Welcome to

THE NORTH AMERICAN MOOSE CONFERENCE & WORKSHOP

54TH NORTH AMERICAN MOOSE CONFERENCE AND WORKSHOP

A virtual conference

November 30–December 2, 2021

WELCOME

Welcome to the 54th North American Moose Conference and Workshop!

We are so excited to be able to get together this year, even in virtual format. After the disappointment we felt when the 2020 International Moose Symposium in Finland was postponed, followed by the postponement of the conference in Grand Portage, MN, all of us wanted to find a way to carry on the traditions of the North American Moose Conference and Workshop. This 3-day virtual conference is the culmination of that effort, and we think that the array of 36 scientific presentations (30 papers and 6 posters) on moose ecology and management assembled will be stimulating and informative.

Many conference traditions were championed by our dear friend and colleague, Dr. Vince Crichton, whom we lost in December last year. A brief memorial tribute to Vince will be held on Tuesday, November 30, and we will offer a chance for friends and colleagues to share a story or memory of Vince. The 2019 recipient of the Distinguished Moose Biologist Award, Lee Kantar, will be giving his keynote address on Wednesday afternoon – titled "Cliches, Demons, and the Orchestra"! We also hope that everyone can attend one of the two virtual social events scheduled, one on Tuesday evening and the other on Thursday morning, to catch up with old friends, or to make new acquaintances.

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 states, provinces, and territories 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. We mourn together when we've experienced a loss. We've even been known to share a glass or two (or more) of beer. We hope that some of you attending this conference decide you want to become part of our Mooser family!

We are grateful for the support of our conference sponsors, Vectronic Aerospace, Lotek Wireless, Inc, Advanced Telemetry Systems, and the Natural Resource Research Institute at the University of Minnesota Duluth. We give a special thanks to Eli Sagor of the University of Minnesota's Sustainable Forests Education Cooperative for hosting our virtual conference and doing all the technical work in front of and behind the scenes to make this thing go as smoothly as it can!

We hope to see you all at the International Moose Symposium in Joensuu, Finland, August 22-26, 2022! And then in Grand Portage, Minnesota, in May 2023. Until then, we appreciate you joining us for the 54th North American Moose Conference and Workshop!

Sincerely,

54th North American Moose Conference and Workshop Organizing Committee

Michell Carstensen	Bill Faber	Nancy Hansen
Martha Minchak	Ron Moen	Roy Rea
Art Rodgers	Mike Schrage	Steve Windels

Cover photograph by Paul Sundberg

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All times Central Standard Time

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SESSION 2 - POLICY AND MANAGEMENT I – Moderator: Rolf Peterson

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SESSION 3 - POLICY AND MANAGEMENT II – Moderator: Mike Schrage

WEDNESDAY, DECEMBER 1, 2021

WELCOME

11:00 HOUSEKEEPING
Steve Windels, Eli Sagor

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12:40 POSTER SESSION – Breakout Rooms. If you installed the Zoom program on your computer you will be able to go to Breakout Room by poster number. If you use Zoom with your browser, we will explain how to switch between different posters at the conference.

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DISTINGUISHED MOOSE BIOLOGIST PRESENTATION

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Use http://z.umn.edu/MooseGT2 to join.
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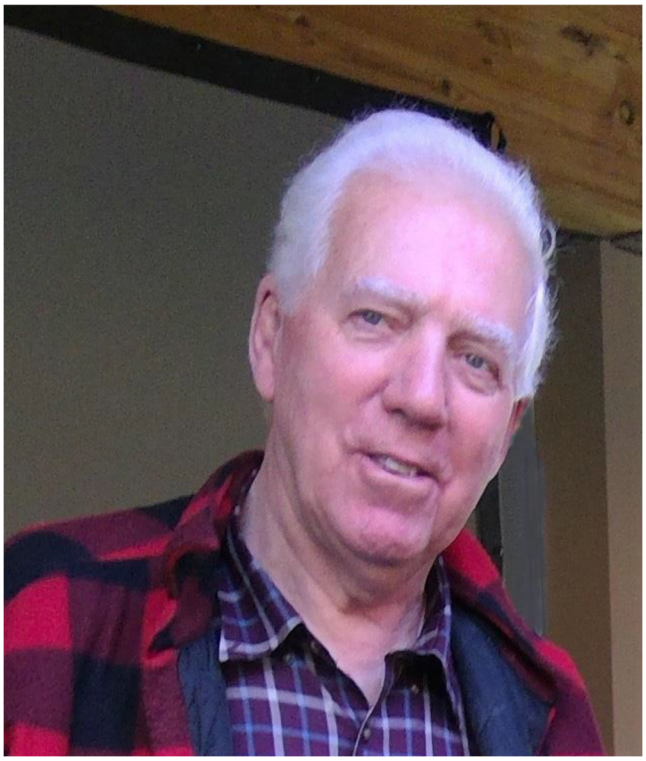
SESSION 8 – BEHAVIOUR – Moderator: Ed Addison

IN MEMORIAM

We mourn the loss of our great friend and colleague Dr. Vince ("Doc Moose") Crichton. The many accomplishments and contributions of Doc Moose listed here are published in an announcement from the journal Alces.



Dr. Vince Crichton, 1942-2020

It was a very sad day for Alces and the North American Moose Conference and Workshop group when we learned that Vince, a near-inaugural member, a regular scientific contributor, a relentless inspirational leader, and treasured friend of so many, was taken from us on December 3, 2020, at 78. His presence at every meeting since 1972 was hugely important to the scientific and social development of our association. First and foremost, he will always be the beloved husband of Kim, Dad to Scott (Vita), Susan (Craig), and Grampy to Julia.

Dr. Vincent Frederick Joseph Crichton was born November 7, 1942 in the small northern town of Chapleau, Ontario. His love of the outdoors and wildlife undoubtedly developed during his early years travelling in the bush with his father Vince Crichton Sr. who was Fish and Wildlife Supervisor of the Chapleau region. Vince earned his Bachelor and Masters of Science degrees at the University of Manitoba and his Doctorate at the University of Guelph in the field of wildlife diseases. His 40-year-career with the Province of Manitoba began in 1972 as Eastern Region Wildlife Biologist and culminated in 2012 as Manager of Game, Fur and Problem Wildlife, Manitoba Conservation, Wildlife and Ecosystem Branch.

An annual opportunity to exchange scientific information with colleagues and a journal in which to publish it, doesn't happen on its own, especially in the absence of a formal organization. But for moose biologists, this was the case for more than 50 years, in large part due to Vince Crichton's influence. In the early days of Alces and the NAMCW, Vince was a key member of a small steering group, affectionately called the "Moose Mafia", who never allowed the ball to be dropped. And he continued until his last days to provide that key leadership. He was a regular scientific contributor to Alces, an issue Editor and a permanent Associate Editor. Vince originated and co-sponsored the antler DMB Award carved each year since 1981 by Tom Copper, AK, and now presented 36 times. He was instrumental with others in producing the acclaimed "Ecology and Management of the North American Moose" in which he has two chapters. As an aside, he initiated and co-edited the "Moose Call" newsletter intending to bring moose research and interesting stories to readers who might otherwise never pick up a journal. Assisted by Kim, they produced 27 issues. Vince organized and hosted three NAMCWs, one of which (50th), was combined with the 8th International Moose Symposium. In 1988 he received the Distinguished Moose Biologist Award, and in 2016 at the 50th, was presented with the first NAMCW Professional Commitment and Appreciation Award. This was his 45th consecutive annual meeting, including all 8 International Symposia, the only "mooser" to have done so. Vince served as Associate Editor of The Wildlife Society Bulletin and was the Canadian Vice-President of the North American

Moose Foundation. For these reasons he will be remembered by many colleagues from around the northern hemisphere wherever moose roam.

Vince's unique character and persuasiveness came from his never failing pursuit of good wildlife management, not to mention his tall stature. One might presume that his outspokenness survived in the civil service only because of the principled and absolute conviction of his positions. His objective he said was to get people "into the same canoe, paddling in the same direction".

Dr. Crichton was given an award of merit from the Province of Manitoba for 40 years of service and was the recipient of the 2014 Conservation Award from the Manitoba Chapter of The Wildlife Society for support of the conservation and management of wildlife and their habitats. In retirement he became an expert on the spread of CWD in North America and continued to pursue his passion for moose and caribou management as a consultant, public speaker, environmentalist, conservationist, hunter and writer. He was always ready and willing to give a talk on his beloved moose, whether to an international scientific conference, the Gynecological Association of Montreal, the Idea City symposium, Toronto, his local university, the local chapter of The Wildlife Society, or to a class of local elementary students. He was a recorder for the Boone and Crockett Club for many decades, measuring trophy heads at big game nights all over Manitoba, and along with others, founded the Manitoba Big Game Trophy Association. In November while hospitalized, Vince was recognized in the Manitoba Legislative Assembly "for being one of the first advocates for co-management of moose by First Nations and government and for his passion, dedication and commitment to moose management provincially, and around the world"; he was awarded the first ever honorary Manitoba moose hunting license which brought a smile to his face.

Riding Mountain National Park was Vince's second home. In the spring and fall he spent much of his spare time, cameras in hand and infant grand-daughter Julia in tow behind his bike searching for his "rubber-nosed swamp donkeys". He was an accomplished photographer and was involved in the production of several videos for naturalists and hunters. On his 78th birthday, the CBC aired the documentary "Giants of the Boreal Forest" documenting his never ending passion for moose. His work has been featured on Discovery Channel (Champions of the Wild) and Animal Planet (The Man Who Would be Moose). His private entrepreneurial interests ranged from Telonics Canada, to speculating on the price of winter-dried moose pellets; that is until the bottom fell out of the souvenir stick-creature market leaving him with a garage full of pellets needing to be turned into his garden.

To paraphrase an old physicist (Newton), if we have all moved a little further in our views of moose management and of how to communicate those ideas to the public, in part, it is because we have sat with a genuine giant. Vince's absence from future meetings of the North American Moose Conference and Workshop will leave a hole in our hearts but he will always be there to remind us of the much needed moose research left to be accomplished and shared.

2019 DISTINGUISHED MOOSE BIOLOGIST

Lee Kantar, Maine Division of Inland Fish and Wildlife

Lee is the principal moose biologist in Maine where he manages the largest (by far) moose population (>60,000 animals) in the lower 48 states. This extremely dynamic population at the southern range extent of moose requires expertise in biology/ecology, forest management, economics, politics, and human dimensions. Lee's excellent communication skills, motivation, perseverance, and passion provide excellent foundation for the (his) managerial and leadership skills necessary to effectively manage a population of >60,000 animals on private, commercial forestland. Since his hire, he has transformed and built a moose management program that is arguably one of the most modern and comprehensive programs in the States. It is a progressive program that successfully integrates a large harvest (>2000 animals annually), continuous aerial population surveys, field-based research, and constant outreach. Given that the population rebound occurred since the early 1980s, his efforts have been hindered by a lack of historical and local experience – his work truly represents novel and progressive management in the state and region. He is conducting the largest research effort with radio-collared moose in the States (675 marked animals in 8 years) while working cooperatively with NH and VT as part of a larger regional effort. His management and research programs include both objective and open-ended approaches – he is a student of moose. Through interactions at NA Moose Conferences, everyone becomes acutely aware of his passion, integrity, and knowledge, and importantly, his openness, humor, motivation, and positive personality. He has become a pillar of moose management in the northeastern US and North America, and without question, is deserving of this honor and recognition (despite his quiet, oh shucks manner).

Lee Kantar, Maine Division of Inland Fish and Wildlife

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.

PAST RECIPIENTS

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 Ministry of Agriculture and Forestry, 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 Resource Management Division, 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

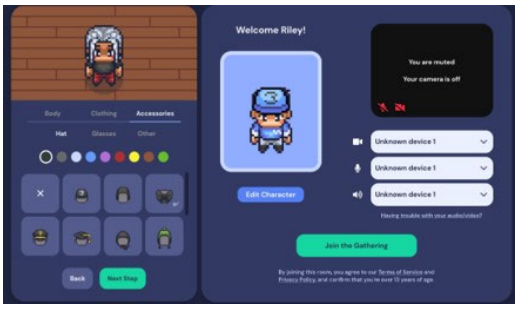
1974 — Prior to the establishment of the Distinguished Moose Biologist Award the group recognized the pioneering moose research of the late Laurits (Larry)Krefting, U. S. Fish and Wildlife Service, with an individual award

SOCIAL EVENTS ON GATHERTOWN

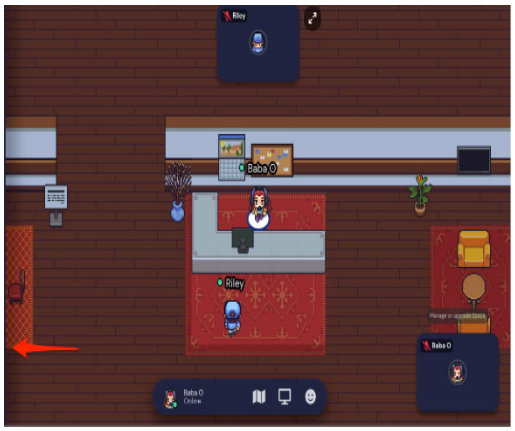
We welcome registered conference participants to join us for two virtual social events we are hosting via the online platform called Gather.Town. Of course, no virtual gathering can ever be good as meeting in person to share a drink and catch up with old friends, but until that time this will have to do.

Evening Social: Tuesday, Nov. 30, 5-7p CST

Morning Social: Thursday, Dec. 2, 9-11a CST



How does it work? Everyone who is registered will receive an email with the link to the Gather.Town events, one for Tuesday evening and another one for Thursday morning. When you click on the link you will be taken to the Gather.Town event (termed a "Space"), where you will be prompted to create and name your avatar that will represent you during the event. Once you are satisfied with the avatar you've created, just click "Finish", and then "Join the Gathering".



Once in the event, you use the arrow keys on your keyboard (or the virtual arrow pad on your smart phone) to move around the event space. When you come into proximity to other people their audio and video become visible to you, allowing you to interact with them. You can also look for someone's name on the toolbar on the left hand side; right click on their name and you can locate them on the map or click "follow" and you will be taken right to them. It's really quite easy once you are there.

To get the most out of the event, you need to have a functioning camera and microphone on your computer or smart phone. While Gather.Town can be used from your smart phone, they recommend you access the event from your personal computer for the best experience.

We will try to run through a brief tutorial on Tuesday, Nov. 30 at the start of the day so that everyone knows more what to expect. You can also find more basic information about to get started in Gather.Town here. (https://support.gather.town/help/movement-and-basics)

CONFERENCE ORGANIZING COMMITTEE

Michelle Carstensen, Minnesota Department of Natural Resources

Bill Faber, Central Lakes College

Nancy Hansen, Minnesota Department of Natural Resources

Martha Minchak, Minnesota Department of Natural Resources

Ron Moen, University of Minnesota, Duluth

Roy Rea, University of Northern British Columbia

Art Rodgers, Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry

Mike Schrage, Fond du Lac Resource Management Division

Steve Windels, Voyageurs National Park

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ABSTRACTS

EVALUATING UNMANNED AERIAL SYSTEMS FOR THE DETECTION AND MONITORING OF MOOSE IN NORTHEASTERN MINNESOTA

Michael C. McMahon[1], Mark A. Ditmer[2], Edmund J. Isaac[3], Seth A. Moore[3], and James D. Forester[1]

[1]University of Minnesota, Department of Fisheries, Wildlife, and Conservation Biology, St. Paul, MN, USA; [2]Rocky Mountain Research Station, U.S. Forest Service, Ogden, UT, USA; [3]Grand Portage Band Of Lake Superior Chippewa, Trust Lands Department, Grand Portage, MN, USA

The use of unmanned aerial systems (UAS) for wildlife surveying and research has widely expanded in the past decade, but with varying levels of success. Applying UAS paired with Forward Looking Infrared (FLIR) technology to survey forest-dwelling species has been particularly challenging because of unreliable animal detection. We describe our application of UAS and FLIR technology to detect GPS-collared moose (*Alces alces*) and their calves in the heavily-forested region of northeastern Minnesota, USA, during 2018 and 2019. We conducted grid-pattern UAS thermal surveys over GPS-collared cows during the calving seasons (April to June) of 2018 and 2019 to determine the feasibility of using a FLIR-equipped UAS for detecting cow moose, and for quantifying their number of calves. We also collected data on environmental and flight characteristic variables to model moose detection. Our best fitting model of moose detection showed increased detection with more cloud cover at the survey site ($\hat{\beta} = 1.13$, SE = 0.43), whereas increased forest canopy ($\hat{\beta} = -1.10$, SE = 0.38), and vegetative greenness (enhanced vegetation index, EVI; $\hat{\beta} = -1.37$, SE = 0.32) both reduced detection success. By adjusting our methodology based on our detection model findings, we increased our adult moose detection success from 25% during our first season, to 85% during our second season, and calf detection from 27% to 79%, respectively. We report on our methodological improvements and identify persisting limitations to UAS-based wildlife research in forested systems. Overall, we found that UAS with FLIR sensing is a promising tool for quantifying moose calving success, twinning rate, calf survival, and may be effective for monitoring the reproductive success and survival of other wildlife species in densely forested regions.

A REVIEW OF METHODS TO ESTIMATE MOOSE DENSITY AND ABUNDANCE

Remington J. Moll[1], Henry Jones[2], Mairi Poisson[1], David R. Heit[1], and Peter J. Pekins[1]

[1]Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH, USA; [2]New Hampshire Fish and Wildlife Department, Concord, NH, USA

Obtaining accurate and precise estimates of moose (*Alces alces*) population parameters is fundamental to building ecological understanding and making effective management and conservation decisions. Of these parameters, density estimates are among the most essential because decisions are frequently focused on maintaining moose populations at particular densities over time. However, moose density is challenging to estimate for logistical, financial, and ecological reasons. Traditionally, a method used to estimate moose densities has been winter aerial surveys but numerous alternative approaches exist, including harvest analysis, public observation, drone surveys, and camera trapping. While accurate moose density estimates are critical to obtain, doing so is difficult and survey methodologies are rapidly evolving. There is a need to review and synthesize these methods and their strengths and limitations so that researchers, biologists, and managers can effectively navigate the trade-offs associated with various approaches.

Here, we provide such a review by conducting a formal literature survey of methods used to estimate moose densities, with an emphasis on studies with management implications. We reviewed 60 primary source studies reporting moose densities that employed 84 distinct methods to estimate moose density. As expected, aerial surveys were the most common method used (N = 57) but more recent studies tended to employ more diverse methods (e.g., drone surveys). Less than half of all methods (N = 41; 48.2%) accounted for imperfect detection or sightability and 58.8% of methods (N = 50) required snow cover. A total of 53 methods reported moose density, which ranged from 0.02 to 10.57 individuals/km^2 (mean: 0.78, median: 0.41), while population precision, as measured by the 90% confidence interval, ranged from 1% to 120% of the density estimate (mean: 39.8%, median: 23.0%). A total of 45 methods were formally compared to other methods, with high variation in reported correlation among approaches. This literature survey highlights 1) that moose density estimation methods have been dominated by aerial flights but are diversifying, 2) density estimate precision is, on average, lower or equal to the benchmark suggested by Gasaway et al. 1986 and has high variability, and 3) the majority of methods have not formally accounted for sightability and have thus likely underestimated moose densities. We reflect on these trends and look ahead to how potentially useful emerging methods, such as drone surveys and camera trapping, can be integrated with and expand upon traditional approaches.

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

Sydney Belleau and Brian E. McLaren

Dept. of Natural Resource Management, Lakehead University

Since the 1980s, Ontario biologists have led the public interest in moose management and has since established a sustainable moose management framework, which unfortunately contains mechanisms to address specific social interests that continue to discourage meaningful Indigenous participation. The aim of this qualitative study is to measure the space between Canadian Indigenous and Non-Indigenous ontologies with respect to moose. I propose 3 objectives to achieve this aim: (1) to explore Indigenous and Western belief systems in the context of moose; (2) to provide an institutional analysis on the levels of Indigenous and Non-Indigenous participation in moose management in Ontario; and (3) to co-create a set of recommendation for moose management with First Nations who have moose hunting territories in the Kenogami Forest Management Unit in northern Ontario. Working from a complex systems lens, a qualitative multi-methods approach is proposed: (1) data collection will take form of open-structured interviews with “expert” knowledge holders, which will then be transcribed and coded for data interpretation; (2) Cognitive Effective Mapping will follow, providing an analysis of the interpreted data; (3) a supplementary analysis of Ontario's moose management framework will be applied to Arnstein’s Ladder of Citizen Participation; and finally, (4) once the results can be interpreted, participating Indigenous knowledge holders will be invited to co-create recommendations for moose management in the Kenogami Unit.

A CANADA-WIDE COLLABORATION ON MOOSE MANAGEMENT: LEARNING FROM OTHERS

Maxime Lavoie[1], Jason Airst[2], Terry Armstrong[3], Wayne Barney[4], Holger Bohm[5], Rob Corrigan[6], Sophie Czetwertynski[7], Daniel Dupont[8], Patrick Hubert[9], Brian Joynt[8], Gerald Kuzyk[10], Dwayne Sabine[11], and Jamie Stewart[9]

[1]Ministère des Forêts, de la Faune et des Parcs du Québec, Service de la gestion des espèces et des habitats terrestres, Québec, QC, Canada; [2]Nova Scotia Department of Lands and Forestry, Renewable Resources Branch, Kentville, NS, Canada; [3]Northwest Territories Department of Environment and Natural Resources, Wildlife and Fish Division, Fort Smith, NT, Canada; [4]Newfoundland and Labrador Department of Fisheries, Forestry and Agriculture, Wildlife Division, Corner Brook, NL, Canada; [5]British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Wildlife and Habitat Branch, Cranbrook, BC, Canada; [6]Alberta Ministry of Environment and Parks, Fish and Wildlife Policy Division, Edmonton, AB, Canada; [7]Yukon Department of Environment, Fish and Wildlife Branch, Whitehorse, YK, Canada; [8]Manitoba Department of Agriculture and Resource Development, Wildlife and Fisheries Branch, Winnipeg, MB, Canada; [9]Ontario Ministry of Natural Resources and Forestry, Wildlife Section, Peterborough, ON, Canada; [10]Saskatchewan Ministry of Environment, Fish, Wildlife and Lands Branch, Meadow Lake, SK, Canada; [11]New Brunswick Natural Resources and Energy Development, Fish and Wildlife Branch, Fredericton, NB, Canada

Moose (*Alces alces*) are an integral component of the boreal forest in Canada. They are a primary food source for many Indigenous groups and highly valued as a harvested species by licensed hunters. Recently, moose populations have been declining in parts of many Canadian provinces and Territories with some reports of increasing populations in other areas. The factors responsible for a decline in abundance are numerous, ranging from environmental sources such as forest fires, predation, parasites and diseases to human-induced changes such as forestry, harvesting, and road mortalities. Each of these factors requires specific management actions which if enabled by policy or indigenous governance, may take several years to be effective. Therefore, it is essential that moose managers and researchers share their experiences to effectively improve management strategies, including collaboration with indigenous organizations. In 2018, the Canadian Wildlife Directors Committee created the Canadian Moose Management Subcommittee with a purpose to bring together expertise and experience of its members and provide a national forum for collaboration on moose management and conservation challenges in Canada. The

subcommittee is composed of one technical representative, designated by the Director, from each of the provincial and territorial jurisdictions that have moose (Alberta, British Columbia, Manitoba, Newfoundland and Labrador, New Brunswick, Northwest Territories, Nova Scotia, Ontario, Québec, Saskatchewan, and Yukon). The current project of the Moose Management Subcommittee is a Canada-wide survey on the current status and management challenges for moose among jurisdictions in Canada. A key component of the survey is to determine major factors influencing moose declines and the feasibility of management actions to reverse these declines. The survey will provide an assessment of the status of moose across Canada and available management actions to improve sustainable moose populations. The survey results are not yet available, but sharing the scope and structure of the survey with other moose specialists will help refine the methodology and increase the future benefits of this work.

TROPHY HUNTING OF UNGULATES - EXAMPLES OF NUANCED DIALOGUES

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Trophy hunting has become a controversial topic. Indeed, the term “trophy hunting” has become increasingly ambiguous. This imprecision and resulting generalizations often result in overly broad and sometimes erroneous conclusions about this activity and its effects on wildlife. This allowed some individuals and advocates to maintain strong individual opinions by citing seemingly conflicting data, when the arguments were about different circumstances or issues entirely. Years of reporting insufficient or inadequate details without discussion of important nuances inherent in the act of hunting for specific phenotypes, especially large, mature males, has allowed personal attitudes to become entrenched. This situation has hampered unbiased reporting, which is the hallmark of good science. Trophy hunting is a biologically and socially complex issue. A multitude of topics must be considered to render valid conclusions about its effects, whether presented in the popular or scientific literature. Those topics include an unambiguous, context-dependent definition of the term trophy, use of appropriate metrics for identifying costs and benefits, and clearly defined spatial and temporal scales over which effects are reported. Explicit definitions, metrics, and scales are essential to provide impartial information to decision-makers, and to improve discussions on the collective costs and benefits of trophy hunting. Here, we use moose (*Alces alces*) and other ungulates, to illustrate how proper application of each of these principles contributes to informed management.

APPLICATIONS OF A RAPID RESPONSE MODEL OF THE NORTHEAST MINNESOTA MOOSE POPULATION BASED ON AERIAL SURVEY RESULTS

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The northeast Minnesota moose population has been surveyed using a consistent methodology since 2005. The value of the aerial survey can be enhanced by incorporating survey data into a population model that is updated each year with survey results. Ecological relationships among moose, deer, wolves, and beaver changed as the moose population has declined by about 50% in northeastern Minnesota from 2009 to 2012. Since 2012 there has been a period of relative stability in the moose population based on the annual aerial survey. Species management options potentially available include a moose harvest, a wolf harvest, and continuation of deer harvest seasons. The effect of each of these management options can be simulated. Under current conditions, model predictions are that if 50 bulls are harvested each year the moose population would decline 9% in 10 years. The population model was also used to predict the effect of increases in survival and reproduction. For example, to achieve a 50% increase in the moose population in 10 years, about 100 more adults and 200 more calves would need to survive each year. The model can be best used as one tool in the toolbox that makes it possible to improve understanding of potential impacts of management decisions on the moose population.

POPULATION AND HARVEST TRENDS OF MOOSE IN SASKATCHEWAN

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The purpose of this paper is to provide an overview of licensed harvest (2015-2020), population trends (2005-2020) and other factors affecting moose (*Alces alces*) populations in Saskatchewan to help inform management actions. Moose are an important food source for many Indigenous groups and highly valued by licensed hunters. From 2015 to 2020 annual harvest of moose by licensed resident hunters ranged from 4,525 to 5,535 with composition of harvest being 59% bulls, 32% cows and 9% calves. The percent of antlerless harvest (i.e. cows and calves) ranged from 4% in the Boreal Shield to 60% in the Parkland region. Information from aerial surveys and field reports indicate moose populations across the Southern Boreal Forest are declining and several Wildlife Management Zones (WMZs) are 30 to 50 per cent below long term objectives. In response, licensed hunting seasons were changed in 2021 to bulls-only within all boreal forest WMZ's to help slow the population decline and garner public support for sustainable moose management. The significance of these moose population declines in the Southern Boreal Forest has prompted the Ministry of Environment to initiate a moose survival research project in partnership with the University of Saskatchewan in the east-central part of the province in an area that has undergone landscape change. This will enable wildlife managers to determine cause-specific mortality of cow moose and help inform management direction. Moose populations in the Boreal Forest Fringe, Parkland and Grassland appear to be stable due to a combination of optimal foraging conditions in agricultural crops and lack of predators. These populations will continue to be monitored and managed in relation to social carrying capacity. Monitoring moose health is ongoing with regular testing for Chronic Wasting Disease (CWD) and attention to P. tenuis and winter ticks. Regular communication with all user groups will be required to inform management actions to benefit sustainable moose populations in the province.

ABUNDANCE AND HARVEST OF ALASKA MOOSE FOLLOWING PREDATOR CONTROL

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A review of studies from boreal Alaska and Yukon (Gasaway et al. 1992) concluded that moose (*Alces alces*) commonly exist at <0.4/km^2 (~1.1/mi2) in a low-density dynamic equilibrium (LDDE) with a limited harvestable surplus because large predator abundance is not limited by harvest. Harvestable surplus of moose can be increased where nutrition is not limiting productivity and predation by black bears (*Ursus americanus*), brown bears (*U. arctos*), and wolves (*Canis lupus*) is periodically reduced significantly. With knowledge of the LDDE concept and controversy over predator management to increase prey abundance, the Alaska Legislature issued statutory guidance to the Alaska Board of Game in 1994. The Board was required to set population and harvest objectives for moose as regulatory process triggers by management unit. Thereafter if harvest reductions are proposed to ensure sustained yield, the Board must consider Intensive Management (IM) practices of predator control and habitat enhancement to restore or elevate harvestable surplus. The desired yield rate for moose can be approximated from IM objectives (harvest/abundance). We evaluated pre-treatment and post-treatment parameters in 6 IM programs where reduction of 1-3 predator species was attempted over 6-16 years during 2003-2019 in areas with moose populations mostly at <0.4/km^2. Our post hoc assessment included 13 treatment and 11 spatially associated non-treatment survey areas (sites), smaller than management units, for which we compiled available data on moose nutritional condition, density, and harvest. We estimated magnitude of predator reductions from available information as an index to the control effectiveness (potential to cause prey numeric response) and compiled data on environmental factors possibly affecting numeric response. Change in moose density was generally consistent with a LDDE where a population starting at <0.4 moose/km^2 remained in low density unless non-harvest mortality was effectively reduced or immigration possibly occurred. Four programs with effective reduction of predators had >1 treated site where moose went from <0.4/km^2 by the last survey before predator control to >0.4/km^2 by the last survey after predator control. Two programs with exception to LDDE had effective reduction of >1 predator and subsequent moose density increase but

remained at <0.4 moose/km^2, suggesting other concurrent mortality factors. Two low-density non-treatment sites increased to >0.4 moose/km^2 (possibly immigration from nearby irruption) whereas another 7 non-treated sites remained at <0.4/km^2 (2 non-treated sites remained >0.4/km^2). We did not extrapolate moose abundance beyond survey areas to the management unit scale to evaluate achievement of IM population objectives. Apparent harvest rate on treated sites averaged half the desired IM yield rate for the larger management units. At the larger (regulatory) scale where IM objectives are defined for programs, 4 of 11 affected management units met harvest objectives for 1, 4, 4, and13 years post-control, suggesting that harvest rate on the remaining management area outside of treated sites was also less than the rate intended by IM objectives. However, trend in moose harvest post-treatment or difference in harvest pre to post treatment was positive for 10 treated sites and 7 non-treated sites. Each IM program is a unique situation of biological, environmental, and human factors best understood as a case study. We cannot clearly assign treatment causation but will discuss confounding factors other than predator control that may have influenced observed changes in moose density and harvest and how monitoring in future programs might be designed for better inference on treatment effects.

USING REMOTE SENSING TO ESTIMATE POPULATION CAPACITY FOR MOOSE IN A DYNAMIC FORESTED LANDSCAPE IN NEW YORK

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In the temperate forests of the northeastern US, moose populations thrive in heterogeneous landscapes that provide abundant forage in warm months and thermal refugia colder months. Heterogeneity within a forested stand is typically driven by timber harvest which results in a dynamic multi-age forest. Unfortunately, the intertwined interests in large ungulates and timber removal results in a complex relationship that can often lead to conflict with newly cut stands experiences greater browse pressure than the surrounding forest, negatively impacting future timber products. Additionally, the dynamic nature of timber harvest makes it difficult for wildlife managers to easily mitigate the impacts of browsing ungulates. We sought to develop a method to accurately predict areas of timber harvest in the Adirondack Park (AP) in northeastern New York. Furthermore, we then sought to apply values of forage abundance per cover type to estimate abundance moose in the AP. We used Landsat Imagery from 2013-2018 for the AP, and associated training polygons from those respective time periods, to predict whether a forested landscape fit into one of three cover classes, mature forest, intermediate timber removal or overstory timber removal. Our three-class prediction for each of the selected years resulted in a mean prediction accuracy of 86.9% (Khat = 0.76) for the AP. We applied previously calculated summer crude protein values per cover type to our predicted landscape. The application resulted in an estimated average capacity of 760 moose (SD ± 428) across all sampling years, similar in magnitude to a density estimate of 716 moose (95% CI = 566-906), calculated during the same time period as part of a multi-year distance sampling survey. Our prediction methods were able to both accurately predict forest timber treatments across dynamic landscapes at differing spatial and temporal scales, and provide accurate estimate of landscape-level population capacity. The ability to accurately identify areas of potential conflict from overbrowsing, or to highlight areas in need of land cover treatments can significantly increase the toolset for ungulate management in areas of timber harvest.

WINTER HABITAT USE OF MOOSE IN CAPE BRETON, NOVA SCOTIA

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Aerial survey data collected between 2001 and 2020 were used to assess moose (*Alces alces*) winter habitat use in the Greater Highland Ecosystem of Cape Breton, Nova Scotia. These data were analyzed using generalized additive mixed models. Moose favoured areas comprised of greater proportions of coniferous forest with moose showing a preference for younger forests. This was also true for areas with higher percentages of conifer forest experiencing abnormal forest succession due to high moose herbivory (moose meadow). Moose were more likely to be found farther away from roads. This suggests that moose prefer areas with younger plant forage and low human access.

MOOSE CALF SURVIVAL AND NUTRITION IN NORTH WEST ALASKA

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The nutritional status of moose (*Alces alces*) is an important biological component to understand for managing moose populations. Weights of 10-month-old calves indicate population health and nutritional limitation. Typically, it is assumed that forage available in winter and winter severity drive 10-month-old weights. Dam condition and summer weather also contribute to variation in 10-month-old calf weights. To better understand the potential drivers of 10-month-old calf weight we captured, weighed, and collared 5-month-old calves and recaptured them as 10-month-olds. Tracking weight from fall to spring may inform causes of limited growth of the moose population on the Seward Peninsula, Alaska. We estimated a low (16.2%) rate of current annual growth removal from preferred browse species initially. Four years of captures resulted in 329 capture events including 120 collared female calves. The average fall weight between 2017-2019 was 197 kg. Average spring weight between 2018-2020 was 181 kg, resulting in an average of 9.2% over-winter weight loss. These fall and spring weights correspond with some of the heaviest fall weights and lightest spring weights recorded in Alaska. Correlation between spring and fall weights was 0.59 (Multiple R^2), with little variation of between study years (0.63, 0.62, 0.73). Average survival rate to 1 year of age (from capture at 5-months to 12-months) was 89%. Estimated survival to 2-years of age (5-months to 24-months) was 74%. Over-winter mortality for all winters was low with four mortalities occurring between 2017 – 2021. One of these mortalities was due to starvation and three to wolves (*Canis lupus*). All other mortalities (22) occurred during other times of year and have been attributed to grizzly bears (*Ursus arctos*). Recent data has identified parturition rates of two and three-year-old cows to be high. Based on low browse removal rates, and the high estimated reproductive output, we surmise that forage is not currently limiting abundance in this population. This along with high amounts of overwinter weight loss implies that winter severity plays a large role in the relative body condition of this population. The landscape potential for maintaining higher densities appears possible. Nutrition and subadult survival appear to be adequate. A potential limiting factor in this population may be survival of the neonate to 5-month-old age class. Neonatal mortality rates may provide further insight to predator driven mortality limiting this population. The interaction between summer conditions, overwinter conditions and the resulting 10-month-old weights is complex. Further investigation is needed to understand how climatic variables influence summer weight gain and winter weight loss and how these weights influence lifetime productivity.

SPATIAL MODELING OF HABITAT PREFERENCES QUANTIFIES INDIVIDUAL VARIATION IN MATERNAL TRADEOFFS AMONG MOOSE IN BRISTOL BAY, ALASKA

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Individual variation in habitat selection can lead to different fitness outcomes. For moose (*Alces alces*), selection of calving sites may influence calf survival, especially in areas where predation rates are high. Past research has examined calving site selection in the context of maternal tradeoffs between nutritional requirements and predation risk; however, research has largely been at the population-level. Our objectives were to: 1) understand habitat selection of female moose during the calving season in Bristol Bay, Alaska and 2) quantify individual maternal tradeoffs in relation to habitat preferences. We predicted that: a) reproductive and non-reproductive cows would select for abundance of forage willows (*Salix*); b) reproductive cows would exhibit more diverse habitat preferences because of maternal tradeoffs; c) not all reproductive cows make maternal tradeoffs. We used a path selection framework, continuous covariates for vegetation and topography, and explanatory and predictive statistical models. We also calculated a relative index of maternal tradeoffs as the deviation of reproductive cows from the habitat preferences of non-reproductive cows. Consistent with the forage hypothesis, explanatory models were similar for both groups of cows with positive selection coefficients for forage willows and neutral selection coefficients for distance to forest edge. Predictive maps showed substantial spatial overlap between habitat preferences of reproductive and non-reproductive cows. However, habitat preferences of reproductive cows were more dispersed, moving away from floodplains and into forested areas and lower mountain slopes. About 50% of reproductive cow-years made detectable maternal tradeoffs at a 95% confidence level. Contrary to prior work, our results show that not all individuals exhibit maternal tradeoff behaviors. The number of individuals that adopt these behaviors likely depends on the spatial structure of the landscape. At the landscape scale, our results can be used by managers to prioritize areas where maternal tradeoffs are possible and therefore more likely to lead to positive fitness outcomes.

DETERMINING THE THRESHOLD OF SERUM PROGESTERONE TO DIAGNOSE PREGNANCY IN MOOSE

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Pregnancy determination is necessary for sound management of animals and understanding population dynamics. Pregnancy rates are sensitive to environmental and physiological factors, and may indicate the overall trajectory of a population. Pregnancy can be assessed through direct methods (rectal palpation, sonography) or indicated using hormonal assays (serum progesterone or pregnancy-specific protein B, fecal progestagen metabolites). A commonly used threshold of 2 ng/ml of progesterone in serum has been used by moose biologists to indicate pregnancy but has not been rigorously investigated. To develop a more precise threshold, we examined the relationship between serum progesterone and pregnancy. We measured progesterone concentrations in serum samples from 87 moose (64 female, 23 male) captured 2010 to 2020 in the Grand Portage Indian Reservation in northeastern Minnesota, USA. In females, pregnancy was confirmed via rectal palpation (n = 25), necropsy (n = 2), calf observation (n = 25), or a characteristic pre-calving movement (n = 6), with a total of 58 females determined pregnant and 29 moose not pregnant (6 cows and 23 males). We utilized receiver operating characteristic (ROC) analysis to quantitatively determine an optimal threshold of 0.45 ng/mL with a specificity of 0.93 (95% confidence interval [CI] = 0.83-1.0) and a sensitivity of 0.97 (95% CI = 0.91-1.0). Progesterone levels were significantly higher in cases of pregnant vs. non-pregnant animals, but we did not detect a difference between single and twin births. We then applied our newly developed threshold to calculate annual pregnancy rates for all female moose (n = 133) captured in Grand Portage from 2010-2021. Mean pregnancy rate during this period was 90% and ranged from 83 to 100%. Developing a reliable method for determining pregnancy status via serum progesterone levels will allow wildlife managers to assess pregnancy rates of moose without devoting substantial time and resources to palpation and calf monitoring.

INVESTIGATING THE ROLE OF CLIMATE CHANGE IN AN EXPANDING MOOSE POPULATION IN SOUTHWEST ALASKA USING A MULTI-STATE MODEL

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Climate change is altering the ecosystem structure of areas across the Arctic and sub-Arctic. One of the fastest-changing regions is southwest Alaska, where a combination of shrubification, decreasing sea-ice concentration, and increasingly inconsistent winter snowpack has already affected local ecology. Another potential result – and, in turn, driving force – of these changes is the rapid colonization by moose (*Alces alces gigas*) across the region into areas in which moose previously never or only intermittently inhabited, and even then only in low densities. The primary objective of this study is to identify links between an expanding moose population in Togiak National Wildlife Refuge and changes in the regional landscape by incorporating various environmental, spatial, and biological covariates into an Integrated Population Model (IPM) that brings together long-term telemetry and count data into one model. This IPM will relate covariates with estimated demographic parameters, population counts, and emigration dynamics using spatial, multi-state, and matrix models.

This presentation will be a mid-study update on the project, focusing on both a series of Generalized Linear Mixed Models (GLMMs) in a model selection framework to determine which covariates should be included for various demographic parameters in the more computationally-intensive IPM, and the multi-state model in a Bayesian framework, which links covariates with parturition and twinning rates, and cow and calf survival. Preliminary results from the model selection analysis show that, for most of the aforementioned demographic parameters, moose age and parturition in the previous year are important biological covariates, that Game Management Unit (GMU) inhabited is an important spatial covariate, and summer vegetative productivity as measured by NDVI is an important environmental covariate. Winter severity was not found to be an important environmental covariate for any of the survival parameters. Preliminary analysis on the multi-state model validate that the moose population in the area continues to exhibit high twinning, parturition, and survival rates, with considerable variation in between years.

UNDERSTANDING THE EFFECTS OF VITAL RATE IMPORTANCE AND SPATIAL VARIATION ON SHIRAS MOOSE POPULATIONS ACROSS IDAHO

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Harvest data suggest that Shiras moose (*Alces alces shirasi*) populations in Idaho have been stable or declining since the mid-1990s. Similar population trends near the southern periphery of moose range in North America have been attributed to a suite of factors including disease, parasites, predation, and habitat modification. We initiated a multi-year project in January 2020 to better understand population dynamics and habitat use by moose in Idaho. During January-March 2020 and 2021, we fitted 163 adult females and 17 9-month-old calves with GPS collars in 5 of the 7 Idaho Fish and Game (IDFG) regions. We monitored collared moose since capture to document survival, movement patterns and habitat use, and facilitate investigation of mortalities. To document calf production and summer calf survival, we conducted ground observations of parturient collared moose during May-August 2020 and 2021. Between January 2020 and August 2021, adult female survival was moderately high (85%). Blood samples analyzed for pregnancy-specific protein B collected during capture indicated that 88% and 86% of females were pregnant in 2020 and 2021, respectively. Birthrates were comparable between years (2020 = 73% and 2021 = 71%). Observed calf survival was relatively high during spring (May-June: 2020 = 80% and 2021 = 79%) and summer (July-August: 2020 = 86% and 2021 = 91%). However, overwinter survival of calves was considerably lower (53%). Our initial findings suggest that fetal losses and/or early neonatal mortality (before first observation) in addition to overwinter calf mortality may be resulting in depressed calf recruitment, while adult survival, remains consistently high. Collared moose will be monitored through December 2022 to document adult survival and calf recruitment. Demographic data will be used to model contributions of each vital rate to population trends and evaluate spatial variation among study regions within Idaho.

CAUSES OF MORBIDITY AND MORTALITY IN ADULT AND JUVENILE MOOSE IN IDAHO

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Recent harvest data indicate that Shiras moose (*Alces alces shirasi*) populations are stable or declining across core portions of their western range after peaking in the 1990s-2000s. This trend is not unique to Shiras moose as other North American moose subspecies are exhibiting similar trajectories across their southern range extents. Causes for these declines are diverse; however, climate change is hypothesized to underly an increase in incidence of parasitic diseases in some populations. In January 2020, we initiated a prospective investigation of GPS-collared adult female (n=109) and 9-month-old calf (n=17) moose in Idaho to evaluate survival, cause-specific morbidity and mortality, and parasite prevalence and burden via collection of samples during capture and postmortem examination. We are also conducting necropsies on carcasses of uncollared moose to identify sources of mortality not represented in the sample population. Statewide annual survival of collared females was relatively high during Year 1 (67/77; Kaplan-Meier survival = 90%). Preliminary results from necropsy, histopathology and ancillary diagnostic testing on mortalities of GPS-collared adult females (n=11) indicated that disease was the most common proximate cause of mortality (n=5). All five of the collared moose that died of disease were emaciated and diagnosed with moderate to severe elaeophorosis (*Elaeophora schneideri*; n=2), winter tick (*Dermacentor albipictus*; n=1), septic endometritis (n=1), or echinococcosis (*Echinococcus granulosus*; n=1). Predation (n=2), accidents (n=1), harvest (n=1), and vehicle collision (n=1) were also proximate causes of mortality of collared adult females. Statewide mortality of GPS-collared 9- to 13-month-old moose was high (8/17; K-M survival = 43%). The most common source of mortality for calves during late winter through mid-summer was emaciation/winter tick infection (n=5), followed by bacterial infection (n=1), wolf predation (n=1), and trauma (n=1). Winter-tick associated calf mortalities were concentrated during late April – early May. Necropsy of uncollared animals (n=17) also indicated the importance of disease in mortalities, with bacterial infections identified or metabolic and/or parasitic causes considered likely in the majority of cases (n=11). Trauma was the second most frequent cause of mortality (n=5), with vehicle collision the most common (n=4). Diagnostics on collared and uncollared moose will continue for three years to elucidate patterns of spatiotemporal variation in survival and cause-specific mortality.

EFFECTS OF LANDSCAPE CHANGE ON CERVID-PARASITE RELATIONSHIPS IN INTERIOR NORTHERN BRITISH COLUMBIA

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Moose (*Alces alces*) in North America are facing adverse environmental affects that are decreasing overall health of populations. Cutblocks and timber salvage in British Columbia due to mountain pine beetle (*Dendroctonus ponderosae*) have paralleled with moose decline showcasing the susceptibility of moose to landscape change. The recent BC Moose Health Assessment shows the decline in forested corridors which has led to increased predation and additional opportunities for parasites. Winter tick (*Dermacentor albipictus*) is a primary parasite of moose in British Columbia and a knowledge gap is present in their range and habitat selection in this region, especially with the altered landscape of cutblocks. I intend to use existing collared moose data to create a winter tick risk assessment in study areas in the British Columbia Provincial Moose Research Project (BCPMRP). In the Fall I have sampled 250 m plots, flagging for larval winter tick. I will estimate their abundance in the Prince George South study area using 5 designated forest treatment categories (early seral stage, recovering cutblock, regenerating cutblock, old growth forest and deciduous forest). I sampled random transects on the landscape at least 50 m from the road and measured vegetation at the start, in the middle, and end of the transect including canopy cover, temperature at questing height, temperature at ground level, humidity, and Daubenmire method. Using ArcGIS, I will plot larval tick abundance across established habitat types among transects sampled. By assessing larval winter tick abundance associated with potential winter tick infestation, more informed forest management decisions can be made to assist the survival of the already dwindling moose populations.

A CIRCUMPOLAR SURVEY OF MOOSE (*ALCES ALCES*) MANAGEMENT THROUGHOUT THEIR GEOGRAPHIC RANGE

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Moose (*Alces alces*) are widespread throughout the circumpolar north. Population declines throughout the range of moose have been reported, but some populations appear to be stable while others are expanding. To better understand such trends and what might be driving them, we created and distributed a standardized survey to moose biologists and managers in every jurisdiction (provincial, territorial, state, and country level) where free-ranging moose currently exist. The survey included, but was not limited to questions around: population estimates, amount of available habitat for moose, biological factors affecting moose populations, management practices and objectives, and harvest regulations. Out of fifty-one surveys distributed, forty-two were completed and returned, giving us a response rate of 82%. Out of the fifty-one jurisdictions surveyed, twenty reported a decrease in the moose population, three reported decreasing to stable, three reported stable, eight reported increasing, and one was unknown; fifteen were no response or data deficient for a population trend. In no order of importance, the most consistently reported reasons for populations declines captured in the surveys were: climate change, habitat degradation and/or loss, over harvest, predation, parasites, and lower than expected recruitment rates. We continue to attempt to get data from jurisdictions that have not responded. We also are preparing a full report on the survey to present at the 9th International Moose Symposium in Finland.

With the information from these surveys, we hope to educate professionals and public alike on the global pressures that moose currently face and to inform future management decisions regarding moose management and health.

IMPACT OF FOREST LANDSCAPE STRUCTURE ON MOOSE DISTRIBUTION IN EAST FENNOSCANDIA AND URALS

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The territorial distribution of moose in East Fennoscandia and Urals is considered by us, at the level of generalization of the territory, approximately corresponding to the level of β – diversity of habitats. We find it interesting to compare the data on the territorial distribution of moose in these two regions, which are far from each other, but have common geographic features. As an example, along with the plain and swampy landscapes in these regions, rugged rocky and moraine landscapes (Eastern Fennoscandia) and low-mountainous and mountainous (Urals) are widely represented. These common features distinguish them from the territory of the taiga forests of the huge Russian Plain, which is located just between the Urals and Fennoscandia. The data bases are the Wildlife Triangle Scheme in Finland (Lindèn et al. 1996) and the Winter Track Counts (WTC) in Russia (Priklonski 1973). In the boreal forests of the macroslope of the Ural Range, the population density of moose increases in the direction from the northern taiga to the southern one. The same is observed in Eastern Fennoscandia. A strong negative correlation was found between the density of moose and the proportion of wetlands in the subzones of the northern and middle taiga (the correlation coefficient in the Urals is 0.8, in eastern Fennoscandia - 0.60, $p<0.01$). Bogs here are represented by low-forage pine habitats, in contrast to the southern taiga willow ones. The second factor determining the spatial distribution of moose in all subzones is the mosaic nature of their habitats. The relationship between the population density of elk and this factor in the landscapes of the Urals turned out to be significant and very close - for the northern and middle taiga, $R^2 = 0.56$; for the southern one - $R^2 = 0.42$.A similar positive relationship has been reported for Eastern Fennoscandia. For the southern taiga, a connection with habitat mosaicity was also revealed at the local level, corresponding to the level of α-diversity of lands ($R^2 = 0.26$-0.38). Very strong and generally predictable changes are taking place in the intensity of the mooses' use of biotopes of the succession series: from felling to mature coniferous forests.

Here, a consistent increase in the intensity of the use of felling areas by moose (indicator of defecation and WPC) was recorded with an increase in the logging age from 1 to 10 years (r = +0.98) and a very strong correlation between the indicator of defecation accounting and the amount of winter branch feed in the biotope (+0.99). Based on the foregoing, we assume that when analyzing and comparing the patterns of territorial distribution of moose, it is important to keep in mind the landscape-geographical features of large regions, in terms of the level of generalization approximately corresponding to β-diversity. The similarity of the dependence of the distribution of moose on the structure of the landscape in regions significantly distant from each other testifies to the high role of the listed factors in the spatial distribution of this species.

SEASONAL PATTERNS IN FARMLAND MOOSE ROAD CROSSINGS AND VEHICLE COLLISIONS

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Anthropogenic habitat loss and fragmentation is widespread throughout North America and is one of the primary drivers of declines and extinctions in mammal populations. Agriculture has drastically changed a large portion of the global terrestrial landscape, replacing native habitats with annual and perennial crop cover and livestock production. Some native ungulates in North America have been particularly successful in agroecosytems, such as white-tailed deer (*Odocoileus virginianus*), but also elk (*Cervus canadensis*) and more recently moose (*Alces alces*) survive on agriculture-dominated landscapes. Moose have expanded their range dramatically their over the last 30 years out of the Boreal Plains Ecozone in Western Canada, into areas dominated by agricultural crops across much the of Prairie Ecozone. Our objectives in this study were to (1) characterize spatial, seasonal, and hourly pattern of adult female moose occurrences near highways and gravel roads, (2) examine patterns of reported moose-vehicle collisions, and (3) examine the role of habitat in attracting farmland moose to highways. As part of the first comprehensive study of farmland moose we deployed Global Positioning System collars collecting hour locations on 19 adult female moose for three years across six seasons (late winter, spring, calving, post-calving, fall, and early winter). We used all relocation data to determine spatial and temporal patterns of moose occurrences within 100 m of highway #11 in southern Saskatchewan, the busiest highway in the province for vehicle traffic, that has a speed limit of 110 km/hr for most of its length in rural areas. There was moderate variation in hourly occurrences near the highway, with a peak at 1-4 am and lowest at midnight but there was very high variation in the frequency of occurrences by month, with a peak from December to March and much lower from April to November. Moose occurrences within 100m of other paved highways had the same hourly pattern, but much different monthly pattern, with a strong peak in February only, moderate levels of occurrences in March, May, June and January, and very low levels in other months. Our analysis of moose-vehicle collision data from Saskatchewan Government Insurance (the province's compulsory and only auto insurance company) on moose-vehicle collisions (that included males and females) found that there was a peak in reported collisions in September, October, and November, and the lowest period was March, April, and May. Collisions peaked on Saturdays and Sundays. The majority (80%) of collisions occurred at night, ; however, when

standardized by collisions per hour, the most collisions were at dusk (0.14 collisions/hr) compared to day (0.02), dawn (0.04), and night (0.92). There was no significant difference between collision rates on regular weekends and holiday weekends. Additional analysis for this presentation will examine spatial and temporal patterns of highway crossings. Our findings have important implications for managing and mitigating moose-vehicle collisions, informing placement of signage and potentially adjustment of speed limits during highest risk periods.

HISTORICAL RESPONSE OF MOOSE TO CHANGES IN FOREST COMPOSITION IN MINNESOTA, 2006–2020

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In Minnesota, moose (*Alces alces*) are at the southern extent of their range and are susceptible to climate-induced stressors that are expected to become increasingly pronounced in the future. Being a cold-adapted species, moose are experiencing year-round thermal heat stress from a warming climate, which may be exacerbated by the loss of their thermoregulatory habitat due to a shift from boreal towards temperate forest communities. Simultaneously, changes to disturbance regimes in the region have altered vegetation trajectories, affecting forage quality and availability. These factors, among others, have contributed to a 60% decrease in the moose population in northeastern Minnesota since 2005. ~~K~~ Understanding how moose have responded to forest composition and structure in the past can help managers project moose population changes in response to predicted future forest changes with changing climates. While there is a large body of literature on the influences of various forest cover types for thermal cover and forage, much of this research has been conducted at the individual-level, with only a few studies investigating how large-scale forest composition affect moose at the population-level throughout their entire range in Minnesota. Here we evaluated the influence of various forest cover types on moose population estimates from 2006–2020 in northeastern Minnesota.

We related moose aerial population estimates to LANDFIRE-Existing Vegetation Types composition at the aerial survey plot level. We used a generalized linear model (GLM) to assess the influence of cover type on moose abundance through time. We developed a candidate set of a priori models based on the importance of cover types to foraging and cover (thermoregulation) and selected a best fit model based on Akaike's information criterion (AIC). We re-classified LANDFIRE- Existing Vegetation types into 20 vegetation types based on species composition, hydrology, and age in relation to hypothesized functional importance to moose. These 20 vegetation types were further grouped into one of four cover types: lowland food, upland food, lowland cover, and upland cover. Using these four cover types, we developed eight candidate models each for three different spatial extents (plot-level, plot-level plus 2.8 km buffer, and

plot-level plus 3.8 km buffer) to test the influence of food, cover, and the combination of food and cover on moose abundance. There was no strong influence of an interaction between spatial extent and cover type on moose abundance, so we only assessed relationships at the plot-level extent for final analyses.

The model including upland food and upland cover was the best performing model from all models we tested. Exploring our best-fit model, Pine-Black Spruce-Hardwood forests and Balsam Fir-Spruce forests were thermal cover types that were positively correlated with plot-level moose abundance. Food cover types that were positively correlated with moose abundance included Northern Hardwood forests, Aspen-Birch forests, and Successional Grasslands and Forests. Moose abundance decreased in plots with greater amounts of Forest Plantations, Ruderal Forests, and Successional Shrublands.

These results highlight the importance of thermal cover and foraging habitat for moose across large spatial scales. Retaining some level of thermal cover and forage on the landscape likely provides the necessary habitats for moose to change their behavior based on the current environment and surrounding resources. Management focused on juxtaposing high quality thermal cover and forage may provide a path forward for managing moose habitat in the region. Further, because some species that appear to be positively correlated with moose abundance may be more susceptible to climate change, like black spruce and balsam fir, management strategies that prioritize these species should be considered when developing land management guidelines for moose.

LANDSCAPE DISTURBANCE ALTERS THE COMPOSITION AND DIVERSITY OF THE DIET OF A GENERALIST HERBIVORE

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One of the major threats to large herbivores is human-caused landscape disturbance. Across central British Columbia (BC), Canada, industrial forest harvesting is resulting in rapid change to forest structure and composition. Concurrent with the increase in forest harvesting, moose (*Alces alces*) populations across central BC have declined dramatically. We studied moose diet across three seasons in two regional study areas that represented a range of logging intensity and rate of apparent starvation of moose. We used microhistological analysis of pellets to identify the proportional consumption of major plant groups that were known forage for moose across the study areas, as well as the diversity of the diet of moose. We used regression models to explore hypotheses which may explain the composition and diversity of moose diet. In areas of increased density and size of clearcuts, moose consumed fewer shrubs and fir and their diet was more diverse. In areas of increased use of herbicides, moose consumed fewer forbs and their diet was more diverse. In areas of increased disturbance by wildfire, moose consumed less fir and more shrubs. Our results reveal that landscape disturbance in the form of forest harvesting alter the diet composition and diversity of moose, a generalist herbivore.

CLICHES, DEMONS, AND THE ORCHESTRA

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Careers can be linear or haphazard. Our paths are not always clear nor easy, but always informing. Time is critical in nature; figuratively and literally. Timing is everything and passes in a blink of the eye. Lessons we learn along the way, hard fought or gifted, are important in applying to the resources we manage and the collaborators we align with. I will discuss building a moose management program that integrates research and management within the context of life's experiences; that adaptively managing resources considering climate change, scientific gaps, and human conflict is requisite in making continued progress in our management programs and knowledge base. Being adaptive is required as well amongst humans sharing a challenging world. Our lives and careers continuously shaped by outside forces provides opportunity as well as instruction in how we navigate the societal, political, and ecological challenges we all face. For today more than ever we must find the goodness, positivity and alliances that resonate a tone more towards collaboration than dissent. We are all part of the orchestra, locally and globally. Our collections of instruments and voices have the potential to create extraordinary synergy to assess, understand and manage complex phenomenon. Inviting new members, mentoring them, engaging with seasoned players can bolster and invigorate all. Finding courage to set aside cliches, manage our own demons, and move forward despite roadblocks and setbacks can be found in our attentiveness to the resources we manage. That is, in continuing to explore the inherent complexities of nature as well as the appreciation of it, we may find solace that inspires us to fully engage in the orchestra in a way that supports and sustains our colleagues and perhaps the natural resources we are called to understand and manage.

NO EVIDENCE OF MOOSE-ASSISTED SPREAD OF AN AMPHIBIAN FUNGAL PATHOGEN

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The fungal pathogens *Batrachochytrium dendrobatidis* (Bd) and *Batrachochytrium salamadrivorans* (Bsal) cause chytridiomycosis in amphibians and are of considerable conservation concern. Bd and Bsal encyst in keratinized tissues of amphibian hosts, disrupting critical processes like respiration and osmoregulation, and sometimes causing death. It is not clear how Bd and Bsal spread spatially, but pathogen detection data for Bd in the Rocky Mountains suggests large leaps in Bd colonization that are inconsistent with amphibian-mediated spread alone. Non-amphibian organisms like waterfowl or ungulates are potential vectors of these pathogens, due to their keratinized structures (i.e., feet, feathers, or hooves). Given the large population of moose (*Alces alces*) in the Rocky Mountains and their association with wetlands that are also used by amphibians, we designed a research study to test whether moose serve as Bd vectors. We swabbed the hooves of 21 moose captured in Rocky Mountain National Park and 31 moose in North Park, Colorado in 2017-2019 in areas where Bd is known to occur. We did not detect Bd in any of the 52 samples. We conclude that there is no immediate evidence that moose are contributing to the spatial spread of Bd and expect that moose are also unlikely to play a role in the spread of Bsal if it successfully invades North America.

USING METABARCODING TO STUDY EFFECTIVE CONTACT FOR BRAINWORM TRANSMISSION BETWEEN MOOSE AND GASTROPODS

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Moose (*Alces americanus*) are culturally, ecologically, and economically important to Minnesota and experienced a ~50% population decline across the state over the last three decades. Brainworm (*Parelaphostrongylus tenuis*), a nematode with a gastropod intermediate host and white-tailed deer (*Odocoileus virginianus*) definitive host, is associated with 25-33% of those deaths. Moose must consume infected gastropods to contract brainworm, making a sound understanding of this interaction crucial. However, we lack empirical data on the gastropod species moose consume or when they consume them. High-throughput sequencing provides new opportunities to explore this interaction by metabarcoding moose feces. In collaboration with the Grand Portage Band of Chippewa, for whom moose are a historically important subsistence species, we obtained 246 temporally stratified moose fecal samples on or near the Grand Portage Indian Reservation in Minnesota, USA and amplified a fragment of the mitochondrial cytochrome oxidase subunit I gene from each sample. We then sequenced the fragments for each sample and compared the sequences we obtained to a known gastropod sequence database for species identification. We detected moose consumption of two gastropods (*Punctum minutissimum* and *Zonitoides arboreus*) in the 175 moose fecal samples that successfully amplified and were sequenced. This study is the first to empirically document gastropod consumption by free-ranging moose. Although inconclusive due to the small number of gastropod detections, our findings suggest that moose consumption of gastropods is a rare event, that fall may be an important time of contact between moose and gastropods, and that gastropods may be consumed more often in areas where moose browse close to the ground. This study also provides proof of concept that these interactions can be documented through a fecal metabarcoding approach, albeit at a low number of detections. Future studies could utilize a more temporally and spatially targeted sampling approach, where effort is concentrated during autumn and near areas where moose browse close to the ground the ground (i.e. salt licks).

GREY WOLVES REDUCE *PARELAPHOSTRONGULUS TENUIS* TRANSMISSION RISK FROM WHITE-TAILED DEER TO MOOSE

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Predators trigger cascade effects in wildlife communities by influencing prey demography and behavior, and these effects are important mechanisms for modulating disease transmission within populations of prey species. While research is dominated by studies of predator lethality over infectious hosts, less is known about the nonlethal effects of predator presence on disease transmission among prey, particularly as it related to transmission among diverse species (e.g., spillover). In Minnesota, where grey wolves (*Canis lupus*) are a primary predator of moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*), spillover transmission of brainworm parasite (*Parelaphostrongylus tenuis*) from deer causes ~25% mortality in moose. We modeled the risks of parasite spillover between these two prey species, accounting for predator presence and landscape configuration by incorporating high-resolution habitat and movement data of all three species. We found that parasite spillover risk from deer to moose increased with spring migratory movements of the cervid hosts. Wolf presence modulated habitat responses, particularly in deer, which were primarily characterized by changes in elevation selection. We consistently found that wolf presence decreased parasite-spillover risk from deer to moose by influencing host-species segregation across the heterogeneous landscape. Specifically, we identified spatial compartmentalization as a nonlethal mechanism to modulate disease emergence by reducing the spatiotemporal overlap between infected and susceptible prey. These findings enhance our understanding of how wildlife disease patterns may change with landscape disturbance and the loss of large carnivores, which should be considered in the ongoing management of these important species.

GENETIC CONFIRMATION OF MENINGEAL WORM AND MUSCLE WORM L1 STAGE IN WHITE-TAILED DEER FECES IN MANITOBA

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Meningeal worm (*Parelaphostrongylus tenuis*) and muscle worm (*Parelaphostrongylus andersoni*) are protostrongylid nematodes commonly found in white-tailed deer (*Odocoileus virginianus*). In Manitoba, meningeal worm infection in deer has led to conservation concerns for moose as deer disperse larval worms into the environment that can go on to cause neurological disease in moose (*Alces alces*). In contrast, muscle worm is considered to be less of a threat to moose both in terms of its limited morbidity and mortality, and geographic distribution. One common way to determine whether protostrongylid species are present in an area is to assess white-tailed deer fecal samples for the presence of the L1 stage. However, the L1 stage has no distinguishing morphological characteristics between the two species. Therefore, without the use of genetic markers, it is unclear whether fecal samples contain either or both of these species. We sequenced DNA of L1 stages collected from fecal pellets of white-tailed deer in several localities in Western and Southern Manitoba. We amplified a region of the cytochrome oxidase I gene to identify the species of protostronglyid larvae. Our preliminary results suggest that *P. tenuis* and *P. andersoni* are present in white-tailed deer in Manitoba. This result is notable as we found *P. andersoni* in areas where it has not been previously reported. Our results also suggest hybridization between the species but sequencing at other genes is required to confirm. Detecting both species in white-tailed deer in Manitoba suggests that estimates of the prevalence of meningeal worm from white-tailed deer feces will require further corroboration to ensure more accurate estimates of the risk of meningeal worm transmission to moose.

TERRESTRIAL GASTROPOD SPECIES-SPECIFIC RESPONSES TO FOREST MANAGEMENT: IMPLICATIONS FOR PARELAPHOSTRONGYLUS TENUIS TRANSMISSION TO MOOSE

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Multiple taxa of terrestrial gastropods are important intermediate hosts in the lifecycle of the parasitic nematode *Parelaphostrongylus tenuis*, for which white-tailed deer (*Odocoileus virginianus*) are definitive hosts. Moose (*Alces alces*) become infected with *P. tenuis* when they incidentally ingest gastropod intermediate hosts, leading to morbidity and mortality. Landscape management can influence the distribution, abundance, and diversity of terrestrial gastropods that are known hosts of *P. tenuis*. We investigated the role of forest management on the terrestrial gastropod community, and specifically known intermediate host species of *P. tenuis*, on the Grand Portage Indian Reservation in northeastern Minnesota, USA. Field crews surveyed gastropods through timed searches of soil and litter, and opportunistic collections from browse and pellets of white-tailed deer and moose. We digested all identified gastropods to determine prevalence of *P. tenuis* infection. We examined gastropod community responses to management and forest cover type using multivariate regressions. We additionally used Poisson regressions to examine total gastropod richness and abundance, as well as *P. tenuis* intermediate host responses to cover type, soil moisture class, canopy, treatment, and years since treatment. Digestions detected no infected gastropods. Gastropod community assemblages shifted with recent treatment, but no other predictors. Total gastropod abundance and host abundance were highest in 16–30-year-old boreal clearcuts and lower in sites treated within the last five years. Canopy closure differentially affected metrics: overall species richness and *Discus cronkhitei* both increased with increasing canopy closure, whereas pooled intermediate host and *Succinea ovalis* group abundances decreased. Wet mesic sites contained higher species richness and *Succinea ovalis* group abundance. For known intermediate host

taxa, we observed species-specific responses to forestry treatments through time. Specifically, *Deroceras spp.* recolonized sites post-treatment (0–30 years), *Discus cronkhitei* were higher in abundance immediately following treatment, and the *Succinea ovalis* group, along with pooled intermediate hosts, displayed no discernable patterns. Our results underscore the complexity of *P. tenuis* lifecycles and transmission dynamics to moose, the importance of management disturbance in regulating gastropod populations, and a potential need for additional treatments after clearcutting to combat *P. tenuis* infection in moose.

A LOOK AT GENOME-WIDE SINGLE NUCLEOTIDE POLYMORPHISM DIVERSITY AMONG THREE MOOSE SUBSPECIES IN THE CONTIGUOUS U.S.

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Here we present the results of our recent manuscript submitted to Conservation Genetics, "Genome-wide SNP analysis of three moose subspecies at the southern range limit in the contiguous United States."

A number of moose (*Alces alces*) subpopulations are in decline along the southern edge of their range in North America. Multiple factors including disease, species interactions, and marginal habitat contribute to these declines, all of which may be exacerbated by climate change. Genome-wide evaluations of genetic diversity and population structure are important for informing management and for the conservation of trailing-edge populations, which often face a greater number of stressors than populations in the core of a species' range. We employed a genotyping by sequencing (GBS) approach in an effort to assess genome-wide variation of these moose subpopulations. Our samples included 155 moose representing the three subspecies in the contiguous U.S. (state origin of sample in parentheses): *A. a. americana* (New Hampshire), *A. a. andersoni* (Minnesota), and *A. a. shirasi* (Idaho, Montana, and Wyoming). Following sequencing and quality filtering, we had 1,920 single nucleotide polymorphisms (SNPs) remaining for our assessment. Multiple molecular analyses supported three geographically isolated clusters, congruent with currently recognized subspecies. Additionally, while moderately low genetic diversity was observed, there was little evidence of inbreeding. Results also indicated >20% shared SNPs between *A. a. shirasi* samples from the northern range of Montana and *A. a. andersoni* samples in Minnesota, which may represent a hybrid zone but warrants further investigation. The use of GBS has proven to be a simple and effective method for genome-wide SNP discovery in moose, greatly increasing resolution and providing insight to inform herd management and conservation priorities. As pressure increases on these subpopulations due to disease, predation, and climate change, the ability to assess population-level genomic changes via SNP analyses may prove a powerful tool for moose management and recovery.

PHYLOGEOGRAPHY OF MOOSE IN WESTERN NORTH AMERICA

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Subspecies designations within temperate species' ranges often reflect populations that were isolated by past continental glaciation, and glacial vicariance is believed to be a primary mechanism behind the diversification of several subspecies of North American cervids. We used genetics and the fossil record to study the phylogeography of three moose subspecies (*Alces alces andersoni*, *A. a. gigas*, and *A. a. shirasi*) in western North America. We sequenced the complete mitochondrial genome (16,341 base pairs; n = 60 moose) and genotyped 13 nuclear microsatellites (n = 253) to evaluate genetic variation among moose samples. We also reviewed the fossil record for detections of all North American cervids to comparatively assess the evidence for the existence of a southern refugial population of moose corresponding to *A. a. shirasi* during the last glacial maximum of the Pleistocene. Analysis of mtDNA molecular variance did not support distinct clades of moose corresponding to currently recognized subspecies, and mitogenomic haplotype phylogenies did not consistently distinguish individuals according to subspecies groupings. Analysis of population structure using microsatellite loci showed support for 2–5 clusters of moose, including the consistent distinction of a southern group of moose within the range of *A. a. shirasi*. We hypothesize that these microsatellite results reflect recent, not deep, divergence and may be confounded by a significant effect of geographic distance on gene flow across the region. Review of the fossil record showed no evidence of moose south of

the Wisconsin ice age glaciers ≥15,000 years ago. We encourage the integration of our results with complementary analyses of phenotype data, such as morphometrics, originally used to delineate moose subspecies, for further evaluation of subspecies designations for North American moose.

GEOPHAGIA OF MOOSE IN THE CENTRAL YAKUTIA (RUSSIA)

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The area of research can be classified as circumpolar regions, which fall under the regions where geophagia is most manifested (Panichev & Gulkov, 2001). The study of the geophagia of wild ungulates in Northern climatic conditions is relevant because stressful conditions for the animal's organism such as cold temperatures, sharp change of seasons, accelerated phenology of animals themselves and plants eaten by them, rapid physiological reorganization of the animal's organism from one type of food to another can lead to disorders of the gastrointestinal tract and other organs. We have already covered some aspects of the geophagia peculiarities of wild ungulates in Yakutia in previous works (Stepanova, 2003; Stepanova & Okhlopkov, 2009; Argunov & Stepanova, 2011; Argunov et al., 2015).

The aim of the work is to study the geophagia etiology (temporal, seasonal, daily, age and sex) of moose (*Alces alces pfizenmayeri* Zukowski, 1910) in Central Yakutia.

The registration of summer-autumn geophagia of moose with Bushnell and Super Scouter camera-traps was carried out at five natural mineral licks in Central Yakutia, Russia (Fig. 1). During the summer, inspectors added rock sodium salt at three salt licks. The camera-traps with the set date and time were fixed on trees at a height of 3-4 m from the ground. The photographing of moving objects was recorded at intervals of 5 seconds. A total of 235 camera-trap-days were spent, breaking down by months as follows: June – 34, July – 60, August – 65, September – 60, October – 16. Over this period, they registered 122 single and group visits to the mineral licks. Totally 215 moose visits of the mineral licks were spotted, with the same individuals coming repeatedly. In terms of age and sex, only 31 moose individuals were identified. The statistical processing of the material was carried out under the standard statistics with the use of the Excel program.

The research results in the following conclusions:

1) The duration of geophagia of moose takes from 1 to 40 minutes. Cows use licks 13.1% longer than bulls.

2) Moose come to the mineral licks mainly during the dark hours from 20 to 8. Cows are more cautious than bulls, and they are usually observed at the mineral licks after the midnight.

3) In our case, the percentage of attendance was high in June-July, though in June the number of camera-traps-days halved compared with the following months. This fact is explained by the greatest requirement of wild ungulates in mineral nutrition during the growth of antlers and during lactation for cows. In the following months (August-September), the geophagia of moose fell sharply and it dropped to zero in October.

4) In June, cows visit the salt licks more frequently than bulls, which are caused by calving and lactation of the dams. In July, on the contrary, bulls prevail, which is associated with the ossification of antlers this month. In August and September, males are registered on the mineral licks twice as often as cows, which may be explained by the preparation of males for the upcoming rut, fattening up and long migration passages.

5) Cows with calves, whose lactation just starts in June, visit the mineral licks more in June than cows without calves, which come to the mineral licks evenly within the two months.

6) The sex ratio in the population is 1:1, with the calves making 32.2% in the population structure.

THE MAIN PROVISIONS OF THE METHODOLOGY FOR THE QUANTITATIVE ASSESSMENT OF SEASONAL MOVEMENTS OF ELK

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The study of moose movements by methods of trailing, GPS-navigation and control of the composition of prey did not lead to the creation of a method for quantifying migrations, since temporary associations of individuals that do not have a single migration flow are formed at winter camps. For exploited moose populations, the emigration of individual individuals from summer stations to large forest areas and protected areas is a way to optimize the impact of negative factors of the winter period, and the return in the spring to summer stations is a confirmation of the high biological role of seasonal migrations in ensuring the reproduction of the livestock of this species. Due to the coincidence of the peak of migration activity with a period of intensive hunting, in the extraction is constantly increasing, or decreasing (depending on the migration status of the territory) the proportion of migratory moose, but the difference between the estimated and actual number and the share of migrants in the realized quota remain unknown. Effective management of elk populations does not occur, the efficiency of management is low. A quantitative assessment of movements is required to determine the level of fishing abundance and adjust quotas. Such a task is relevant, systemic, significant for the entire range of the species. Isotopic analysis is recognized as the most functional and accurate method of identification of animals and their summer habitats, by chemical markers in animal feed and tissues. With a known chronology of hair growth, the coincidence of the amount of carbon isotopes C13 and nitrogen N15 in the hair and in the summer diet of elk, allows you to localize the areas of summer habitat of immigrant individuals. The reliability of the proposed method of localization of summer forage sites of identified individuals is confirmed by one of the postulates of system isotopic analysis (SIA), "which allows solving previously inaccessible problems in the field of ecology of biological invasions, etc." Comparison of the data identified in the coordinate system, the isotopic composition of the cover tissues of the extracted moose with the isotopic background of the summer diet of elk in individual areas - selection units, allows us to calculate the values of all parameters of the migration process, including 200th characterizing the number of migrants in production and the total number. To reduce the complexity of the work, it is planned to create a software package for recording sampling points and processing the values of the isotope content in animal feed and tissues. State support is required in the organization and financing of approbation works.

MOOSE BEHAVIOUR IN RELATION TO OPERATING WIND TURBINES IN NORTHERN SWEDEN

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Increasing energy demand around the world and concomitant challenges in mitigating the climate change lead to increasing use of alternative energies, such as wind power facilities. Whereas the effect of wind turbines on volant species are well-studied, the responses of terrestrial mammals remain mostly unknown. Large ungulates such as moose (*Alces alces*) are ecologically important as well as they provide key services for society. Both for management purposes and for future wind park planning processes, knowledge about potential effect of wind turbines on mammals habitat use is crucial. Here, we investigated moose behaviour (11 females, 5 males) over three years in northern Sweden in relation to three small operating onshore wind parks using high-resolution GPS-data. The primary objectives of this study were to: 1) investigate moose activity (meter/hour), 2) avoidance of wind turbine proximity (using step selection functions), and 3) potential shifts in habitat preference based on proximity to wind turbines (using the Ivlev-Index). Our findings emphasized that moose moved less in proximity to wind turbines, but became more active beyond five kilometre from the nearest turbine. We did not find any indication that moose avoided wind turbines, but our results suggest that moose selected for wind turbine proximity. Furthermore, we found that moose with core areas closer to wind turbines (within 5 km distance) used proportionally more forested habitats than those further away. Our study gives first insights into moose behaviour in relation to wind power parks and does not indicate a major impact on moose habitat use and activity.

MOVEMENT, ACTIVITY, AND BEDDING BEHAVIOR OF MOOSE IN MINNESOTA

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Moose (*Alces alces*) are cold-adapted ruminants with a relatively low tolerance for warmer temperatures. With current technology, the movement and activity of free-ranging moose can be recorded simultaneously through GPS locations and activity sensors. Frequent concurrent measurements of moose movement and activity improves our understanding of how season, temperature, and bout duration affect the movement and bedding behavior of moose. Nine adult moose were fitted with GPS collars and dual-axis activity sensors in the Superior National Forest in northern Minnesota. GPS locations were recorded every 20 minutes and synchronized with activity counts. Intervals with activity counts of 0 were considered inactive while intervals with activity counts greater than 0 were considered active. Short 20-minute bouts were the most frequent across all seasons and periods where moose moved less than an average of 0.5 m/minute for an hour were more common in bouts over 2 hours long. During active bouts, activity and distance moved during each 20-minute interval peaked at the middle of each bout. This pattern may be caused by the smaller comfort movements that characterize the beginning and end of active bouts or by increasing rumen fill during the latter half of active browsing bouts. The duration of inactive bouts decreased as temperature increased while the duration of active bouts increased until reaching a maximum. The percent of each day spent active varied by season with moose spending more time active from Julian day 100 in spring to Julian day 250 in late summer. The male moose had an additional spike at the beginning of rut lasting from Julian day 215 to Julian day 247. Daily moose movement and activity was crepuscular, peaking about 2 hours after sunrise and sunset. Moose activity also increased slightly between 1 to 4 hours before sunset in all seasons except winter. Activity and travel distances during daily maximums were highest during summer when nocturnal activity and movement also increased. The maximum bout duration for female moose occurred at a higher temperature than the maximum for the male. The effect of temperature on distance moved was more pronounced during the warmer months where average travel distance stopped increasing around 12 degrees Celsius during spring and decreased around 18 degrees Celsius in summer. Moose modified their activity and movement during warmer temperatures, suggesting feeding behavior during spring and summer may be affected by higher temperatures brought about by climate change.

REDEFINING PHYSIOLOGICAL RESPONSES OF MOOSE (*ALCES ALCES*) TO WARM ENVIRONMENTAL CONDITIONS

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We tested the concept that moose (*Alces alces*) begin to show signs of thermal stress at ambient air temperatures as low as 14°C during the warm season. We determined the response of Alaskan female moose to environmental conditions from May through September by measuring core body temperature, heart rate, respiration rate, rate of heat loss from exhaled air, and skin temperature. Heart rate declined with increased ambient air temperature and was the lowest during the middle of the day. Respiration rate increased with ambient air temperature and was highest during midday. The rate of heat loss in exhaled air was greatest during midday and decreased with increasing vapor pressure, while the difference in ear skin temperature (difference between the ear artery and pinna) was the smallest during midday. Using established daily moose body temperature values, we used large changes in body temperature (≥1.25°C in 24hr) to indicate days of physiological tolerance to thermal stressors. Thermal tolerance correlated with high ambient air temperatures from the prior day and with seasonal peaks in solar radiation (June), ambient air temperature and vapor pressure (July). At midday (12:00hr), moose exhibited daily minima of body temperature, heart rate and skin temperature (difference between the ear artery and pinna) that coincided with daily maxima in respiration rate and the rate of heat lost through respiration. Our results suggest that free-ranging moose do not have a static threshold of ambient air temperature at which they become heat stressed during the warm season. In early summer, body temperature of moose is influenced by the interaction of ambient temperature during the prior day with the seasonal peak of solar radiation. In late summer, moose body temperature is influenced by the interaction between ambient temperature and vapor pressure. Thermal tolerance of moose depends on the intensity and duration of daily weather parameters and the ability of the animal to use physiological and behavioral responses to dissipate heat loads.

MOOSE DAM RESPONSES TO NEONATE CAPTURE: CAN WE MINIMIZE ABANDONMENT AND COLLECT NEEDED SAMPLES AND DATA?

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In response to a precipitous (46.0%) decline in northeastern Minnesota's moose (*Alces alces*) numbers, from 7,840 (2009) to 4,230 (2012), the Department of Natural Resources launched a study of calf production, survival, and cause-specific mortality from 2013 to 2016. A unique aspect of this study was that it was the first to fit global positioning system (GPS) collars to moose neonates, the value of which was enhanced by their respective dams also being GPS-collared, and collecting spatially accurate, hourly locations synchronously. Ultimately, this study succeeded in quantifying the negative impacts of low reproductive success and calf survival rates on the performance and trajectory of the population, and in identifying wolf (*Canis lupus*) and black bear (*Ursus americanus*) predation as the primary mortality forces. However, to achieve this we had to overcome a major challenge imposed by capture-induced abandonment of neonates by their dams. Although this behavior had been documented in many species of ungulates worldwide for decades, it had been addressed with littler more than anecdotal speculation in the literature. Our unique ability to closely monitor movements and distances of dams before, during, and following neonate captures, and of their respective neonates post-capture, relative to the capture (birth) site and each other, facilitated a much more thorough understanding, including the ability to identify it as it occurred. This understanding was enhanced by our examination of potentially predisposing factors, all of which was of value in developing a contingency plan for responding to abandonment. Our findings also facilitated informed consideration of alternative approaches for minimizing its occurrence without sacrificing data and sample collection. This deeper and more comprehensive understanding of this behavior in moose also may prove to be of value to capture operations of other ungulates.