from hotel provided.
Wednesday, May 24	• Breakfast served buffet style in Conference Room from 7:30-9:00a. • Box lunch at Grand Portage National Monument • Banquet/Auction in Conference Room from 6:00-9:00p. Buffet style dinner, complimentary beer, cash bar.
Thursday, May 25	• Breakfast served buffet style in Conference Room from 7:00-8:00a. • Coffee breaks in Conference and Lobby • Lunch served buffet style in Conference Room from 12:00-1:00p.

- The Casino's Island View restaurant is open every day from 8a-8p
- The Antler Lounge bar is open from 12p-midnight daily, and has a limited bar menu.
- The Trading Post gas station/convenience store is located adjacent to the casino, off Hwy 61. This is essentially the end of the road in MN to get gas, groceries, beer, etc.
- Grand Marais, MN, 35 miles southwest of Grand Portage, is the last town with all the normal amenities.

ABSTRACTS

Abstracts for oral presentations are in the order of presentation.

DISTINGUISHED MOOSE BIOLOGIST PRESENTATION

WORKING AND LIVING WITH MOOSE IN FINLAND – A NARRATIVE

Tuire Nygren

Retired from Natural Resources Institute Finland

As an invited recipient of the 2022 Alces Distinguished Moose Biologist Award, I have prepared for the 55th North American Moose Conference and Workshop 2023 in Grand Portage Minnesota a presentation about the 50 years of moose research and management in Finland. The talk is a narrative about moose in the lives of two moose biologist´s family in the remote wilderness near the Russian border. The presentation includes a short description about the present situation of the Finnish moose management.

MAPPING MOOSE FORAGE AVAILABILITY AND QUALITY ACROSS ITS RANGE IN NORTHERN MINNESOTA

John Hak[1], Deahn Donner[2], Amanda McGraw[3], Alejandro A. Royo[4], Brian Miranda[5], Barry (Ty) Wilson[6], Eric Margenau[7], Michelle Carstensen[8], and Véronique St-Louis[9]

[1]US Forest Service, Ashley National Forest, Vernal, UT, USA; [2]US Forest Service, Northern Research Station, Rhinelander, WI, USA; [3]Wisconsin Department of Natural Resources, Forestry Division, Rhinelander, WI, USA; [4]US Forest Service, Northern Research Station, Irvine, PA, USA; [5]US Forest Service, Northern Research Station, Rhinelander, WI, USA; [6]US Forest Service, Northern Research Station, St. Paul, MN, USA; [7]US Forest Service, Northern Research Station, Rhinelander, WI, USA; [8]Minnesota Department of Natural Resources, Division of Fish and Wildlife, Wildlife Health Program, Forest Lake, MN, USA; [9]Minnesota Department of Natural Resources, Wildlife Research Unit, St. Paul, MN, USA

In Minnesota, the long-term viability of moose is of critical concern and substantial resources have been allocated to develop state-wide habitat management plans. Although the current moose management plan identifies long-term forage availability as a concern, the spatial distribution and quality of forage resources across all forest community types is not well mapped. Broad-scale mapping of forage biomass is challenging because it involves quantifying preferred forage species growing beneath the tree canopy layer for some forest types. There have been efforts to quantify under-canopy forage structure from satellite imagery or airborne laser scanning, but these approaches do not delineate species. Here, we describe a novel approach to develop and map a preference weighted index of forage biomass (i.e., quantity and quality) by integrating the US Forest Service, Forest Inventory & Analysis Big Data, Mapping, & Analytics Platform (BIGMAP). BIGMAP uses Landsat time series imagery and auxiliary raster data with the FIA field sample in an ecological ordination model to impute representative FIA subplots to each cell of a 30-m resolution raster based on similarity in the output feature space (i.e., via k-nearest neighbor imputation). We first developed a forage preference index (0-1) for 25 tree and shrub species known to be forage resources for moose, based on literature and expert knowledge. Then for each representative FIA subplot, we tabulated the understory total dry biomass (DRYBIO_SAPLING) for each of the 25 forage species. DRYBIO_SAPLING data includes tree-level estimates of aboveground dry biomass for all sapling and woody shrubs 1 – 4.9 inches DBH, which we further filtered for live stems and stems < 4.9 m in height. We used BIGMAP to provide cell-level mean forage biomass values by species, which averaged values from the representative k subplots imputed to each cell. Next, we multiplied each species biomass by the species' preference score and summed across species to get a total preference-weighted forage biomass for each cell. We compared our results to a subset of FIA plots containing P2 Vegetation Profile data, which focuses on forest structure, recorded as cover by growth habitat by layer of the four most abundant species. We used only the lower growth form or vegetation under the forest canopy. We did not find a suitable correlation between understory biomass cover and our total preference-weighted forage biomass index that supports our argument to use species-specific total biomass from BIGMAP. Our approach will be further validated by comparing results with empirical browse data. Integrating BIGMAP with literature- and expert-based knowledge of moose's browse preferences allowed for species-specific estimates of woody biomass available to moose across a large landscape where mapped estimates do not exist currently.

FORESTS, FORAGE, AND FIRE SHAPE MOVEMENT PATTERNS AND INFLUENCE WINTER SURVIVAL OF THE MINNESOTA MOOSE POPULATION

James D. Forester[1], John L. Berini[2]

[1]University of Minnesota, Department of Fisheries, Wildlife, and Conservation Biology, St. Paul, MN, USA; [2]Carleton College, Department of Biology, Northfield, MN, USA

The spatial distribution and temporal dynamics of wildlife populations are becoming increasingly difficult to predict as land-use practices change and uncertainty grows about how animals will respond to novel climate conditions. In Minnesota, moose (*Alces alces*) are at the edge of their bioclimatic range, presenting a unique opportunity to explore how trade-offs between thermal cover, forage availability, and predation risk affect individual behavior and population dynamics.

We used Forest Inventory and Analysis (FIA) and remotely-sensed land-cover data along with spatial climate models and a 16-year time series of spatially-explicit moose survey data from Northeastern Minnesota to understand how changes in land cover affect moose population dynamics and trends. Then, after collecting biomass estimates of 32 forage species at 123 field sites distributed across the moose range, we measured the stable isotope compositions of 2835 plant samples and used regression kriging to model the spatial variation in forage availability and quality. Finally, we used stable isotope analysis of 191 moose to estimate how the summer diet of individual animals interacted with ambient temperature, forage availability, and the distribution and abundance of land-cover types to affect winter mortality risk in moose.

The per capita rate of increase of the moose sub-populations within survey units was positively correlated with the proportion of mixed forest and young forest in the landscape, but was negatively correlated with summer heat stress index. We found strong spatial patterns in the distribution of forage quality across moose range (with clear impacts of recent fires) and stable isotope analysis of moose hair showed gradients in diet that were also linked to the land-cover composition and ambient temperature within animal home ranges. Generally, moose in warmer areas consumed more aquatic vegetation and less terrestrial vegetation than moose in the cooler region. A survival analysis suggests that animals consuming more high and medium-preference forage and less low-preference forage in the late summer have a higher chance of winter survival; however, these forage types are not evenly distributed across the moose range. Ultimately, we found that moose in warmer areas have a higher risk of mortality, supporting the initial results from our population model. Our results suggest that targeted manipulations of the size and arrangement of different land-cover types and forest stand ages can have important demographic effects on moose populations that are at the edge of their bioclimatic range.

RISK OF PREDATION AND HUNTING DRIVES USE OF VERTICAL AND HORIZONTAL COVER BY MOOSE (*ALCES ALCES*)

Lisa Jeanne Koetke[1], Dexter P. Hodder[2], and Chris J. Johnson[3]

[1]Natural Resources and Environmental Studies Graduate Program, University of Northern British Columbia, Prince George, BC, Canada; [2]John Prince Research Forest, Fort St. James, BC, Canada; [3]Ecosystem Science and Management, University of Northern British Columbia, Prince George, BC, Canada

Human-caused landscape disturbance is one of the major threats to large herbivores, globally. Across central British Columbia, Canada, industrial forest harvesting has resulted in rapid changes to forest structure and composition. Changes in forest structure have implications for the availability and distribution of cover, an important habitat feature for many ungulates. Cover can be used to mitigate the risk of predation, mortality by hunters, human harassment, energetic costs of locomotion, and thermal stress. Although previous studies have reported a number of ways that moose use cover, most studies have relied on broad vegetation categories and few have accounted for fine-scale variation in cover throughout vegetation stands. We used LiDAR and GPS-collar data from the John Prince Research Forest to explore how moose use horizontal and vertical cover at a fine spatial scale. We tested hypotheses related to direct mortality (predation and hunting), thermal stress, and locomotion. Our results indicate that the risk of direct mortality risk is the primary driver of use of both horizontal and vertical cover by moose. Moose used less vertical cover in areas with higher wolf densities and shortly after giving birth. Moose used more horizontal cover in areas with higher wolf densities, unless they had recently given birth; then they used less horizontal cover in areas with higher wolf densities. Moose used less horizontal and vertical cover in the fall than in other seasons, but they used more horizontal and vertical cover during peak hunting season. Our results suggest that in a landscape whose vegetation structure has been altered by forest harvesting, the risk of mortality by predation and hunting outweighed the costs of thermal stress and locomotion as drivers of the use of both horizontal and vertical cover by moose.

BROWSE SELECTION BY MOOSE AND SILVICULTURAL IMPACTS ON BROWSE PRODUCTION AT GITCHI ONIGAMING (GRAND PORTAGE), MN AND MINONG (ISLE ROYALE), MI

Matt Petz Giguere[1], William J. Severud[2], Kim Teager[3], and Seth A. Moore[4]

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The Grand Portage Band of Lake Superior Chippewa is concerned about the declining moose (*Alces alces*) population in the 1854 Treaty area of Minnesota. A declining moose (*Alces alces*) population in the 1854 Treaty area of northeastern Minnesota is a serious subsistence and cultural concern for the Grand Portage Anishinaabe. Forest management modifies the landscape in ways that affect habitat availability and quality for fish and wildlife species. Forest management practices which increase preferred forage of herbivores can be an effective tool. To understand how forest management impacts browse quality and quantity for moose, areas used by GPS-collared moose were identified at Minong (Isle Royale National Park) and at managed and unmanaged sites at Gitchi Onigaming (Grand Portage Reservation). In 2019, remaining and used woody plant “bites” available to moose were measured at 297 transects at 97 sites at Grand Portage and Isle Royale. Woody browse production was modelled as a function of stem height, and year-round species preferences were estimated using log-linear regression. Differences in densities of preferred and neutrally used species were examined across Grand Portage cover types and treatment regimes. Although available bites generally declined as stem height increased, peak production and rate of decline with height varied among species. Conifers and paper birch (*Betula papyrifera*) produced more browse per unit height than quaking aspen (*Populus tremuloides*). Moose preferred fire cherry (*Prunus pensylvanica*), paper birch, quaking aspen at both places. Moose preferred mountain maple (*Acer spicatum*), red maple (*A. rubrum*), and red osier dogwood (*Cornus stolonifera*) at Grand Portage, but not Isle Royale. Moose preferred balsam fir (*Abies balsamea*) at Isle Royale, but not Grand Portage. White cedar (*Thuja occidentalis*), dwarf-bush honeysuckle (*Diervilla lonicera*), Canada fly honeysuckle (*Lonicera canadensis*), black ash (*Fraxinus nigra*), speckled alder (*Alnus incana*), elderberry (*Sambucus racemosa*), and beaked hazelnut (*Corylus cornuta*) were significantly avoided at both places. Preferred browse densities were lowest in mature pure conifer stands, highest in low-density managed conifer and maple hardwood clearcut treatments, and intermediate in clearcut aspen-birch, mature aspen-birch, and mixed boreal stands. While initially high post-harvest, preferred browse densities in aspen-birch clearcuts declined to levels at or below those of mature aspen-birch and mixed boreal stands after 8 years. In contrast, managed conifer stands maintained high preferred browse densities for about 17 years. We recommend low density conifer plantations intensively managed toward mixed stands to improve the quality and quantity of moose browse.

WORKING WITH NOVA SCOTIA'S MI'KMAQ PEOPLE TO BETTER UNDERSTAND OUR SHARED IMPACT ON MOOSE

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Moose are an important species in Nova Scotia that is collaboratively managed by both the Nova Scotia government and Mi'kmaq people. However, one of the greatest challenges with managing this species is trying to determine the impact of First Nations harvest. To address this question the Nova Scotia Department of Natural Resources and Renewables, the Unama'ki Institute of Natural Resources, Kwilmu'kw Maw-klusuaqn (the Mi'kmaq Rights Initiative), and the Confederacy of Mainland Mi'kmaq partnered to run a voluntary moose check station in Cape Breton. The project ran from September to October each year from 2019 to present. The check station was staffed by a government and a Mi'kmaq representative each day and all project materials were printed in English and Mi'kmaq. Our other goal was to improve communication and trust between the Nova Scotia government and Mi'kmaq communities. The project involved hunters voluntarily filling out survey forms and submitting tissue samples. Since 2019 we have collected 237 surveys (2019: 61, 2020: 70, 2021: 70, 2022: 36) and 379 tissues samples (2019: 101, 2020: 116, 2021: 102, 2022: 50). Of the 319 moose organs voluntarily submitted from 2019 to 2021, 40 showed signs of parasites. A subset of those organs suspected of parasites were submitted to the University of Saskatchewan, and came back positive for *Echinococcus canadensis*, the first record of this zoonotic tapeworm in Atlantic Canada. Overall, the project has successfully improved communication between the government and our Mi'kmaq partners and has allowed us to collect significant amounts of important biological samples. It also represented a rare opportunity for wildlife managers to better understand the impacts of First Nations harvest and allowed for a more transparent sharing of information between our groups. It has also generated positive feedback from both Indigenous and non-Indigenous communities. Finally, this work shows that First Nations and government can work together to overcome challenges and develop a stronger relationship.

MOOSE AS A COMMON SYMBOL: WHAT IS MISSING FROM ONTARIO LAW AND POLICY?

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Lakehead University

Since the 1980s, Ontario has had an important interest in moose management and has since established a sustainable moose management framework. While the framework intends to ensure sustainable moose populations into the future, mechanisms to address social interests continue to discourage meaningful Indigenous participation. This qualitative study aims to measure the space between Canadian Indigenous and Non-Indigenous ontologies. I propose 3 objectives to achieve this aim: (1) explore Indigenous and Western belief systems in the context of moose; (2) provide an institutional analysis on the level of Indigenous and Non-Indigenous participation in moose management in Ontario; and (3) co-create a set of recommendation for moose management with First Nations who have moose hunting territories in the Kenogami Forest Management Unit. Working from a complex systems lens, a qualitative multi-methods approach has been applied. Firstly, data collection has taken the form of open-structured interviews with 'expert' knowledge holders, which were then transcribed and coded for data interpretation. Secondly, cognitive effective mapping was used to provide an analysis of the interpreted data. Thirdly, a supplementary analysis of the moose management framework was completed and further explored with the application of Arnstein's Ladder of Citizen Participation. Finally, once the final interpretation of the results is shared with participating Indigenous knowledge holders, recommendations for Ontario moose management will be co-created and shared with the provincial government. As the data analysis process is underway, the results regarding the first two objectives will be discussed during the 55th North American Moose Conference.

AN EXPERT ELICITATION STUDY OF MOOSE POPULATION DECLINE IN NORTHEAST MINNESOTA

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Estimated moose (*Alces alces*) abundance in northeast Minnesota has declined markedly during the period 2005 to 2022. Numerous factors affect moose reproduction and survival with implications for long-term population trends. Although recent research and discussions among moose biologists in Minnesota have identified key parameters pertinent to moose population ecology—including survival, cause-specific mortality of adults and calves, and habitat selection—substantial uncertainty remains. This is true of the interactive effects of multiple stressors on moose population dynamics, and especially the efficacy of potential management actions designed to increase moose abundance. Knowledge of the efficacy of management solutions is required to meet goals related to moose recovery in support of the flow of benefits moose provide to people. Continued research into moose population ecology will generate insights into system dynamics but will take time. In the interim, decision makers are charged to develop moose conservation strategies under high degrees of uncertainty. Leveraging experts' opinions about the causes and consequences of moose population decline, and potential solutions to that decline is one method for reducing uncertainty.

We conducted an assessment of moose research and management experts' opinions about the factors contributing to the observed decline in estimated moose abundance in northeast Minnesota during the period 2005 to 2022, and potential management solutions. We developed a list of experts using snowball sampling, beginning with an existing work group on the subject (n=51). The elicitation procedure consisted of three rounds. In the first round, experts provided open-ended descriptions of their beliefs about the causes of moose population decline. We coded these descriptions into themes and presented them back to participants to evaluate for accuracy and completeness. Themes included a) parasites and disease, b) predation, c) forage quality and availability, and d) direct human mortality. We presented themes back to participants and asked them to evaluate them relative to two sets of relationships, 1) the strength of the effect of that theme on proximal factors controlling moose population dynamics (age and sex specific survival, body condition, and fecundity), and 2) the strength of the effect of distal factors contributing to the potential effect of that theme on moose, as described by respondents. For each theme, we asked respondents to describe potential management actions that could alleviate the negative effect of that theme. In the final round, we summarized management actions described by participants in the previous round and asked them to rate their perception of the efficacy of that action. At the time we wrote this abstract, we were currently engaged in the final round of data collection. We intend to hold a workshop with participants at the completion of the final round. Results of this work may inform future revisions to the Minnesota Department of Natural Resources Moose Research and Management Plan.

POPULATION DYNAMICS AND TERRITORIAL DISTRIBUTION OF THE MOOSE IN EURASIAN FORESTS: REGIONAL AND LANDSCAPE ASPECTS

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The areal of the moose (*Alces alces*) covers a vast area of Eurasian forests. We analyzed the dynamics of the moose population at several levels of extrapolation: First, in the 5 large regions - Eastern Fennoscandia, Arkhangelsk region, Komi and Urals, Central Siberia; second, the abundance indicators of the species in three subzones of the taiga were compared; third, individual points of relatively small specially protected areas were compared. The Central Forest Reserve, the Chuvash Reserve (Chuvash Republic), the Shulgan-Tash Reserve (Republic of Bashkiria), the Yugyd-Va National Park (Komi Republic). The Sikhote-Alin Reserve occupies a special position. Another subspecies lives here - the Ussuri moose (*Alces alces cameloides*).

All data were collected during the last 25-30 years according to a single standard method: Winter Route Registration (Priklonsky, 1973). The Index of Winter Track Counting was calculated (the number of tracks recorded per day per 10 km of the route, or the WTC Index). All five largest studied regions differed from each other in this index. The number of moose in the subzone of the middle taiga is about 1.3-1.5 times higher than in the subzone of the northern taiga.

In the territory of Eastern Fennoscandia, 20 types of landscapes were identified, they significantly differed in the abundance of the species (discriminant analysis). In the territory of the Russian Plain, the basins of large rivers (Northern Dvina, Pechora) are looking important in terms of population differences. We assume that they can be centers of individual populations. The observed changes in the abundance and range of the Ussuri moose may be associated with climate change.

STATISTICAL POPULATION RECONSTRUCTION OF MOOSE IN NORTHEASTERN MINNESOTA USING INTEGRATED POPULATION MODELS

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Objective: Given recent and abrupt declines in the abundance of moose (*Alces alces*) throughout parts of Minnesota and elsewhere in North America, accurately estimating statewide population trends and demographic parameters is a high priority for their continued management and conservation.

Methods: Statistical population reconstruction using integrated population models provides a flexible framework for combining information from multiple studies to produce robust estimates of population abundance, recruitment, and survival. We used this framework to combine aerial survey data and survival data from telemetry studies to recreate trends and demographics of moose in northeastern Minnesota, USA, from 2005 to 2020.

Results: Statistical population reconstruction confirmed the sharp decline in abundance from an estimated 7,841 (90% CI = 6,702–8,933) in 2009 to 3,386 (90% CI = 2,681–4,243) animals in 2013, but also indicated that abundance has remained relatively stable since then, except for a slight decline to 3,163 (90% CI = 2,403–3,718) in 2020. Subsequent stochastic projection of the population from 2021 to 2030 suggests that this modest decline will continue for the next 10 years. Both annual adult survival and per-capita recruitment (number of calves that survived to 1 year per adult female alive during the previous year) decreased substantially in years 2005 and 2019, from 0.902 (SE = 0.043) to 0.689 (SE = 0.061) and from 0.386 (SE = 0.030) to 0.303 (SE = 0.051), respectively. Sensitivity analysis revealed that moose abundance was more sensitive to fluctuations in adult survival than recruitment; thus, we conclude that the steep decline in 2013 was driven primarily by decreasing adult survival.

Conclusions: Our analysis demonstrates the potential utility of using statistical population reconstruction to monitor moose population trends and to identify population declines more quickly. Future studies should focus on providing better estimates of per-capita recruitment, using pregnancy rates and calf survival, which can then be incorporated into reconstruction models to help improve estimates of population change through time.

MODELING HARVEST SCENARIOS FOR THE NORTHEASTERN MINNESOTA MOOSE POPULATION

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The northeastern Minnesota moose population has declined by over 50% since 2005. I used a population model to simulate effects of different harvest scenarios on the northeastern Minnesota moose population. Sixteen years of survey data, from 2005 to 2020, were used to train and validate the model. After calibrating the model using survey data from 2005-2020, I simulated the effect of different harvest scenarios on moose population size and composition from 2021 to 2030. Harvest levels were simulated based on absolute values, percentage of the yearling and adult bulls in the population, and adaptively, with harvest scaled to population size. By design the No Harvest scenario resulted in a stable population. The Low Harvest group included 5 harvest scenarios in which from 40 to 80 moose were harvested each year. The Low Harvest scenarios resulted in a population decline of about 250 to 450 moose relative to the No Harvest scenario by 2030. One hundred or more bulls were harvested each year in the High Harvest group, with a predicted population decline of over 1,000 moose when more than 100 bulls were harvested each year, and a declining bull:cow ratio. The Low Harvest scenarios might be worth considering from the perspective of balancing long-term moose population size with a bull moose harvest each year. I also predicted the effect of management actions that could increase the moose population by simulating a harvest of 80 bull moose each year and increasing either calf survival or adult survival until the population was stable through 2030. An increase in annual calf survival from about 23% to about 28% would offset the 80 moose harvested each year. In order to maintain the simulated moose population, about 500 calves would need to survive each year, compared to about 400 calves surviving each year with a harvest of 80 bulls and no change in calf survival. Similarly, if adult survival were to increase from 88.7% to 90.1%, the population would be stable through 2030 with a harvest of 80 bull moose each year. The simulated harvest scenarios were used to explore how different harvest levels affected the simulated moose population and to inform discussions about harvest decision-making if a moose hunting season were opened in the future.

UPDATE ON THE STATUS OF MOOSE AT VOYAGEURS NATIONAL PARK

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Voyageurs National Park (VNP), a 883-km^2 protected area in northern Minnesota, is a part of the US National Park system whose mission is to maintain functioning ecosystems and healthy wildlife populations for future generations. The park sits at the current southern range limit of moose range in North America, where several moose populations have experienced recent declines. Voyageurs National Park started conducted our own moose population surveys in 2009; population estimates fluctuated between 41-51 for the period 2009-2019, demonstrating a low-density but stable population outside of the Minnesota's core moose range. We report here the results of aerial surveys conducted from 2020 to 2023 and summarize the current state of Voyageurs National Park's moose population.

MOVEMENT AND MORTALITY OF GPS COLLARED MOOSE ON GRAND PORTAGE RESERVATION

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Moose (*Alces alces*) are a primary subsistence species of the Grand Portage Band of Lake Superior Chippewa. Regional population declines have necessitated studies of moose habitat and population demographics. We determined home range and survival of moose on the Grand Portage Indian Reservation and surrounding areas in northeastern Minnesota, to explore spatial and temporal variations in both. A total of 203 moose were collared with GPS transmitters between 2010 and 2020 during each winter by reservation biologists. We used 137 (100 females and 37 males) adult and yearling moose for survival estimation. We investigated if survival varied by month, year, sex, age, and body condition using a live-dead model. Our top ranked model suggested that survival varied by month with an annual adult survival of 0.866. Monthly adult survival was 0.987. We set out to classify moose as either resident or migratory using net square distance and autocorrelated kernel density estimates of home ranges, but it appears that the distinction between resident and non-resident is not clear enough, so the moose in the data set have all been considered residents for the analysis. Home range size for 112 resident moose differed by age and sex (Adult females n = 80, $\bar{x}$ = 59.0 km^2, SE = 7.04 km^2, adult males n = 24, $\bar{x}$ = 116 km^2, SE = 23.2 km^2, yearling females n = 5, $\bar{x}$ = 229 km^2, SE = 133 km^2, yearling males n= 3, $\bar{x}$ = 26.3 km^2, SE = 9.40 km^2). Known calf mortality was also recorded in the data set and was analyzed. We saw that calf mortality was highest at parturition (i.e., May and June), mainly by black bears (*Ursus americanus*) and wolves (*Canis lupus*). Knowledge of spatial ecology and survival can help inform management and give insight into how the moose are using the reservation and surrounding areas.

EXPLORING THE RELATIONSHIP BETWEEN AMBIENT TEMPERATURE AND HEAT STRESS IN WILD MINNESOTA MOOSE

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The moose (*Alces alces*) population in Minnesota has experienced a rapid decline in the past 20 years. Climate change has been listed as one of the potential underlying causes via direct (e.g., physiological changes) or indirect (e.g., behavioral changes) effects. To better understand moose physiological and behavioral responses to increasing ambient temperatures, internal body temperatures of wild moose (n=41; 23 females, 18 males) were monitored at 15-min intervals from 2013-2017 using a rumen bolus (mortality implant transmitter [MIT]). We examined how frequently wild moose experienced ambient temperatures above published thresholds (≥-5 and -2.2°C, and ≥ 14 and 20°C for increased metabolism and panting in winter and summer, respectively; Heat Days) shown to induce physiological responses in captive moose indicative of heat stress. During summer, moose experienced Heat Days on average 49.3-67% (depending on the year) and 81.8-92.5% of the time for panting and increased metabolism, respectively. Similarly, wild moose experienced winter Heat Days on average 36.3-60.2% and 49.2-78.5% of the time for panting and increased metabolism, respectively. However, moose rarely experienced elevated body temperature beyond their normal internal range (>39.17°C) during winter (0.3-1.2% of winter days), suggesting Heat Days during that season do not predict heat stress. Our models suggest, however, that moose are more likely to be heat stressed in the summer (44-50.9% of summer days) on Heat Days. Both the maximum daily MIT and the probability of moose being heat stressed increase significantly with increasing ambient temperatures in the summer. The duration of time a moose maintained an elevated internal body temperature was highly variable (mean = 32 minutes, range = 5 to 1,065 minutes). Predictions from our models suggest that wild moose may experience heat stress symptoms at maximum daily temperatures >25°C in summer. We also found that moose experiencing heat stress >50% of summer days were more likely to die within in a year following that a summer. There may be behavioral tradeoffs moose have to make to mitigate heat stress, especially in the summer, that may reduce overall fitness and impact survival.

GRAY WOLF SPACE USE CHANGES SEASONALLY IN RESPONSE TO MOOSE AND MIGRATORY WHITE-TAILED DEER

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Prey are considered more vulnerable during migration due to decreased knowledge of their surroundings and synchronicity of space use. Predators may respond to apparent prey vulnerability by shifting their ranges to match prey via migratory coupling. We examined the possibility of migratory coupling on the Grand Portage Indian Reservation (Gichi Onigaming; GPIR), Minnesota, USA by examining seasonal movements of gray wolves (ma′iingan; *Canis lupus*), moose (mooz; *Alces alces*), and migratory white-tailed deer (waawaashkeshi; *Odocoileus virginianus*). Moose and white-tailed deer remain important subsistence species for the Anishinaabe people of the Grand Portage Band of Lake Superior Chippewa, and their interrelationships with gray wolves are of high value to the band's seven-generation management objectives. We deployed GPS collars on 45 gray wolves (beginning in 2008), 135 moose (2010), and 72 white-tailed deer (2016) and used locations collected through 31 December 2021.We analyzed the associated location data using Brownian bridge movement model and mechanistic range shift analysis to estimate individual- and population-level occurrence distributions and determine the presence and timing of range shift behavior. We estimated the proportion of gray wolf ranges overlapping moose and white-tailed deer ranges and tested for differences between seasons and populations using analysis of variance. We identified a single migration corridor through which white-tailed deer synchronously departed their winter ranges occupied by monitored gray wolves on GPIR in April and asynchronously returned from their summer ranges in Ontario, Canada beyond monitored gray wolves' ranges in October–November. Gray wolves used the migration corridor equally across seasons and did not shift their ranges during seasonal migrations. However, gray wolves altered their space use seasonally in response to prey availability. Seasonal space use shifts were identified as increased overlap of gray wolves and white-tailed deer during their fall migration and increased overlap of gray wolves and moose during summer. Greater fall overlap between gray wolves and white-tailed deer was likely due to the protracted asynchronous pattern of white-tailed deer movements facilitating repeated predation success in the migration corridor. Greater overlap between gray wolves and moose during summer could be a result of co-occurrence with American beaver (amik; *Castor canadensis*) and reduced white-tailed deer abundance when many are on their summer ranges. Our results support seasonal space use shifting akin to potential prey switching by gray wolves but not the occurrence of migratory coupling. These results suggest potential increased predation pressure on moose in summer and white-tailed deer in fall warranting further examination in the context of declining moose populations and Anishinaabe subsistence objectives.

BEHAVIORAL THERMOREGULATION DIFFERS BETWEEN MALE AND FEMALE MOOSE

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Animals use behavior to smooth exposure to environmental extremes. Intrinsic traits that increase sensitivity to extremes therefore intensify behavioral responses. In endotherms, sex and reproduction affect the generation and dissipation of heat, thereby shaping heat load. We tested how sex and reproductive status affect behavior in a heat-sensitive herbivore (*Alces alces*). During the warm season, moose select bed sites that reduce heat gain and increase heat loss. Selection of beds was therefore an apt metric to compare behavior among individuals. All moose selected bed sites with cooler microclimates, greater ground moisture, and denser vegetation relative to what was available. Despite increased heat load associated with lactation, we detected no differences in selection between reproductive and non-reproductive females. Sex altered selection in the tradeoff between convective cooling (wind) and radiative shelter (canopy cover). Females selected areas of high cover and low wind. Relative to females, males selected bed sites with low cover and high wind. Despite the behavioral differences we detected, our biophysical models revealed minimal difference in predicted risk of overheating between male and female moose. These seemingly incongruous results uncover potential differences in the capacity of the sexes to use wind as a mechanism to mitigate heat stress.

EVALUATING MATING EFFORT, TACTIC, AND SUCCESS IN MALE MOOSE

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Intrinsic traits influence reproductive behavior and output. In moose (*Alces alces*), prime age males with large bodies and large antlers are assumed to have high probabilities of reproductive success during the autumn mating season. We evaluated how antler class and age shape mating tactic, effort, and success for Shiras moose in northwestern Wyoming using 36 unique animal years from 16 male moose. We quantified mating tactic using hidden Markov models to distinguish between female-defense and mate-searching behaviors and measured mating effort as hourly relocation distance. To index mating success, we summed instances when marked males were within 50 meters of marked females. We anticipated that time spent in female-defense, hourly mating effort, and proximity to females would be greatest in males with large antlers and of prime-age. Contrary to our expectations, old males (9–11 years) spent a greater proportion of time (75 ± 4%) in female-defense than prime-aged (5–8 years; 68 ± 3%) or young males (1–4 years; 61 ± 2%). The mating effort of old males (235 ± 76 m/hour) and young males (258 ± 37 m/hour) was similar and was greater than prime-aged males (194 ± 39 m/hour). Antler size was not associated with mating tactic or effort, but did predict proximity to females. Males in the largest antler class were associated with females (378 ± 227 hours) far more than males in the smallest antler class (57 ± 23 hours). Thus, in Shiras moose, age was a strong predictor of mating effort and tactic, whereas antler class better predicted mating success. Though females are typically the focus of reproductive studies, the mating behavior of male moose merits inquiry because understanding the dynamics of male reproductive effort can aid in the conservation of mating systems that retain favorable traits within the population.

PHYSIOLOGIC OUTCOMES AFTER THIAFENTANIL AND XYLAZINE IMMOBILIZATION AND THE COMPARISON OF OXYGEN OR OXYGEN AND DOXAPRAM TREATMENTS IN FREE-RANGING MOOSE

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Evaluation and refinement of immobilization protocols using ultra-potent opioids are necessary to mitigate adverse effects on wildlife. Physiologic outcomes after immobilization with thiafentanil and xylazine were evaluated and the effects of oxygen versus oxygen and doxapram treatments for hypoxemia were compared in free-ranging moose (*Alces alces*) in Minnesota. Fifty adult moose were immobilized by darting from a helicopter with thiafentanil (10 mg) and xylazine (30 mg) during February 2020 and March 2021. Pursuit time (PT), induction time (IT), recovery time (RT), temperature (T), and body position were recorded. Twenty-one adult females with an SpO_2 < 90% were randomly treated with nasal oxygen insufflation alone (4 L/min, O_2) or including IV doxapram (80 mg; O_2D80). Respiratory rate (RR), pulse rate (PR), pulse oximetry (SpO_2), arterial oxygen (PaO_2), and carbon dioxide ($PaCO_2$) tensions were obtained pre-treatment and 5 min post-treatment. Moose were reversed with naltrexone (200 mg) and tolazoline (800 mg) IM. Individuals included in the analysis of response had RR = 20 bpm. Mixed-effects model and Bonferroni's post-hoc compared normally distributed data. Wilcoxon matched-pairs signed rank test or Mann-Whitney test compared non-normally distributed data. A P-value of < 0.05 was considered significant. Median PT was 4 min and median IT was 4 min, with 98% remaining sternal and 77% holding their head upright. Median RT was 3 min. T remained < 41.2 ? Celsius. SpO_2 increased significantly in O_2D80 ($p = 0.0014$) but not O_2 ($p = 0.2198$) after treatment for hypoxemia. The PaO_2 increased by 26±4 ($p = 0.0056$) mmHg in the O_2D80 group and 31±25 mmHg ($p = 0.2451$) in O_2 group; however the standard deviation of the differences was 6.3-fold greater with O_2 alone than O_2D80. RR increased significantly in the O_2D80 group (by 81% ± 58% or 10 bpm ± 7 bpm) but not in the O_2 group (by 31% ± 22% or 5 bpm ± 5 bpm). There was no significant $PaCO_2$ change in either group ($p > 0.9999$). All moose survived immobilization. Thiafentanil and xylazine combination was a safe and effective immobilization protocol in free-ranging moose. Additionally, oxygen supplementation and, more predictably, 80 mg of doxapram with oxygen supplementation, can be used to effectively improve arterial oxygenation and augment therapy for hypoxemia in immobilized moose.

FOREST AND WILDLIFE UNDER PRESSURE - SYSTEMS ANALYSIS FOR SUSTAINABLE SOLUTIONS

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Norway has one of the highest densities of moose populations globally, a result of meticulous and decentralized moose management, as well as active forestry that consistently provides young forest stands, a favored habitat for browsing. However, climate change is expected to alter forest growth and tree species distribution, with an increase in disturbances such as wildfires, windthrows, and pathogens. Meanwhile, the societal shift from black to green carbon is likely to raise the demand for wood biomass to substitute fossil fuels and non-renewable materials. Furthermore, the expansion of ungulates, such as red deer, fallow deer, and wild boar, northward is anticipated to have an ecological impact on the moose population. This is due to the significant food overlap between these species, especially in terms of browsing on forest floor vegetation. To provide decision-making tools for forest and wildlife management, a comprehensive forest and wildlife model is being developed in close collaboration with stakeholders. The model will enable long-term simulations of underlying climate scenarios in addition to pre-defined scenarios for forestry, hunting, biodiversity, and recreation. The goal is to create strategies for the multiple-use of forests in light of the changing ecosystem, which can promote innovative solutions that foster sustainable development.

SPACE USE AND HABITAT SELECTION OF MOOSE IN RESPONSE TO SHORT-TERM WEATHER CONDITIONS IN NORTHEASTERN MINNESOTA

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The size and location of moose (*Alces alces*) home ranges are a result of behavioral decisions individuals make to meet their energetic and life-history needs. Variability in ungulate home range sizes is often attributed to the distribution and abundance of food, but the use of thermal cover during warmer weather has also been documented. We evaluated how weekly home range sizes of male and female moose varied in response to local weather conditions and habitat types (i.e., thermal cover and forage) across seasons in northeastern Minnesota. Using moose (N = 113 females, 45 males) GPS locations from 2013 – 2018, we estimated home range size for each individual moose during successive, non-overlapping 7-day windows using a 95% kernel density estimator. We used generalized linear mixed-effect models to determine the best-fitting weather-only model by sex and season, and then modeled home range size as a function of the most informative weather variables and the proportion of thermal cover (lowland conifers) and foraging habitat (preferred browse species). Our preliminary results indicate males responded primarily to temperature, while females responded to both temperature and precipitation, and responses varied across seasons. In general, when temperatures warmed in summer and winter, female home range sizes increased and contained more thermal cover habitat. Males also used more thermal cover during warmer winter periods, but their home range sizes decreased. Males also decreased their home range sizes during cooler summer periods. During these periods, they increased forage habitat indicating they spent much of their time foraging when temperatures were not a limiting factor. Females also had greater foraging habitat within smaller home ranges, but it was during wetter summer weeks and in winter during periods of greater snow depth. Minnesota's moose are at the southern edge of their North American distribution where climate is projected to be warmer and wetter by the end of the century. Our findings show these conditions are already influencing their adaptive behavior to cope with current high temperatures in summer and winter. Broad-scale habitat management that includes a mix of foraging and thermal cover within the home-range scale are important factors, especially if the possible effects of temperature become stronger with climate change.

EXAMINING THE CO-BENEFITS OF MOOSE HARVEST AS A CARIBOU RECOVERY LEVER

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1. In many areas of the boreal forests and temperate mountains of Canada, resource extraction activities have created forage conditions that are favorable to the growth of moose (*Alces alces*) populations. In turn, these increased moose populations buoy the abundance of wolves (*Canis lupus*), which then have spillover impacts on caribou (*Rangifer tarandus*). Consequently, caribou have been declining where increased resource extraction, moose, or wolves occur.

2. To abate unsustainable predation pressure on caribou, antlerless moose hunting regulations were implemented to first reduce and then stabilize the moose population in the Revelstoke Valley, British Columbia, Canada (between 2003-2020). At the same time, a reduction in forestry activity paired with habitat protections slowed the early seral conditions that favor moose.

3. Given both bottom-up and top-down drivers of moose population growth were operating simultaneously, we sought to understand two research objectives. First, we evaluated how antlerless moose hunting regulation influenced the cumulative harvest yield for moose hunters amidst changing moose habitat quality. Secondly, we tested how different forest cut scenarios might influence moose carrying capacity, wolf densities, and thus caribou populations into future decades.

4. We used data from moose GPS collars (41 individuals), nine aerial population surveys, hunter harvest statistics, estimates of carrying capacity thresholds, and forest cutting records. These data spanned 1961-2020 and informed the resource selection function and calculations for our first research objective as well as the predictive modeling for our second research objective.

5. We found that moose habitat declined from 2003-2020 by 44.8%. There were 42% more moose harvested under antlerless regulations than had status quo harvest occurred. As the moose population stabilized, we observed higher recruitment rates (e.g., calf:cow ratios) that further contributed to the number of harvested moose. Our simulations indicated that if forest cutting were to cease entirely in 2020, moose carrying capacity would be low enough to stabilize caribou populations by 2040.

6. As a result of the observed antlerless moose harvesting policies amidst declining moose carrying capacity, moose did not act as a doomed surplus that would have further buoyed wolf populations for additional years, but rather aided in caribou recovery while facilitating food-security opportunities for moose harvesters.

FACTORS AFFECTING MOOSE DECLINES IN BRITISH COLUMBIA: SUMMARY AND RECOMMENDATIONS, 2012-2022

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In 2012-13, the British Columbia Ministry of Forests initiated a 5-year moose research project to determine the factors affecting moose population change in central British Columbia (BC) and to evaluate the effect of landscape change on adult female moose survival and population change. The project was extended in 2016 to evaluate the effect on calf recruitment as well. After a decade of monitoring moose populations, the Provincial Moose Research Project has tested hypotheses about mechanisms of moose decline, and on-going work continues to address hypotheses that have not yet been rejected.

We initially expected adult female survival to be the most important parameter in driving population change, however, adult female survival in most years and study areas was consistently high enough to maintain a stable population. Instead, calf recruitment, or the interaction with adult female survival, appears to have driven the population decline. Adult female survival was not higher in study areas with lower disturbance, but individual moose responded to disturbance features at the home range scale and within their home ranges. These responses included avoidance of new cutblocks and roads, but also varied extensively by individual, by season, and by study area.

The mechanism of decline was unknown, but hypothesized to be linked to increased hunting success, nutrition or health factors, or increased predation. After 10 years of mortality investigations, there was no evidence that hunting caused the decline. There were also no infectious or non-infectious diseases driving population dynamics. There was some support for the role of nutrition, and analysis is on-going. Wolf predation was the primary cause of death for collared cows and 8-month-old calves. Wolf and moose behaviour and selection in a highly modified landscape have likely led to shifting predation patterns and trade-offs for moose between energy acquisition and risk avoidance. Several aspects of the project are still under active investigation with final products expected in 2023-24. The results of this work are expected to further inform next steps for the project and provide management recommendations.

Management recommendations based on work to date include maintaining landscape heterogeneity and connectivity, maintaining interior forest conditions for thermal/snow interception cover, encouraging deciduous stands and moose browse, maintaining dead standing pine for horizontal cover, reducing roads, and maintaining current licensed hunting opportunity.

LANDSCAPE FEATURE DETERMINANTS OF BRAINWORM TRANSMISSION IN NORTHEASTERN MINNESOTA

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Parelaphostrongylus tenuis infection is a leading cause of adult death in Minnesota's at-risk moose population. Lowering densities of white-tailed deer, *P. tenuis*'s natural definitive host, is currently the only management option for reducing transmission to moose. Deer density reduction varies in feasibility, so other options are needed. Because moose habitat use predicts *P. tenuis* infection probabilities, habitat management strategies could reduce transmission. However, whether certain habitat features serve as barriers or corridors for *P. tenuis* transmission remains unexamined. To explore this question, we employed a landscape genomics modeling framework and used *P. tenuis* gene flow as a proxy for transmission. We collected 129 geo-labeled, spatially stratified *P. tenuis* larval samples on Grand Portage Indian Reservation (GPIR) in Minnesota, USA, from which we identified 72,479 single nucleotide polymorphisms indicative of population structure. We then used principal component analysis, ancestry coefficient plots, and geographic mapping tools to determine the number and location of *P. tenuis* populations on GPIR. Combining our sample location and genomic data with geographic data, we then measured how values of the intervening landscape features (for example, high vs low elevation) shape gene flow. We found five *P. tenuis* populations that cluster together spatially. Rivers, deer dispersal routes, and high elevation may shape *P. tenuis* gene flow, but their effects may not be strong since significant genetic mixing between populations is also evident. We are now exploring the relative importance of landscape features in shaping *P. tenuis* gene flow with machine learning. This study is a step toward understanding how habitat management might reduce *P. tenuis* transmission to moose and is particularly relevant to the 1854 Ceded Territory in northeastern MN, where the Grand Portage Band and other Chippewa tribes retain treaty-reserved rights to preserve culture and subsist through moose hunting and other forms of hunting, fishing, and gathering.

CO-INFECTION OF ANAPLASMA AND WINTER TICK DECREASES MOOSE CALF SURVIVAL IN MAINE

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Parasite coinfection has been shown to increase host susceptibility to other pathogens and decrease host fitness. Winter ticks (*Dermacentor albipictus*) are negatively impacting the Maine moose (*Alces alces*) population, causing hair loss, reduced fecundity, anemia, and even death. Furthermore, a bacterial blood parasite from the genus Anaplasma has recently been detected in Maine moose, with prevalence increasing over the study period (54% 2014-2018; 85-93% in 2021 and 2022). Prior phylogenetic work has shown the *Anaplasma* spp. in moose to be specific to cervids, sharing a common ancestor with *A. marginale*, which is known to cause weight loss, abortion, and death in cattle. However, the effects of Anaplasma infection on moose survival, as well as the compounding impacts of winter tick and Anaplasma co-infections remains unknown. Here, we examine the impact Anaplasma infection and co-infection with winter ticks has on moose calf survival in Maine. We utilize six years of live capture moose data (2017-2019; 2021-2023) to model calf overwintering survival probability (using the Kaplan-Meir estimator) as a function of winter tick load and Anaplasma infection status. Our results show that moose with heavy winter tick loads have a significantly lower survival probability than their moderately and lightly infected counterparts. Furthermore, for moose calves with heavy winter tick infestations, the survival probability of those infected with Anaplasma is 22% lower ($p < 0.05$) than those that are uninfected. Our data suggest Anaplasma infections and winter ticks have additive negative effects on calf survival. These results highlight an urgent need to understand how co-infections influence moose health, particularly given the concerns of a declining moose population in the Northeastern United States.

SEROLOGICAL TESTING OF PARELAPHOSTRONGYLUS TENUIS INFECTION IN WILD MINNESOTA MOOSE (*ALCES ALCES*) AND ELK (*CERVUS CANADENSIS*) USING A NOVEL ENZYME-LINKED IMMUNOSORBENT ASSAY (ELISA)

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Parelaphostrongylus tenuis, often referred to as brainworm or meningeal worm, is a neurotropic parasite of wild cervids that can cause neurological disease through aberrant migration within the central nervous system (CNS). While white-tailed deer (*Odocoileus virginianus*) are the natural host and rarely have clinical disease, other cervid species including moose (*Alces alces*), elk (*Cervus canadensis*), and caribou (*Rangifer tarandus*) have variable to severe morbidity and mortality leading to potential population impacts. Minnesota's moose population has declined >60% from 2005 to present. Exposure to *P. tenuis* is believe to be one of the main drivers impacting this population's performance through both direct and indirect mortality (e.g., increasing vulnerability to predation). This study involved analyzing banked sera of 1211 moose and 169 elk from Minnesota (2002-2021) for evidence of *P. tenuis* antibodies utilizing a novel enzyme-linked immunosorbent assay (ELISA) previously developed and validated in our laboratory at the University of Tennessee. Of the moose samples, 14.8-23.5% tested positive for *P. tenuis* antibodies, depending on chosen positive cut-off value. Elk appeared to have substantially lower seroprevalence with 0.59-6.51% testing positive. This serological test is still in the process of more rigorous validation using serum from known *P. tenuis*-positive animals, determined via necropsy. However, thus far the ELISA has provided promising results and insights into the exposure of aberrant hosts without the need for post-mortem diagnosis. Numerous applications of this test are planned for future research projects that can have significant management implications.

AN EFFECTIVE ACARICIDE TREATMENT TO EXPERIMENTALLY MANIPULATE WINTER TICK LOAD ON MOOSE

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Quantifying the contribution of winter ticks (*Dermacentor albipictus*) on moose (*Alces alces*) demographic parameters is difficult because parasitism interacts with other stressors such as winter severity or predation. Under natural conditions, acquiring data at the individual level from resightings or necropsies can also be challenging. Even for marked moose, identifying an unambiguous cause of death can depend on several logistical constraints such as carcass location or time since death, and physiological aspects, for example winter severity might combine with parasitism and lead to death by inanition. Experimentally reducing tick load at capture could prove useful to isolate the contribution of parasitism from that of other stressors in moose survival. We tested the efficacy of an acaricide treatment on hair loss, a symptom of moose infestation by winter ticks. We specifically compared hair loss occurrence and hair loss severity between control (untreated) and treated moose calves fitted with GPS collars in three regions of eastern Canada (southern New-Brunswick, Lower-St-Lawrence and Central Quebec). Moose (N=75) were captured in early winter and 31 of the captured individuals received an acaricide treatment consisting in a permethrin based topical acaricide (45% - K9-Advantix®; Bayer Healthcare, 2011) combined with a fluralaner based oral acaricide (25 mg/kg - Bravecto®; Merck Animal Health, 2016). All individuals were resighted about 3 months later using aerial surveys in late April to early May or necropsies. The acaricide treatment reduced probability of hair loss occurrence by 98% (Odds ratio [95% CI] = 0.020 [0.003; 0.122]), while 93% of control moose had hair loss. Treated individuals typically had hair loss representing less than 20% of their coat, if any hair loss at all, while over 60% of control individuals had hair loss covering more than 20% of their coat. Hair loss varied more in the neck and shoulder areas than for other body parts in both control and treated individuals, but it was typically very low in treated individuals when hair loss was observed. Our results suggest that contrary to previous trials with a 5% permethrin topical acaricide, the combined use of fluralaner and 45% permethrin is an efficient acaricide to experimentally reduce winter tick load in moose calves. We conclude that this acaricide treatment has the potential to extend our comprehension of winter ticks' effects on moose survival across their first winter, and more broadly to improve our understanding of the interactions between host, climate and this parasite.

MOOSE HEALTH ASSESSMENT INDICATES HIGH PARASITE EXPOSURE IN NEW YORK

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Moose (*Alces alces*) have experienced population fluctuations along the southern limits of their range in North America and high juvenile mortality from epizootic events in the northeastern United States. While this has highlighted the importance of winter ticks (*Dermacentor albipictus*) and internal parasites to moose population dynamics in the region, we have yet to understand the role of parasites and other mechanisms in potentially regulating the smaller and less dense population of moose in neighboring New York State. We investigated parasite occurrence in live-captured and necropsied moose in New York to assess individual health, causes of death, and factors associated with moose mortality and internal parasite infection. Our health assessment revealed high levels of exposure to internal and external parasites, major sources of mortality from vehicle collisions and parasites, and higher parasite burdens in adult moose. We also assessed factors important to moose infection with *Parelaphostrongylus tenuis* and *Fascioloides magna* using generalized linear models and found age, year, and deer density to be important for predicting moose infection probability. These results are important for prompting further investigation of the population-level impacts of parasites and managing threats to moose persistence in the state.

AN EXPERIMENTAL STUDY OF THE IMPACT OF WINTER TICKS ON THE ECOLOGY AND SURVIVAL OF MOOSE IN EASTERN CANADA

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Moose (*Alces americana*) populations have generally increased in eastern Canada for at least 30 years. Concomitantly with increasing moose populations, we have also witnessed an increase of winter ticks (*Dermacentor albipictus*) abundance and prevalence across a vast geographic area. Winter ticks are believed to have increase due to a combination of more favorable climate conditions and high moose density. Managers, sport hunters and the public in general are concerned with this increase in winter ticks parasitizing moose and the increased number of moose seen with patches of lost hair in the spring and carcasses found in the forest. To answer these concerns, we launched in 2019 a research program to better understand and predict the interactions between winter ticks and moose in eastern Canada in relation to changing climate conditions. We focus on a large-scale experiment assessing the relationship between the body condition of moose infected with different abundances of winter ticks and survival. We also address space use strategies and movements of moose according to their level of infestation with winter ticks and how habitat choice of moose and ticks interact to determine patterns of co-occurrence. We assessed the effects of environmental conditions on the prevalence and abundance of winter ticks using a large spatial gradient of climate conditions and evaluated the impact of multi parasite species on moose infected with different winter tick abundances. We found that prolonged periods of cold weather in spring were negatively correlated with tick numbers in the fall. Early spring and long periods of low humidity in summer were associated with lower number of winter ticks. Our program also includes a citizen science component of observations of alopecia in moose using remote cameras to help increase the spatio-temporal resolution and the monitoring of winter tick infestations. We used an experimental approach in which we treated moose calves in early winter with an acaricide treatment consisting in topical permethrin (45% - K9-Advantix®) combined with fluralaner, an oral acaricide (25 mg/kg - Bravecto®), and subsequently monitor their survival using GPS collars throughout the year. We captured 286 moose during three winters and treated half of them with acaricides to greatly reduce their winter tick load and used the other half as controls. We used five populations on a latitudinal gradient from southern New Brunswick to north of the St. Lawrence river where climate conditions varied significantly as well as moose density and wolf predation. We observed a winter mortality rate of about 3% for treated moose calves as opposed to ca. 23% for controls. At term, our results will help parameterize a spatially-explicit epidemiological model to predict the spatio-temporal interactions between winter ticks and moose under different scenarios of climate conditions.

WHY ARE WE HERE? - TREATY DEPENDENCE AND OBLIGATIONS

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This presentation observes that the inherent sovereignty of Native nations endures as the exclusive justifiable basis for any and all governance authority on this continent. Contemporary settler federalist systems are premised upon treaties with Native nations, and those systems are legitimate only to the extent that treaty obligations are fulfilled. Extreme settler neglect of those obligations has created a long-standing and ongoing crisis. While that crisis is dauntingly massive in scope and scale, there are nevertheless countless things that can and should be done, and the arena of wildlife stewardship provides many opportunities for remedy. This presentation invites all conference participants, regardless of who they are, to consider how their own stories are very likely intertwined with settler-Indigenous diplomacies, and to think directly about how those diplomacies should impact their work.

MODERN RECOGNITION OF TREATIES, CO-MANAGEMENT RESPONSIBILITIES, A NEW ERA OF CO-STEWARDSHIP

Seth Moore

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This presentation will cover two major themes in moose research and management to set the stage for the workshop. The first thematic area is to describe the strong federal encouragement to develop co-stewardship and co-management plans between tribes and the federal government for protecting and stewarding federal lands. The second thematic area is a brief description of the current state of moose science in North America to assist in identifying knowledge gaps and research and management needs.

MOVING BEYOND MANAGEMENT: INDIGENOUS PERSPECTIVES ON MOOSE

Jesse Popp

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Dr. Jesse Popp is a Canada Research Chair in Indigenous Environmental Science at the University of Guelph. She is a member of Wiikwemkoong Unceded Territory and strives to promote inclusive science that embraces multiple ways of knowing while on her journey of learning and sharing. Her work contributes to conservation, sustainability, and the progression of the natural sciences in the spirit of reconciliation.

PREVALENCE AND MORTALITY OF MOOSE INFECTED WITH ARTERIAL WORMS (*ELAEOPHORA SCHNEIDERI*) IN MONTANA, USA

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Elaeophora schneideri is a filarial nematode of North America that occasionally infects aberrant ruminant hosts such as moose. The role *E. schneideri* plays in clinical morbidity or mortality of moose remains uncertain. We first sampled predominantly hunter-killed adult moose (n = 127) to characterize the spatial patterns of prevalence and intensity of worms in carotid arteries of moose in Montana. Second, we compared prevalence and intensity of *E. schneideri* infection within these moose to a separate sample of adult moose that died of health related causes (n = 34). We found lower prevalence in northwest Montana (0.06) than in the remainder of the state (0.42). We also found both higher prevalence of *E. schneideri* and higher intensity (number of worms) to be correlated with increased probability of health-related mortality for moose. Our results suggest presence and intensity of *E. schneideri* may play a role in the mortality of adult moose, though the acute and/or chronic mechanisms of mortality remain uncertain.

ADULT COW AND CALF SURVIVAL IN MAINE (2014-2020): A WINTER TICK DRIVEN SYSTEM

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During a seven-year study on adult cow and calf survival in Maine (2014-2020), 417 calves (~8 months of age) and 128 adult cows were fitted with Global Positioning System (GPS) collars, ear tagged and sampled for winter ticks, blood parameters and internal parasites. The study was implemented in Wildlife Management Districts (WMD) 8 (2014-2020) and 2 (2016-2020) to investigate winter tick abundance on annual survival of adult cows and on over-winter survival of calves' adult survival was assessed up until the collar battery quit or the animal died (individuals were often monitored over multiple years). Field necropsies were conducted on moose that died within 12-48 hours of a mortality notification, excepting moose that were legally harvested, wounded, or illegally taken. We conducted limited necropsies on carcasses found in late stages of decomposition or those that had been heavily scavenged.

From May until the end of July, we conducted 'walk-ins' or stalked near enough to directly observe all adult female moose to determine reproductive status and calf survival. Due to time constraints, mature cows (3+ years of age) were prioritized for observation over known yearling or 2-year-old cows less likely to calf.

Annual survival rates of adult cows were relatively high (90-92%) throughout the study except in 2014, when an abnormally high loss of adult cows (48%) was observed. Mean overwintering survival of calves in WMD 8 was 38% compared to 63% overwintering survival of calves in WMD 2. Winter tick abundance was higher on moose in WMD 8 and was associated with higher over-winter calf mortality and depressed reproduction; we recorded reduced ovulation rates and very low rates of twinning. Additional research is recommended to increase understanding of the relationships between moose densities and winter tick abundance considering expected climate change.

TRIBAL MONITORING OF PARASITE PREVALENCE IN NORTHEASTERN MINNESOTA

Morgan Swingen

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In the treaty of 1854, the Native Americans in present-day northeastern Minnesota ceded 5 million acres of land to the United States government but retained rights to hunt, fish, and gather on those lands. The 1854 Treaty Authority is an inter-tribal natural resource agency that today manages those off-reservation treaty rights for the Bois Forte Band of Chippewa and Grand Portage Band of Lake Superior Chippewa. Our agency is interested in protecting and preserving the resources in this area and therefore conducts many research and monitoring projects on species of interest and potential threats to their persistence on the landscape. One of the most important species for subsistence harvest for tribal members is moose. Moose in northeastern Minnesota are threatened by many factors including climate, predation, and parasites. Previous research has shown that the parasites *P. tenuis* (meningeal worm) and *F. magna* (liver fluke), spread by white-tailed deer, are major sources of mortality for adult moose. The 1854 Treaty Authority has been monitoring the prevalence of these parasites in white-tailed deer pellets (feces) across the 1854 Ceded Territory since 2017. We have found *P. tenuis* larvae prevalence levels in deer pellets have varied from 43-73% annually, and F. magna egg presence in pellet samples has varied from 19-33% annually. We expect that parasite prevalence in pellet samples will vary with changing deer density, and plan to continue this monitoring in the future to determine the potential impacts of deer management strategies on parasite transmission.

CAUSE-SPECIFIC MORTALITY OF MOOSE IN GRAND PORTAGE AND VOYAGEURS NATIONAL PARK, MINNESOTA, OVER 12 YEARS: BRAINWORM'S CONTRIBUTION TO THE DECLINE AND INDICATIONS OF WOLF PREY SWITCHING

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Northeastern Minnesota's moose population experienced a ~50% decline 2010-2014 and has since stabilized but not recovered. Minnesota moose population growth rates are most sensitive to changes in adult survival, so a finer scale understanding of how different adult mortality sources shaped the decline and subsequent stabilization would help managers identify ways to recover the moose population and prevent future declines. However, moose deaths in Minnesota are often multifactorial, which can result in misleading population-wide estimates of cause-specific mortality. For example, moose can be predisposed to predation by parasitism or poor nutrition, but this important nuance cannot be captured in a frequentist cause-specific mortality analysis framework. To overcome this limitation, we used a Bayesian framework which allowed us to specify the relative contribution of causes to a given moose death via prior probability distributions. We applied this framework to GPS collar, field observation, and necropsy data from moose captured and observed on Grand Portage Indian Reservation (GPIR; 2010-2022, n=153 individuals, 89 mortalities) and in Voyageurs National Park (2010-2017, n=22 individuals, 11 mortalities). We categorized mortality into 5 predictive prior bins: wolf predation, *Parelaphostrongylus tenuis* (meningeal worm) infection, winter tick-related, other health-related, and other (including senescence, accidents, hunter harvest, and capture-related causes). We then calculated cause-specific mortality probability for the course of the entire study, as well segmented the data into 'decline' and 'stabilization' periods (2010-2014 and 2015-2022, respectively). While wolf predation was the top source of mortality across the entire study (probability = 24%, 95 percent credible interval =14-36%), *P. tenuis* infection caused the most mortality during the decline period (probability = 34%, 95 percent credible interval = 13-62%) and wolf predation during the stabilization period (probability = 37%, 95 percent credible interval = 23-52%). This indicates that different ecological mechanisms may be responsible for the decline and stabilization periods. Examining GPIR white-tailed deer density data during these periods revealed that deer peaked at 1.4 deer/km^2 during the decline and then dropped to ~0.2 during the stabilization. Hence, we posit that high deer numbers and increased *P. tenuis* transmission to moose was an important driver of the decline, whereas reduced deer density resulted in wolf prey switching to moose during the stabilization period, preventing population recovery. Furthermore, we suggest that there may be a threshold (~0.4 deer/km^2) where deer densities remain high enough to prevent prey-switching but low enough to reduce *P. tenuis* transmission. This study demonstrates the utility of long-term collaring studies to evaluate parameter trends over time and thereby uncover subtle ecological dynamics that are highly relevant to effective management. This study can inform management in most landscapes where moose, white-tailed deer, and wolves coexist, but is particularly relevant to the 1854 Ceded Territory in northeastern MN, where the Grand Portage Band and other Chippewa tribes retain treaty-reserved rights to preserve culture and subsist through moose hunting and other forms of hunting, fishing, and gathering.

EVALUATING AN UNPILOTED AERIAL SYSTEM FOR MONITORING UNMARKED MOOSE IN NEW HAMPSHIRE

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Accurate and precise estimates of moose (*Alces alces*) density are pivotal for understanding population dynamics and for making informed management decisions in a changing climate. One new promising method for obtaining this information is unpiloted aerial systems (UASs). However, this technology still requires critical evaluation, especially with respect to its application to monitoring unmarked moose populations over large spatial scales (hundreds to thousands of square kilometers). One acute challenge is properly accounting for imperfect detection, or 'sightability', which occurs when moose within sample transects are not detected and therefore uncounted. A recent review found that less than half of studies estimating moose density adequately accounted for sightability, suggesting that many moose population estimates might be biased low. Our objectives were to 1) quantify sightability using UASs flown over unmarked moose populations, and 2) evaluate the general efficacy of UASs for estimating moose density. We conducted 35 UAS flights in northern New Hampshire, USA during January and February 2023 using a DJI Matrice 300 RTK quadcopter equipped with a DJI Zenmuse H20T sensor that recorded both RGB and infrared thermal images. We recorded 59 moose detections across 30 km^2 of high-quality moose habitat. We also recorded sampling effort per unit of area to evaluate the potential costs and spatial scale limitations of UAS monitoring of moose by managers and researchers. We detected moose in conifer cover up to 90 percent which is similar to findings in a previous study. Detection was near 100% up to a mean conifer canopy cover of 25%. Beyond that level of cover, detection declined, and we will present preliminary data on the slope of this relationship based upon trials using a modified double observer analysis approach. Using this data, we describe a method for quantifying sightability based on observation angle, conifer cover, ambient temperature, and cloud cover. Overall, this study suggests that UASs offer a promising method for estimating moose densities over broad spatial scales, even in the absence of tagged or GPS-collared individuals. We conclude with future directions for improving the efficiency of UAS surveys and reflect upon lessons learned while deploying this promising technology for moose research and management.

USING DISTANCE SAMPLING TO ESTIMATE THE ABUNDANCE OF ISLE ROYALE MOOSE

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Accurately estimating the abundance and growth rate of large ungulates is important for forest management and conservation in the face of global environmental change. We used distance sampling to estimate the moose (*Alces alces*) population on Isle Royale National Park (IRNP), an archipelago in Lake Superior, Michigan, USA. The NPS is also evaluating the use of distance sampling vs. a Gassaway approach to estimate moose abundance. Moose are the largest mammal on the island, influence plant diversity and distribution, and are an important indicator species for ecosystem health. We conducted aerial surveys in February 2022 and 2023 when snow cover facilitated detecting moose. A team of observers covered 507 sq km by flying 149 transects spaced 500 m apart in a helicopter and recording the distance from the transect to each moose. We used the Distance package in program R to estimate the density and total population size of moose on the island. In both years the top model was the hazard-rate model with canopy cover decreasing and group size increasing detection probability in 2022. The moose population appeared to decline from 1023 (95% CI = 792.5-1321) in 2022 to 864 (95% CI = 496-1505) in 2023. Our 2022 estimate is lower than the MTU Gasaway derived estimate of 1,346 (90% CI = 925-1842). A declining moose population in IRNP could reduce browsing pressure on vegetation and increase plant diversity. Distance sampling appears to be an effective method for estimating the moose population on IRNP and could be applied to populations in similar environments.

USING A TRAINED CONSERVATION DETECTION DOG TEAM TO EVALUATE POTENTIAL PARTURITION AND MORTALITY SITES OF NEONATAL MOOSE AND THEIR FINDINGS

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Following the population decline of moose (*Alces alces*) in Minnesota from their peak in 2006, there has been an added emphasis on monitoring calf recruitment rates on the tribal lands of the Grand Portage Indian Reservation. Moose are a culturally significant species and sustenance hunts are held annually on the reservation and adjacent 1854 Ceded Territory. To study cause-specific mortality and survival of calves, the Grand Portage Band of Lake Superior Chippewa contracted Find It Detection Dogs to use an experienced handler and trained conservation detection dog team to evaluate and confirm suspected birth and mortality events. Search areas were determined by evaluating cow moose GPS collar movements whereas a certain pattern would indicate a calf birth or mortality. During three field seasons spanning 2020 - 2022, we confirmed 40 calf mortalities that have probable causes attributed to 24 wolf (*Canis lupus*) kills, 8 black bear (*Ursus americanus*) kills, and 5 health-related deaths or still-births. In 2022 we also used the detection dog to confirm 19 birth-sites following a cow localization. Future directions include an expanded field season to include white-tailed deer (*Odocoileus virginianus*) fawn survival and cause-specific mortality rates in this multi-predator, multi-prey system. Understanding predation pressure and survival rates of these sympatric species can give land managers insight into predator-prey dynamics and have future management implications.

IS A NEW WAY BETTER? SAMPLING WINTER TICK DENSITIES ON TRIBAL LAND IN MAINE

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Parasites are one of the biggest threats to moose populations in Maine. Winter ticks (*Dermacentor albipictus*), brainworm (*Parelaphostrongylus tenuis*), and lungworm (unknown species) are the three parasites that are most detrimental to moose. Data from the Maine Department of Inland, Fisheries, and Wildlife (MDIF&W) radio-collar moose study has shown that dead moose, when necropsied, most often have at least two of the species of parasites listed above. In particular, moose that die in early spring usually have an extremely high load of winter ticks. Little is known about winter tick densities on the landscape. As such, the Penobscot Nation (PIN) Department of Natural Resources has begun a long-term study to measure winter tick densities on Tribal lands using a novel survey method. We created a new survey method in order to learn where, within these harvest areas, ticks were occurring as our previous method, did not obtain reliable data on distribution and habitat requirements. We selected tree harvests from 2 – 8 years old and 5 – 15 acres in size. We then created a 10-acre block and randomly placed it with the harvest area. We broke down that grid into even blocks of 50 square meters and created a centroid for each. We sampled 8 of those blocks weekly from October 13 – December 21st in 2021. To gain insight about factors influencing detection probability and abundance, we analyzed tick abundance data from 2021 using N-mixture models. Our preliminary results indicate that ambient temperature has a strong and positive effect on detection probability ($\beta = 0.51$, SE = 0.05, $P < 0.0001$) and winter tick abundance is significantly higher ($P < 0.05$) in the Grindstone, Matagamon, and Mattamiscontis regions. We are currently analyzing data from 2022 season (and October 13 – December 3rd in 2022) to evaluate the influence of different silvicultural practices on winter tick abundance.

DRIVER- AND LANDSCAPE-RELATED FACTORS ASSOCIATED WITH WILDLIFE-VEHICLE COLLISIONS IN THUNDER BAY, ONTARIO

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An analysis of 1,332 wildlife-vehicle collisions, most involving moose (*Alces alces*) or white-tailed deer (*Odocoileus virginianus*), from 2011-2021 on highways around Thunder Bay was undertaken to determine whether deer or driver behaviour is more influential on where and when the accidents occurred. Ontario's Land Cover Classification produced ambiguous results, with forest cover less associated than expected with collisions on the major highways (11/17 and 61) but more associated than expected on two of six rural highways (589 and 591). Disturbed forest was more associated with collisions on the major highways and less associated with collisions on the same two rural highways. In developed areas there were more collisions than expected in two cases (highways 61 and 130) but fewer than expected in one case (highway 527), and agricultural areas were in two cases associated with more accidents than expected (highways 588 and 590). Stream crossings were associated with more accidents than expected on highways 11/17 and 590. There was no association with posted speed limits and the occurrence of collisions. Between 30 and 100% more accidents occurred during sunrise and sunset hours in every month except July, and higher frequency of accidents occurred between 6 am and 8 am and between 6 pm and 11 pm. Weekday occurrence was approximately even, between 13 and 15% of all accidents occurring each day of the week. Peaks in accident occurrence happened in June, likely with dispersing juveniles, and in November, likely with the rut occurring in white-tailed deer. The idea that driver behaviour is more influential on where and when accidents occurred was ruled out by this review, with moose and deer associations with disturbed areas, development and stream crossings stronger factors to bear in mind when posting warning signs and other mitigative measures like shoulder clearing and reducing curves in roadways.

UNDERSTANDING HOW THE HEALTH OF MOOSE IN ISLE ROYALE NATIONAL PARK IS INFLUENCED BY WEATHER AND WOLF PREDATION.

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Moose populations throughout many parts of the species range are thought to be exposed to increasing stressful environmental conditions due to climate change as well as the recent recovery of one of their main predators, grey wolves (Canis lupus). In order to conserve and manage healthy moose populations there is a growing need to better understand how changes in environmental conditions (i.e. weather patterns and predation risk) influence various aspects of moose health and cause it to fluctuate from year to year.

Here we synthesize the findings of long-term research which assessed the influence of wolf predation and several weather variables on three different aspects of health for the moose population in Isle Royale National Park. First, we assessed the extent that winter tick (Dermacentor albipictus) burdens for moose were influenced by seasonal temperatures and precipitation and the risk of being killed by wolves using data collected over a 19-year period. Second, we assessed the extent that the nutritional condition of moose in winter was influenced by seasonal temperatures and precipitation and the risk of being killed by wolves using data collected over a 29-year period. Third, we assessed how the prevalence of a non-communicable disease, osteoarthritis, in the moose population was influenced by wolf predation and stressful environmental conditions using data collected over a 60-year period.

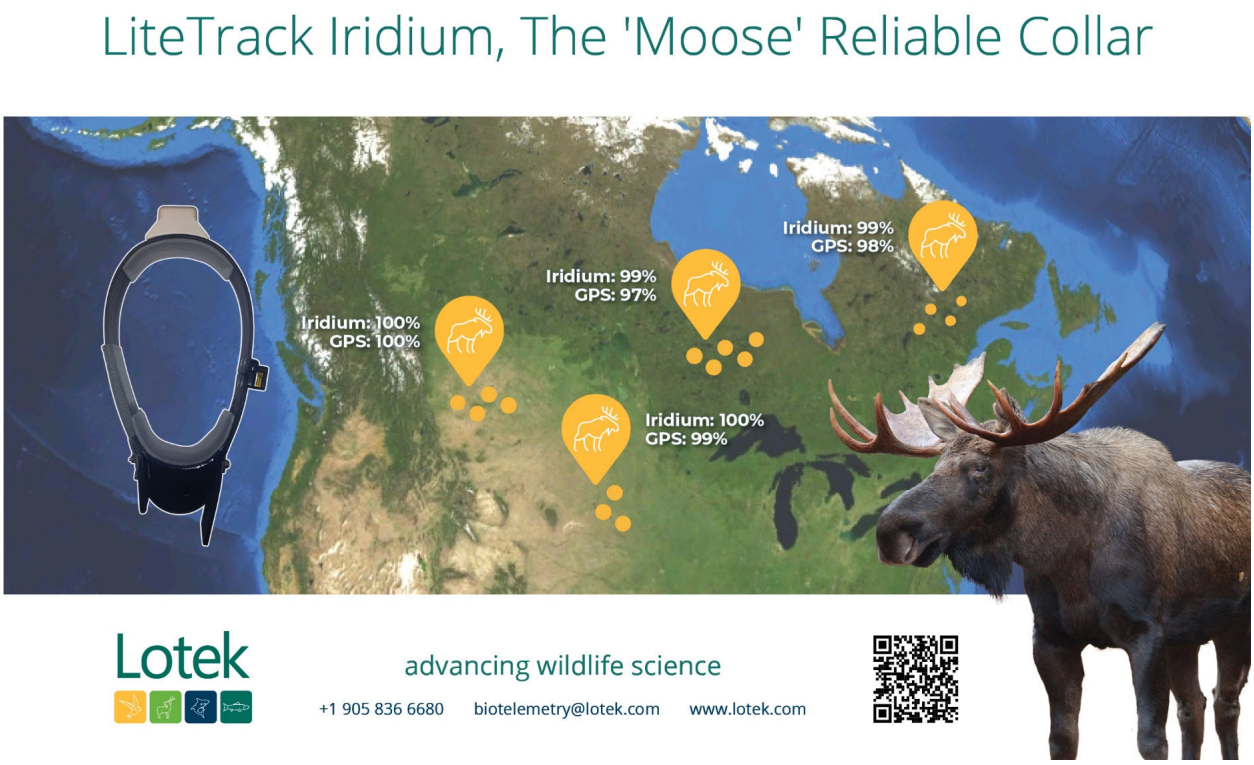
We monitored tick-burdens for moose using photographic surveys in spring to determine the extent that moose had lost or damaged their winter coat hair because spring hair-loss surveys have been shown to provide a good indication of interannual variation in the number of winter ticks on moose. We monitored the nutritional condition of moose in winter by collecting urine-soaked snow and analyzing the ratio of urea nitrogen to creatinine which is an index of nutritional restriction for ungulates in mid-winter. We monitored the prevalence of osteoarthritis by examining the skeletal remains of moose that died from natural causes.

Tick burdens tended to be greater for moose following warmer summers, presumably because warmer temperatures accelerate the development of tick eggs and increase egg survival. Tick burdens were also positively correlated with wolf predation rate, maybe due to moose exhibiting risk-sensitive habitat selection (in years when predation risk is high) in such a manner as to increases the encounter rate with questing tick larvae in autumn. However, that positive correlation could also arise if high parasite burdens make moose more vulnerable to predators.

Moose tended to be more nutritionally stressed during winters with deep snow and during winters that followed warm summers. An adverse effect of deep snow on the nutritional condition of moose most likely arises because it is more energetically costly for moose to travel and find food when the snow is deep. The adverse effect of warmer summers on the nutritional condition of moose may be partly due to warmer summers increasing tick burdens for moose. Warmer summer temperatures may also cause moose to become heat-stressed and reduce food intake rates. Lastly, we found that moose which experienced stressful conditions in early life were more likely to develop osteoarthritis as adults. We also found evidence to suggest that the prevalence of osteoarthritis in the moose population declined following years when wolves killed more moose – a relationship which arises because wolves were selective killing moose with osteoarthritis and thereby removing diseased individuals from the population.

POSTER SESSION ABSTRACTS

Poster #1 was withdrawn



POSTER #2

RISK FACTOR ANALYSIS AND GEOGRAPHIC DISTRIBUTION OF ANAPLASMA INFECTIONS IN MAINE MOOSE

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Anaplasma is a genus of bacteria that are intracellular blood parasites known to infect a wide range of mammalian hosts. Moose (*Alces alces*) in Europe have been found to be infected with a tick-borne zoonotic Anaplasma species, *A. phagocytophilum.* In North America, our prior work has shown moose are infected with a non-zoonotic *Anaplasma* species that is specific to cervids and shares a common ancestor with *A. marginale*, which is known to cause weight loss, abortion, and death in cattle. Maine moose calves have been experiencing reduced overwintering survival while adult female moose have seen a decrease in calving rates; both declines have been attributed to severe infestations by the winter tick (*Dermacentor albipictus*). Our preliminary work shows that *Anaplasma* infections may also further affect the overwintering survival probability of calves, emphasizing the need to better understand the epidemiology and fitness effects of this parasite in moose. Here, we examine the distribution of *Anaplasma* infections in Maine moose, utilizing two years (2021 and 2022) of biological samples collected from hunter-harvested moose throughout the state. Our specific goals were to (1) evaluate geographic variation in *Anaplasma* infection prevalence, (2) determine risk factors predicting infection, including age, sex, and location of harvest, and (3) examine relationships between infection and female corpus luteum counts (as an index of reproductive output) in moose across the state. We collected biological samples representing 215 moose, from age 1 to 15 years old, and across 11 Wildlife Management Districts (WMDs) managed by the Maine Department of Inland Fisheries and Wildlife. Preliminary results show a widespread distribution of *Anaplasma* infections in moose throughout the state of Maine, with prevalence being the highest in areas of higher moose density (e.g., WMDs 4 and 5). Furthermore, preliminary analyses show a negative correlation between corpus luteum counts in females and individual infection probability, such that female moose infected with *Anaplasma* spp. have significantly lower corpus luteum counts than their uninfected counterparts. These data provide a deeper understanding of both the distribution and potential health effects of *Anaplasma* parasites to help inform the management of moose in Maine.

POSTER #3

EVOLUTION AND STRAIN DIVERSITY OF ANAPLASMA BACTERIAL INFECTIONS IN NORTH AMERICAN MOOSE

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Moose (*Alces alces*) populations in the northeastern United States have recently experienced increased calf mortality due to parasite infections. While winter ticks (*Dermacentor albipictus*) have been found to be the primary driver of calf mortality events, co-infecting parasites such as the *Anaplasma* intracellular blood bacteria may also affect moose fitness, particularly in individuals already suffering from blood loss due to severe tick infestations. Moose in Scandinavia have been found to be infected with a zoonotic *Anaplasma* species, *A. phagocytophilum*, which causes anaplasmosis in humans. In North America, while reports of Anaplasma infections have been documented in moose, little is known about the variation, prevalence, and distribution of strains among populations as well as the potential for cross-species transmission. We genetically characterized Anaplasma infections in moose from three states (Maine, Minnesota, Idaho) with the following objectives: (1) to taxonomically identify Anaplasma spp. infecting moose; (2) to evaluate strain variability, distribution, and prevalence in populations across their range; and (3) to examine evolutionary relationships among moose strains identified in the context of *Anaplasma* spp. derived from other host species, including elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), cattle (*Bos taurus*), humans, and potential vectors (ticks, Tabanid flies, deer ked). We found that North American moose are infected with non-zoonotic Anaplasma variants, which have only been found in cervids but share a common ancestor with those found in domestic livestock (*A. marginale*, *A. bovis*). Anaplasma strain diversity was low within and between moose populations. In Maine, a single genetic variant was found in 54% of moose (n = 157), which has increased in prevalence to 97% between 2017 and 2022. In Idaho, two divergent Anaplasma variants were found in moose, one of which was shared with Maine moose, and the infection prevalence was 46% (n = 54). Our data further suggest that winter ticks and Tabanid flies are not likely vectors for this potential bacterial pathogen in moose, but further work is needed to elucidate the transmission mode. Ongoing analyses are expected to reveal how widespread Anaplasma infections are in North American moose as well as the potential for cross-species transmission.

POSTER #4

TERRITORY IN TRANSITION: HABITAT SELECTION AND APPARENT COMPETITION IN BOREAL PLAINS MOOSE

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Apparent competition refers to a hypothesis wherein two prey species indirectly compete with each other by sharing a common enemy. While it is far from a new discovery, apparent competition is an emerging threat to cervid populations residing in the Boreal Plains of western Canada. White-tailed deer (*Odocoileus virginianus*) have typically been excluded from inhabiting the moose (*Alces alces*) and boreal caribou (*Rangifer tarandus caribou*)-occupied boreal forest due to extreme winter cold and snow depths in the region. These population dynamics, however, have begun to gradually shift as rapid climate — landscape change facilitates extensive modification of the terrestrial environment. The invasion of white-tailed deer northward has correlated with declines in populations of moose and boreal caribou, both of which are an important species for northern and Indigenous food sovereignty. Apparent competition with white-tailed deer has been identified as a driver of boreal caribou declines through increased wolf (*Canis lupus*) predation pressure, as deer act as an alternate prey species and supplement the wolves' diet. The question remains, however, if the observed ~30% moose population decline since 2000 in the Boreal Plains may also be explained through apparent competition. We aim to determine the preferred seasonal habitats of female moose relative to that of white-tailed deer, and how this may factor into differential annualized mortality and recruitment of moose in the context of apparent competition.

White-tailed deer can present an indirect threat to moose by increasing the potential for contact with predators, like wolves, but also pathogens (meningeal worm, winter ticks, novel chronic wasting disease). We predict that female moose and white-tailed deer, as browsing ungulate prey species, will generally select habitats offering high nutrition leading to potential apparent competition through range overlap. For the first phase of this research, we plan to use resource selection functions to determine preferred moose habitat at the population and individual level using used vs. available landscape features (vegetation cover type, distance to linear features, disturbance layers) to investigate variation in mortality and calf recruitment across landscapes. This data will serve as the basis for future analyses considering whether moose with resource selection patterns that more closely overlap with invading white-tailed deer will suffer higher overwinter mortality and lower annual recruitment (calf survival) than individuals with alternate habitat usage.

Proximate causes of population decline in moose in the western Boreal Plains remain largely unknown, yet they are already having profound impacts on the natural environment and lifestyle of Indigenous and northern communities in Saskatchewan. Our research sits at the front of emerging techniques for quantifying the influence of indirect ecological interactions in food web dynamics. The patterns of habitat selection in a vastly changing landscape provide valuable empirical evidence for the significance of these novel indirect interactions, and importantly, how they relate to environmentally and culturally significant species in the region.

POSTER #5

SEASONAL MOOSE HABITAT USE AND OVERLAP IN THE CONTEXT OF WINTER TICK

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In recent years, the moose (*Alces alces*) population in the northeastern United States has declined, primarily due to parasitism by winter ticks (*Dermacentor albipictus*). Three factors drive winter tick (WT) epizootics: climate change, moose density, and overlap in moose seasonal habitat use. Previous research has shown that moose density increases with the proportion of optimal habitat (regenerating forest stands aged 4-16 years) available on the landscape. Average individual WT load is positively correlated with moose density. Given that moose concentrate their time in optimal habitat patches, presumably WT density is disproportionately high in these areas. We used data from GPS-collared moose from 2014–2020 in Maine to estimate seasonal home ranges of moose corresponding to the questing (fall) and drop-off (spring) periods of WT. Our objective was to explore factors driving variation in seasonal habitat use and overlap and how these variables relate to WT loads of moose. Using dynamic Brownian bridge movement models, we calculated 352 fall and 405 spring home ranges across 7 years for 192 moose (161 female, 31 male). Fall home range size was larger than spring home range size ($\bar{x}$ fall = 25 / 55 km^2 ; $\bar{x}$ spring = 6 / 7 km^2 for females/males respectively). We analyzed seasonal home range overlap using volume of intersection for females only; proportion of overlap between spring and fall home ranges ranged from 0 to 36%. Preliminary results gathered using generalized linear mixed models indicate that in addition to sex and season, home range size and overlap vary with age, spring snow depth, and the proportion of optimal habitat within moose home ranges. We hope that the results of this research will help inform the dynamics of this system and potentially guide management decisions.

POSTER #6

LANDSCAPE SCALE TREATMENTS TO MEET MULTIPLE OBJECTIVES ON THE SUPERIOR NATIONAL FOREST

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Natural disturbance in Northeast Minnesota is largely from wildfires that historically occurred at spatial scales of 400-4000s hectares (1000s to 10,000s acres). Such large-scale disturbances create a landscape mosaic providing important wildlife habitat for many species, including moose (*Alces alces*). Moose population surveys within Minnesota demonstrate a multi-decadal population decline; these surveys also suggest that moose numbers have had a positive temporal response to large-scale prescribed burns and wildfires. In contrast, past management on the Superior National Forest (SNF) has resulted in fragmented landscapes with smaller spatial scales averaging 19ha (47ac). With consultation from tribal biologists and following objectives within our Forest Plan, we recognize the need to better emulate the role of larger-scale disturbance on the landscape to support viable populations of moose. Such treatments can be challenging to design, operationally difficult, and sometimes conflict with other planning objectives. We have made strides, however, in creating new young forest patches of 400ha (1,000ac) or greater using an array of treatments. These treatments include timber harvest, prescribed fire, and non-harvest mechanical treatments using an interdisciplinary approach.

In fall 2017, the SNF began implementing a 131ha (324ac) timber harvest followed by a 316ha (781ac) prescribed burn in a fire-dependent ecosystem defined by jack pine, aspen, paper birch, and artificially planted red pine. The project planning approach used a team of silviculturists, wildlife biologists, foresters, and prescribed fire specialists to identify a future young patch that extended to wetland features and roads. The team decision was made to final harvest some red pine plantations earlier than usual and to make reforestation consistent with native plant communities. Project level design features were added for legacy patches, burn inclusions, and reserve trees. In June 2019, the entire project area was prescribed burned; this encompassed all harvested and non-harvested areas and extended to natural holding features to emulate a historic fire event. This case study provided a learning opportunity for current and future planning efforts focused on landscape-level management. Multiple, and at times, conflicting objectives necessitated facilitated teamwork discussions. Logistical struggles in large-scale burn planning are often national in scope. The size of the units and year-to-year uncertainty with available burn windows caused logistical problems procuring appropriate planting stock. A small pool of local operators for large-scale harvest was a capacity challenge given a relatively short timeframe needed to harvest and meet burn plan parameters.

This approach has been extended to other projects at various stages of implementation across the SNF. Identifying quality patches at spatially appropriate scales within core moose habitat requires a mix of available land management tools in an interdisciplinary approach. Benefits include optimizing multiple resource objectives, expanded funding opportunities and generally lower implementation cost per hectare. Further improvements should focus on the need to work across administrative ownerships and leverage partnerships in shared landscape level goals.

POSTER #7

NEW APPROACHES TO WILDLIFE DETECTION FOR BOREAL PLAINS LARGE MAMMALS; DRONE-LEVEL RESOLUTION WITH AIRCRAFT-LEVEL COVERAGE

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New approaches to wildlife detection tackle the fundamental, yet intractable, problem of how we might more cost-effectively obtain accurate, precise, and simultaneous data on multiple wildlife populations at the scale of the Boreal Plains ecozone to monitor complex population dynamics and test ecological theory. We aim to develop the foodweb dynamics modelling that has been beyond the reach of ecologists due to lack of data on densities of interacting species, especially for species that are costly to monitor like large mammals in forested environments. Moose (*Alces alces*) are present throughout the Boreal Plains ecozone, while other large mammals including white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), bison (*Bison bison*), feral horses (*Equus caballus*), wolves (*Canis lupus*), and bears (*Ursus* sp.) have varying distributions and densities across the ecozone. While traditional survey methods are often forced to focus on one target species at a time, aerial imagery provides a permanent recording of all large species flown over, allowing for multiple usages of the same data. To work towards our goal, we purchased a TK-7 imaging payload from Overwatch Imaging in 2022. It allows a multi-spectral, high resolution but scalable imaging payload (up to 3-cm colour resolution plus co-boresighted infrared; coverage up to 1000 km^2 per day using fixed-wing aircraft) to remotely census large mammals. We are working in conjunction with the Department of Computer Science at the University of Saskatchewan to use artificial intelligence and deep learning to optimize automated identification and counting in complex environments. Equipped on a Cessna 182 aircraft, the system is designed to bridge the resolutions obtainable from drone imagery and the scale of surveillance obtainable from aircraft imagery. The purpose of initial flights has been to optimize and test the system under various scenarios related to acquiring colour and thermal imagery of wildlife in zoo situations, as well as in the wild in spring, summer, and winter. Our initial data are being annotated to create training images for development of a deep learning algorithm with the ultimate goal of streamlining a pipeline of data acquisition (transects of imagery) for computer-aided identification of targets of significance (large mammals bearing signatures of colour and thermal gradients) leading to human-assisted identification and counting. Research and development largely relates to optimizing flight factors (temperature, sunlight, snow, and leaf-out conditions; altitude and thus resolution and transect-strip width) and logistics (e.g., estimated on-line flying hours accounting for refueling and daily restrictions on accumulated hours for pilots). Initial data are promising, and we anticipate that exposed large animals can and will be detected by our imagery and algorithms. Animals in the open, where no deciduous leaves are present, are much easier to observe. After leaf-out, animals are detectable in thermal but unidentifiable due to leaves obscuring colour; and so, we are likely to optimize our flights to occur from mid-April (in the south) to as late as early June (in the north, including in caribou habitat). Once flight optimizations and algorithms are in place, future work includes ecological modelling of multiple-prey ecosystems using the large mammal densities.

POSTER #8

TEMPORAL VARIATION IN ISLE ROYALE WOLF DIET

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Wolves (*Canis lupus*) can exert top-down pressure and shape ecological communities through the predation of ungulates and beavers (*Castor* spp.). Therefore, understanding wolf foraging is critical to estimating their ecosystem-level effects. Specifically, if wolves are consumers that optimize tradeoffs between the cost and benefits of prey acquisition, changes in these factors may lead to prey-switching or negative-density dependent selection with potential consequences for community stability. For wolves, factors affecting cost and benefits include prey vulnerability, risk, reward, and availability, which can vary temporally. We described the wolf diet by the frequency of occurrence and percent biomass and characterized the diet using prey remains found in wolf scats on Isle Royale National Park, Michigan, USA, during May–October 2019 and 2020. We used logistic regression to estimate prey consumption over time. We predicted prey with temporal variation in cost (availability and/or vulnerability) such as adult moose (*Alces alces*), calf moose, and beaver (*Castor canadensis*) to vary in wolf diets. We analyzed 206 scats and identified 62% of remains as beaver, 26% as moose, and 12% as other species (birds, smaller mammals, and wolves). Adult moose were more likely to occur in wolf scats in May when moose are in poor condition following winter. The occurrence of moose calves peaked during June–mid-July following birth but before calf vulnerability declined as they matured. By contrast, beaver occurrence in wolf scat did not change over time, reflecting the importance of low-handling cost prey items for recently introduced lone or paired wolves. Our results demonstrate that the wolf diet is responsive to temporal changes in prey costs. Temporal fluctuation in diet may influence wolves' ecological role if prey respond to increased predation risk by altering foraging or breeding behavior.

POSTER #9

WOLF PREDATION RISK TO MOOSE IN NORTH-CENTRAL BRITISH COLUMBIA

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In response to concerns about the role of wolves as potential drivers of moose population change, we investigated several aspects of predator-prey dynamics between wolves and moose in two of the Provincial Moose Research Project study sites, south of Prince George (PGS) and north of Fort St. James at the John Prince Research Forest (JPRF). The objective was to assess wolf predation risk to moose in two study areas with differing landscape disturbance: more mountain pine beetle salvage logging in the early 2000s in PGS, and less impacted/more recent pine salvage in JPRF. Predation risk is a function of wolf density, space use, habitat selection, and predation patterns (prey species and characteristics, kill rates, habitat use), and a better understanding of these factors will be key to evaluating options for moose enhancement.

We collared 33 wolves in 11 packs, six packs in PGS and five in JPRF. Based on mid-winter pack counts and home range size, wolf density is about 11-14 wolves/1000 km^2 in PGS and 7 wolves/1000 km^2 in JPRF (not including lone wolves, which are usually around 10% of the population). To assess kill site and prey characteristics, we used a cluster algorithm on hourly collar locations and investigated 1208 clusters on the ground. We identified 290 kills, predominantly moose in PGS (87%) and JPRF (75%). Wolves also killed deer, elk, black bears, and cattle. Wolves appeared to select calves, as 27% of the moose kills we found were calves while the mid-winter calf component of the population was 13-20%. Kill sites on neonates were not accounted for due to short handling time. Both kill sites and the midwinter calf estimate only consider these larger-bodied calves, and the calf proportion decreases through late winter when most mortality occurs, suggesting an underestimation of the selection for calves.

We determined kill rates based on complete time series of kills when we were able to visit all clusters that likely contained a kill (this varied depending on the collared wolf; some had predictable clustering behaviour around kills while others required more investigation of smaller clusters). We adjusted the observed kill rates for the probability of attendance of a collared wolf at any of the pack's kills. Wolf packs in PGS killed a moose every 4-8 days in the winter and every 8-11 days in the summer (excluding neonate predation which we were not able to detect). In JPRF, wolf packs killed a moose every 7-12 days in the winter and every 19-26 days in the summer, but when we considered the number of wolves per pack in the two study areas, the kill rates per wolf were similar. Kill rates are the number of prey killed by a predator, but predation rates translate that to the effect on the prey population, typically as the proportion of the prey population lost to predation. Based on recent midwinter moose density estimates (Scheideman and Anderson 2021), these kill rates would equate to 7-20% of the moose population for PGS and 2-8% of the moose population for JPRF (excluding any neonate mortality, but this is also accounted for in midwinter density estimates). Sustainable predation rates depend on the ability of the prey population to recruit new individuals to replace those lost to predation or other causes, and the predation rates here are likely sustainable. These predation rates may not be indicative of predation rates during the moose decline in the 2000s, so it is important to consider what mechanisms could contribute to changes in kill rates.

POSTER #10

EXPANDING OUR UNDERSTANDING OF HOW MOOSE USE AVAILABLE FOREST RESOURCES IN NORTHEAST MINNESOTA

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Moose (*Alces alces*) populations at the southernmost edge of their geographic range can be particularly vulnerable to the impacts of climate on critical habitat resources, disease dynamics, and interspecific interactions. In northeast Minnesota, the moose population has experienced a >60% decline over the past two decades; the projected changes in forest composition, as a result of climate change, pose a challenge to both forest and wildlife managers desiring to maintain if not increase the current moose population levels and geographic distribution. Understanding how moose use the available forest resources currently is important for managing the species and its habitat and enhance moose resilience to future climates. We used GPS collar data from 158 radio-collared moose (45 males, 113 females) collected between 2013 and 2018 to investigate the forest types that moose select for within seasonal home ranges, and to evaluate if the patterns of selection vary across years, seasons, and sex. Based on 95% kernel estimates of home ranges, across all moose, the most frequent types of forests available to moose in northeastern MN included forested and open swamps, wetlands and meadows, pine (*Pinus* sp.) & black spruce (*Picea mariana*), balsam fir (*Abies balsamea*) & white spruce (*Picea alba*), and northern hardwood forests. Resource selection models suggest moose are slightly more likely to use northern hardwood, aspen birch, and flood plain forests than fir spruce forests. Conversely, moose are less likely to use forested wetlands and pine and black spruce forests than fir spruce forests compared to the availability of these forest types. The patterns we observed were consistent across seasons, years, and sex with only slight variations. Males and females exhibited similar habitat selection patterns when combining all seasons and years, but showed more substantial differences across seasons. These preliminary results indicate male and female moose are using habitats with greater composition of forage (e.g., aspen, preferred woody species in floodplain and northern hardwood forests) as well as benefiting from the thermal function of coniferous forests (e.g., fir spruce forests) throughout the year. In addition to discussing these results, we will explore the importance of forage and thermal cover habitat using finer-scale classifications that incorporate forest structure (e.g., browse quantity and quality available < 16 feet). This information will provide a more complete understanding of the relationship between forest cover types and their function as it relates to moose forest resources requirements. Our results will also inform how changing forests in response to climate might influence moose habitat use and ultimately distribution throughout NE MN.

POSTER #11

MODELING FOREST CHANGE WITHIN MINNESOTA MOOSE RANGE UNDER DIFFERENT CLIMATE SCENARIOS

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Forest landscape models provide a tool to project how forest conditions may change into the future under different scenarios. These simulations can help forest managers foresee the potential long-term consequences of decisions being made today, within the context of dynamic environmental drivers such as a changing climate, and natural and anthropogenic disturbance regimes. Changes to forest conditions over time have the potential to impact wildlife species as the abundance and configuration of their habitats change. Here we present a demonstration of preliminary forest simulation model outcomes for the area within moose range in northeastern Minnesota using current forest management prescriptions by land ownership under multiple climate scenarios.

We used the simulation model LANDIS-II to represent forest successional dynamics, along with disturbance regimes representing wind, fire, insects and “business as usual” timber harvest. The disturbance regimes were calibrated based on recent historical patterns. We simulated scenarios utilizing multiple climate projections (current conditions, RCP4.5, RCP8.5) to evaluate the impacts of climate on forest conditions. These simulations are part of a larger project evaluating whether climate adaptive forest management strategies can mitigate negative impacts of climate change on moose while also reducing contact with white-tail deer that transmit fatal parasites. Landscape simulation models produce voluminous outputs that can be summarized in many ways. We present a sampling of landscape scale results for moose-relevant variables, comparing the outcomes from the three climate scenarios.

POSTER #12

SEASONAL PLASTICITY OF RESOURCE SELECTION DIFFERS BETWEEN MAINLAND AND ISLAND MOOSE POPULATIONS

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Ecological seasonality describes the dynamic adaptation of species to changes in the biotic community of their environment. Such patterns manifest as altered behavior (e.g., movement speeds) and resource selection (e.g., forage, cover) dependent on the local predator-prey community. We hypothesized adjacent mainland and island large mammal populations would exhibit differing ecological seasons dependent on their respective predator-prey communities. We compared seasonal resource selection of mainland moose (mooz; *Alces alces*), white-tailed deer (waawaashkeshi; *Odocoileus virginianus*), and gray wolves (ma′iingan; *Canis lupus*) on and near the present and ancestral homelands of the Anishinaabe people of the Grand Portage Band of Lake Superior Chippewa including the Grand Portage Indian Reservation (Gichi Onigaming; GPIR), Minnesota, USA and island moose and gray wolves in Isle Royale National Park (Minong; IRNP), Michigan, USA. Moose and white-tailed deer remain important subsistence species for the Anishinaabeg, and their interrelationships with gray wolves are of high value to the band's seven-generation management objectives. We deployed GPS collars on mainland gray wolves (beginning in 2008), moose (2010), and white-tailed deer (2016) plus island gray wolves (2018) and moose (2019) and used locations collected through 31 December 2021. We extracted landscape covariates from public databases and applied cluster analysis and principal components analysis to determine the timing and drivers of seasonal behavioral changes among populations. We used weighted autocorrelated kernel density estimation for weighted resource selection functions to assess within-season third order selection for each population. Mainland populations generally exhibited two behavioral seasons with transitions coinciding with changing weather and the timing of white-tailed deer migration, though moose exhibited two additional brief seasons before parturition. Selection for landscape attributes varied between seasons for mainland populations with resource selection appearing to correspond with seasonal forage availability. In contrast, island moose and gray wolves did not exhibit ecological seasonality. Resource selection was instead driven by geographic patterns whereby gray wolves remained near the island's shorelines while moose used more interior parts of the island. The lack of seasonal transitions in IRNP is likely due to the seasonally static nature of predator-prey interactions but may alternatively be attributed to differences in snow conditions and/or behavioral instability of gray wolves following their recent reintroduction. Our findings support theoretical predictions of community-level transitions through ecological seasons resulting from species-specific responses to varying landscape conditions and predator-prey dynamics. These results demonstrate the importance of managing moose within the context of local associated species communities.

POSTER #13

ISOTOPE SPATIAL-ECOLOGY OF MOOSE FROM SWEDEN

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The discipline of spatial ecology is increasingly applied to conservation and management issues to find effective ways to preserve biodiversity. The first step to allow ecosystem preservation is to study how wildlife species move across the landscape and to quantify and predict their spatial distribution. Today this is possible through an integrative approach that brings together ecological theory, statistical modelling and geochemical analyses. It is now well established that mobility patterns are imprinted in the geochemical signature of human and animal bones and teeth, enabling the study of animal movement during tissue formation. The strontium (87Sr/86Sr) and oxygen (δ18O) isotope analyses on modern moose samples will be useful as an integrative approach to ecological studies on this animal, complementing traditional methods of tracking mobility (i.e. radio-, satellite- and GPS-tracking) and providing a new tool for management and conservation practices.

Here we used n = 65 modern wild-shot *Alces alces* from Sweden to understand the potential of isotope markers unravelling moose home-range and migratory behaviour. To do so, we measured strontium (87Sr/86Sr) and oxygen (δ 18O) isotopes in moose bones and antlers and compared their values with isoscapes of Scandinavia. The Sr isoscape was built using Random Forest machine learning algorithm with literature data on natural samples from Scandinavia (i.e. vegetation, waters, soils leachates, snails, modern and archaeological fauna). The δ 18O isoscape was downloaded from waterisotopes.org and represents the mean modelled climatological prediction based on annual precipitations. The 87Sr/86Sr ratio of moose samples is on average 0.7301 [0.7119, 0.7530]. Such radiogenic values reflect the bedrock geology of Scandinavia, which is dominated by old (Precambrian) rocks. O isotopes of the carbonate moiety structurally bound in the bone bioapatite yielded a mean δ18OVSMOW value of 21.5 [18.5, 24.7] ‰, in agreement with environmental values observed in Scandinavia. Most individuals have isotope compositions compatible with their place of death, suggesting limited mobility during the last years of life. In contrast, some moose display values not compatible with their place of death (i.e. > 100 km distance), thus being non-local in origin. By statistically comparing the data with regional-wide isoscapes, we obtained a first glimpse on *Alces alces* large-scale mobility. The workflow presented here can be transferred to the study of other animal species and to other fields.

POSTER #14

ARTICULATION AND 3D PHOTOGRAMMETRY OF A MOOSE NEONATE SKELETON

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Moose (*Alces alces*) are a well-studied species in North America. Taxidermy and skeletal articulations of moose are found in hunting lodges and nature museums worldwide. Unfortunately, access to these educational specimens is limited to those who live near one of such displays. On top of the accessibility limitations, typically only mature specimens are on public display. In May of 2017, a moose neonate came into UNBC's possession after passing away from a sepsis infection. After its passing, we methodically extracted, cleaned, and articulated the immature skeleton; new methods had to be formulated to accomplish the never-before documented task. After the articulation was complete, the skeleton was scanned using 3-dimensional photogrammetry. This scanning created a virtual object that can be examined from anywhere, and likewise 3D printed to any scale, enabling greater accessibility to the educational specimen. These novel methods and techniques present an opportunity to fill gaps in the literature on both methods of working with immature bones of neonate moose as well as increasing accessibility of biological specimens via 3D technologies.

POSTER #15

BEHAVIOURAL ECOLOGY OF MOOSE AT ROADSIDE MINERAL LICKS IN NORTH-CENTRAL BRITISH COLUMBIA

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The use of mineral licks by moose (*Alces americanus*) has been well-documented throughout much of their range in North America. Moose are thought to visit mineral licks primarily for the acquisition of minerals, particularly sodium, which may be lacking in the diet but are required for many physiological processes. Roadside mineral licks are formed mostly by the accumulation of de-icing salts used on road surfaces in winter, and as a result become highly attractive to moose and other ungulates seeking mineral supplementation. Consequently, moose travelling through transportation corridors to access roadside mineral licks can become a hazard to motorists and put themselves at risk of vehicle collisions. In north-central British Columbia, hundreds of moose-vehicle collisions (MVCs) occur annually, resulting in loss of human and animal life, human injury, and expenses due to vehicle damage, heightened insurance premiums, highway cleanup, carcass disposal, lost revenue from hunting and recreation, vehicle towing, and medical costs, among others. Moose visitation to mineral licks, including roadside mineral licks, is known to be highly dependent on season and time of day, peaking in late spring and early summer and between the hours of sunset and sunrise. This knowledge has helped wildlife managers and transportation agencies gain a better understanding of the risks of MVCs, as well as develop strategies on how to mitigate them. The specific behaviours exhibited by moose exposed to traffic at roadside mineral licks, however, has not been sufficiently explored, leaving a gap in our knowledge about risks to the motoring public of moose using roadside areas. The primary goal of this study was to identify and describe the behaviours demonstrated by adult moose of various demographic classes (bulls, solitary cows, and cows with young) at five roadside mineral licks in north-central British Columbia from July 2012 to July 2020 using video-enabled camera traps. In addition, seasonal variation of proportions of time spent engaged in the most prominent behaviours was investigated using generalized additive mixed models. Site and year were controlled for as random effects in these models. Visitation of moose to roadside mineral licks by month and time of day was also explored. Major behaviours (those most often observed) included vigilance, licking, moving, smelling, and foraging. Minor behaviours (those briefly or rarely observed) were grooming, urinating, lying, nursing, aggression, and scratching. Vigilance and licking were the two most prominent behaviours for all classes of moose, followed by moving and smelling. Relatively little time per visit was spent foraging. Between May and October, moose spent the highest proportion of time licking, with this behaviour peaking in June. Bulls spent more time per visit licking than did solitary cows, but not more than cows with young. Proportion of time spent vigilant was less variable by season and did not vary between different demographic classes of moose but was highest in April. Visitation for all moose was highest between the months of May and July and during the night. Bull visitation peaked in May, solitary cows in June, and cows with calves in June and July. Time of year did not sufficiently explain the variation in proportion of time that moose spent licking and being vigilant, suggesting a multitude of factors such as site, year, individual behavioural repertoire/age, mineral composition, and traffic volume may influence moose behaviours at roadside mineral licks. With a more comprehensive understanding of how moose behave at roadside mineral licks and when they are likely to be present, wildlife managers and transportation agencies can develop informed strategies to provide public awareness of the hazards of moose and prevent MVCs.

POSTER #16

INTERPRETING CAMERA TRAP PHOTO DATA OF MOOSE USING ROADSIDE MINERAL LICKS: WHAT IS BIOLOGICALLY RELEVANT?

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Camera traps are increasingly being used to study wildlife distribution, abundance, and behaviour, but researchers often encounter challenges when trying to study unmarked individuals. One such challenge is efficiently defining independent visits when individuals are not easily distinguishable. In a review of camera trap papers, we found that the time thresholds and combination methods used to define independent visits were often unclear, arbitrary, or did not consider the specifics of the study system, including the biology of the focal species. Hereafter, we refer to the time thresholds and combination methods used to define independent visits as rules. In this study, we assessed the number of generated independent visits following the application of a number of rules for combining wildlife camera monitoring data. We focused the analysis on images of moose (*Alces alces*) visiting a camera trap set up at a roadside mineral lick in north-central British Columbia, Canada from January 2020 to December 2021. No camera or memory card failures occurred during this time period. We compared the generated independent moose visits to the total number of images, recognizing that total number of images is a simpler and more efficient measure of moose trend data. By applying common rules used in the literature that combined visits with a time threshold of 15 min, 30 min, 1 h, and 1 day between consecutive series of images, we generated independent moose visits compared to the total number of images of moose. We used correlation analysis to determine if there was a relationship between the total number of images and the number of independent visits, after applying the various rules to classify independent visits. We used Kruskal-Wallis tests to determine if the total number of images were significantly different by month and if the number of visits were significantly different by rule. We found a strong correlation between the patterns of the total number of images and the number of independent visits for all rules. As the total number of images increased, the difference in the number of independent events to the total number of images among rules increased, accordingly. The Kruskal-Wallis test showed a significant difference between the total number of images by month between the month of January and the month of June only. However, there were no statistically significant differences between the number of independent visits by rule. Our findings demonstrate that the total number of images is representative of the number of generated independent moose visits. The number of independent moose visits did not differ greatly among rules, but those differences increased proportionally to the total number of images collected. The difference between the number of images between the month of January and the month of June could be explained by the relatively low total number of images collected in January when compared to June, resulting in fewer visit combinations. Our results suggest that the total number of images at a camera location could be used as an index of moose trend data, saving time needed to classify images into independent events. By understanding how to define independent visits, researchers can more accurately analyze moose activity and make informed management decisions.