Rangeland Research Institute

2021-2022 Annual Report

UNIVERSITY OF ALBERTA

Rangeland Research Institute

Table of Contents

Cover photo: L-R, Dr. Trevor Coates (AAFC), Dick Puurveen, and Marcel Busz install methane sensors at the Mattheis Research Ranch, 2021

Photo by Lisa Raatz

1. Introduction

Ranchers, farmers and those linked to the agriculture industry experienced well below average precipitation during much of 2021 and into 2022 across western Canada and the northern US; described as an "epic drought" in parts of Montana. Many ranchers in Canada's prairie provinces were forced to destock herds that they had carefully selected and genetically improved for decades. Compounding the effects of drought were issues with gaining access to feed over winter due to blocked borders, occasional rail worker strikes, higher costs of fuel to transport and conduct feeding activities, and an overall reduction in the feed available for sale because of the geographically widespread drought. While producers face multiple challenges to production, markets, and economics, drought and the risk of wildfire certainly became dominant pressing concerns again in 2021-22 with long-lasting effects likely to be realized for several years to come.

Elk winter grazing on the pivots at the Mattheis Research Ranch, winter 2022. Photo by Marcel Busz.

Researchers affiliated with the Rangeland Research Institute (RRI) investigate a wide array of topics that broadly relate to rangelands and their management, but often with a focus on the environmental goods and services provided by rangelands. These are areas of research that have not typically received research funding by major funding agencies. Among these topics, climate change research and its links to grassland management and grazing have been a key focus in order to improve our understanding of the long-term effects of worsening issues such as drought and wildfire, coupled with the need to markedly improve grazing management practices so as to maximize the ability of rangelands to tolerate and recover from disturbance. Much of this research takes place at the Mattheis Research Ranch as either the primary location, or one of several locations through network-based research activities. Situated in SE Alberta, the Mattheis Ranch represents a key agroclimatic region of the northern Great Plains, including more than 6.6 M ha of Dry and Mesic Mixedgrass prairie in Alberta, 2.6 M of which remains as native grassland.

Understanding the need for a research location in the ranching heartland of Alberta, University of Alberta alumni, Edwin and Ruth Mattheis generously and strategically donated their 5000 ha ranch to the University of Alberta. They realized the value of the land and chose to invest in

building an important legacy that would serve the ranching community they love, as well as others who have yet to learn about the value of this threatened grassland ecosystem. The Mattheis Research Ranch, the majority of which is intact native prairie, contains diverse plant communities and habitats, and combined with its multiple land use activity, is highly representative of a typical grassland and ranching operation in the northern extent of the Great Plains. This region is well-adapted to grazing and typically experiences lower precipitation relative to more northerly regions of the province, which help ensure that the native vegetation found there is dominated by perennial grasses. The Mattheis Ranch is a central location to much of the research conducted by researchers affiliated with the RRI, and complements other key research ranches in the province, including the Roy Berg Kinsella Ranch, Onefour and Stavely Ranches, as well as research locations on public and private land.

This report summarizes key activities undertaken by the RRI from April 1, 2021 through March 31, 2022. The report includes a brief summary of research activities, including three profiles of recently completed research projects; capacity building; a summary of communication and outreach activities for the RRI; current Strategic Advisory Council membership; as well as a financial summary of the previous year.

A newborn pronghorn is perfectly hidden by the prairie grass leaf litter in early spring at the Mattheis Ranch. Photo by Marcel Busz.

2. Research

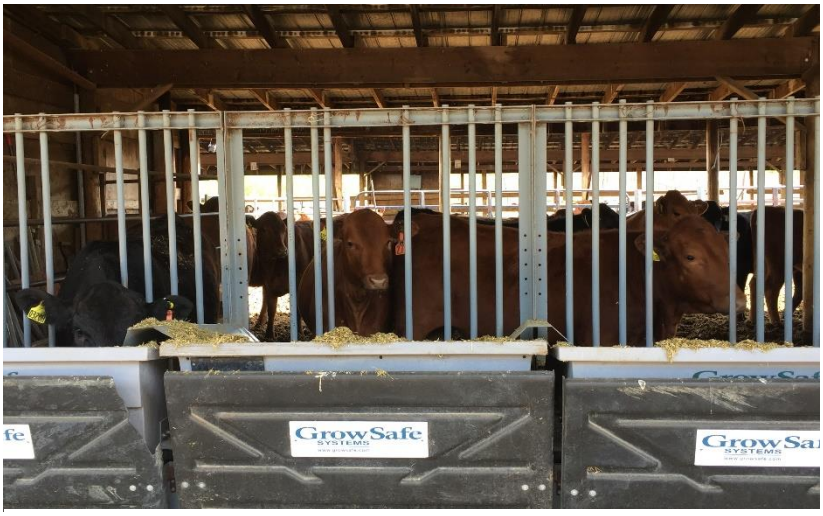
The coronavirus pandemic continued to have major impacts on travel, business, research and day-to-day life in 2021-2022 as increasingly contagious variants posed new risks to manage. Similar to 2020, University of Alberta (U of A) leadership closely followed the direction provided by the provincial government and Alberta Health Services. As a result, the 2021-2022 field season had reduced activity at all Research Ranches due to ongoing travel and accommodation limitations. However, as vaccines became available to the broader population during the summer months, some travel for research projects was approved, and activities have been slowly ramping up ever since.

Early spring blooms of moss phlox at the Mattheis Ranch, April 2021. Photo by Lisa Raatz.

The primary mandate of the RRI is to conduct research and expand our understanding of rangelands, including their biology and ecology, associated land uses, and responses to management. Many research projects are conducted at the two key U of A Research Ranches: the Mattheis Research Ranch and the Roy Berg Kinsella Research Ranch, as well as at Onefour and Stavely research stations, and on public and private land. Projects all relate to some aspect of rangeland ecology and management including those that focus on quantifying the environmental goods and services provided by rangelands. Projects that are still ongoing are listed in Appendix I. Select projects that have recently been completed are summarized in the following Research Profiles (Section 3).

The RRI directly funds research projects through the Competitive Grants Program, but also welcomes collaborations from within the U of A as well as outside organizations and partners. Several researchers used Mattheis and Kinsella Ranches for their projects despite the added challenges of traveling during the pandemic. A few projects are briefly outlined in the following paragraphs:

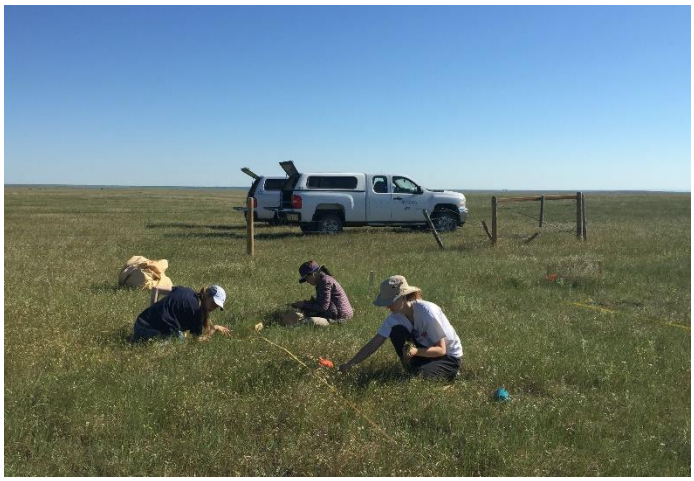
Dr. Edward Bork, RRI Director and Mattheis Chair, initiated a multi-faceted project on "Precision Ranching" that is relating cattle genomics and production to habitat and diet selection at the Roy Berg Kinsella Research Ranch. The study has several components including monitoring cattle habitat selection by tracking cattle locations using GPS collars and ear tags, evaluating cattle movement as they are rotationally grazed using pedometers and virtual fencing, and cattle diet intake and weight gain based on the herd's genomic RFI (residual feed intake) scores in drylot and in pasture. The study also includes a diet selection component: researchers assess which plants the cattle are eating in pasture by creating a DNA barcode library of native and agronomic plant species and then matching those species to the DNA from fecal samples of cattle on pasture.



Cows in the GrowSafe pens at the Kinsella Ranch.


L-R: Ava Ostad-Aghaei, Sidney Zemlak, Dr. Edward Bork and Jacqui Gironella assemble GPS cattle ear tags and pedometers for the precision ranching project at Kinsella Ranch, July 2021.

MSc student Anabel Dombro, supervised by Dr. Edward Bork, took on a project that was initiated in 2019 to evaluate the efficacy of the herbicide indaziflam applied in fall and spring to control invasive annual brome in southern Alberta. Annual bromes, including downy brome or cheatgrass (*Bromus tectorum*), Japanese brome (*B. japonicus*) and several other introduced species are replacing native grasslands across large geographical regions of the central and western US. Many of these species are moving northward through hay and feed shipments or on contaminated equipment and have now been found in native grasslands of southern Alberta. Few management tools exist to contain the problem, however, Bayer herbicide Rejuvra™ (indaziflam) has been registered for annual brome control in the US with registration pending in Canada. Anabel's project assesses the efficacy on annual bromes over several years, as well as the impacts of this herbicide on native forbs and grasses.



MSc student, Anabel Dombro (L) and research assistants, Ankhaa Battur and Jordan McLean (R) sample invasive annual brome in southern Alberta, June 2021.

Michelle Reid, an MSc student supervised by Dr. Boyd Mori, used Mattheis Ranch in 2021 as a survey location as well as a home base for conducting an alfalfa weevil survey in multiple crops in southern Alberta. Dr. Boyd Mori also used Kinsella Ranch as a location to survey for a native midge species that is found on native mustard species (Brassicaceae family). The survey will help determine whether the native midge has expanded its host range to include economically important crops such as canola.

Dr. Boyd Mori places insect traps for sampling endemic midge populations as far from the nearest canola crop as possible at Kinsella Ranch, July 2021.

Angelica Aguirre, an MSc student supervised by Dr. Derek McKenzie, collected soil samples at Mattheis and Kinsella ranches and other private ranches in Alberta to assess

soil quality in agricultural soils across the province resulting from farm management practices. The study also compares the quality of agricultural and non-agricultural soils. The project expands the baseline data set of the Soil Quality Monitoring Program, established by the ASRD in 1998, and will attempt to develop a decision-making framework for land users and farmers to assess the influence of their actions on soil quality within their landscapes.

The bright blooms of pincushion cactus at the Mattheis Ranch. Photo by Marcel Busz.

Research activity at the Mattheis Ranch was still reduced compared to a typical year due to a second season managing with Covid-19. A total of 39 individuals spent 115 person-days at the Mattheis Ranch in 2021-22, including 7 principal scientists, 13 graduate students, 10 undergraduate students, and 9 post-doctoral researchers, senior technologists, and other staff. Researchers using the ranch and housing were from the University of Alberta, mostly from the Faculty of ALES (Agricultural, Life and Environmental Sciences; Depts. of Agricultural, Food and Nutritional Sciences and Renewable Resources). Other U of A users included those from the Faculty of Science (Dept. of Earth and Atmospheric Sciences) and the Faculty of Arts (Anthropology). External organizations included Agriculture and Agri-Food Canada, University of Saskatchewan, and AJM Environmental based out of Calgary.

The Roy Berg Kinsella Ranch had pre-pandemic levels of use, mainly due to the initiation of the large multi-faceted Precision Ranching project. The ranch was used by a total of 44 individuals for 346 person-days, including 9 principal scientists, 17 graduate students, 13 undergraduate students, and 5 post-doctoral researchers, senior technologists, and other staff. Researchers using the ranch and housing were from the University of Alberta, mostly from the Faculty of ALES (Agricultural, Life and Environmental Sciences; Depts. of Agricultural, Food and Nutritional Sciences and Renewable Resources), as well as the Faculty of Science (Dept. of Biological Sciences and Earth and Atmospheric Sciences). External organizations included the University of Saskatchewan, Thompson Rivers University, and the Canadian Wildlife Service.

Pens at the north end of the Kinsella Research Ranch, April 2021.

Like the previous year, there was no call made for competitive grants in 2021-22. As before, this decision was made in order to maximize the contribution to the endowment principle and increase the spending allocation for research in the long-term. The RRI yearly spending allocation is a function of annual interest rates, and in recent years, has been used by the department in order to make up for budget shortfalls. Transferring funds from the RRI spending allocation to the endowment these past two years has also proved to be a practical approach since many research projects have been delayed or otherwise deferred in response to the challenges of conducting off-site research due to Covid-19. However, the RRI made a call for competitive grants in Feb 2022 (Table 2.1 lists successful applications in 2022) and anticipates increased research activity at both ranches this coming year.

Table 2.1. Competitive Grant proposals that were awarded funding from the RRI in March 2022.

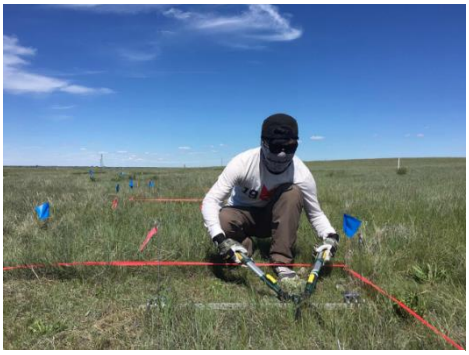
Researcher(s)	Project title	Location(s)
Holden, Cahill	Using network analyses to better predict ecosystem goods and services in Alberta rangelands	Mattheis & Kinsella
Amgaa, Carlyle, Cahill	The resilience of Alberta's grasslands to the combined effects of drought and defoliation	Mattheis ranch
Chang, Chen	Do defoliation intensity and time since defoliation affect plant carbon transfer and soil carbon accumulation?	Kinsella Ranch
Silva	*In Vitro* ruminal fermentation characteristics of different pasture types found at the Dry Mixedgrass natural subregion of Alberta	Mattheis Ranch
Thilakarathna, Carlyle	Effect of Cicer Milkvetch on soil carbon, nutrient availability, and soil microbiome in mixed prairie grassland	Mattheis Ranch

Herds of cows and elk graze near each other at the Mattheis Research Ranch, 2021. Photo by Marcel Busz.

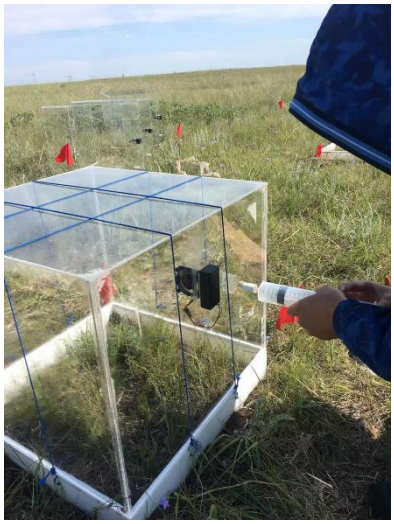
Understanding the effect of defoliation intensity on carbon flow in grassland plants and soils at the Mattheis Ranch

Prepared by Zilong Ma, Edward Bork and Scott Chang, University of Alberta

Livestock grazing is an important driver of the carbon (C) cycle in grasslands and can strongly affect the C source-sink relationship in the ecosystem, with implications for both the sustainability of managed grasslands and the potential contribution of grasslands to mitigate climate change via C sequestration. One key aspect affecting C cycling in grasslands is the intensity of grazing. High-intensity grazing removes much of the leaf area of grassland plants, thereby reducing the amount of C fixed via photosynthesis. With grasslands having most of their biomass belowground, this change also alters the potential flow of C belowground to build the root system and support soil microbes, which in turn may adversely affect the sustainability of the ecosystem. The response of grasslands to grazing intensity in terms of the allocation of photosynthates across the plant-soil system could also be affected by ecosite, which includes factors such as soil texture.



Post-doctoral fellow, Dr. Zilong Ma, applies the defoliation intensity treatments to research plots at the Mattheis Ranch, as a way of simulating cattle grazing.



Chambers built for applying the ^{13}C-enriched CO_2. ^{13}C-enriched CO_2 is injected into the chambers so that plants inside the chambers can take up this CO_2 having differential ^{13}C abundance, allowing its tracking in plant biomass and soil over time.

To improve our understanding of the effect of defoliation intensity and ecosite type on carbon flow, we tested the hypotheses that 1) photosynthetic C allocation in the plant-soil system of grasslands is differentially affected by the grazing intensity imposed the prior growing season, and 2) the C allocation would also be affected by ecosite type. We studied the fate of new C assimilates, using a $^{13}CO_2$ pulse-labelling technique. This technique follows C assimilates as they move from aboveground shoots to roots and soil in vegetation previously

exposed to different defoliation (emulating grazing) intensities in two semiarid Mixed Prairie grassland ecosites having contrasting soil textures (sandy vs. loamy) at the Mattheis Ranch.

Our research found that within 24 h after photosynthetic uptake of the $^{13}CO_2$, 34.5% of the labelled C was translocated out of shoots, with 21% of the labelled C moved belowground and into the mineral soil. Notably, grassland treated with high-intensity defoliation during the previous growing season had more of the newly fixed ^{13}C translocated into live roots at both ecosites throughout the chase period (the interval between the ^{13}C labelling and the time of destructive sampling of the labelled plant community), indicating a higher demand for photosynthetic C by the root system of heavily defoliated plants. Twenty-five days after labelling, ^{13}C transfer into the top 30 cm of mineral soil was consistently greater at the loamy (26% of total ^{13}C remaining) than at the sandy ecosite (10.4% of ^{13}C remaining) (Fig. 1). Our results therefore reveal that both grazing intensity and ecosite conditions alter patterns of C allocation within the plant-soil interface of grasslands.

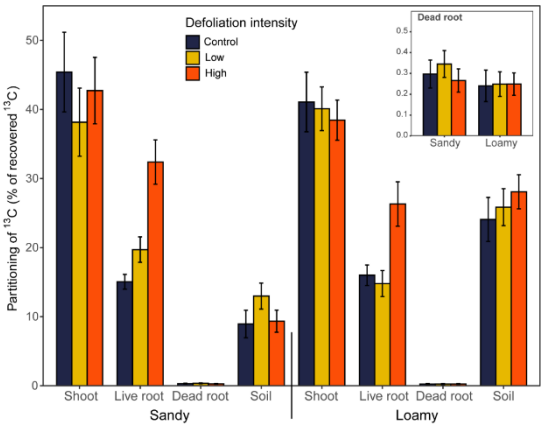


Fig. 1. Partitioning of 13C (percentage of 13C recovered) in plant shoots, roots (both live and dead), as well as mineral soil under previous exposure to different defoliation treatments and within different ecosites at the end (day 25) of the chase period. Results for roots and soil are shown for the combined sampling layers (0-30 cm). Error bars indicate ± SE (n = 4).

We conclude that conditioning grasslands with pulses of high-intensity defoliation the prior growing season may stimulate short-term C allocation to roots in these semiarid grasslands. Additionally, our findings highlight the greater overall potential of loamy rather than sandy soils to accumulate belowground C. Ultimately, the effect of defoliation intensity and ecosite in regulating short-term C allocation in the plant-soil system of temperate grasslands should be incorporated into future climate change and C sequestration models describing C cycling. This includes practical applications when predicting C dynamics under different management strategies employing contrasting grazing intensities.

A portion of this work is published: Ma, Z., E.W. Bork, J. Li, G. Chen, and S.X. Chang. 2021. Photosynthetic carbon allocation to live roots increases the year following high intensity defoliation across two ecosites in a temperate mixed grassland. Agriculture, Ecosystems and Environment, 316: 107450. DOI: 10.1016/j.agee.2021.107450

Finding new species of lichen

Prepared by Megan Lewis, Dr. Diane Haughland, and Dr. Cameron Carlyle

Biological soil crusts (BSC) are an important component of many ecosystems that are often overlooked because they occur on the soil surface, are small in stature and sometimes obscured by the overlying plant community. Yet despite their small size, BSC can make big impacts on ecosystem health by helping to cycle nutrients, protect soils from erosion, moderate soil moisture, and contribute a unique component of grassland biodiversity. Biological soil crusts are communities of different types of organisms including lichen, bryophytes and small statured vascular plants. They are also affected by land management and can serve as indicators of environmental change. Critically, the individual species within grassland BSC are not well described which makes it difficult to assess changes in these communities.

Megan holds a plug of biocrusts at the Mattheis Ranch containing two lichens: *Xanthoparmelia wyomingica* and *Cladonia symphycarpa*

MSc student, Megan Lewis, and her field assistant, measure cover of biocrust constituents at the Mattheis Research Ranch.

Megan Lewis, an MSc student at the University of Alberta co-supervised by Drs. Diane Haughland and Cameron Carlyle, undertook a project to resolve the identity of some lichen species commonly found in grasslands, including the University of Alberta's Mattheis Research Ranch. The *Cladonia cariosa* group of lichen has imprecise taxonomic boundaries that may inhibit the detection of changes in biocrust communities.

To resolve the species grouping within *Cladonia cariosa*, Megan measured morphological, chemical and molecular differences from many individual *Cladonia* specimens that were collected from throughout their nearly-global range (Plates 1 and 2 show morphological differences between the species). Megan's combined dataset suggests that where we had previously identified three species (*Cladonia cariosa*, *Cladonia symphycarpa*, and *Cladonia acuminata*) there were two additional undescribed species (Figure 1, Plates 1 and 2). One of the

potentially new species occurs in Alberta, including at the Mattheis Ranch, while the second appears to be limited to Europe.

Megan's work has highlighted the undescribed biological diversity right beneath our feet. However, the identification of BSC is challenging and often considered a highly specialized skill set. Without increased taxonomic training for lichen and better resources for lichen identification we may unknowingly misidentify or lose species from our grassland ecosystems.

Closeup of *Cladonia* cup lichen. Photo by Megan Lewis.

Publications are in preparation. Authors gratefully acknowledge funding for this project from the University of Alberta Rangeland Research Institute and the Royal Alberta Museum.

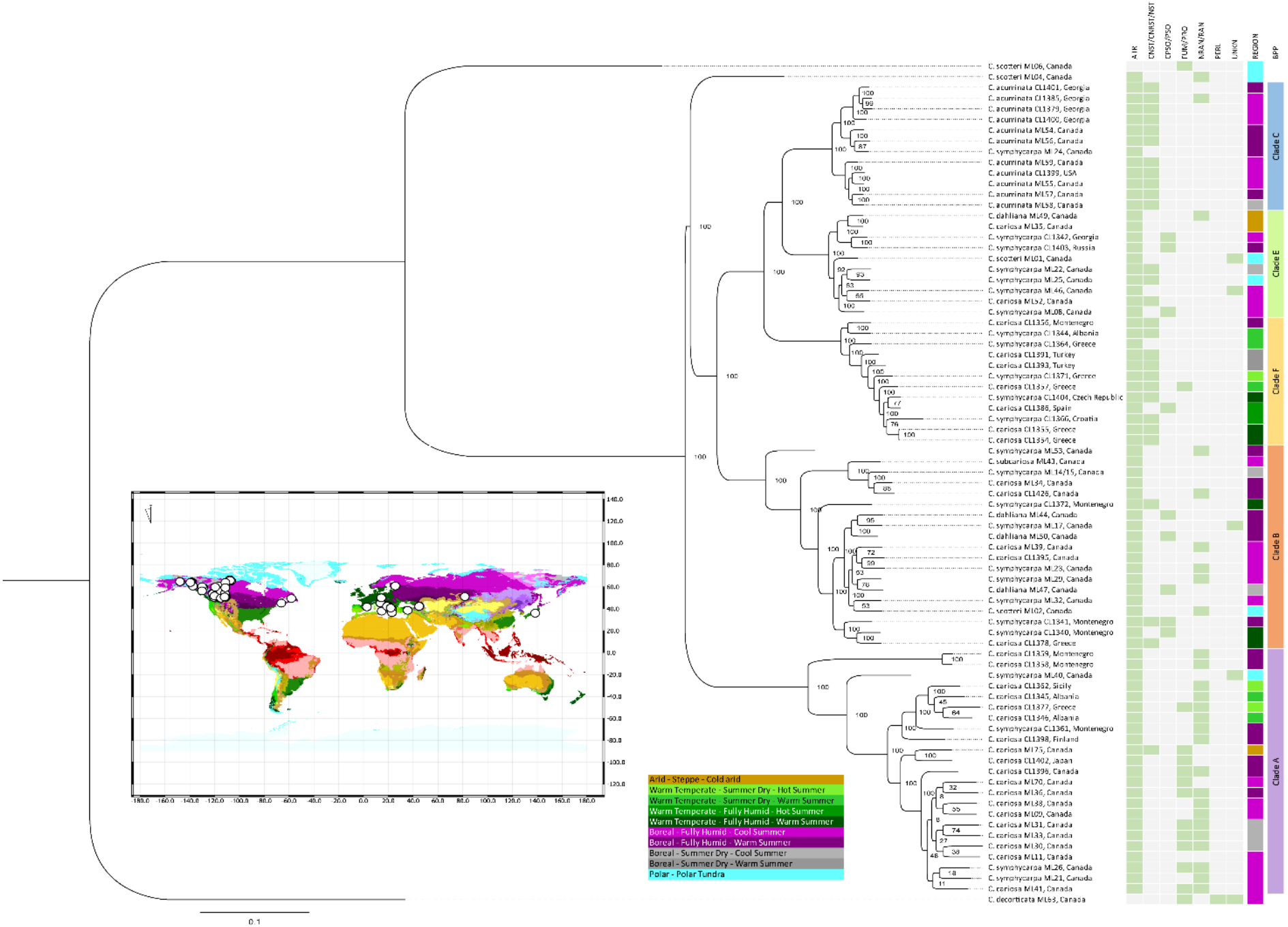


Figure 1. Family tree of the *Cladonia cariosa* group based on maximum likelihood analysis of a single nucleotide polymorphism (SNP) dataset produced by a Genotyping by Sequencing (GBS) method (LnL= -6,771,611.51). Bootstrap values are noted at tree nodes. Secondary metabolites present in specimens are denoted with green boxes next to the specimen name. Secondary compound abbreviations: ATR = atranorin, CNST = constictic acid, CNRST = connorstictic, CPSO = conpsoromic acid, FUM = fumarprotocetraric acid, NORANG = norrangiformic acid, NST = norstictic acid, PSO = psoromic acid, RANG = rangiformic acid, UNKN = unknown compound. The Koppen-Geiger climate classification of the specimen is denoted in the region column, and the Bayesian Phylogenetics and Phylogeography species delimitation results are denoted in the final column.

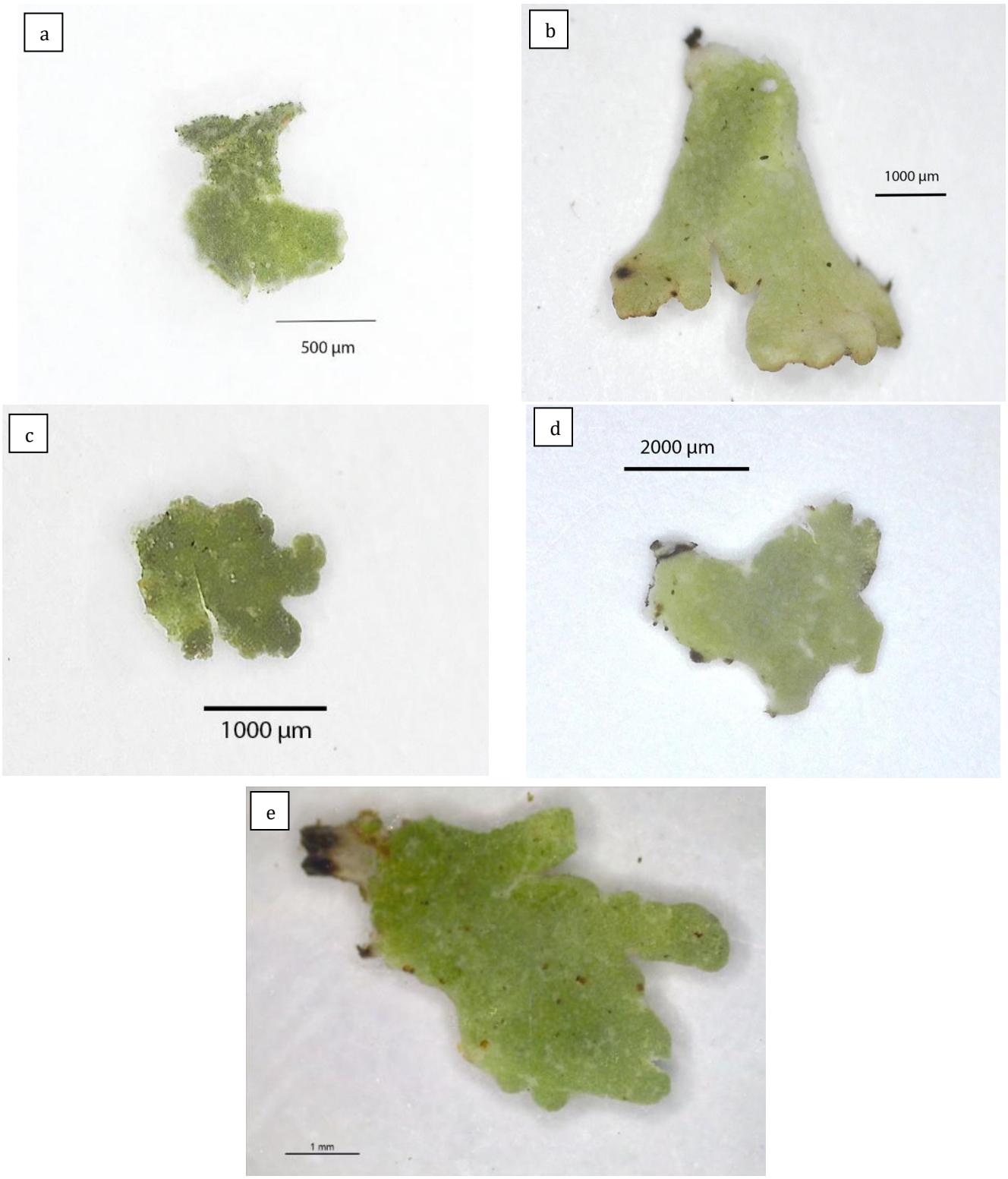


Plate 1. Side-by-side photographs of representative squamules from delineated genetic species *C. cariosa* (a), *C. symphycarpa* (b), *C. acuminata* (c), Clade E (d), and Clade F (e).

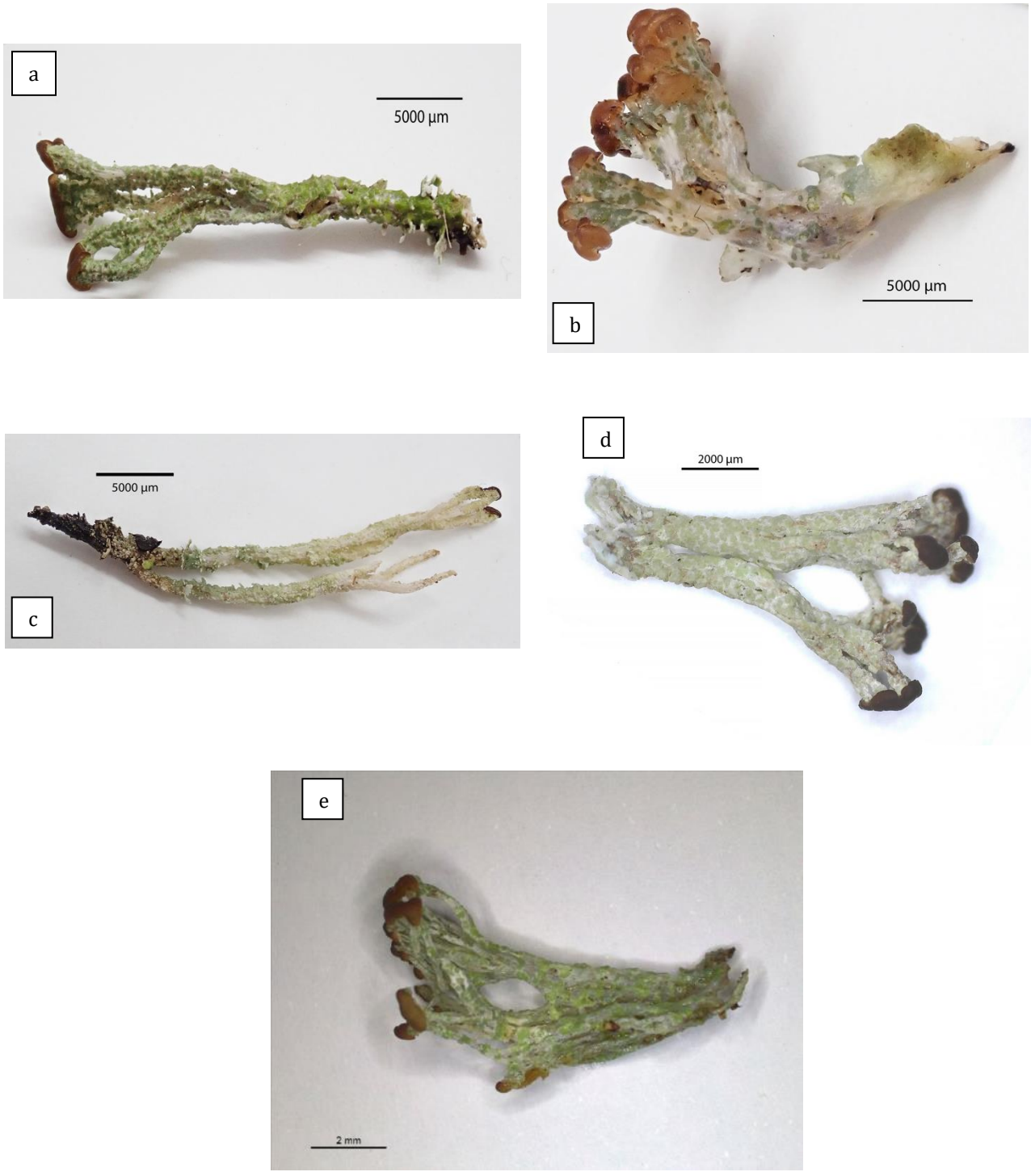


Plate 2. Side-by-side photographs of representative fruiting structures from delineated genetic species *C. cariosa* (a), *C. symphycarpa* (b), *C. acuminata* (c), Clade E (d), and Clade F (e).

Using drones to measure heat stress in cattle

Prepared by Justin Mufford, Dr. John Church, Dr. Cameron Carlyle

The long-term sustainability of livestock production is threatened by climate change. Due to increasing amounts of carbon dioxide in the atmosphere, the earth's climate is warming and precipitation patterns are changing. In 2021, the Canadian prairies experienced record-setting temperatures, in which cattle experienced detrimental environmental conditions, risking heat stress, or even death. Measuring heat stress in cattle, and ultimately identifying and selecting cattle that can tolerate higher temperatures, will be critical to ensuring cattle welfare and productivity are simultaneously maintained into the future.

In North America, Black Angus, a breed commonly used in beef production, may be more susceptible to the effects of climate change due to its dark hair coat that absorbs more solar radiation than light-coloured hair. Thus, there is a greater risk of susceptibility to heat stress, and associated reductions in productivity, as well as enhanced morbidity and mortality in these animals, relative to those with lighter colouring. However, observing and assessing cattle responses to heat can be challenging, especially on 'open-range' pasture, where animals may be difficult to locate and monitor.

Unmanned aerial vehicle (UAV) or drone image of variously coloured cattle in a feedlot setting.

Observing heat stress in cattle in a ranch setting poses challenges because of the potentially expansive land base. UAV image of cattle grazing at the Mattheis Ranch.

In a study conducted by Justin Mufford, an MSc student at Thompson Rivers University working with John Church (TRU) and in collaboration with Cameron Carlyle (U of A), unmanned aerial vehicles (UAVs) were used to observe cattle in pasture at the Mattheis Research Ranch and in a privately-owned feedlot setting to measure respiration rate, and other behaviours (e.g., time spent standing) to make

comparisons among cattle with different coat colours. The UAVs allow remote viewing of multiple animals at the same time through recording of high-resolution video, which can then be analyzed using specialized software in the lab. Environmental data were measured at the same time to generate a heat load index (HLI).

The researchers found that animal respiration rate (a common indicator of 'stress') increased with HLI, and darker coated animals had a larger response in the feedlot (Figure 1A), but not in pasture environments (Figure 1B). Importantly, temperatures in the pasture did not get as high as those in the feedlot, thereby allowing pasture-based animals to experience less heat stress regardless of their hair colour. Additionally, the likelihood that an animal would be standing increased with HLI in both the feedlot and pasture scenarios. Standing increases the rate of

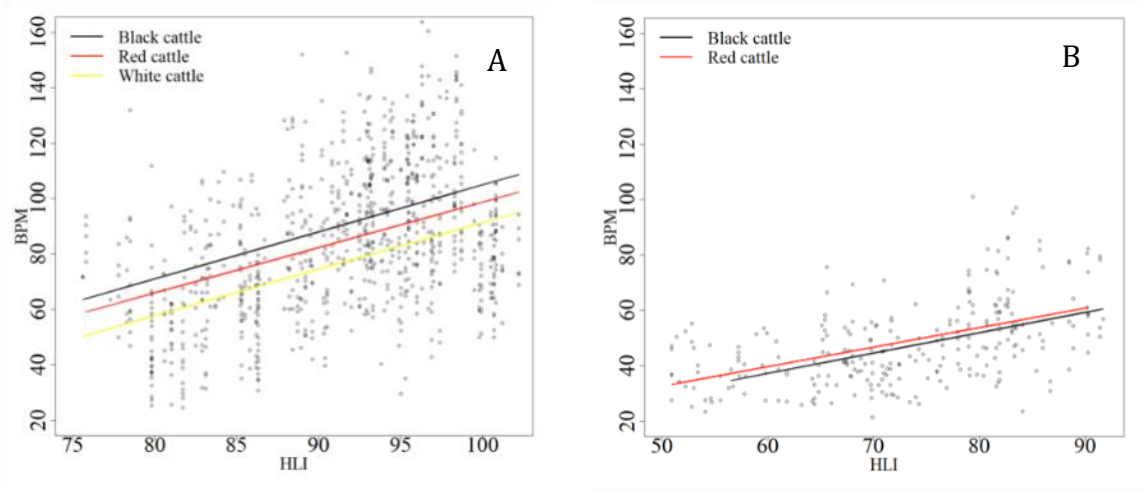


Figure 1. A, Dark coated cattle exhibit more signs of heat stress (e.g. higher respiration rate in beats per minute, BPM) as heat load index (HLI) increases compared with light-coated cattle in feedlot. However, B, cattle with dark- and medium-coloured coats did not exhibit much difference in a pasture setting.

convective heat loss and may be a means to reduce body temperature, in turn reducing the risk of heat stress.

This study demonstrated that consumer grade UAVs are capable of measuring heat stress behavioural responses in cattle and could serve as a new tool to identify and monitor cattle heat stress responses resulting from anticipated future changes in climate and associated weather patterns.

MSc student, Justin Mufford observes heat stress in cattle using an UAV or drone at the Mattheis Research Ranch. Photos by: Justin Mufford.

This study was supported by NSERC and the University of Alberta Rangeland Research Institute. We thank the Kasko Cattle Company (Ltd.) for access to their herd, and the U of A Mattheis Research Ranch land donors, Edwin and Ruth Mattheis, as well as ranch staff for support.

The study has been published as: *Mufford, J. T., M. W. Reudink, M. Rakobowchuk, C. N. Carlyle, and J. S. Church. 2021. Using unmanned aerial vehicles to record behavioral and physiological indicators of heat stress in cattle on feedlot and pasture. Canadian Journal of Animal Science.* https://doi.org/10.1139/cjas-2020-0125

4. Capacity Building

The University of Alberta has been undergoing many changes in response to the provincial government funding cutbacks announced over two years ago. As a result, the U of A leadership launched the 'University of Alberta for Tomorrow' initiative, which restructured and consolidated administrative and technical support from individual faculties into three main Colleges. Effective July 2021, the Faculty of Agricultural, Life and Environmental Sciences joined with the Faculty of Engineering and Faculty of Science to form the College of Natural and Applied Sciences. While each Faculty, including Departments within each Faculty, are still able to retain their own identity, many of the services are now streamlined and shared between all three Faculties; Staff and services have been reduced. While many of these changes have been challenging, there are opportunities for further cross-collaboration across Faculties within the College that may be explored.

The restructuing process also involved rebranding the University of Alberta image, including the logo. Individual Faculties, Departments, and Institutes (including the Rangeland Research Institute) will use a single logo to reflect that we are part of one central and unified university. The updated logo can be viewed on the cover of this annual report.

On March 15, 2022, the United Nations General Assembly in New York unanimously declared 2026 as the International Year of Rangelands and Pastoralists (IYRP). This initiative began in 2015 and was proposed and led by the Government of Mongolia. Early in the process, Canada became a co-sponsor and as of March 2022, 102 countries have announced their support for this proposal. Additionally, 303 organizations, including the Rangeland Research Institute, have indicated their support for the IYRP. This resolution aims to raise awareness and address issues related to rangelands including global biodiversity, climate change and socio-economic issues. Rangelands make up approximately 54% of the worlds terrestrial landscape, but are among the most threatened ecosystems. They are critical to the ranchers and pastoralists who directly depend on them for their livelihoods including their "cultures, identities, traditional knowledge and historical experience of coexisting with nature". Additionally, the ecosystem goods and services provided by rangelands (animal products including meat, milk, fibre; wildlife

habitat; clean water and air; biodiversity; etc.) are critically important to everyone. To learn more about the International Year of Rangelands and Pastoralists and view videos featuring rangelands across the world, visit www.iyrp.info. The RRI will be taking the opportunity to join the global focus on IYRP in 2026.

The RRI experienced a huge loss in July 2021 when Lori Schroeder passed away unexpectedly. Lori had been spending her summer doing what she loved best: working as a plant ecologist and training field staff in her beloved Yukon. Lori was an RRI research collaborator, rare plant expert, and had worked on several projects at the Mattheis Research Ranch as a research assistant as well as an MSc student co-supervised by Drs. Fiona Schmiegelow and Edward Bork. Lori visited Mattheis Ranch often in order to find plants and investigate plant communities and her enthusiasm and passion for plants and the natural world were contagious. She was an excellent researcher, teacher, and friend and was always willing to share her experience and knowledge with a boisterous laugh and giant smile. She is missed!

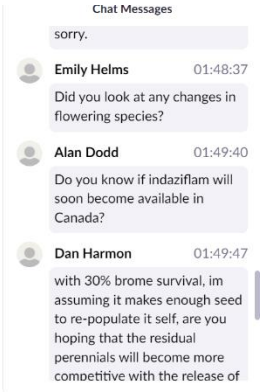
Top: Lori speaks about her Wet Areas Mapping project at the Mattheis Research Ranch field tour in 2016. Bottom: Lori presents her MSc thesis seminar in 2019.

5. Communications

The RRI engages in outreach, extension, and teaching in a variety of ways. Researchers affiliated with the RRI communicate their research findings at conferences, workshops, symposia, and meetings both online and in-person to diverse audiences including ranchers and producers, resource managers, government and non-government organizations, policy-makers, researchers, students, and the general public. Graduate students also gave thesis defense seminars to communicate about their specific projects. Select outreach and extension activities are listed in Appendix II, however, a few highlights include the following:

In April 2021, RRI-affiated researchers, Drs. Scott Chang, Edward Bork, Cameron Carlyle, and graduate students, Cole Gross and Zhengfeng An, gave an online workshop entitled, Agroforestry for Climate Change Mitigation available on YouTube and also on the RRI website (rri.ualberta.ca/resources/presentations). The workshop summarized key findings from a large 8-year project studying the "role of trees in agroforestry systems and of manure compost and manure compost biochar applications to agricultural soils in carbon sequestration (storage in the soil and vegetation), carbon stability and greenhouse gas emissions".

The Society for Range Management (SRM) Annual Meeting was held in Albuquerque, New Mexico, as well as online as a hybrid conference in February 2022. While the University of Alberta leadership were not authorizing travel outside of Canada due to the Covid-19 omicron variant spread and high case numbers, two RRI-affiliated graduate students gave online presentations to diverse audiences. The advantages to giving an online presentation is that they often have a much higher attendance from a broader audience and the presentations are recorded so that conference



MSc student, Anabel Dombro, presents her research at the Society for Range Management conference held in Albuquerque, NM and online. She received many audience questions and lots of interest in her work.

attendees are still able to access them anytime. Because SRM recognizes the value of offering online conference content, as well as keeping the traditional in-person conference, future meetings are very likely to host a hybrid event. The 2023 SRM annual

meeting will be held in Boise, Idaho with an online option for those who cannot travel in person.

Dr. Edward Bork gave two podcast interviews in early 2022. 'Flagstaff County: The Podcast' offers a 1 hour conversation between Agricultural Fieldman, Harry Brook and Edward Bork discussing Native Range Management, including managing for drought. 'Cows on the Planet', a podcast based out of the Univeristy of Lethbridge, includes an interveiw between hosts, Drs. Kim Stanford and Tim McAllister, and guest, Dr. Edward Bork discussing the question, Are Cattle Using Too Much Land?, and what happens if grazers are removed from the landscape. Links to both podcast episodes are also available on the RRI website (rri.ualberta.ca/resources/presentations).

The RRI continues to support teaching activities for both undergraduate and graduate student courses, as well as other organizations that use the ranches for training purposes. While teaching activities were still reduced due to Covid travel and accomodation restrictions, Mattheis and Kinsella Ranches hosted several student groups. A newly-created, advanced soil science field school was offered for the first time by Drs. Miles Dyck and Sylvie Quideau and was attended by 7 graduate students. Students had the opportunity to classify soils and dig soil pits and take cores, which proviced them with a hands-on learning opportunity at both ranches. Fourth year undergraduate students in the Wildlife and Range program also stayed at the Kinsella and Mattheis Ranches to learn about some of the research projects taking place at the ranches and conduct range health assessment exercises for some hands-on learning. They also visited several private ranches to learn from producers about their unique challenges, including managing grazing during drought. Private companies also used the Mattheis Ranch for technical training exercises for their new staff.

Researchers also communicated their research by publishing their work in peer-reviewed journals during 2021-2022, with select publications listed in Table 5.1. These outreach and extension activities increase the profile of the RRI, the University of Alberta and the Research Ranches. These activities communicate to a diverse audience by expanding our knowledge on the importance of grasslands and rangelands.

L: Pheasant nest full of eggs at the Mattheis Research Ranch. Photo by Mary Busz.
Below: Elk grazing at the Mattheis Ranch. Photo by Marcel Busz.

Table 5.1. Select peer-reviewed publications authored by RRI affiliated researchers between April 2021 and March 2022

*Heida, I.P., Brown, C., Dettlaff, M.A., Oppon, K.J., Cahill, J.F. 2021. Presence of a dominant native shrub is associated with minor shifts in the function and composition of grassland communities in a northern savannah. AOB Plants. 13(2): plab011. DOI: 10.1093/aobpla/plab011.

Watkinson, A.D., Naeth, M.A., Pruss, S.D. May 2021. Modeling *Artemisia cana* landscape cover as a function of planting density and age to inform restoration of sagebrush habitats. Rangeland Ecology & Management. 76(1): 22-29. DOI: 10.1016/j.rama.2021.01.005

*Chu, H.S., Luo, X.Z., Ouyang, Z.T., Chan, W.S., Dengel, S., Biraud, S.C., Torn, M.S., Metzger, S., Kumar, J.,… Gamon, J.A…May 2021. Representativeness of Eddy-Covariance flux footprints for areas surrounding AmeriFlux sites. Agricultural & Forest Meteorology. 301: 108350. DOI: 10.1016/j.agrformet.2021.108350.

Kotula, H.J., Peralta, G., Frost, C.M., Todd, J.H., Tylianakis, J.M. June 2021. Predicting direct and indirect non-target impacts of biocontrol agents using machine-learning approaches. PLOS One. 16(6): e0252448. DOI: 10.1371/journal.pone.0252448.

Lin, S.S., Hernandez-Ramirez, G. Jun 2021. Nitrogen turnover and N_2O production in incubated soils after receiving field applications of liquid manure and nitrification inhibitors. Canadian Journal of Soil Science. 101(2): 290-304. DOI: 10.1139/cjss-2020-0102

Davison, J., Moora, M., Semchenko, M., … Batbaatar, A., Brown, C., Cahill, J., … Zobel, M. July 2021. Temperature and pH define the realised niche space of arbuscular mycorrhizal fungi. New Phytologist. 231(2): 763-776. DOI: 10.1111/nph.17240.

*Ma, Z., E.W. Bork, J. Li, G. Chen, and S.X. Chang. Aug 2021. Photosynthetic carbon allocation to live roots increases the year following high intensity defoliation across two ecosites in a temperate mixed grassland. Agriculture, Ecosystems & Environment, 316: 107450. DOI: 10.1016/j.agee.2021.107450

Schweiger, A.K., Cavender-Bares, J., Kothari, S., Townsend, P.A., Madritch, M.D., Grossman, J.J., Gholizadeh, H., Wang, R., Gamon, J.A. Sept 2021. Coupling spectral and resource-use complementarity in experimental grassland and forest communities. Proceedings of the Royal Society Biological Sciences 288(1958): 20211290. DOI: 10.1098/rspb.2021.1290.

Sabatini, F.M., Lenoir, J., Hattab, T., …, Wagner, V., …; Zobel, M., Bruelheide, H. Sept 2021. sPlotOpen - An environmentally balanced, open-access, global dataset of vegetation plots. Global Ecology & Biogeography. 30(9): 1740-1764. DOI: 10.1111/geb.13346.

*Bork, E.W., Döbert, T.F., Grenke, J.S.J., Carlyle, C.N., Cahill, J.F., Boyce, M.S. Sept 2021. Comparative pasture management on Canadian cattle ranches with and without Adaptive Multi-paddock Grazing. Rangeland Ecology & Management. 78: 5-14. DOI: 10.1016/j.rama.2021.04.010

Siegmann, B., Cendrero-Mateo, M.P., Cogliati, S., Damm, A., Gamon, J., Herrera, D., Jedmowski, C., Junker-Frohn, L.V., Kraska, T., Muller, O., Rademske, P., van der Tol, C., Quiros-Vargas, J., Yang, P.Q., Rascher, U. Oct 2021. Downscaling of far-red solar-induced chlorophyll fluorescence of different crops from canopy to leaf level using a diurnal data set acquired by the airborne imaging spectrometer HyPlant. Remote Sensing of the Environment. 264: 112609. DOI: 10.1016/j.rse.2021.112609.

Filazzola, A., Cahill, J.F. Oct 2021. Replication in field ecology: Identifying challenges and proposing solutions. Methods in Ecology & Evolution. 12(10): 1780-1792. DOI: 10.1111/2041-210X.13657

*Dettlaff, M.A., Erbilgin, N., Cahill, J.F. Oct 2021. An invasive grass and litter impact tree encroachment into a native grassland. Applied Vegetation Science, 24(4): e12618. DOI: 10.1111/avsc.12618

Roman-Perez, C.C., Hernandez-Ramirez, G., Kryzanowski, L., Puurveen, D., Lohstraeter, G. Oct 2021. Greenhouse gas emissions, nitrogen dynamics and barley productivity as impacted by biosolids applications. Agriculture Ecosystems & Environment. 320: 107577. DOI: 10.1016/j.agee.2021.107577

*Ma, Z.L., Shrestha, B.M., Bork, E.W., Chang, S.X., Carlyle, C.N., Döbert, T.F., Sobrinho, L.S., Boyce, M.S. Nov 2021. Soil greenhouse gas emissions and grazing management in northern temperate grasslands. Sci. of the Total Environment, 796: 148975. DOI: 10.1016/j.scitotenv.2021.148975

Wang, R., Gamon, J.A., Moore, R., Zygielbaum, A.I., Arkebauer, T.J., Perk, R., Leavitt, B., Cogliati, S., Wardlow, B., Qi, Y. Nov 2021. Errors associated with atmospheric correction methods for airborne imaging spectroscopy: Implications for vegetation indices and plant traits. Remote Sensing of the Environment. 265: 112663. DOI: 10.1016/j.rse.2021.112663

*Döbert, T.F., Bork, E.W., Apfelbaum, S., Carlyle, C.N., Chang, S.X., Khatri-Chhetri, U., Sobrinho, L.S., Thompson, R., Boyce, M.S. Nov 2021. Adaptive multi-paddock grazing improves water infiltration in Canadian grassland soils. Geoderma. 401: 115314. DOI: 10.1016/j.geoderma.2021.115314

Soulodre, E.M.J., Dhar, A., Naeth, M.A. Nov 2021. Mixed-Prairie well site reclamation with natural recovery, seeding, and grazing. Rangeland Ecology & Management. 79(1): 208-216. DOI: 10.1016/j.rama.2021.09.002

Coates, T.W., Alam, M., Flesch, T.K., Hernandez-Ramirez, G. Nov 2021. Field testing two flux footprint models. Atmospheric Measurement Techniques. 14(11): 7147-7152.

*Wang, Z-P., Li, X-P., Pelletier, R., Chang, S., Bork, E. Nov 2021. Grassland soil organic carbon and the effects of irrigated cropping in Alberta, Canada. Soil Use & Management, 38(2): 1189-1202. DOI: 10.1111/sum.12780

An, Z.F., Bernard, G.M., Ma, Z.L., Plante, A.F., Michaelis, V.K., Bork, E.W., Carlyle, C.N., Baah-Acheamfour, M., Chang, S.X. Nov 2021. Forest land-use increases soil organic carbon quality but not its structural or thermal stability in a hedgerow system. Agriculture Ecosystems & Environment. 321: 107617. DOI: 10.1016/j.agee.2021.107617

*Batbaatar, A., Carlyle, C.N., Bork, E.W., Chang, S.X., Cahill, J.F. Jan 2022. Multi-year drought alters plant species composition more than productivity across northern temperate grasslands. Journal of Ecology. 110 (1): 197-209. DOI: 10.1111/1365-2745.13796

Cavender-Bares, J., Schweiger, A.K., Gamon, J.A., Gholizadeh, H., Helzer, K., Lapadat, C., Madritch, M.D., Townsend, P.A., Wang, Z.H., Hobbie, S.E. Feb 2022. Remotely detected aboveground plant function predicts belowground processes in two prairie diversity experiments. Ecological Monographs. 92(1): e01488. DOI: 10.1002/ecm.1488.

*Thompson, K.A., James, K.S., Carlyle, C.N., Quideau, S., Bork, E.W. Feb 2022. Timing and duration of access mat use impacts their mitigation of compaction effects from industrial traffic. Journal of Environmental Management, 303: 114263. DOI: 10.1016/j.jenvman.2021.114263

Kim, K., Daly, E.J., Flesch, T.K., Coates, T.W., Hernandez-Ramirez, G. Feb 2022. Carbon and water dynamics of a perennial versus an annual grain crop in temperate agroecosystems. Agricultural & Forest Meteorology. 314. DOI: 10.1016/j.agrformet.2021.108805

Ma, Z., Bork, E.W., Carlyle, C.N., Tieu, J., Gross, C.D., Chang, S.X. Feb 2022. Carbon stocks differ among land-uses in agroforestry systems in western Canada. Agricultural & Forest Meteorology, 313. DOI: 10.1016/j.agrformet.2021.108756

Lin, S.S. and Hernandez-Ramirez, G. Feb 2022. Increased soil-derived N_2O production following a simulated fall-freeze-thaw cycle: Effects of fall urea addition, soil moisture, and history of manure applications. Biogeochemistry. 157(3): 379-398.

Gross, C.D., Bork, E.W., Carlyle, C.N., Chang, S.X. Feb 2022. Biochar and its manure-based feedstock have divergent effects on soil organic carbon and greenhouse gas emissions in croplands. Science of the Total Environment, 806: 151337. DOI: 10.1016/j.scitotenv.2021.151337

*Smith, E.A., Holden, E.M., Brown, C., Cahill Jr, J.F. Mar 2022. Disturbance has lasting effects on functional traits and diversity of grassland plant communities. PEERJ, 10:e13179. DOI: 10.7717/peerj.13179

*Santangelo, J.S., Ness, R.W., Cohan, B., Fitzpatrick, C.R., Innes, S.G., Koch, S., Miles, L.S., Munim, S., Peres-Neto, P.R., Prashad, C., Tong, A.T… Cahill, J.F… Dettlaff, M.A….Mar 2022. Global urban environmental change drives adaptation in white clover. Science, 375(6586): 1275. DOI: 10.1126/science.abk0989.

*Bagnall, D.K., Morgan, C.L.S., Cope, M., Bean, G.M., Cappellazzi, S., Greub, K., Liptzin, D., Norris, C.L., Rieke, E., Tracy, P., … Bruhjell, D., Carlyle, C….Mar 2022. Carbon-sensitive pedotransfer functions for plant available water. Soil Physics & Hydrology. DOI: 10.1002/saj2.20395

Bischoff, B., Bork, E., Carlyle, C. Mar 2022. Forage productivity is resilient to timing of post-wildfire defoliation in Mixedgrass Prairie. Canadian Journal of Plant Sci. DOI: 10.1139/CJPS-2021-0229

*Mufford, J.T., Reudink, M.W., Rakobowchuk, M., Carlyle, C.N., Church, J.S. Mar 2022. Using unmanned aerial vehicles to record behavioral and physiological indicators of heat stress in cattle on feedlot and pasture. Canadian Journal of Animal Sci, 102(1): 1-8. DOI: 10.1139/cjas-2020-0125

An, Z.F., Bork, E.W., Duan, X., Gross, C.D., Carlyle, C.N., Chang, S.X. Mar 2022. Quantifying past, current, and future forest carbon stocks within agroforestry systems in central Alberta, Canada. Global Change Biology & Bioenergy, 2022: 00:1-12. DOI: 10.1111/gcbb.12934

* Research that includes U of A research ranches for at least one location

Cleome or bee plant that blooms along the roadways in summer at the Mattheis Ranch. Photo by Marcel Busz.

6. Strategic Advisory Council

The Rangeland Research Institute continues to be active in fulfilling its original mandate to conduct research, engage in outreach and extension, and partner with instructors as well as participate directly in teaching activities. While a Strategic Advisory Council meeting in 2021-2022 was deferred due to the uncertainty within the U of A and Faculty of ALES, an Annual Report was prepared and shared with SAC members. The current composition of the SAC as of March 31, 2022 is provided in Table 6.1.

Table 6.1. Members of the RRI Strategic Advisory Council, March 2021.

Name	Position, *Agency*	Location
Barry Adams*	Head, Rangeland Resource Management Program (Retired) *Alberta Environment and Sustainable Resource Development*	Lethbridge, AB
Dr. Stan Blade	Dean, Faculty of Agricultural, Life & Environmental Sciences, *University of Alberta*	Edmonton, AB
Dr. Edward Bork	RRI Director; Professor and Mattheis Chair in Rangeland Ecology & Management, *University of Alberta*	Edmonton, AB
Dr. Cameron Carlyle	Associate Professor, *University of Alberta*	Edmonton, AB
Edwin Mattheis	Producer (Retired)	Calgary, AB
Ruth Mattheis	Producer (Retired)	Calgary, AB
Karin Schmid	Research and Production Manager, *Alberta Beef Producers*	Calgary, AB
Josie Van Lent	Dean, Agriculture Technology & Applied Research, *Lakeland College Canada*	Vermillion, AB
Dr. Walter Willms	Researcher (Emeritus), *Agriculture & Agri-Food Canada*	Lethbridge, AB
Dave Zehnder	Producer; Program Lead, *Farmland Advantage*	Invermere, BC

* Chair of RRI Strategic Advisory Council

7. Financial Overview

The RRI 2021-22 financial statement is shown in Appendix III and summarizes revenue and expenses. The RRI operational revenue is largely generated from oil and gas extraction surface leases and utility (powerline) activity resulting from the Mattheis Research Ranch. However, this revenue is expected to decline as natural resource extraction diminishes over time either due to resource depletion, reduced market value for natural resources leading to reduced activity, or a transition away from reliance on fossil fuels. The RRI expenses include costs associated with outreach and extension, RRI operating and administration costs, and support for research activities and capacity building. Many of the research costs have been transferred to the REMF spending allocation to maximize the funds that can be recapitalized back into the endowment principal (listed as Transfer to Endowment in Appendix IV).

Ground plum or buffalo plum, a native legume, at the Mattheis Ranch. Photo by Lisa Raatz.

The Rangeland Ecology and Management Fund (REMF) is an endowment that was created in 2015. Most of the principal comes from revenue received upon construction of the major powerline that runs parallel to Hwy 36 bisecting the Mattheis Ranch, a generous donation from the Alberta Beef Producers, and a large contribution from the conservation easement placed on the Mattheis Research Ranch in partnership with Western Sky Land Trust. As in previous years, $500,000 was transferred from the RRI Operations budget to the REMF in 2021-2022 to continue growing the endowment principal. This strategy builds long-term capacity to conduct research by increasing the interest generated annually so that a larger sum is available each year to award research grants. The Department of Agricultural, Food and Nutritional Science began taking a proportion of the endowment spending allocation to offset ongoing budget constraints starting in 2018. As expected, the proportion the department is taking has increased annually and will increase further over time. The market value of the REMF as of March 31, 2022 was $9,807,732.53 (Appendix IV).

Appendix I. Summary of ongoing research projects led by RRI affiliates

All projects listed are being undertaken by various research affiliates associated with the RRI during 2021-2022. * Indicates projects that have received support from the RRI Competitive Grants Program.

Project Title	Principle Investigators
Mitigation of high voltage powerline construction on mixedgrass prairie	Edward Bork, Cameron Carlyle & Sylvie Quideau
Long-term monitoring of rangeland ecosystem functions on the Mattheis and Kinsella Research Ranches*	Cameron Carlyle
Differentiating and understanding the roles of soil nutrient and soil community heterogeneity on plant growth, carbon storage and biodiversity*	James Cahill
Economic and C-capture benefits of including forages in long-term crop rotations at Breton	Edward Bork, Miles Dick, Sylvie Quideau, Scott Jeffrey, & Dick Puurveen
Site specific control of Canada thistle by drone	Markus Webber, Edward Bork, John Church, JP Pettyjohn, and 6 others.
Assessment of altered precipitation and defoliation on rangeland EG & S	Cameron Carlyle, Scott Chang, James Cahill, Ben Willing & Edward Bork
Quantifying the carbon balance and associated ecosystem properties at the Mattheis Ranch*	Dick Puurveen, Trevor Coates, John Gamon
Use of plant growth regulators for enhancing forage grass seed production in NW Alberta	Nitya Khanal & Edward Bork
Precision ranching of cattle: Integrating cattle genomics, grazing behavior, and production	Edward Bork, Carolyn Fitzsimmons, Cameron Carlyle, Graham Plastow, James Cahill, Eric Lamb, John Church, John Basarab, Leluo Guan & Changxi Ling
Effect of adaptive multi-paddock grazing on carbon storage and greenhouse gases	Mark Boyce, Edward Bork, Cameron Carlyle, Scott Chang, James Cahill & others

Quantifying the effects of adaptive multi-paddock grazing on soil carbon sequestration and soil organic matter quality	Kim Schneider, Ira Mandell, James Longstaffe, Edward Bork, James Byrne & Paul Voroney
Survey of cattle rumen microbiome under different grazing systems: Linkage to grazing behavior and productivity	Leluo Guan, Graham Plastow, Edward Bork & John Basarab
Comprehensive study of the human prehistory and history of the Mattheis Ranch*	Jack Ives & Kisha Supernant
Using plant traits to assist conservation and management of Alberta's rangelands*	James Cahill
Collaborative development of precision ranching to address climate change issues in cow-calf production*	Cameron Carlyle & John Church
Evaluating the contribution of lichens to Alberta's grassland biological soil crusts through baseline taxonomic research and manipulative grazing and drought experiments*	Cameron Carlyle, Diane Haughland, & Raquel Pino-Podas
Evaluating the efficacy of herbicide indaziflam applied in fall and spring to control invasive annual brome in southern Alberta rangeland	Edward Bork, Anabel Dombro, Lisa Raatz, Tanner Broadbent, & Darren Bruhjell

Appendix II. Select presentations by RRI affiliates in 2021-2022

Outreach and promotional activities undertaken in support of the RRI during 2021-2022

Abbreviated title	Presenter(s)	Venue	Audience(s)	Date
The connected cow: How UAVs and sensors enable "Smart" IoT beef cattle research	Church	2021 Plains Nutrition Council Spring Conference, San Antonio TX & online	Government and non-government organizations, policy-makers, researchers, students, industry	Apr 2021
Common agroforestry systems in Western Canada	Bork	Agroforestry for Climate Change Mitigation Online Workshop	Government and non-government organizations, policy-makers, resource managers, researchers, students	Apr 2021
Research findings from Phase 1 & 2 of the project	Chang, Gross			
Effects of biochar and composted manure application on enzyme activities	An			
Carbon storage in vegetation in agroforestry systems	Carlyle			
Scaling the carbon footprint of agroforestry systems in Central Alberta	Bork*, An, Duan, Carlyle, Gross, Chang			
Cultivation and grazing impact on extracellular enzyme activity in Alberta grasslands	Kaliaskar, Shreshta, Bork, Carlyle, Döbert, Chang, Boyce	Global Symposium on Soil Biodiversity	Government and non-government organizations, policy-makers, resource managers, researchers, students	Apr 2021
Precision ranching supporting SmartBeef production: Putting the right cow, in the right place, at the right time	Bork, Fitzsimmons, Carlyle, Plastow, Cahill, Basarab, Guan, Li, Lamb, Church	TELUS 5G Meeting on Precision Agricultural Workshop	Industry leaders, researchers	Apr 2021
Can planting trees or soil additives improve soil quality and reduce the damaging greenhouse gas emissions produced by agricultural activities?	Gross, Bork, Carlyle, Chang	North American Agroforestry Conference, Association for Temperate Agroforestry	Researchers, students, resource managers, government	Jun 2021

Lichens of Alberta	Haughland	ABMI: It's our Nature to Know online webinar	Researchers, students, government and non-government organizations	Jun 2021
Grazing for water infiltration	Boyce, Döbert	Rural Routes to Climate Solutions, Podcast Episode 40	Ranchers, resource managers, government, public	Aug 2021
Defining adaptive, multi-paddock (AMP) grazing, and testing its impacts on grassland function in western Canada.	Bork*, Döbert, Grenke, Ma, Carlyle, Chang, Cahill, Shrestha, Sobrinho, Khatri-Chhetri, Boyce	Sustainable Fodder Management Technical Assistance Project. Online & Ulaabaatar, Mongolia	Resource managers, government, producers, researchers	Nov 2021
Grasslands and climate change: Understanding biological carbon storage and its response to grazing.	Bork	Alberta Institute of Agrologists, online.	Government and non-government organizations, researchers, resource managers, policy makers	Nov 2021
Carbon sequestration potential in western Canada using grasslands, grazing and agroforestry	Bork, Carlyle, Döbert, Chang, Hewins, Baah-Acheamfour, Ma, Gross, An	Climate Adaptation Research for B.C. Agriculture, online.	Government and non-government organizations, researchers, resource managers, policy makers	Dec 2021
Ecosystem sensitivity to variation in precipitation and defoliation across grasslands of Alberta	Amgaa	PhD thesis defense seminar, online	Researchers, students	Dec 2021
Does indaziflam control annual bromegrass in Canada's mixed prairie?	Dombro*, Bork, Raatz, Broadbent	Society for Range Management Annual Meeting; Albuquerque, NM and online	Ranchers, resource managers, policy-makers, students, researchers	Feb 2022
Adaptive grazing management promotes plant productivity and offtake across the Northern Great Plains	Grenke*, Bork, Carlyle, Boyce, Cahill			
Characterization of adaptive, multi-paddock grazing operations in western Canada and their impact on pastures.	Bork*, Carlyle, Döbert, Hewins, Shrestha, Ma, Cahill, Chang, Thompson, Quideau, Grenke, Khatri-Chhetri, Kaliaskar, Sobrinho, Boyce	Ranching Opportunities Conference, Olds, AB (In-person).	Ranchers, producers, resource managers	Feb 2022

Using grazing as a tool to increase carbon stocks and mitigate greenhouse gases	Bork, Carlyle, Döbert, Hewins, Shrestha, Ma, Cahill, Chang, Thompson, Quideau, Grenke, Khatri-Chhetri, Kaliaskar, Sobrinho, Boyce	Prairie Organics Conference: Think Whole Farm. Brandon, MB	Ranchers, producers, government and non-government organizations, policy makers, resource managers	Feb 2022
Home on the Native Range: native range management	Bork	Flagstaff County: The Podcast	Ranchers, resource managers, government and non-government organizations, public	Feb 2022
Use of access mats for the mitigation of industrial activities on mixedgrass soil and vegetation	Thompson*, Carlyle, Quideau, James, Najafi, Bork	9th Native Prairie Restoration and Reclamation Workshop, online.	Resource managers, government and non-government organizations, industry, researchers, students	Feb 2022
Quantifying the economic benefits of including forage in crop rotations: A test using long-term data (2021-24)	Bork*, Santos, Achtymichuk, Dyck, Quideau, Jeffrey, Ellert, May, Entz, Puurveen	Beef and Forage Research Forum. Saskatoon, SK and online.	Researchers, government, policy makers, ranchers, producers	Mar 2022
Are cattle using too much land?	Bork	Cows on the Planet Podcast: Episode 16	Ranchers, resource managers, government and non-government organizations, public	Mar 2022
Managing pasture to mitigate drought: An ounce of prevention could be priceless	Bork	Battle River Research Group, online webinar.	Ranchers, producers, resource managers	Mar 2022

* indicates the primary presenter where projects have multiple authors credited, but a single speaker.

Appendix III. RRI Financial Statement of Actuals, April 1, 2021 to March 31, 2022

	Actuals
****Opening Balance**	**$0.00**
Revenue	
Lease/Utility (Powerline) Revenue	$538,969.80
Total Revenue	**$538,969.80**
Expenditures	
Transfer to Endowment	$500,000.00
Property Taxes	$972.51
Supplies, Services	$7,315.51
Communications (telephone)	$657.22
Total Expenditures	**($508,945.24)**
Net Balance	**$30,024.56**

*** In 2020-2021, the closing balance for the RRI Operating Budget was $17,356.18. Due to the Government of Alberta's directive that funds could not be carried forward, the opening balance is shown as $0.00. While these funds are not lost, they remain unavailable to the RRI until this directive is lifted.*

Note: This summary excludes U of A (in-kind) support to the RRI through academic staffing, which is currently valued at over $250,000 annually

Appendix IV. Rangeland Ecology and Management Fund Financial Statement of Actuals, April 1, 2021 to March 31, 2022

	Actuals
Principal	
Opening Balance (April 1, 2021)	$7,912,843.85
Current Year Contributions	$500,000.00
Principal Subtotal	$8,412,843.85
Capitalized Investment Earnings	$1,394,888.68
Closing Balance/Market Value (March 31, 2022)	**$9,807,732.53**
Spending Allocation (Revenue)	
Opening Balance (April 1, 2021)	$150,961.01
Current Year Endowment Spending Allocation	$325,364.04
Total Revenue	**$476,325.05**
Current Year Expenditures	
Faculty salary[1]	$97,173.62
Support staff	$96,613.71
Rental Expenses	$6,800.70
Research Projects	$40,175.72
Travel	$250.67
Total Expenditures	**($241,014.42)**
Closing Balance After Encumbrances	**$235,310.63**

[1] A proportion of faculty staff salary was taken out of the endowment starting in 2018/19 in order to remove it from the Department of AFNS operational budget and account for budget shortfalls. As expected, the proportion has increased in subsequent years and will continue to increase over time.

UNIVERSITY OF ALBERTA

Rangeland Research Institute

www.rri@ualberta.ca