UNIVERSITY OF CALGARY

CANADIAN ROCKIES & FOOTHILLS
BIOGEOSCIENCE INSTITUTE

Biogeoscience Institute of the Canadian Rockies and Foothills

2018/2019 RESEARCH AND EDUCATION REPORT

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BIOGEOSCIENCE INSTITUTE NEWS

The Biogeoscience Institute (BGI) welcomes the appointment of Dr. Steven M. Vamosi, PhD, as the Scientific Director of the Biogeoscience Institute, for a five-year renewable term effective July 16, 2018. Vamosi is the current Associate Dean of Diversity, Equity and Inclusion, and a Professor of population biology in the Faculty of Science. Vamosi will work closely with the Office of the Vice-President (Research) team to develop, lead and deliver multi-disciplinary research and educational programs at the Biogeoscience Institute.

Dr. Vamosi is an evolutionary and conservation ecologist, with a special interest in the effects of species introductions on the genetic diversity and long-term viability of native aquatic and semi-aquatic species in western Canada.

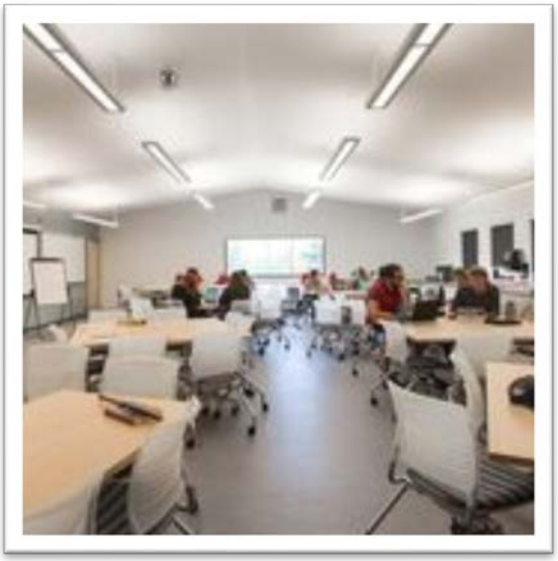
Dr. Edward Johnson stepped down from his role as director, in April 2018, after decades of work leading the BGI with dedication and passion. Johnson redefined the Barrier Lake field station as a well-established research station in Canada while also facilitating university field courses and junior/high school programs focused on experiential, hands-on learning. The BGI staff and VPR office would like to thank Dr. Johnson for his vision, drive and enduring support of the field stations. The BGI would also like to thank interim directors Dr. Robert Barclay and Dr. John Post, both professors in the Faculty of Science.

Spring 2018 saw the completion of facility upgrades at both the R.B. Miller and Barrier Lake Field Stations. The University of Calgary received considerable money from the federal government Secondary Institutions Strategic Investment Fund (SIF) along with a mix of provincial funding, philanthropy and the university's own infrastructure dollars.

The Barrier Lake Field Station has a new Science Building, built upon the existing footprint, featuring three new classrooms layouts, an upgraded wet laboratory, and functional meeting/office spaces. The main lodge saw significant upgrades to the kitchen and dining facilities; both spaces were built with a focus on energy efficiency. All buildings at R.B. Miller were removed and a newly constructed off-grid building was constructed with solar panel and composting toilet. The trailer was moved near the Sheep River Ranger Station in Fall of 2018 and is currently being upgraded to serve year-round researchers.

Renovations to the Main Lodge at the Barrier Lake Field Station

RB Miller building
off–grid building



Newly constructed Science Lab Building featuring classrooms, laboratory and library

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Science, research, and education in the Canadian Rockies.

CANADIAN ROCKIES & FOOTHILLS
BIOGEOSCIENCE INSTITUTE

The University of Calgary's Biogeoscience Institute has been leading field research for over 65 years.

Located at the door to Kananaskis Country, the University of Calgary's Biogeoscience Institute (BGI) is a leading field research station with a rich 65 year history. Serving as the only research station for the Canadian Rockies and Foothills, BGI's mission is to provide and support high quality science through independent research or research clusters.

Full spectrum research support

BGI offers researchers two well-established field stations: Barrier Lake Station, located in the Kananaskis Valley and the R.B. Miller Station, located in the Sheep River Provincial Park.

Both stations attract researchers from across the globe and offer an engaging research environment, accommodations, dining facilities, and access to laboratories and equipment. As a larger facility, Barrier Lake Station also provides classroom space for educational programs, lectures, and lab retreats.

In addition to the two field stations, researchers also have access to a variety of resources on the University of Calgary campus, including laboratories, historical collections and advanced technologies.

Promoting science through education

Aside from coordinating and supporting a science research program, one of the primary focuses for BGI is to promote science through an award winning integrated research-education program of experiential education, research, and outreach.

The programs offered at the Barrier Lake Station foster scientific literacy through engagement of the community, as well as research and scholarship through publications, knowledge exchange, and education research networks.

DID YOU KNOW?

- **The Biogeoscience Institute hosts more than 40 school groups and 30 community groups per year.**
- **Barrier Lake is monitored by Environment Canada's Interagency Monitoring of Protected Visual Environments (IMPROVE) and serves as the clean air standard for North America.**
- **2018 marks 30 years of the Biogeoscience Institute School and teacher programs. Over 100,000+ students and teachers have been taught at the Barrier Lake Station.**

40+
peer reviewed papers each year

75+
researchers annually

8+
countries utilize the station for research and education

Engage with the Biogeoscience Institute

BGI is committed to partnerships, collaborations, and community engagement that promotes science research and education.

There are many ways you can engage with us:

- Partner with us on scientific research to solve some of the greatest environmental challenges of our time.
- Expand your education and take a course or participate in a program in the Canadian Rockies.
- Ask us about becoming an undergraduate summer field assistant or intern at one of our research stations.
- Ask us about education programs, events, conferences and workshops available at the Barrier Lake Station for teachers, teacher educators, school and community groups, and members of the public and UCalgary community.

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Education in the Canadian Rockies

Students thrive in programs and environments enriched by access to world-class research and hands-on experiences. Teachers and university groups can participate in any of our field study programs as professional and educational development. Each program can be modified to suit the needs of teachers and to sharpen the focus of learning a specific subject or area.

Day trips and interpretive science walks are also available at the Barrier Lake Station. These engaging and educational offerings are available to all groups, subjects, and grade levels and can be customized to suit the needs of participants.

Field Study Programs for Schools

The Barrier Lake Station offers programs year round and nearly 100,000 students and teachers have participated globally. Field study programs being offered include:

- Grade 7 - Intro to Ecosystems
- Grade 8 - Freshwater Ecosystems
- Science 10 - Biomes of Canadian Rockies and Foothills
- Biology 20 (including AP/IB) - Inquiry Study of Ecosystems: Streams; Forests; Winter Ecosystems
- Biology 20 (including AP/IB) - Streams and Forest Ecosystems
- Environmental Science AP - What can grow in the mountains of Kananaskis?
- Biology 30 (including AP/IB) - Succession: Completion, Change or Chance

Field Study University Courses

Post-secondary education courses are offered by leading field researchers and scientists at the Barrier Lake Station. These hands-on courses provide real-world training and experience to students.

University of Calgary Courses:

- Department of Biological Sciences - Neuroscience 301: Neuroscience Field Course
- Department of Biological Sciences - Biology 591: Insect Biodiversity
- Department of Biological Sciences - Ecology 413: Field Ecology
- Department of Geomatical Engineering - Geomatics Engineering 501: Field Survey
- Environmental Science Program - Environmental Science 401: Environmental Science Field Course 1
- Haskayne School of Business - MGST559.04: Developing Leaders for a Sustainable World Wilderness Retreat
- Haskayne School of Business - BSEN 749: Rediscovering Leadership Wilderness Retreat
- Faculty of Veterinary Medicine - VETMED 580: Wildlife Field Medicine Practice

University of Alberta Courses:

- Department of Biological Sciences - Biology 432: Field Methods in Ecology

University of Saskatchewan Courses:

- Department of Geography - Geography 827.3: Society for Hydrological Sciences - Kananaskis Short Course on Principles of Hydrology

University of Regina Courses:

- Department of Geology - GEOL 396: Geology Field Camp I

SAIT Courses:

- Environmental Technology Program: Environmental Technology Field School

Wilfred Laurier University Courses:

- Department of Geography and Environmental Studies - GEOL 451: Fourth Year Field Camp

Community Outreach Programs

BGI's Community Outreach Programs connect science, research, and education with the public and cultivates relationships between naturalists and researchers.

Community Programs:

- Citizen Science Program - engages the public with government, non-government, and scientists in the process of science discovery and education.
- Spring Naturalist Weekend - held at the Barrier Lake Station every spring, this program brings together naturalists and researchers for a weekend of field trips, discussions and education.
- Open House - this annual event at the Barrier Lake Station is designed for the whole family and raises awareness about current research in the Canadian Rockies and Foothills.
- Forest Research and History Trail Guides - Barrier Lake Forestry trails are located adjacent to the Barrier Lake Station and highlight forest ecology research and history of the site. These trails are open to the public from May to October.

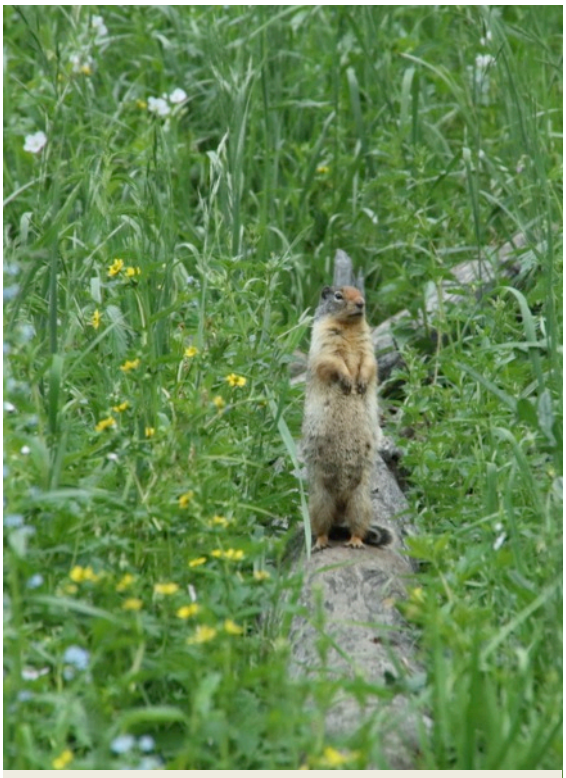
The Barrier Lake Station is also well suited to host community programs, including those from Scouts Canada and the Girl Guides of Canada, as well as many other education based community programs.

SCIENCE RESEARCH PROJECT HIGHLIGHTS

HIGHLIGHT 1: BEHAVIOURAL ECOLOGY OF COLUMBIAN GROUND SQUIRRELS: THE BENEFITS OF FAMILY

Research Cluster: *Animal Ecology*
Project Coordinator(s): *Vincent A Viblanc, Institut Pluridisciplinaire Hubert Curien, CNRS, Strasbourg, France; F. Stephen Dobson, Auburn University, USA; Jan O Murie, University of Alberta*

Columbian ground squirrels (*Urocitellus columbianus*), often mistakenly referred to as gophers, are one of the most common mammals in the foothills of the Rocky Mountains. They are a sciurid rodent species (a family including tree squirrels, chipmunks, prairie dogs, marmots, and flying squirrels) with a short active season extending from mid-April to mid-August (Murie & Harris 1982). During the breeding season, Columbian grounds squirrels have quite an active social life!

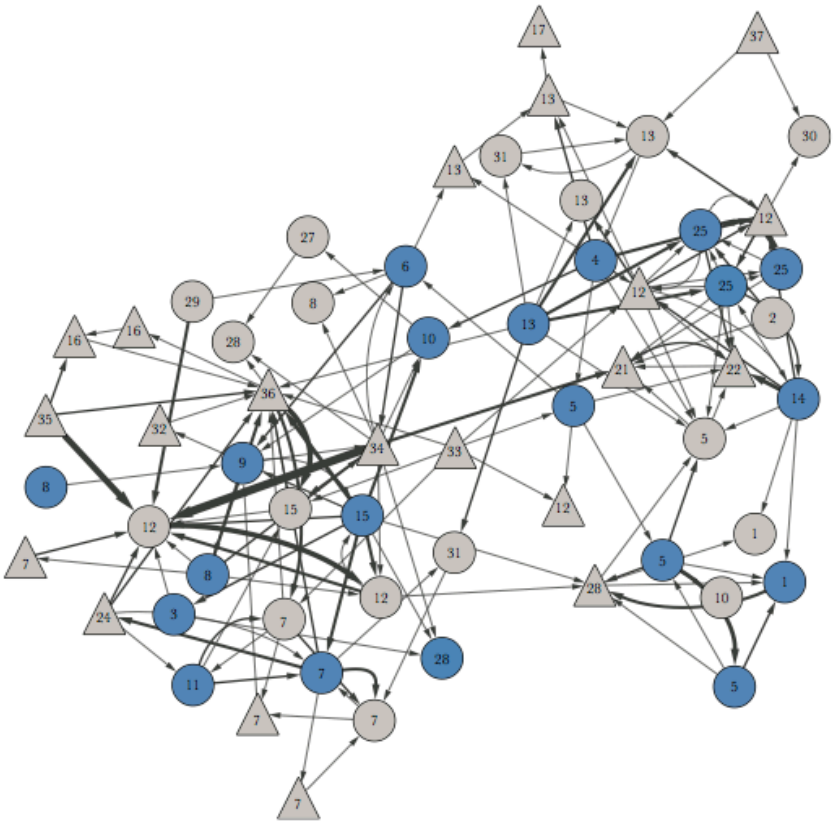


A Columbian ground squirrel scanning its environment above the tall grass, from atop a fallen tree. Photo by VA Viblanc, Sheep River Provincial Park, Alberta, Canada.

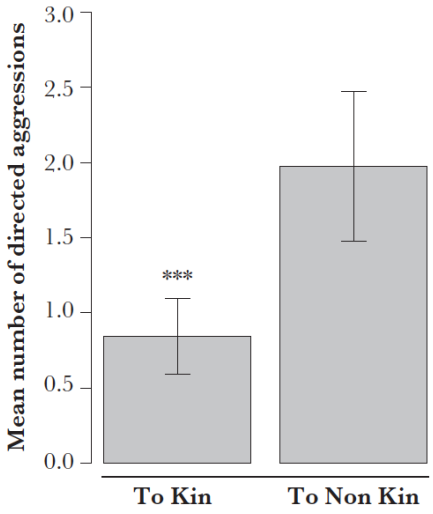
Kin-biased social behavior...

The species is organized in so-called matrilineal societies, where females are philopatric and kin female overlap both in space (King 1989b) and through time (King & Murie 1985) (overlapping generations). Males on the other hand typically disperse out of natal groups as yearlings (Boag & Murie 1981; Wiggett & Boag 1989; Neuhaus 2006). During lactation, females are highly territorial, but appear to be discriminative of kin and non-kin individuals (King 1989a).

Studying female aggression over the course of a breeding season using a social network approach, we found that network measures characterizing received aggression (in-strength, in-degree) decreased as individuals aged, whereas network measures characterizing elicited aggression (out-strength, out-degree) peaked at prime reproductive age before decreasing in older individuals (Viblanc *et al.* 2016a). Further, accounting for age, network metrics of elicited aggression (grouped in a principal component) were positively related to female fitness (standardized estimate $\beta = 0.32 \pm 0.14$, CI [0.04; 0.59]), especially for females with few kin (interaction effect; standardized estimate $\beta = -0.34 \pm 0.14$, CI [-0.67; -0.01]). This result may potentially reflect lower levels of aggression for females with adjacent kin to achieve similar levels of fitness, consistent with the idea that kin provide a safe environment for raising offspring.



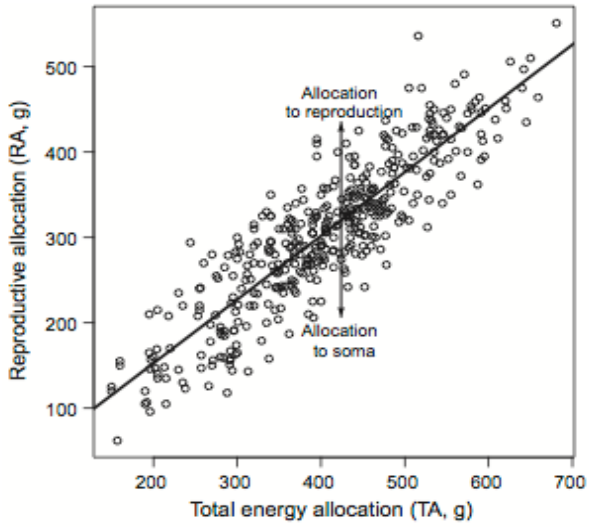
Directed, weighted, social network of aggressions during lactation in Columbian ground squirrels (*Urocitellus columbianus*). Females are symbolized by circles, males by triangles. Kin individuals (regardless of sex or age) sharing the same mother are depicted by the same number. A directed aggression between 2 individuals is symbolized by an arrow pointing from the initiator toward the recipient. Arrows are weighted according to the number of aggressions exchanged. Breeding females are depicted in blue.



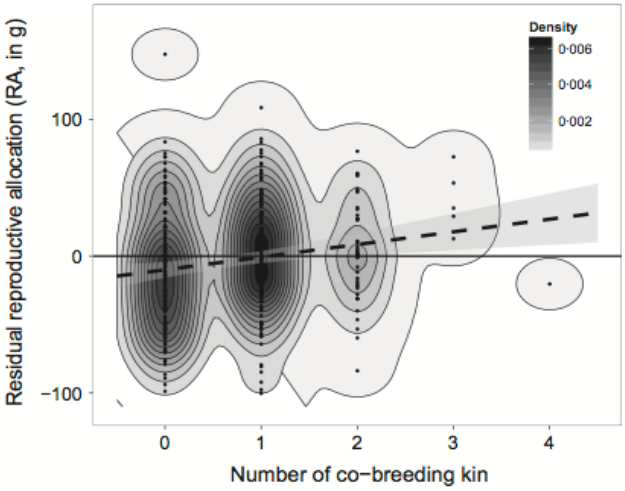
Aggressions directed toward kin or non-kin within a social network of aggressions in Columbian ground squirrels (*Urocitellus columbianus*): the mean number of female–female aggressions directed to kin versus non-kin; ***P < 0.001.

... its consequences on energy allocation strategies...

This highlights one of the benefits of female philopatry: genial neighbor benefits via differential aggressiveness towards kin could arise because of different risks of infanticide for pups (Stevens 1998), or could affect the amount of energy females can allocate to lactation vs. territorial defense, affecting their success at weaning. We tested this hypothesis by investigating the effect of female kin on energy allocation strategies over a 23-year period (Viblanc *et al.* 2016b). Controlling for female age, we found that for breeding mothers, the balance of energy allocated to somatic (growth, maintenance) vs. reproductive functions was significantly affected by her number of co-breeding kin. Mothers with more co-breeding kin significantly biased their allocation of energy towards offspring production (estimate = 8.35 ± 2.87 more grams of offspring for mothers with kin present; t = 2.91; P = 0.004, n = 359, N = 138), supporting the hypothesis that breeding females are able to allocate more energy into reproduction when kin are present. In turn, the increased energy allocation had positive effects on litter size at weaning and thus female fitness.



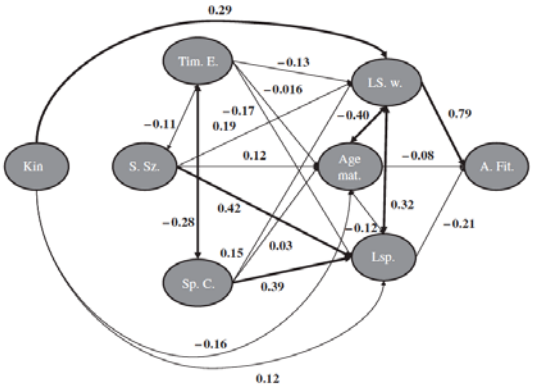
Relationship between reproductive (RA) and total (TA) allocation in female Columbian ground squirrels. Reproductive allocation is calculated as offspring mass gain from birth to weaning. Somatic allocation SA is calculated as female mass gain (in g) from emergence of hibernation to offspring weaning. Total allocation is the sum of reproductive and somatic allocations TA = SA + RA. Residuals from the regression line (residual RA) represent the balance of allocation between reproductive and somatic functions. Positive residuals represent higher allocation to reproduction than predicted for a given total allocation and negative residuals higher allocation to the soma.



Overall effect of co-breeding kin numbers on the balance between somatic and reproductive allocation (residual RA) in Colum- bian ground squirrels. Relative to the average population, positive values of residual RA (above the horizontal line) indicate an alloca- tion bias towards reproduction, whereas negative values (below the horizontal line) indicate an allocation bias towards the soma. The prediction is figured by a dashed line with its 95% confidence intervals. Kernel densities are figured for illustration purposes.

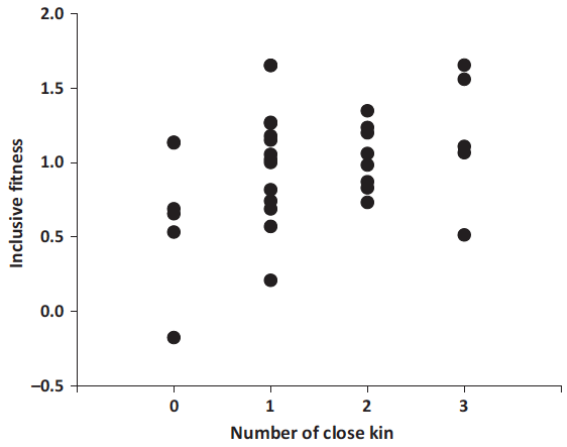
... and on female fitness

Indeed, in an integrative analysis where female reproduction was monitored throughout the entire life of 70 individual females, we examined the variance in female fitness and compared this with the average number of kin present for each female over her lifespan (Viblanc *et al.* 2010). Our analysis, a path model describing causal direct and indirect links relating individual kin to female fitness, revealed positive direct effects of kin on female fitness through enhanced litter sizes at weaning: female with higher close kin numbers (averaged per year) achieved higher fitness over their lifetime.



Influence of kinship on female fitness: overall path diagram with path coefficients. Variables: Kin, mean number of kin present over lifetime; Sp. C., mother's spring body condition; S. Sz., mother's structural size; Tim. E., timing of emergence; LS. w., litter size at weaning; Lsp., mother's lifespan; Age mat., age at maturity; A. Fit., adjusted fitness. Significant paths ($p < 0.05$) appear in bold. Single headed arrows indicate causality, whereas double-headed arrows indicate correlations (n = 70).

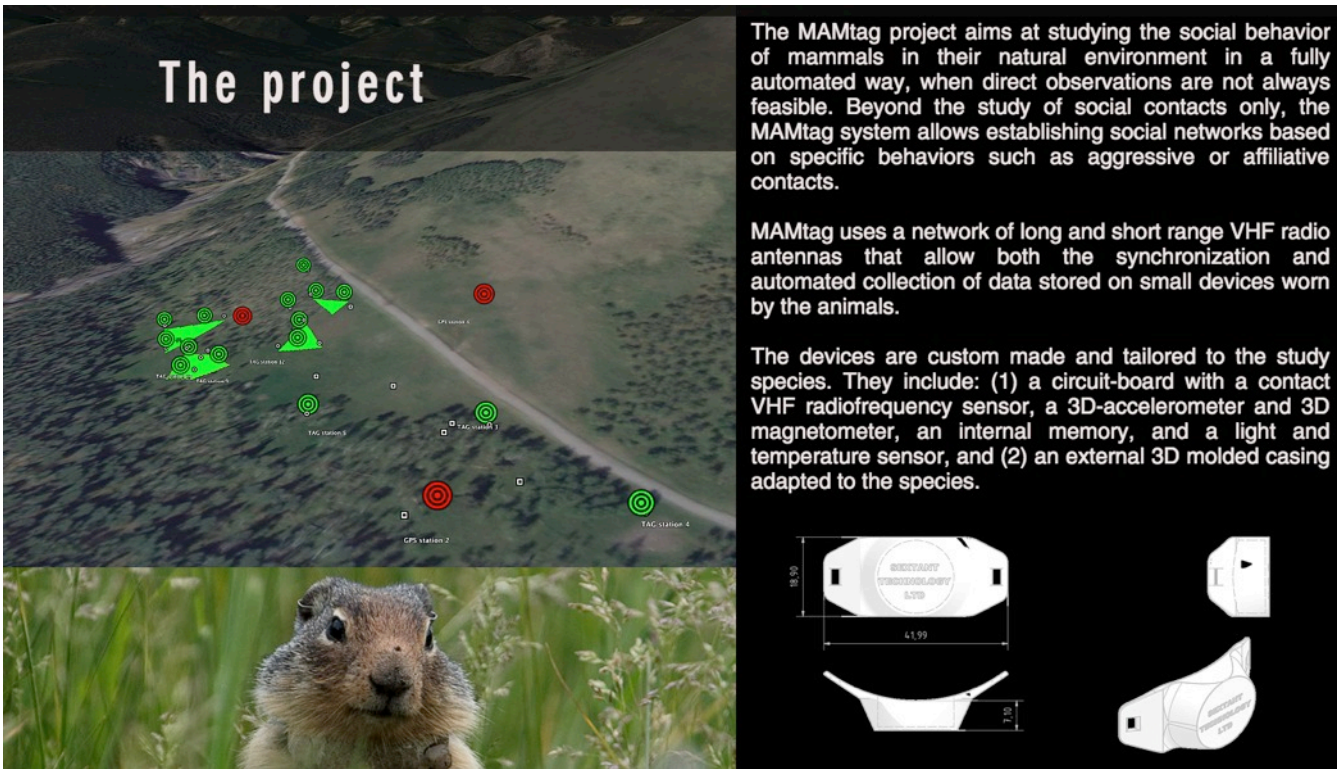
Going a step further, we evaluated the net benefits of the presence of kin on inclusive fitness, i.e. not only considering a female's own reproduction, but also considering the reproduction of her close kin (mother, daughter and litter mate sisters) with whom she shares a certain proportion of her genes by common descent. Shared genes are important to fitness, since a portion of a female's genes may be transmitted into future generations through the reproduction of close kin. In this study, we calculated direct fitness benefits of females with co-surviving adult close kin and compared it to the fitness benefits of females without such kin (Dobson *et al.* 2012). The fitness of females without co-surviving kin produced an estimate stripped of social benefits. This estimate could then be subtracted from the direct fitness of close kin to estimate the net fitness benefit of cooperation for both kin-related mothers. The indirect fitness component (about 40% of total fitness) was estimated by multiplying this value by the coefficient of relatedness and summing over close kin. This resulted in a substantial inclusive fitness increase for the 'kin cooperation' trait, which increased as the number of co-surviving kin increased.



Estimated inclusive fitness and number of co-surviving close kin (mother-daughter and littermate sister dyads) that were both of reproductive age (2 years old and older) and actively reproducing at the same time.

So where next?

We are now turning towards a more mechanistic approach, questioning the effects that social settings may have on individual physiology. Specifically, we are interested in understanding (1) whether kin individuals may act as a buffer to social stress; (2) the consequences of social aggression on adult stress, oxidative stress, and ageing; and (3) the consequences of different social rearing environments during lactation on the development of offspring. To do so, we are using a mix of different ecophysiological approaches, measuring glucocorticoid (stress) hormones, oxidative stress levels (Viblanc et al. 2018) and telomere length (DNA sequences that deteriorate both with age and experienced stressors) in individual females experiencing different social environments. We are combining those measures with a novel bio-logging approach to monitor social contacts between individuals both above and below-ground, using contact collars and 3D accelero-magnetometers.



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HIGHLIGHT 2: TREES ON THE MOVE: THE ROLE OF NON-CLIMATIC FACTORS ON SEEDLING ESTABLISHMENT BEYOND ALPINE TREELINES

Research Cluster: *Vegetation Dynamics and Forestry*
Project Coordinator(s): Emma Davis and Ze'ev Gedalof, University of Guelph

Forest systems around the world are being affected by changes in temperature and precipitation associated with climate change (Harsch et al. 2009). Subalpine forests, which grow at the upper limit of their distributional ranges, are particularly sensitive to environmental change, and records of tree establishment and repeat photography have shown that many subalpine forests in the Canadian Rocky Mountain region have shifted upward in elevation in response to climate warming over the past century (Brown 2013; Kavanagh 2000; Roush 2009). The response to climate change has been inconsistent, however, with some treeline systems showing little response to warming temperatures, and the rate of treeline advance often lags behind the rate of climate warming (Gray and Hamann 2012; Harsch et al. 2009; Roush 2009). The objective of our project was to evaluate the role of non-climatic factors in mediating the relationship between climate change and treeline advance in an effort to explain these inconsistencies, and to gain insight into how subalpine forest systems in the region are likely to change in the years to come. We combined field experiments with growth chamber and greenhouse studies to identify the effects of soil properties, seed availability, herbivory, competition, and microclimate on the establishment success of tree seedlings beyond their current elevational range.

Soil properties affect tree seedling establishment and growth

Soil samples from the forest, transition, and alpine zones of four study locations in the Canadian Rocky Mountains (Figure 1) were collected to study the effects of soil properties on the establishment and growth of Engelmann spruce seedlings. The samples were analyzed for various physical and chemical properties (e.g., grain size, organic content, nutrient availability), and were used in a growth chamber and greenhouse study at the University of Guelph, Ontario, Canada. Engelmann spruce seeds collected from a common provenance in south-western British Columbia (provided by the B.C. Tree Seed Centre, Surrey, B.C.) were planted in the soils collected from the field. Seedlings were grown under controlled conditions for three months, during which their germination, growth, and survival was monitored.

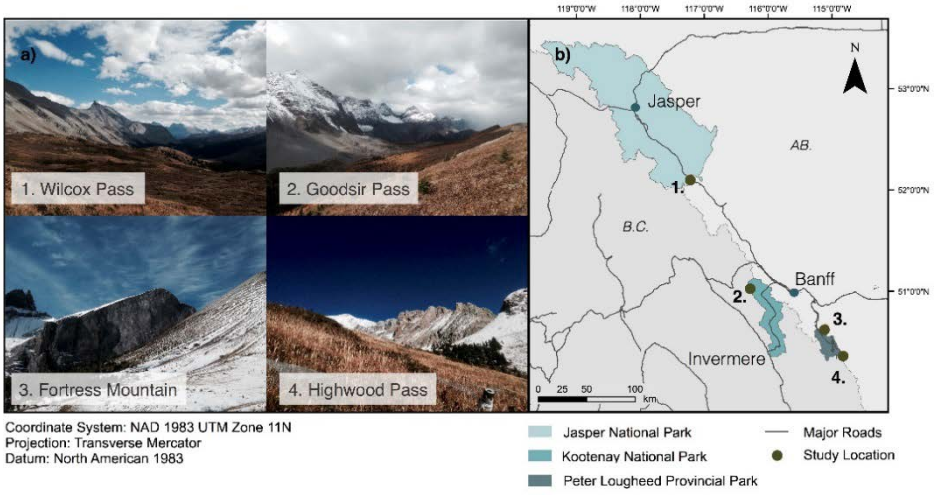

Figure 1 Location of study sites in the Canadian Rocky Mountains. Soil samples were collected from the forest, transition, and alpine zones of each site and transported to the University of Guelph for use in a greenhouse and growth chamber study (figure adapted from Davis et al. in press).

The results of our study suggest that soil properties become more unfavourable for seedling establishment with increasing elevation. Seedling

height, root mass, and survival were lowest for seedlings grown in soils collected from beyond the current species range (Figure 2), indicating that future establishment in the alpine may be constrained by unsuitable soil properties. Alpine soils tended to have smaller grain size distributions and were slightly less nutrient rich than their forest counter-parts, likely making it more difficult for tree seedlings to acquire the water and nutrients required for growth and survival (Davis et al. in press). Our research indicates that even if the climate beyond the current treeline becomes suitable for the growth and survival of Engelmann spruce trees in the future, soil properties may limit or slow the process of tree seedling establishment.

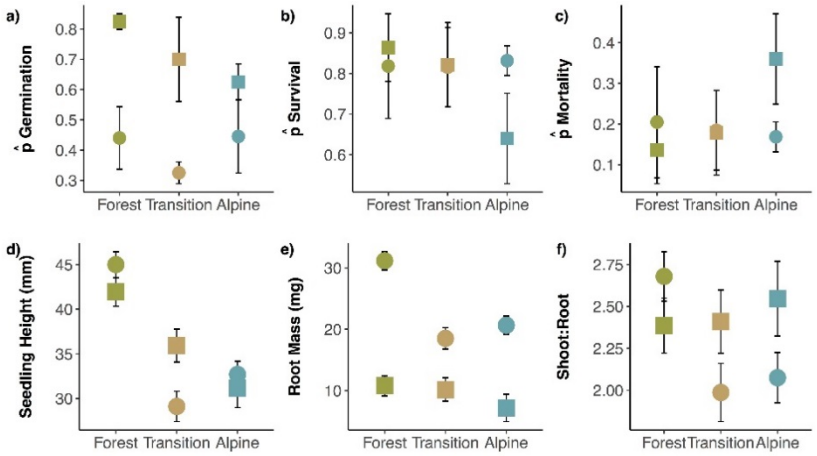

Figure 2 Average measures (+/- standard error) of seedling viability and growth across elevation zones and pooled by site. The data is divided by trials 1 (■ - growth chamber experiment) and 2 (● - greenhouse experiment) (figure adapted from Davis et al. in press).

The effect of non-climatic factors on seedling establishment in the alpine

Non-climatic factors play an important role in the establishment of tree seedlings at small temporal and spatial scales, and can cause variability in the relationship between climate and establishment processes (e.g., Brown and Vellend 2014; HilleRisLambers et al. 2013; Wagg et al. 2011). We conducted a seed addition experiment to test for the effects of seed availability, seed predation, competition, and microclimate on the establishment of Engelmann spruce and subalpine fir seedlings beyond their current elevational ranges.

Seed addition plots were established in the field at the same study locations and elevation zones as the soil suitability study described above, and seedling germination was monitored for three years (2015-2017). Experimental protocols followed those of the Global Treeline Range Expansion Experiment (G-TREE; Brown et al. 2013), and replicated plot treatments included: (1) a split-plot seed addition treatment (known quantity of Engelmann spruce or subalpine fir seeds added) with a herbivore exclosure placed over half the plot; (2) a split-plot seed addition treatment with soil scarification (upper layer of soil and vegetation removed) and herbivore exclosure; (3) a control treatment; and (4) a scarified control treatment. iButton temperature sensors (Maxim Integrated™) were buried within the control plots of each elevation zone at 3 cm depth, allowing us to infer the growing season temperatures and snow cover experienced by germinating seedlings. By manipulating vegetation cover, applying herbivore exclosures, and monitoring soil temperatures, we were able to identify the effects of non-climatic factors on the germination and survival of tree seedlings across the four treeline ecotones (Figure 3).

Insufficient seed availability, competition with other plants, and predation by small mammals and birds restricted the establishment of tree seedlings across the treeline ecotone. We found that the magnitude of these factors declined with increasing elevation, however, such that seedlings in the alpine did not greatly benefit from reducing pressure from competitors or herbivory

(Figure 3). This may have been caused by the overriding importance of soil suitability (described above) and microclimate beyond the current treeline. A correlation analysis revealed average seedling establishment to be negatively associated with growing season temperatures (Figure 4; rho = -0.61, P = .007) and positively associated with snow cover duration (rho = 0.70, P < .001). Surprisingly, we found that alpine environments had warmer growing seasons and less snow cover compared to the lower elevations, making high elevation habitat less amenable to establishment. This indicates in addition to the limitations imposed by soil properties identified our greenhouse study, tree regeneration in the unshaded and exposed alpine may also be constrained by intense heat during the growing season and greater winter exposure due to a reduced snow cover duration.

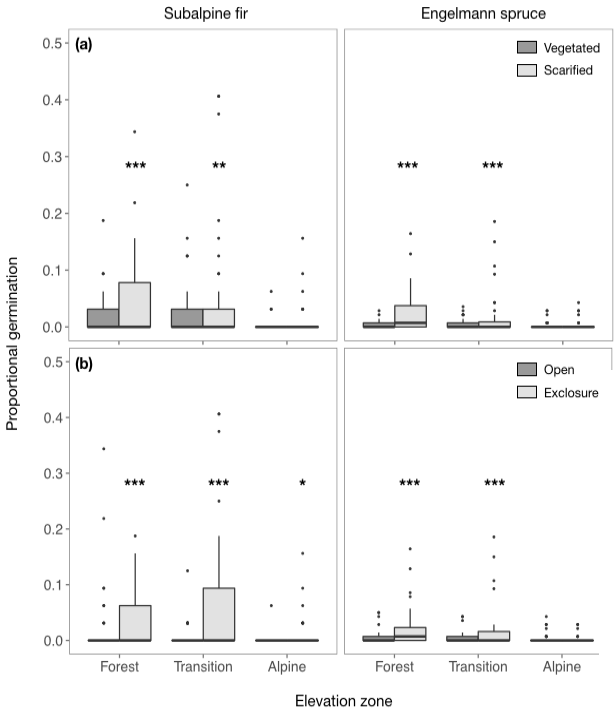

Figure 3 (Left) Mean proportion of established subalpine fir and Engelmann spruce seedlings by elevation zone, vegetation treatment (a) and cage treatment (b). The proportional germination of both species appears to be favoured by both the removal of neighbouring vegetation (scarification treatment) and protection from herbivores (closed cage), particularly in the forest zone (significant differences between treatment effects at each elevation zone; *** P < .001; ** P < .01; * P < .05).

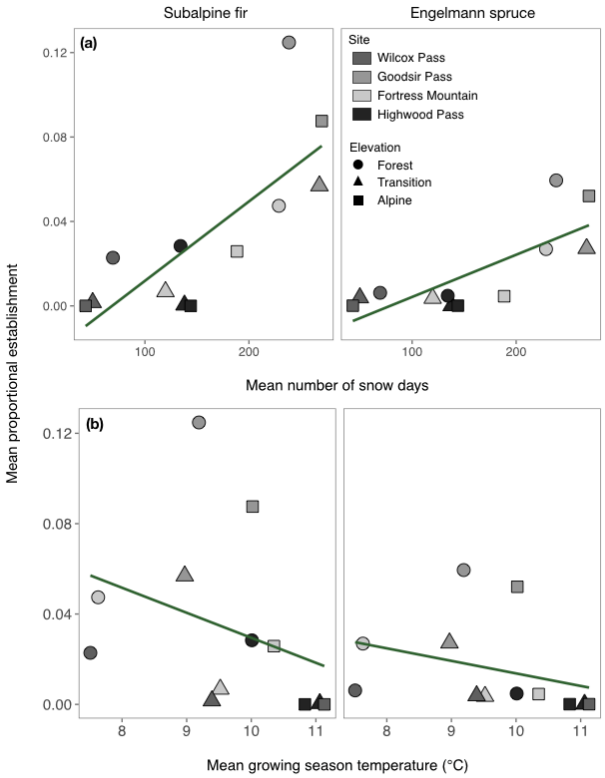

Figure 4 (Right). Relationships between mean seedling establishment, snow cover duration (a), and mean growing season temperatures (b). Species were pooled together for the analysis but are separated here for visualization.

Future seedling establishment beyond Rocky Mountain treelines

The results of our field and greenhouse experiments suggest that it will be challenging for seedling establishment to keep pace with the degree of climate change anticipated for the study region over the next century. Growing season temperatures will very likely continue to rise and winter precipitation to continue declining in the coming decades (Wang et al. 2012), factors we identified to be associated with reduced seedling establishment, and soil properties are unlikely to improve on relevant time scales. Our findings support the idea that non-climatic factors will continue to play an important role in mediating the response of forest systems to climate change (HilleRisLambers et al. 2013; Macias-Fauria and Johnson 2013) and should be considered when forecasting imminent changes in species distributions. Future research for this project will be focused on refining our understanding of the role of microclimate conditions on seedling establishment in alpine treelines throughout the Canadian Cordillera.

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HIGHLIGHT 3: BEAVER-MEDIATED WATER TABLE DYNAMICS IN A MONTANE PEATLAND

Research Cluster: Ecohydrology, Groundwater and Watersheds
Project Coordinators: *Daniel Karran, Cherie Westbrook, and Angela Bedard-Haughn, University of Saskatchewan*

Note: The following research is a summary of results presented in Karran et al. (2017)

Introduction

Peatlands are one of the largest terrestrial carbon sinks in the biosphere (Loisel et al., 2017) because they form in areas where an excess of water creates high and stable water tables that inhibit the decomposition of organic matter produced locally. Plant community composition and the amount of carbon stored, depends largely on the dynamics of the water table dictated by a number of internal and external controls (Waddington et al., 2015). Some controls have been investigated extensively, whereas others, such as beaver, have not. Beaver (*Castor canadensis*) are well known for their ability to disrupt local hydrologic regimes and engineer ecosystems with the structures they build (Naiman et al., 1986). However, the bulk of this research has been focused in mineral soil environments, where water tables are typically much deeper than they are in peatlands. Thus, the goal of this study was to determine what impact beaver dams had on water tables dynamics in a Rocky Mountain fen at the peatland scale.

Study location and methods

The setting for this study is the Sibbald Research Wetland, a rich flow-through fen in Kananaskis country, ~ 70 km west of Calgary (Fig. 1). Beaver have been very active in the peatland, maintaining a series of 15-20 beaver dams since at least the early 1950s, as evident in historic aerial photos. In 2006, a network of 50 shallow wells was installed in the basin and monitored weekly over the summer season of 2006-2009 (Fig. 1). In June 2013, a major rain-on-snow flood event swept through the basin and breached many of the largest beaver dams, which had been intact for nearly 70 years. The well network was monitored again over the summers of 2014 and 2015 in order to have data sets with “intact” and “breached” beaver dams. Each year of well data was classified as either a wet or dry year based on a standardized precipitation index and then maps expressing water table stability and groundwater flow were created. Semivariogram models were created to test the regional dependency of water table stability in wells to beaver dams. Furthermore, wells were grouped based on their distance to beaver dams and the stream (to isolate the stream impacts on water tables), and analyzed for water table depth and stability using a variety of different statistical techniques (see Karran et al. 2017).

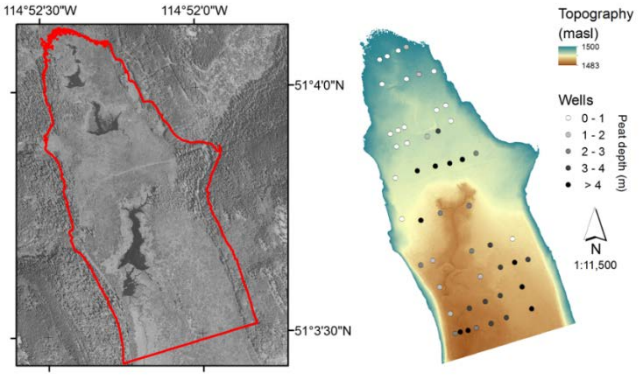


Figure 1 Satellite photo from August 8, 2008 of Sibbald Research Wetland (left) and digital elevation model of peatland (right) with the location of wells in the well network. Wells are shaded relative to the depth of the peat measured at each location

Results and Discussion

We found that beaver dams can raise and stabilize water tables in peatland environments, even though they are already high. When the dams were intact, the median water table was on average 12.8 cm higher and more than twice as stable within a 150-m proximity. This was evident in the group distributions, where near proximity to intact dams produces a strong amplitude signal that nearly disappears when dams are breached (Fig. 2). Semivariograms models (Fig. 3) also showed a clear regional dependency between water table stability and beaver dams (that also dampens after dams breach).

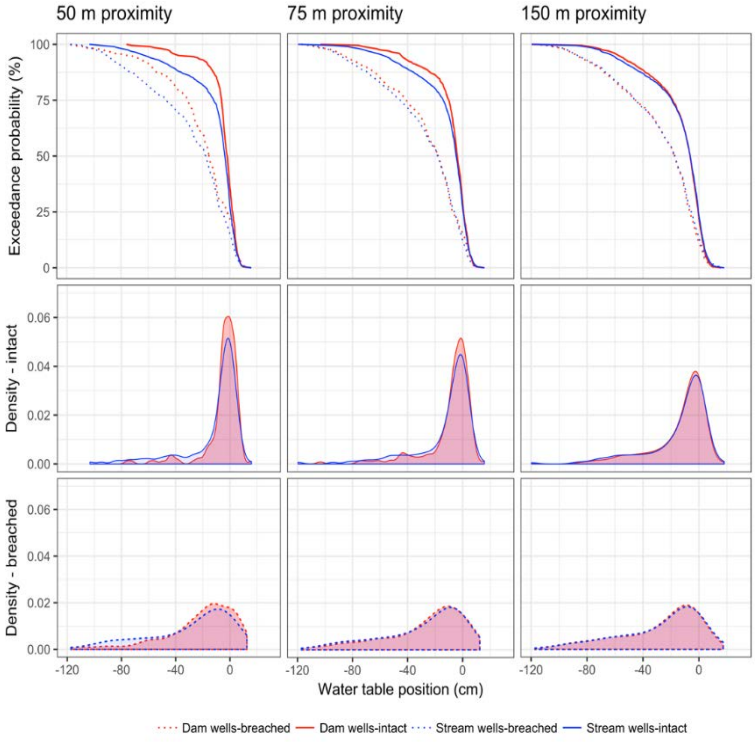
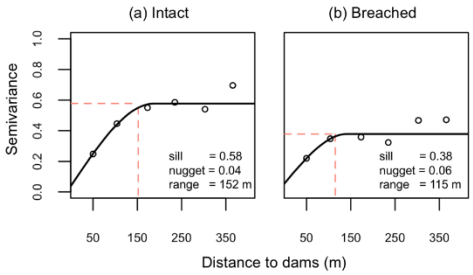


Figure 2 (Left) Distributions of water table positions (cm) for the different groups of wells in the years with intact and breached beaver dams. Distributions expressed as exceedance probability curves (top) and density plots (middle and bottom)

Figure 3 (Above) Spherical semivariogram



models for water table stability using the distance to beaver dams as predictor variables, when the dams were (a) intact and (b) breached. The zone of influence boundary is denoted by the dashed red lines

Groundwater maps show that beaver dams were focal areas for high hydraulic head and that they created flow patterns whereby streamflow was diverted away from the stream and into the peatland (Fig. 4). This was likely a result of the way beaver build dams in these environments; contrary to landscapes with mineral soils, peatland beaver dams resemble berms as they are built with excavated peat piled above the land surface. Relatively flat topography in peatlands allows dams to extend far beyond the stream channel, raising head over much larger areas and making the environment significantly wetter.

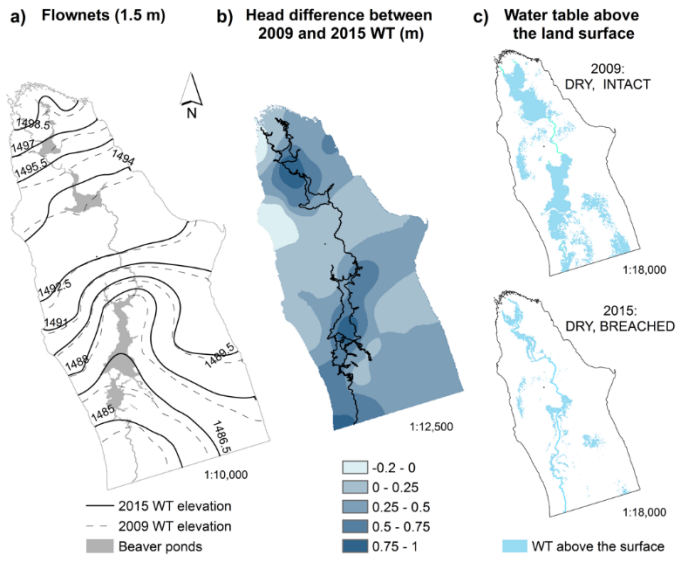


Figure 4 (a) Groundwater flow nets (1.5 m) for the seasonal water table during the driest years with intact and breached beaver dams; (b) the difference in head between seasonal water tables; and (c) the spatial distribution of the seasonal water table that resides above the surface of the peatland during the driest years with intact and breached beaver dams

These findings have both hydrological and ecological implications. By raising and stabilizing water tables, beaver dams increase groundwater storage. This translates into more water available for baseflow, which is particularly important during times of drought (Hood & Bayley, 2008). Furthermore, by changing the peatland water table dynamics, beaver exert control on the plant assemblages that eventually become peat. Higher and more stable water tables may increase carbon sequestration in mountain peatlands (Chimner et al., 2002), enhancing peatland resiliency to climate change.

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HIGHLIGHT 4: ALPINE LAKES BUT NOT MONTANE VALLEY LAKES REQUIRE RESCUE FROM THE ECOLOGICAL IMPACTS OF INTRODUCED SPORTFISH

Research Cluster: Mountain Limnology and Global Change
Project Coordinator: Rolf Vinebrooke

Alpine ecosystems are implicitly more affected by novel environmental changes (i.e. stressors) than those located at lower elevations. Here, the assumption is based upon there being inherently fewer alpine species that compensate for any loss of biodiversity and still insure proper ecosystem functioning in the presence of stressors. In contrast, lower valley lakes contain greater biodiversity and are more productive, resulting in an expected higher probability of there being species that are tolerant of various stressors. As a consequence, stressed local alpine ecosystems may rely more heavily than valley ecosystems on rescue via colonization by tolerant taxa from the broader regional species pool (MacLennan and Vinebrooke 2016). Metacommunity theory predicts that a regional species pool should be able to rescue a biologically impoverished local community via "mass effects" if potential colonists are not dispersal-limited by long distances or topographical barriers (e.g., massive mountain ridges).

To date, the most striking stressor of mountain lake ecosystems in the national and provincial mountain parks of Canada has been their stocking with non-native sportfish during the 20th century (Schindler and Parker 2002). Although this practice was halted in the national mountain parks by the 1980s in response to them being designated as UNESCO World Heritage Sites, introductions of sportfish into mountain lakes continues elsewhere both here in North America and aboard. Non-native sportfish that were introduced into the Canadian Rockies (e.g., European brown trout, Eastern brook trout, Rainbow trout) often functioned as novel predators, especially those in naturally fishless lakes. Here, these visually-feeding consumers exerted size-selective predation pressure on those invertebrates that were easily detectable – e.g., large and colourful taxa that are typically otherwise found in fishless alpine lakes. Biological impoverishment of these stocked lakes by these invasive fish also deteriorated water quality because of they reduced grazing pressure and also provided nutrients to algae, especially in heavily stocked, smaller alpine lakes located along the Cascade Valley in Banff National Park.

In comparison, more recent effects of higher temperatures and extreme climatic events on mountain lake ecosystems have in general been subtle. Summer heating events were earlier hypothesized to favour a shift towards smaller species as they experience relatively less metabolic cost in having to thermoregulate their body mass. Indeed, shorter and/or warmer ice-free conditions did stimulate smaller phytoplankton and zooplankton species across a series of alpine lakes and ponds in Banff National Park, Alberta (Strecker et al., 2004; Parker et al., 2008). Elsewhere, the negative effects of higher temperatures on consumers are attributable to them not being as responsive as their prey to earlier ice-out or onset of thermal stratification.

Introduced non-native sportfish may confound the future effects of higher temperatures on mountain lakes. The sportfish can stimulate smaller species through selective feeding on their larger invertebrate competitors or predators, thereby leaving in place those species that can better tolerate warming. As a result, if certain smaller invertebrate species are present within certain stocked mountain lakes, then these communities may even become more productive under warmer conditions. In other words, introduced sportfish may reduce or even reverse the ecological effects of higher temperature, which equates to them having a combined impact that does not equal the sum of their individual direct effects, termed by some as constituting an "ecological surprise."

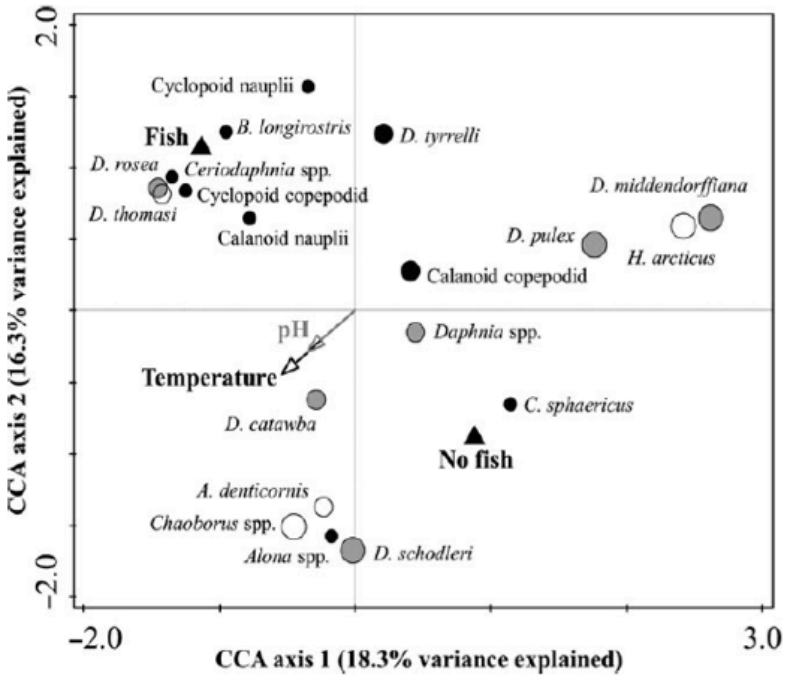
The main goal of our recent research at the field station has been to determine how local biological communities from naturally fishless alpine and lower montane lakes respond to the

combined effects of non-native sportfish and higher temperatures, and whether either requires rescue by the regional species pool. In particular, we have conducted two large-scale mesocosm experiments (Fig. 1) in which we have crossed a sportfish treatment (single rainbow trout fingerling vs fishless) with a heating treatment (~+4°C).

Figure 1 (Left) Matrix of experimental pond mesocosms at the University of Calgary Biogeoscience Institute Barrier Lake field station.

The first experiment was conducted by Megan MacLennan as part of her doctoral research (MacLennan et al., 2015). Her response variables focused on lower montane plankton communities assembled from a number of lakes that had returned to their naturally fishless status over the past 20 years. She discovered that the negative effect of fish on the body size of zooplankton, including the top invertebrate predator (the phantom midge *Chaoborus*) actually resulted in a net increase in species diversity because of several smaller calanoid and cyclopoid species to flourish in the presence of fish while not being detected in the fishless control (Fig. 2).

Figure 2 (Right) Ordination plot showing associations of lower montane zooplankton species with experimental fish-introduction and higher temperature treatments. Proximity of species to fish/no fish symbols and the temperature vector indicates strength of their responsiveness to each factor.



MacLennan also found that the positive effect of the introduced sportfish on zooplankton diversity further significantly stimulated production by the zooplankton while warming had little effect; however, when the zooplankton simultaneously experienced both fish predation and warming, their growth responded synergistically (Fig. 3; i.e. a net response that was far greater than the sum of individual response to each stressor).

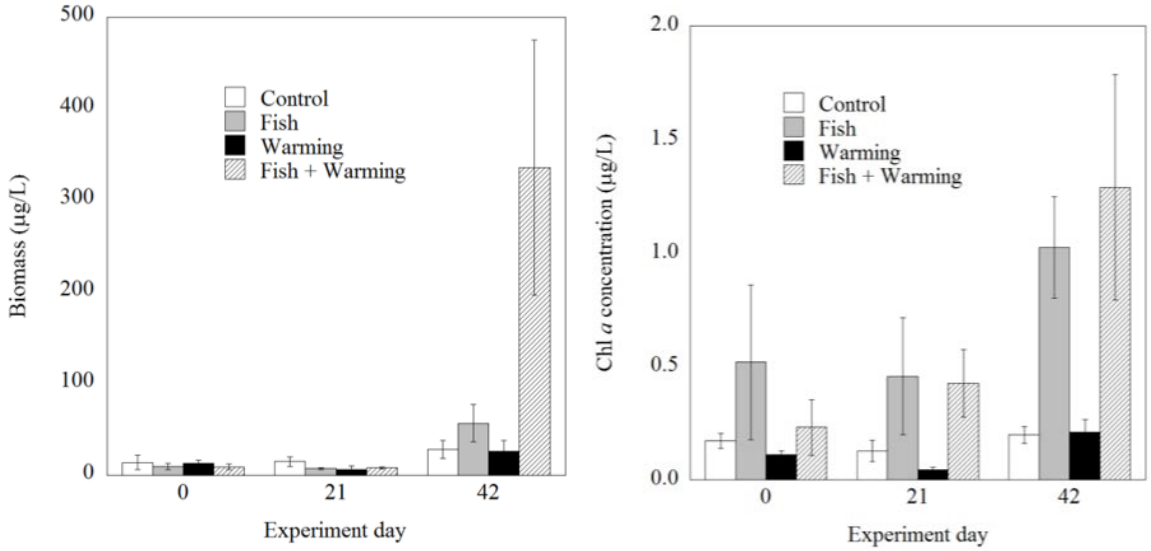


Figure 3 (Left). Effects of introduced rainbow trout fingerlings and warming on total biomass of a lower montane zooplankton community across the 42-day mesocosm experiment. Error bars depict standard error (n = 5). **Figure 4 (Right).** Effects of introduced rainbow trout fingerlings and warming on phytoplankton biomass as measured using chlorophyll concentrations across the 42-day mesocosm experiment. Error bars depict standard error (n = 5)

The synergistic positive effect of fish and warming on zooplankton production was attributable to an increase in the availability of their food base, namely phytoplankton as measured using their chlorophyll content (Fig. 4). The increase in phytoplankton abundance reflected the fertilizing effect of the rainbow trout as they exert, and enhance recycling of, nutrients, such as phosphorus. Higher concentrations of phytoplankton in the presence of fish was also likely in part attributable to their consumption of the dominant grazers in the zooplankton community, namely daphnids. As a consequence, it became clear that lower montane zooplankton communities likely do not require functional rescue from the surrounding regional species pool because they appear to already contain the necessary species needed to compensate for the impacts of introduced sportfish and higher temperatures. In fact, they appeared in the experiment to even overcompensate for these stressors by increasing in both species diversity and net production.

Charlie Loewen conducted a complementary study focusing on fishless alpine lake community responses to introduced rainbow trout fingerlings and an average increase in water temperature of ~+4°C (Loewen and Vinebrooke 2016). Using the same experimental setup as Megan's, he also showed that the impacts of fish far outweighed the subtle influence of warming. Charlie, however, found that the relatively species-poor (6 species) alpine communities did not contain the species that could compensate for the significant negative effect of sportfish on zooplankton diversity (Fig. 5). Here, he had also included a potential rescue treatment in his experimental design where he added on day 28 of the experiment a regional species pool of zooplankton (18 additional species) collected from 25 other mountain lakes and ponds to half of the mesocosms. Surprisingly, the regional species pool not only rescued the local alpine community from the negative effects of the novel predator, but actually reversed it so as to increase zooplankton diversity and biomass (Fig. 6).

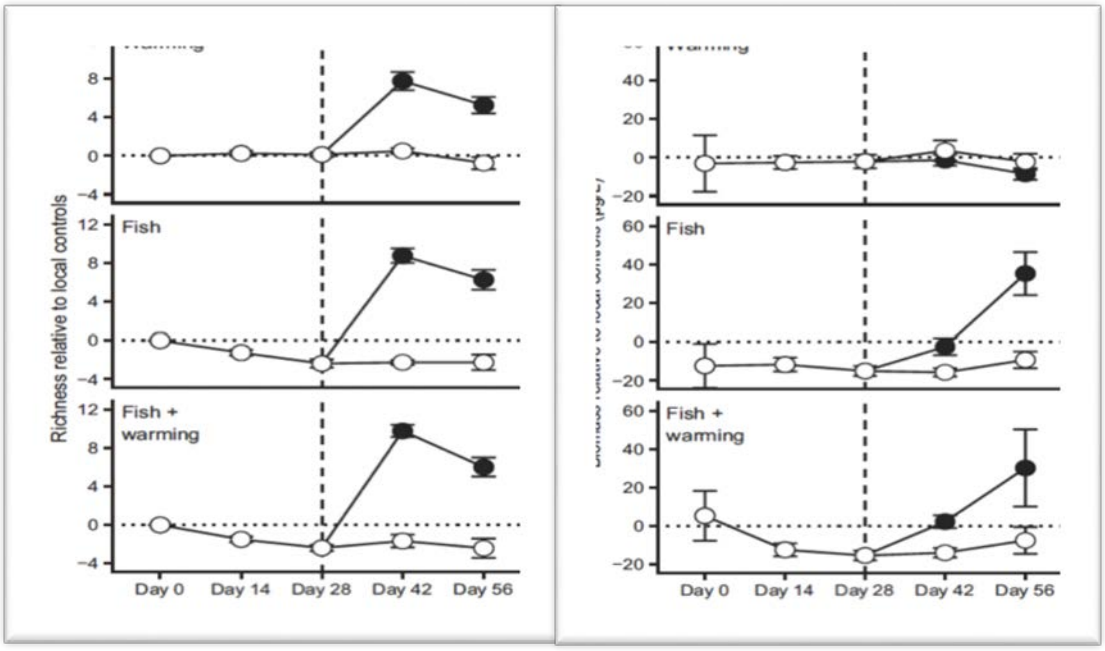


Figure 5 (Left) Effects of the additional of a regional species pool, introduced rainbow trout fingerlings, and warming on species richness of an alpine zooplankton community across the 56-day mesocosm experiment. Error bars depict standard error (n = 4). **(Right)** Effects of the additional of a regional species pool, introduced rainbow trout fingerlings, and warming on the total biomass of an alpine zooplankton community across the 56-day mesocosm experiment. Error bars depict standard error (n = 4).

In summary, Megan's and Charlie's findings highlight that restoration efforts involving the return of previously stocked mountain lakes to their fishless state should likely focus on those in the alpine rather than in lower montane valleys. Alpine lakes may fail to recover on their own in terms of species diversity and production once introduced sportfish populations have collapsed or been extirpated. In contrast, lower montane lakes appear to contain sufficient biodiversity to adjust functionally to changes in the abundance of sportfish. However, we still only have limited evidence of the natural ecological resilience of mountain lake communities following the removal of non-native sportfish.

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Dr. Bourgoin is a visiting researcher working in collaboration with Dr Susan Kutz, Dr. Jocelyn Poissant, Dr. Kathreen Ruckstuhl and Dr. John Gilleard from the University of Calgary. Despite the important effects of parasites on wildlife health and population dynamics, high resolution non-invasive diagnostic tools to study parasitism are lacking. We aimed to adapt a recently developped molecular assay to characterize nematode communities from 13 populations of bighorn sheep across Alberta. Classical coprological analyses revealed a high prevalence of *Nematodirus* sp. and *Marshallagia marshalli*, and a high variability in the abundance of strongyle eggs in different populations. Preliminary results from molecular analyses refined the level of identification of nematodes by detecting different species of *Nematodirus* sp. and strongyles. We observed a variability in species composition of nematodes among bighorn sheep populations but the causes need further investigation.

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Flowers from different plant species provide their pollinators with a different range of rewards (nectar and pollen amount) and costs (metabolic, predation, and wear-and-tear). We are currently studying a particular plant-specific cost: how floral attributes influence wing wear in foraging worker bumble bees. The focus is on how these costs influence lifetime foraging performance and age- specific foraging decisions. Our research therefore considers how foraging decisions, physical deterioration, and lifespan are linked.

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Dr. Cully is the principal investigator for ABOVE (the Array for Broadband Observations of VLF/ELF Emissions). The Van Allen radiation belts are regions of near-Earth space filled with energetic particles. During geomagnetic storms, these particles precipitate into Earth's atmosphere in two bands centered on the magnetic poles. Much of the Prairie Provinces lie in the northern of these bands. To better understand the physical processes driving this precipitation, we are deploying an array of sensitive radio receivers across Western Canada. We installed our first instrument at Barrier Lake field station in summer 2013.

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Dr. Stephen Dobson's research focuses on behavioural and population ecology, population genetics, evolutionary ecology, and conservation biology of mammals. His major field work is on ground-dwelling squirrels in alpine environments in western Canada. Most recently, he is studying how individual fitness of Columbian ground squirrels changes with the changing climate of the mountain environment. He also collaborates on international cooperative research programs with colleagues in Europe, including a study of the mating system of King Penguins. He and his graduate students share a common curiosity about the behaviour, ecology, evolution, genetics, and conservation of birds and mammals, and his students conduct independent research projects.

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Dr. Brett Eaton conducts research on stream channel morphodynamics, with the goal of improving our understanding of the way rivers respond to land use and environmental changes. Currently, his research group is focusing on the influence of disturbances such as forest fire on channel morphology, the effect of large wood on sediment transport dynamics and the influence of hydropower generation on stream channel processes and fish habitat.

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The project EcoWorm investigates "Ecosystem responses to exotic earthworm invasion in Northern American forests". Earth is experiencing substantial biodiversity losses at the global scale, while both species gains and losses are occurring locally and regionally. Nonrandom changes in species distributions could profoundly influence ecosystem functions and services. However, few experimental tests have examined the influences of invasive ecosystem engineers, which can have disproportionally strong impacts on native ecosystems. Invasive earthworms are a prime example of ecosystem engineers that influence many ecosystems around the world. In particular, European earthworms invading northern North American forests may cause simultaneous species gains and losses with significant consequences for essential ecosystem processes like nutrient cycling and crucial services like carbon sequestration. Using a synthetic combination of field observations, field experiments, lab experiments, and meta-analyses, the work in the framework of the EcoWorm project will be the first systematic examination of earthworm effects on relationships between plant communities, soil food webs, and ecosystem processes. Further, effects of a changing climate on the spread and consequences of earthworm invasion will be investigated. Meta-analyses will be used to test if earthworms cause invasion waves, invasion meltdowns, habitat homogenization, and ecosystem state shifts. Global data will be synthesized to test if the relative magnitude of effects differ from place to place depending on the functional dissimilarity between native soil fauna and exotic earthworms. Moving from local to global scale, the present proposal examines the influence of earthworm invasions on biodiversity–ecosystem functioning relationships from an aboveground–belowground perspective.

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The tendency for dramatic temporal variation in annual reproductive effort ("masting") in most higher latitude, non-serotinous tree species is being examined in a unique cross-continental survey of *Picea glauca* and the very close-related *Picea engelmannii*. In particular this project, with now 13 consecutive years of data, will relate cone production in year t to both summer weather in year t-1 as well as the size of the standing cone crop in year t-1 (when the the reproductive buds for the crop in year t were initiated). This simple model (warmer temperatures and a small crop in t-1 lead to a large crop in t) presently explains about 60% of the variation in inter-annual production. Barrier Lake is one of the sites in the survey. In addition, we are also testing the model using an elevational transect both at Kananaskis (Morley to Highwood Pass) and in Colorado.

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Dr. Hargreaves's research focuses on interactions among species (biotic interactions) and the dynamics of species range limits. Much of the research is field-based; she conduct's large- and small-scale experiments in natural environments to test and refine theoretical ideas in ecology and evolution that have practical conservation relevance. Dr. Hargreaves is especially interested in adaptation in range-edge populations, and the role biotic interactions play in shaping species' geographic distributions.

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Most of Dr. Masaki Hayashi's research evolves around the water cycle — how the atmosphere and land surfaces exchange water, and how water flows in rivers, soils, and deep geological formations. He is particularly interested in the two-way linkage between plants and the water cycle, a discipline called eco-hydrology. Dr. Masaki leads two long-term projects in the Canadian Rockies at Lake O'Hara and the thermal springs at Sulphur Mountain. At Lake O'Hara, their research goal is to understand hydrological processes in the alpine headwaters of the Rocky Mountains and to strengthen our ability to predict the effects of climate warming on rivers, lakes, and the aquatic ecosystems in mountain environments. Climate warming is expected to increase the relative amount of rain over snow and shift the timing of snow and glacier melt to earlier in the year. While there is evidence of the expected shifts in temperature and precipitation, their effects on river flow are still uncertain because many aspects of hydrological processes in mountain headwaters, particularly in the alpine, are poorly understood. In addition to Lake O'Hara he started another alpine hydrological study at the Fortress Ski Area in Kananaskis to understand the effects of different geological conditions on groundwater storage and release mechanisms in the mountains. At Sulphur Mountain, the research goals include: 1) establish a monitoring program of all major springs in the Sulphur Mountain area in Banff National Park; 2) develop a quantitative model of groundwater flow using the flow data along with temperature and chemistry; and 3) evaluate the effects of climate change on spring flow rates. Long-term, systematic monitoring of discharge is essential for understanding the groundwater flow system and its response to climatic fluctuations.

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Dr. Johnson's research is directed at integrating natural disturbance into plant community organization and dynamics. His applied interests are in global climate change, biological conservation, and ecosystem and fire management. He is a member of the NSF Community Surface Dynamics Modeling System, NSERC GEOIDE, PAGSE (Royal Society of Canada), and Editor-in-Chief of the journal "Bulletin of the Ecological Society of America."

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Measuring selection in nature is a major focus of evolutionary biology, however collecting accurate measures of individual fitness is often time-consuming and costly. One possible solution to this problem is to work with study systems where an individual's fitness is recorded on their body. Such is the case for many insect species in which the female feeds on parts of the male's body during copulation, thus recording male mating success as damage to non-regenerating structures. Hump-winged grigs (Orthoptera, Prophalangopsidae, *Cyphoderris* spp.) are large flightless insects that are distributed widely in the mountainous northwest of North America, including in Kananaskis, AB. Female grigs feed on male hindwings during copulation, and although the damage to males is not fatal, it is permanent. Previous work has suggested that females acquire a nutritional benefit by feeding on male hindwings. My students and collaborators and I are examining

a number of interrelated questions regarding the operation of sexual selection on male grigs in the wild, the geographic distribution of the three known species, as well as mechanisms of species isolation. The Barrier Lake Field Station and surrounding area hosts a thriving population of *Cyphoderris monstrosa* that has been and continues to be a major study site for our research.

Nusha Keyghobadi, PhD
Associate Professor
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Research in Dr. Keyghobadi's lab focuses on understanding the factors that determine genetic diversity within and among populations, and the consequences of that diversity for persistence and adaptation. Her work at BGI examines how genetic diversity changes over space and time in a network of interconnected populations of the Rocky Mountain apollo butterfly.

Susan Kutz, DVM, PhD
Professor
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Dr. Kutz's current and future research includes: investigation of the response to climate change of trichostrongylid and protostrongylid nematodes of caribou; validation of the dried-blood on filter paper technique for detecting exposure to infectious diseases in caribou; examining diversity of parasites in bighorn sheep; and the use of long-term community-based monitoring of caribou, muskoxen, and moose as a method for early detection of population changes.

Jeffery Lane, PhD
Assistant Professor
Department of Biology
University of Saskatchewan
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Website: http://www.lanelab.ca/

Dr. Lane's research group is interested in the causes and evolutionary consequences of life history variation in a hibernating mammal: the Columbian ground squirrel. Specific projects include: the quantitative genetics and plasticity of hibernation phenology; energetic costs of lactation; variation in, and selection on juvenile growth rates; and the influence of climate change on population viability. We attempt to answer these questions using a range of methodologies from multiple disciplines (primarily physiological, evolutionary ecology and quantitative genetics).

Ross Lein, PhD
Adjunct Professor
Department of Biology
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A long-term investigation of the function of song dialects in white-crowned sparrows at Fortress Mountain in the Kananaskis Valley was done from 1984-1992 and a study of song variation in mountain chickadees at Barrier Lake was done from 1993-1995. In 1996 a major investigation of the nature and function of song variation in flycatchers of the genus *Empidonax* was started. The Kananaskis region has the highest diversity of species of this genus in North America (six species), providing an ideal location for comparative studies.

Marc Macias-Fauria, PhD
Associate Professor in Physical Geography
School of Geography & the Environment
University of Oxford

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Dr. Marc Macias-Fauria's research is directed at understanding the interactions between physical and biological systems over spatial scales ranging from study sites to continents and temporal scales ranging from decades to millennia. Ecological processes are coupled with physical mechanisms

such as atmospheric dynamics and/or geomorphology, among others (i.e. ecology is largely controlled or constrained by the physical environment).

Shawn Marshall, PhD
Professor
Department of Geography
University of Calgary
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shawn.marshall@ucalgary.ca

Dr. Shawn Marshall is a glaciologist and climatologist who studies glacier dynamics, cryosphere-climate processes, paleoclimatology, and mountain meteorology. Current research projects include field and modeling studies in the Canadian Rockies, the Canadian Arctic, and Greenland. He is a Fellow of the Royal Canadian Geographical Society and has served on the Council of the International Glaciological Society and as a Chair of the American Geophysical Sciences group.

Yvonne Martin, PhD
Professor
Department of Geography
University of Calgary
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Dr. Martin's research program focuses on drainage basin geomorphology and its interactions with ecology and hydrology, utilizing both field and modeling approaches. To date, she has focused her research at the BGI on post-wildfire geomorphic response and the interactions between tree population dynamics and geomorphological processes. Other projects include bioturbation impacts on soil production, soil mixing and sediment transport.

Stephen F. Matter, PhD
Associate Professor
Department of Biological Sciences
University of Cincinnati
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Dr. Matter's research focuses on spatial population dynamics, particularly understanding factors that affect the long-term persistence of spatial population networks. Current projects approach this basic question from several perspectives. We are investigating how the configuration of alpine habitat is affected by forest encroachment, the mechanisms of forest encroachment, and in turn how these changes in the landscape affect the dispersal and extinction rates of alpine specialists, particularly the Rocky Mountain Apollo Butterfly, *Parnassius smintheus*. We also investigate how abiotic and biotic conditions, temporal changes in these conditions, and complex interactions among them affect the long-term dynamics and persistence of population networks of alpine butterflies. We approach these questions from theoretical, observational, and experimental perspectives.

John S. Millar, PhD
Professor Emeritus
Department of Biology
Western University
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Dr. John Millar's research is focused on the life history adaptations of mammals to seasonal environments, with a special interest in the life histories of small mammals in northern (short- season) environments. His research group has studied small mammals in a wide range of geographic locations, including Mexico, California, and the Northwest Territories. However, much of his work has been conducted in the Kananaskis Valley of southwestern Alberta where the breeding seasons of most small mammals are very short. An understanding of small mammal populations requires an understanding of demography (survival and reproductive patterns), which in turn requires an understanding of life history tactics. His research group has conducted long-term studies of patterns of reproduction and survival, as well as targeted studies on behaviour, genetics, and energetics. Species that have been targeted for intensive study include deer mice, red-backed voles, wood rats, and chipmunks. Long-term data from Dr. Millar's research can be obtained from the Biogeoscience Institute by request at bgi@ucalgary.ca.

Akira Mori, PhD
Associate Professor
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I have been working on disturbance ecology. Disturbance is ubiquitous in terrestrial ecosystems, and drives fundamental processes as long as it is at natural levels. Anthropocentric disturbance is

increasingly becoming prominent in the present era of Anthropocene. Natural disturbance regime is also changing due to climate change. It is thus important, from both basic and applied perspectives, to understand the causes and consequences of disturbance. More focuses are now given to management approaches founded on natural processes. That is, paying special attention to natural disturbance as a key process in natural systems is fundamental. Such management approach, so-called ecosystem-based management, aims to conserve biological diversity while meeting the social, economic, political and cultural needs of current and future generations. Based upon the above considerations, I have been working on issues in forest and tundra ecosystems, and have been contributing to several international frameworks such as the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) reports. I am currently an Associate Editor for Journal of Applied Ecology (UK) and Environmental Management (USA).

Peter Neuhaus, PhD
Adjunct Professor
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Dr. Peter Neuhaus has been working on different topics in the fields of behavioural ecology, population biology, evolutionary ecology, and social behaviour. One of his main foci in the last years has been on life-history decisions and trade-offs involved with the costs of reproduction in Columbian ground squirrels (*Urocitellus columbianus*). He has also been looking at parasite host interactions and their impacts on reproduction and survival. Further, he also works collaboratively with Kathreen Ruckstuhl on the evolution of sociality and sexual segregation in vertebrates. Finally in collaboration with Kathreen Ruckstuhl and Nigel Caulkett research on improving anesthesia in wildlife. For the ground squirrel studies he uses an experimental approach as much as possible, something that is rarely done with wild living mammals. The study of sexual differences in sociality of vertebrates uses a more comparative approach.

Richard Petrone, PhD
Professor
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Dr. Richard Petrone (Professor, University of Waterloo) is a wetland and forest hydrologist and an expert in soil-plant interactions with hydrometeorological conditions. Dr. Petrone has more than 15 years of experience in wetland and forest ecohydrology and biogeochemistry in cold regions, most of which focused in Alberta. He has 5 research sites in the Kananaskis valley, where he and his students are working to improve our understanding of hydrological processes in mountain basins, focusing on forests and wetlands, and their interactions, with a special emphasis evapotranspiration (ET) and water use efficiency by forest and wetland ecosystems. He and his Hydrometeorology Research Group are especially interested in the effect of disturbance (e.g. forestry, fire, linear disturbances) under a changing climate on these processes.

John W. Pomeroy, PhD
Distinguished Professor
Canada Research Chair in Water Resources and Climate Change
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Dr John Pomeroy is the Canada Research Chair in Water Resources and Climate Change (Tier 1), Professor of Geography and Director of Global Water Futures and the Centre for Hydrology at the University of Saskatchewan, a Visiting Professor of the Chinese Academy of Sciences and an Institute Professor for the Biogeoscience Institute of the University of Calgary. He is a Fellow of the Royal Society of Canada, American Geophysical Union and the Royal Geographical Society.

John R. Post, PhD
Professor
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Dr. John Post's research program focuses on the processes that control growth and survival of

juvenile fish and their recruitment into adult stocks. These processes are at the core of our understanding of habitat requirements, fisheries productivity, and harvest dynamics of freshwater fisheries. He and his graduate students use a combination of laboratory and field experiments, field observations, and computer models to identify, quantify, and extrapolate findings over ranges of spatial and temporal scales. Current applications include assessments of: sustainable fish yields, interactions between native and exotic species, instream flow needs, food web interactions, and climate change impacts.

Cindy Prescott, PhD
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Dr. Prescott established research sites in 1984 as part of her PhD in the Lusk Creek Valley. Log segments of pine, spruce, and fir were placed at the three research sites of the same names. The logs have been sampled at 2, 6,10,14,21 and 30 years. The 21-year results were published in the following article:
Herrmann, S. and C.E. Prescott (2008) **Mass loss and nutrient dynamics of coarse woody debris in Rock Mountain coniferous forests: 21-year results.** *Canadian Journal of Forest Research* 38:125-132.
The 30-year results were published in the following article:
Prescott CE, K Corrao, AM Reid, JM Zukswert and SD Addo-Danso. 2017. **Changes in mass, carbon, nitrogen and phosphorus in logs decomposing for 30 years in three Rocky Mountain coniferous forests.** *Canadian Journal of Forest Research* 47: 1418-1423

Mary Reid, PhD
Professor and
ENSC Program Director
Department of Biological Sciences
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Program

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Dr. Reid's lab examines the processes and traits that affect the success of bark beetles attacking trees and the success of trees defending against bark beetles. In lodgepole pine, we are investigating relationships between tree size, growth rate, defences and phloem nutrients to better understand host choice by bark beetles.

Jens Roland, PhD
Professor Emeritus
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Research in Dr. Jens Roland's lab focuses on population ecology and dynamics of insects in a spatial or landscape perspective. Projects examine both the large-scale pattern of population change and the mechanism by which landscape alters the processes that drive those dynamics. His lab works on the long-term dynamics of the Rocky Mt. Apollo butterfly, *Parnassius smintheus*, in collaboration with Steve Matter, University of Cincinnati.

Rebecca C. Rooney, PhD
Assistant Professor
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Dr. Rooney is keenly interested in biodiversity and functioning of mountain peatlands in the upper Bow River Basin. These sensitive ecosystems are assumed to provide valuable ecological services, but not only have these not been previously quantified, the wetlands are not even mapped and included in the Alberta Wetland Inventory. Dr. Rooney enjoys working in this majestic and under studied landscape, guided by the enthusiasm and curiosity of the local watershed stewardship groups.

Kathreen Ruckstuhl, PhD
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Dr. Ruckstuhl's group research focuses on the behavioural ecology of ungulates, particularly Rocky Mountain bighorn sheep, which she and her group have been researching for 25 years. She also works on various ungulates though collaboration within Canda and across the globe (i.e., most

recently on Darwin's wild sheep and Siberian ibex in China, Mouflons in France, red deer in Portugal and Island of Rum in Scotland, elk in Alberta, and Stone's sheep in Northern British Columbia). Research topics range from how parasites and diseases are transmitted between individuals within social groups. We also investigate how bighorn sheep and deer species use social cues and information to avoid predation. Why animals sexually segregate is still a central theme of her research. This topic also addresses potential sex biases in parasite prevalence or disease, and how it is transmitted between individuals in a sexually segregated/aggregated social group. She works across the Province of Alberta, in close collaboration with Alberta Fish & Wildlife, AEP, UCVM and others. All her studies focus on behavioural ecology of a species to find answers to why animals behave the way they do and what trade-offs they face.

Julie M. Thériault, PhD
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Storms and their associated precipitation at the top of the Canadian Rocky Mountains are some of the key water–related issues in North America providing water for the public, but can also lead to devastating flooding. SPADE is a collaborative project that investigates the small-scale processes leading to orographic precipitation passing over the continental divide, with Dr Thériault as a principal investigator. Specifically, there are three science questions and are as follows. First, how much condensate is passing over the continental divide and falling to the surface on the upwind and downwind slopes? Secondly, what are the factors governing this condensate and the surface distribution of precipitation? Lastly, how well are these features of the precipitation simulated? To answer these questions, intensive meteorological data will be collected, using both automatic observations and manual observations, along with numerical simulations using the Global Environmental Multiscale atmospheric model and a computational fluid dynamics model. This experiment will run from May to June 2019 and is funded by Global Water Futures: Solutions to Water Threats in an Era of Global Change.

Jana Vamosi, PhD
Professor
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Dr. Jana Vamosi's research aims to pinpoint hotspots of threatened species in Canada and determine how climate change accelerates extinction risk. Her research program emerged from broad interests in the macroevolution and community ecology of plants and often brings phylogenetic approaches to questions pertaining to the study of plant-insect interactions and the conservation of ecosystem function. Her team is gathering more precise information on the phylogenetic distribution of flowering plants at risk of extinction in Canada.

Vincent Viblanc, PhD
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Dr. Viblanc studies the costs of social living, including stress responses to social and ecological factors, using Columbian ground squirrels as a model species. Social living entails both cooperation and competition, and thus engenders a variety of stresses. We use genetic measures such as telomere length and physiological measures of oxidative and hormonal stress to quantify the influence of environmental stressors on individual fitness. We use lifetime records of growth and reproduction, as well as genealogical history to measure both fitness costs and benefits, as well as heritability, of genetic and physiological indicators of social stress.

Rolf Vinebrooke, PhD
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The main goal of my research group at the field station is to explore past, current, and future population- and community-level responses to climatic variation and other environmental drivers along an elevational gradient of lakes and ponds in the Canadian Rockies. We combine aquatic surveys with mesocosm experiments and paleolimnology to determine the key environmental factors of species composition and related ecological processes, such as primary production and grazing pressure. We are particularly excited by our on-going reciprocal transplant experiment involving alpine and montane-valley pond ecosystems maintained in 1000-litre capacity mesoscosms at both the field station and also above treeline near Sunshine Village, Banff National Park. Here, we are currently testing the hypothesis that alpine species and communities are less adaptive and resilient to higher temperatures than their montane counterparts are to colder temperatures. Future research will investigate if the warmed alpine communities at the field station are more easily invaded than those maintained at treeline by introduced species.

Cherie Westbrook, PhD
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Dr. Cherie Westbrook is the lead researcher of the Wetland Ecohydrology Research Group. The goal of this group is to use principles from hydrology and ecology to improve our fundamental understanding of wetland and riparian ecosystems. We focus on studying the interactive pathways between surface and ground waters, how beavers and humans influence these pathways, and as a result, how water and nutrients are transported from wetlands and riparian areas. Our group uses tools from ecology and hydrology to improve our understanding of mountain wetland systems. In particular, we are focused on examining how beaver activities affect peatland form, ecohydrologic function, and the subsequent export of water and nutrients from these systems. For example, we are studying how increases in open water formation, owing to beaver damming, affects surface water exchange with the alluvial aquifers that underlie the peat. Also, we are trying to determine how important of a role beaver play in maintaining hydrologic conditions suitable for persistent peat formation. Further, we are using sophisticated instruments to "see" beneath the peat surface to figure out how beaver activities over the past 12,000 years have shaped peatland form.

Paul Whitfield, PhD
Senior Research Fellow
Centre for Hydrology
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Dr. Whitfield's research spans the multiple areas where the hydrological response of watersheds to climate is central. The work involves data quality and representativeness, particularly "fitness for purpose"; methods for inputting missing observations; network design and statistical hydrology. The statistical hydrology focus is on extracting signal components that can be used to better understand the relationship of hydrology to climate, and also to model missing observations and ungauged basins.

- Develop physically based and statistical methods to extrapolate meteorological fields between mountain meteorological stations
- Improve methods to in-fill hydrometric data using physical and statistical principles
- Evaluate river basin measurement networks in terms of their fitness for predictive purpose
- Improve hydrological predictions in mountains under climate change

BARRIER LAKE AND RB MILLER STUDENT PROJECT DESCRIPTIONS

Fire Spread Model
Atoossa (Tessa) Bakhshaii, Post-doctoral Associate
Department of Biological Sciences, Supervisor: Dr. Edward Johnson

My current research goal is to initialize and adjust the last version of WRF- SFIRE with Canadian/local fuel data and examine that how well WRF predict the weather and fire events in Alberta.

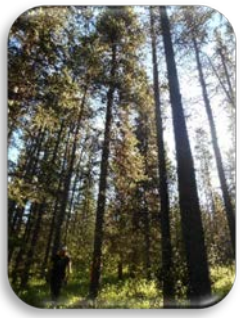
Pollination processes of the Arctic Raspberry (Rubus arcticus) in Alberta
Cole Burns, MSc Student
Department of Biological Sciences, Supervisor: Dr. Jana Vamosi

Field research occurred during the summer of 2017 at the Jumpingpound Demonstration Forest on the Sibbald Lake Trail, in which two separate experiments were conducted. The first experiment's aim was to examine the effects of microclimate on foraging behavior of Rubus arcticus pollinators using time-lapse cameras coupled with data loggers measuring temperature/RH along with the use of hemispherical photography to simulate solar radiation exposure. The focus of the second experiment was to determine if R. arcticus fruitset is pollen limited by means of a pollen supplementation experiment, while also considering which aspect of pollen limitation is more influential of fruit production; pollen quantity or quality.

Groundwater processes of the Fortress Ski Area
Jesse He & Benjamin Roesky, MSc. Candidates
Department of Geoscience, Supervisor: Dr. Masaki Hayashi

Preliminary investigation of the Fortress Ski Area suggests that groundwater plays a significant role in the storage and eventual release of water input (i.e. precipitation and snowmelt) to regions downstream. Groundwater processes are important because they may buffer the effects of climate change on streamflow and can provide stable temperature refugia that are critical for aquatic life. Our research will attempt to determine significant groundwater reservoirs and flow pathways within the Fortress Ski Area. Using a variety of field methods from tracer tests to drone mapping, we hope to quantify groundwater storage and transport throughout the study site and improve our understanding of groundwater processes in alpine regions.

Patterns and Processes of Age, Size, and Defences in Lodgepole Pine
Isabella Hutchison, Bachelor
Department of Biological Sciences, Supervisor: Dr. Mary Reid



The aim of this project was to clarify the influences of tree size and age on defensive tree traits in lodgepole pine, Pinus contorta. Four forest stands were chosen at the U of C Biogeoscience field site, two young (c.a. 40 yrs.) and two old (>100 yrs.), with diameter at breast height used as an indicator of size class (small, medium, large). We wanted to see if age or size could determine how well-defended a tree might be against pests like mountain pine beetle (Dendroctonus ponderosae). From these trees we analyzed resin production, resin duct traits (size, density and area) in both phloem and xylem, because resin is a primary defense of lodgepole pine trees against challenges such as herbivory, pest or pathogen attack. We found that overall this study indicates an ontogenic strategy for resource allocation to defensive traits, younger trees had more defences than older ones, however in both ages, defences increased with tree size.

Determinants of individual foraging effort and colony success in wild bumble bees
Rola Kutbi, PhD Candidate
Department of Biological Sciences, Supervisor: Dr. Ralph Carter

This research tests ideas about a plastic trait—workload—whose level is predicted to reflect an individual's sensitivity to short- vs. long-term colony needs, and its own life history. This research also examine a number of environmental factors that potentially affect colony growth and eventual reproduction, an outcome that will be important to inform conservation efforts of temperate forest bumble bees and their plant mutualists.

Can you catch a behaviour like you catch a cold? Behaviours spread between group members according to the spatial and temporal relationship between the individuals as well as characteristics of the behaviour itself
Petra McDougall, PhD Student
Department of Biological Sciences, Supervisor: Dr. Kathreen Ruckstuhl

Viruses and bacterial infections have long been known to spread between interaction partners. More recently, however, scientists have been investigating the spread of *behaviours* between interactions partners. Unlike viruses and infections, the contagious spread of behaviours is a positive element of group living, as it is essential for group cohesion and coordination. Despite this important role, little is known about why some behaviours spread and others do not. Using vigilance behaviour in free-ranging bighorn sheep (*Ovis canadensis*) as our study system, we are investigating several potential moderators of contagious behaviour.

In our first study, we examined social and spatial aspects of the interacting dyad and determined whether they affected rates of vigilance contagion. We found that vigilance bouts are more likely to spread when neighbouring sheep are more familiar with one another, closer in proximity, and posturally aligned. We interpret these findings in terms of biases in attentiveness to salient stimuli.

In our second study, we investigated the differences between routine and induced vigilance bouts, and whether variation in the way a vigilance bout is performed affects its contagiousness. In contrast with when sheep are routinely scanning their environment, we found that when vigilance bouts were induced by natural stimuli (e.g. vehicles passing, dogs barking, or the presence of other animals such as coyotes or bears) sheep raised their heads quicker, gazed in a fixed direction for a longer period of time, and were more likely to cease chewing upon raising their heads. When examining these three variables in a data set comprised exclusively of routine vigilance bouts, chewing cessation strongly predicted the occurrence of a contagion event. Interestingly, neither head-raise duration, nor fixed-gaze duration predicted contagion events. These results indicate that particular characteristics of a behaviour can affect whether that behaviour spreads to neighbouring individuals. Results are discussed in terms of both attention and learning as possible mechanisms regulating the spread of behaviour between interaction partners.

Characterization of Meltwater Chemistry at Haig Glacier, Canadian Rocky Mountains
Kristina Miller, MSc Student
Department of Geography, Supervisor: Dr. Shawn Marshall

Glaciers are found at the headwaters of the Bow and Kananaskis Rivers and are an important source of water for Calgary and other communities, particularly during the dry summer months. With warming temperatures, the timing, amount, and composition of glacier runoff is expected to change. My MSc research took place on Haig Glacier, found at the headwaters of the Kananaskis River, which flows into the Bow River. The aim of the study was to partition glacier runoff into surface and sub-glacial fractions. I found that the fraction of sub-glacial water increases from approximately 6% to 11% in the early and late melt season, respectively. My findings help understand the seasonal evolution of the glacier's hydrologic system and serve as a contribution to future basin-scale studies that will aim to quantify glacial contributions to major rivers.

Physical modelling of cold regions hydrological sensitivity to climate and vegetation changes in the Canadian Rockies
Kabir Rasouli, NSERC Post-doc Fellow
University of Calgary and Centre for Hydrology, Supervisors: Dr. Masaki Hayashi and Dr. John Pomeroy

Understanding the sensitivity of hydrological processes to climate change in snow-covered mountains is important for water and energy security. The objectives of this study are:
(i) to quantify the sensitivity of simulated mountain hydrological processes to changes in air temperature and precipitation;
(ii) to document the uncertainty in estimations of future mountain hydrological processes due to uncertainty in climate models; and
(iii) to quantify the response of simulated mountain hydrology to climate change when there are transient changes in vegetation and soils.

Mating Strategies of Bighorn Sheep
Ryan Tate, PhD Candidate
Department of Biological Sciences, Supervisor: Dr. Kathreen Ruckstuhl

I am interested in seeing if male bighorn sheep use the same lifelong mating strategy or whether there is some degree of specialization. I use game theory and mathematical modeling to study the bighorn sheep's mating system. My model will look at what might drive males to use different mating tactics over the course of their life rather than specializing in one mating tactic. I am comparing my model against a long term data set of the population at Sheep River Provincial Park to see how males invest in these different tactics over their life and what theoretical frame work this most closely resembles.

Geomorphological & Hydrological factors limiting forest encroachment into alpine meadows
Moujan Toloui-Semnani, MSc Student
Department of Biological Sciences, Supervisor: Dr. Edward Johnson

Elevations above certain temperatures can limit the establishment, growth and survival of trees. These areas are known as temperature treelines and are common in many mountainous areas were the forest advancement abruptly stops at a certain elevation. Immediately below these elevations, regions are known where the alpine meadows are not high enough for the tree distribution to be controlled by climate factors; yet no trees grow in these meadows. My study site Jumpingpound Ridge is one such meadow which is situated in a NE, SW aspects. The SW aspect has a steep slope and the trees cover the slope all the way up to the ridge while the NE slope has a gentle slope and the teeline abruptly stops at a certain elevation. I believe the potential causes for limitation on encroachment into the meadow area in the NE side could be high regolith flux rate which prevents the establishment of tree seedlings, alternatively it could be insufficient soil moisture content or most likely the combination of both.

Geophysical and Geochemical constraints on a regional model of Banff Hot Springs.
Thomas Wilson, PhD
Department of Geosciences, Supervisor: Dr Rachel Lauer

In the Banff area, located within the Front Ranges of the Canadian Rockies, nine thermal springs occur in a linear trend along the Sulphur Mountain Thrust (SMT) fault. In recent years some of the springs have experienced frequent flow stoppages threatening the habitat of the endangered snail, *Physella johnsoni*, and causing operational interruption to a swimming pool which is fed by the Upper Hot Spring. To understand the ecological threat and limit flow disruption to the pool, short- and long-term forecasts of spring discharge are required. We use geophysical and geochemical investigations to provide spatial and temporal constrains for regional scale three dimensional hydrological models of the hot spring system, which will be used to evaluate future spring discharge behaviour.

Ecological resilience in a rapidly changing climate: An alpine-montane reciprocal transplant pond experiment

Mitchell Johnsen, MSc Student
Department of Biological Sciences, Supervisor: Dr. Rolf Vinebrooke

Alpine pond communities are expected to be at greatest risk under a rapidly changing climate due to their low species diversity and the accelerated rate of warming at higher elevations. We tested this hypothesis by conducting a replicated two-factor experiment consisting of a reciprocal transplant of alpine and lower montane pond mesocosms (1000-L capacity) across two elevations (1390 m versus 2345 m asl). At each location, half of the mesocosms were inoculated with regionally sourced alpine plankton and sedimentary egg-banks while the other mesocosms were similarly seeded with a regional species pool collected from lower montane ponds in 2016. After overwintering, the mesocosms were sampled for temperature, water chemistry, plankton and periphyton during the ice-free periods of 2017 and 2018. Preliminary results suggest higher temperatures increased alpine zooplankton biomass in the mesocosms transplanted to the valley site whereas colder temperatures suppressed production by lower montane zooplankton transplanted to the alpine site. Therefore, alpine pond zooplankton may not be as locally adapted as predicted, and instead resilient against future warming trends.

Multiple Stressors and the Role of Dispersal in Freshwater Ecosystems

Charlie Loewen, PhD Student
Department of Biological Sciences, Supervisor: Dr. Rolf Vinebrooke

At the current rapid pace of environmental change, freshwater ecosystems are increasingly affected by multiple ecological stressors. For instance, introduced sportfish have altered the composition and function of freshwater communities globally, including those of previously fishless lakes in the Canadian mountain parks. These cold-adapted mountain lake communities are simultaneously impacted by changing temperature regimes, which may interact with exotic sportfish to generate unexpected ecological surprises. Stressor impacts are additionally confounded by species dispersal, as adverse local effects may be offset by stress-tolerant individuals arriving from neighbouring communities.

Effective management and prioritization of conservation efforts necessitates a detailed understanding of the cumulative effects of multiple concurrent stressors. With a focus on mountain zooplankton community response to biological invasions and climate change, my research is revealing the functional consequences of stressors and how their impacts are mediated by habitat connectivity and species' traits. Our investigations combine field surveys, quantitative literature review, multivariate and spatial analyses of continental-scale biodiversity patterns, and mesocosm experiments conducted at the Barrier Lake Field Station in Kananaskis, Alberta.

Measurements of suspended frazil ice particles in Alberta rivers
Vincent McFarlene, PhD Student
Civil and Environmental Engineering, Supervisors: Dr. Mark Loewen and Dr. Faye Hicks

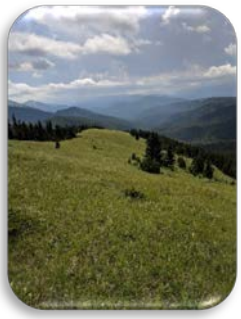
Frazil ice particles are small, disc-shaped ice crystals that form in supercooled river flows. These particles will easily freeze on to almost any surface while the water remains supercooled and can form large accumulations of anchor ice, drastically altering the river geomorphology and negatively affecting fish habitat. Past laboratory studies have identified flow characteristics such as turbulence intensity as a major factor influencing the size distribution of frazil particles, but field measurements have proven more difficult. We have developed an underwater camera system to photograph suspended frazil ice particles produced in natural streams. By studying the particles formed in different Alberta streams including the Kananaskis River, North Saskatchewan River, and Peace River, we aim to determine how frazil particles vary between rivers with different flow characteristics. This will be valuable for calibrating and validating numerical river ice models, making it possible to more-accurately predict how the river freeze-up process will unfold and improve our understanding of one of the most vital aspects of river ice engineering.

AUBURN UNIVERSITY

Testing the thermal mismatch hypothesis: costs of parasitism on host physiological stress, health and fitness in a changing world
Jeffrey Roth, Jeffrey, PhD student
Department of Biological Sciences, Advisor: Dr. Stephen F. Dobson

The interaction of parasites and their hosts is one of the most important topics in co-evolutionary biology. This interaction is especially complicated by the ectothermic metabolism of parasites and homeothermic metabolism of mammal hosts. The “Thermal Mismatch” hypothesis proposes that parasites can tolerate fluctuating temperatures better than their hosts by having broader thermal breadths, thus acclimating more rapidly to changing conditions. We are artificially infesting Columbian ground squirrels with ectoparasites (fleas) during their active season to understand the physiological costs of parasites through various measures of condition and fitness. These effects are additionally being tracked with temperature collars during hibernation, a period of temperature fluctuation that represents conditions under which the Thermal Mismatch hypothesis would operate.

Examining dispersal patterns of *Parnassius smintheus* butterflies
Jennifer Goff, B.S. Environmental Studies
Department of Biological Sciences, Supervisor: Dr. Stephen F. Matter



In an effort to better understand dispersal patterns of *Parnassius smintheus*Doubleday, I joined Dr. Stephen Matter's research crew. This past summer, I helped to census an 18 subalpine meadow metapopulation, each meadow containing a subpopulation that is considered semi-independent. Butterflies were captured, each was given a unique three-letter code that was written on the hind wings with a felt-tipped marker, and released. Data was recorded for individual butterflies: three-letter code, sex, recapture status, and the date, time and location of capture. We are able to track dispersal of individuals using this data to determine if they emigrate from their natal patch.

Ecoevolutionary dynamics of *Sedum lanceolatum*.
Benjamin J. Merritt, PhD Candidate
Department of Biological Sciences, Supervisor: Dr. Stephen Matter and Dr. Theresa Culley

This project aims to characterize the lanceleaf stonecrop, *Sedum lanceolatum* (Crassulaceae; Torr.), along Jumpingpound Ridge in Kananaskis Country. Genetic markers are being used to assess genetic structure and gene flow within and among isolated sub-alpine meadows along the ridge line. Additionally, statistical modeling with population abundances records spanning 15 years along Jumpingpound Ridge is being used to identify climate, meteorological, topographic, and biotic cues that describe change in population growth of this species. Together, these approaches will elucidate variation within and among isolated populations and clarify the mechanisms that are shared and varied among populations in how they interact with their environment.

Modeling Green Roofs using Alpine Meadow Vegetation
Alexus Wimbish, BS
Environmental Studies, Supervisor: Dr. Stephen Matter

Brief project description: Concerns over increased freshwater runoff and pollution has boosted interest in urban green infrastructure, including green roofs. Currently in the U.S., extensive (thin-soil) green roofs provide many beneficial ecosystem services, including reducing storm-water runoff and neutralizing acidic rain water; but also provide an environmental disservice by leaching nitrogen and phosphorus directly into ecosystems, which contributes to surface water eutrophication. This is due to imbalance between nutrient-rich substrate used for green roofs, and the slow-growing plant community, typically drought-tolerant *Sedums*. Alpine meadow vegetation demonstrates survivorship in thin soils and low moisture, therefore, may be applicable to an extensive green roof. In this study, we aim to determine if the alpine meadow habitat may perform as well as typical green roof vegetation.

ECOWORM - Ecosystem responses to exotic earthworm invasion in northern North American forests

Olga Ferlian, Post-doctoral Student
German Centre for Integrative Biodiversity Research (iDiv),
Supervisor: Dr. Nico Eisenhauer

Every year, we sample different forest stands in Canada (aspen forests) and the USA (maple forests) that have earthworm invasion fronts. Here, we can directly compare parts of the forest that have been invaded with parts that have not been invaded. This gives us a unique opportunity to study the effects of earthworm invasion on ecosystems and their functioning. In an additional project, we established soil enclosures to experimentally manipulate plots by adding earthworms to previously uninvaded soils. Here, we can study the effects of earthworm presence in early invasion stages in a highly standardized way that ideally complements our observational studies in the project.

In July 2017, we sampled an aspen forest stand near highway 40 about 60 km south of the Barrier Lake Field Station. This stand was chosen as it indicated a present earthworm invasion front. For the observation study, we used our standard sampling set including assessment of basic forest characteristics, forest crown cover, understory vegetation cover, counting of earthworm middens, measurement of understory species-specific plant biomass, litter biomass, thickness of humus layer, assessments of invertebrate micro-, meso- and macrofauna abundances/species identity (including earthworms), and sampling of soil for measurements of different soil parameters, such as pH, carbon and nitrogen contents, and microbial biomass and community structure. All samplings and measurements were conducted on 1 x 1 m plots (ten in the uninvaded, ten in the invaded part) that were randomly set up in the forest. Most of the samples were shipped to Germany for analyses. Furthermore, we established twenty metal soil enclosures in the uninvaded part of an aspen forest 1 km north or Barrier Lake. The enclosures were inserted into the soil to a depth of 40 cm and a height aboveground of 20 cm. The enclosed soil and vegetation was kept undisturbed; earthworms were added to ten of the plots. In 2018, more earthworms will be added to the plots to further increase earthworm densities. Please click on our video link for more information: https://www.youtube.com/watch?v=Uvp797YCJ14&feature=youtu.be

Non-climatic constraints to tree species distributions in the Canadian Rocky Mountains

Emma L. Davis, PhD Candidate
Department of Geography, Supervisor: Dr. Ze'ev Gedalof

Warming temperatures and changes in precipitation regimes associated with climate change are expected to increase the elevational extent of tree species limits in mountain systems around the world. Increasingly, however, the role of non-climatic factors in limiting the ability of trees to track climate change is being recognized, highlighting the importance of considering multiple biotic and abiotic factors when considering how forest species distributions will change in the future. Through a series of field and laboratory experiments, my research addresses to what extent factors such as seed availability, predation, substrate suitability, and microclimate act as constraints to tree seedling germination and survival across treeline ecotones. This research will improve our understanding of the likely impacts of climate change on high elevation forest systems, and will enable more accurate predictions of the conditions under which treeline migrations are likely to occur in the Canadian Rocky Mountains.

Love/hate thy neighbour: neighbour shifts from hosts to competitors across the ranges of hemi-parasitic plants

Shannon Meadley Dunphy, PhD student
Department of Biology, Supervisor: Anna Hargreaves

As the climate warms, many species are predicted to move towards higher elevations and latitudes, based on the assumption that climate determines species' current distributions. However, interactions between species can also strongly affect where species occur, and we know little about how negative and positive interactions combine to affect species distributions and responses to change. For my PhD, I am examining how positive and negative species interactions determine the high and low-elevation range limits of the herb yellow rattle (Rhinanthus minor) in Alberta's Rocky Mountains. Yellow rattle is ideal for comparing positive and negative interactions, as it is a 'hemiparasite' it does its own photosynthesis but parasitizes nutrients from the roots of its neighbours. Thus below ground, neighbours are positive (acting as hosts), while above ground neighbours are negative, competing for sunlight. I will test the combined impact of positive and negative interactions on yellow rattle's distribution by manipulating above ground competitions while preserving belowground host interactions, and by growing yellow rattle across its range with different host communities.

The role of biotic vs. abiotic factors in imposing contrasting species' range limits
Joshua Persi, MSc Student
Department of Biology, Supervisor: Dr. Anna Hargreaves

What factors set the boundaries of a species' range? One longstanding theory suggests higher range limits are often set by harsh abiotic conditions whereas species' lower range limits are typically imposed by intense interactions with other species. While a recent meta-analysis suggests biotic interactions are a greater constraint at low vs. high altitude range limits, few studies have tested how biotic and abiotic factors constrain a species' fitness across its entire range, including its contrasting (low vs. high) range limits. For my M.Sc. thesis, I'm conducting a series of large-scale field experiments assessing the role of seed predation, a biotic factor, and overwinter snowpack, an abiotic factor, in constraining the altitudinal range of the annual herb, *Rhinanthus minor*.

UQÀM
Université du Québec à Montréal

Storms and Precipitation Across the Continental Divide Experiment (SPADE)
List of students involved with SPADE:
Aurélie Desroches Lapointe, UQAM, M.Sc.
Charlie Hébert-Pinard, UQAM, B.Sc.
Cécile Carton, UQAM, Ph.D.
Selina Mitchell, UNBC, M.Sc.
Project Coordinator: *Juris Almonte*
Department of Earth and Atmospheric Sciences, Supervisor: Julie Theriault

Storms and their associated precipitation at the top of the Canadian Rocky Mountains are some of the key water–related issues in North America providing water for the public, but can also lead to devastating flooding. SPADE is a collaborative project that investigates the small-scale processes leading to orographic precipitation passing over the continental divide. Specifically, there are three science questions and are as follows. First, how much condensate is passing over the continental divide and falling to the surface on the upwind and downwind slopes? Secondly, what are the factors governing this condensate and the surface distribution of precipitation? Lastly, how well are these features of the precipitation simulated? To answer these questions, intensive meteorological data will be collected, using both automatic observations and manual observations, along with numerical simulations using the Global Environmental Multiscale atmospheric model and a computational fluid dynamics model. This experiment will run from May to June 2019 and is funded by Global Water Futures: Solutions to Water Threats in an Era of Global Change.

Investigating the turbulent transport of snow and energy in alpine terrain
Nikolas Aksamit, Postdoctoral Fellow
Centre for Hydrology, Department of Geography and Planning, Supervisor: Dr. John Pomeroy

Coherent atmospheric turbulent structures are responsible for significant transport of energy and snow in mountainous terrain. This impacts cold regions hydrology and engineering, avalanche safety, and glaciology. However, the complexity of these structures are difficult to accurately represent in mathematical models and are often oversimplified for practitioners. The proposed research will further investigate the influence of intermittent turbulence on nonstationary turbulent processes in the Canadian Rockies, focusing on identifying the mechanics of relevant coherent structures. An improved understanding of the physics driving the complex coupling of alpine winds and surface energy and mass budgets will benefit scientists and modelers alike.

Diagnosis and prediction of climate-driven changes in glacier melt contribution to alpine catchment hydrology
Caroline Aubry-Wake, PhD Student
Centre for Hydrology, Department of Geography and Planning, Supervisor: Dr. John Pomeroy

Glacier meltwater provides downstream environment with critical water resources for hydropower, irrigation and agriculture, drinking water and recreation. Due to climate change, mountain glaciers are quickly retreating, impacting the downstream water resources. The proposed research aims to assess the impact of future climate and glacier change on glacierized basin hydrology and streamflow generation. This will be done by combining mountain fieldwork and the Cold Region Hydrological Model, in which a glacier flow model will be developed.

Hydrological Data Assimilation in Cold Mountain River Basins
André Bertoncini, Ph.D. Candidate
Centre for Hydrology, Department of Geography and Planning, Supervisor: Dr. John Pomeroy

The purpose of this research is to estimate snow water equivalent using a data assimilation framework in the Upper Bow River Basin in order to improve the prediction of streamflow magnitude and timing. This framework uses a combination of remotely sensed and modeled hydrological variables, but also relies on ground-based data assimilation and validation using data collected in the research sites located in the Kananaskis region. To this end, two efforts were made during 2018 in Fortress Mountain: we installed a Micro Rain Radar to observe the vertical structure of orographic precipitation and conducted an Unmanned Aerial Vehicle (UAV) surveying to obtain hydrologically relevant data.

Assessing the uncertainties of land surface schemes in simulating snow processes in complex terrains
Abbas Fayad, Post-Doctoral Fellow
Centre for Hydrology, Supervisor: Dr. John Pomeroy

The main objective of this study is to evaluate land surface schemes ability in representing the energy fluxes and water exchange in alpine and montane regions. The model is forced with bias-corrected meteorological datasets and evaluated against measurements and observations collected at relatively well-instrumented sites and research basins in the Canadian Rockies. We focus on assessing the performance of the model in: (1) capturing winter snow accumulation, (2) simulating snow energetics in complex terrain, (3) capturing snowmelt, and (4) capturing melt from glaciers.

Ecological and evolutionary consequences of intraspecific variation in energy allocation strategies of Columbian ground squirrels (*Urocitellus columbianus*).
Adriana L. Guerrero-Chacón, PhD student
Department of Biology, Supervisor: Dr. Jeffrey Lane

The overall objective of my project is to evaluate how intraspecific variation in resting metabolic rates and endogenous fat stores are related to individual variation in female reproductive output, male reproductive success and juvenile growth rate. I will test two models of energy allocation strategies, the increased-intake, and the allocation models. To do so, I will measure resting metabolic rate (through open-flow respirometry) and body composition (through quantitative-magnetic resonance) of adults and juveniles at standardized points throughout the active season in one population of ground squirrels located in Sheep River Provincial Park, Alberta. This project will expand our understanding of how energy is partitioned in a mammalian hibernator, thereby testing some of the key assumptions of life-history evolution theory.

Mass and energy flow through snow
Nicolas Leroux, PhD Student
Centre for Hydrology, Department of Geography and Planning, Supervisor: John Pomeroy

My research focuses on improving the understanding of snowmelt processes in mountainous terrain, particularly the flow of water through snowpacks. A 2D physically-based snow model has been developed to simulate changes in snowpack features and compute snowmelt. This model includes the simulation of flow fingers through snow and presents an advanced theory to represent capillary pressure within snow. My field sites are located in Fortress Laboratory Mountain, Alberta. By improving the prediction of timing and quantity of runoff from snowmelt in alpine terrain, predictions of flood or municipal water supplies can gain accuracy.

Beaver-based Restoration
Gregory Lewallen, PhD student
Centre for Hydrology, Department of Geography & Planning,
Supervisor: Dr. Cherie Westbrook

My research investigates the effects beaver dam analogues have on the processes driving the sediment transport regime of a spring fed mountain stream. Beaver dam analogues are human-constructed structures that mimic the form and function of natural beaver dams and are currently being applied in beaver restoration projects throughout the US.

Snow data assimilation in Canadian Rockies Mountains
Zhibang Lv, PhD Student
Centre for Hydrology, Department of Geography and Planning, Supervisor: Dr. John Pomeroy

The main works of my project are monitoring of interception of snow on forest canopy through remote sensing approach and assimilating the ground observed and remotely sensed data into the Cold Region Hydrological Model (CRHM). Snow interception is a major snow process in cold regions evergreen forests as it controls local snow redistribution. Monitoring intercepted snow in large scale is possible through using satellite remote sensing data. Because snow and tree canopy have different reflect character, few remote sensing indices (NDSI, NDVI, LST, albedo) were used in this research to detect snow presence on forest canopy. This information makes validation of large scale snow interception simulation possible and also can be assimilated into CRHM to improve simulation results.

Data assimilation (DA) combines advantages of model simulation and observation to improve the simulation quality of state variables. Observed snow water equivalent (SWE), snow depth (SD), and snow interception that either from ground observed or remote sensing data were assimilated into CRHM using ensemble kalman filter (EnKF) or simple insertion DA method. The DA enhanced the ability of CRHM in simulation of SWE, SD, and interception as well as snow density and stream flow.

Emergent Phenomena and Model Complexity in Simulating Cold Regions Mountain Hydrology
Christopher Marsh, PhD Candidate
Geography and Planning, Supervisor: Dr. John Pomeroy and Dr. Howard Wheater

There is an ever increasing need for using hydrological models in all aspects of scientific hydrology and water resource management. Although there have been significant advances in our process understanding, there are still substantial uncertainties in modelling approaches. This work is investigating: 1) improved understanding of the importance of processes linkage, and the related issues of emergent phenomena and robustness and the impacts upon model performance when these are ignored; 2) warranted model complexity; and 3) 'sufficient' algorithm complexity to produce emergent phenomena and robustness.

Partnering with beaver: How the dynamics of beaver ponds may assist with climate change adaptation
Amanda Ronnquist, MSc Student
Department of Geography and Planning, Supervisor: Dr. Cherie Westbrook

Due to climate change, the hydrology of the Rocky Mountains is rapidly changing. In order to sustain the ecosystem functions of this region, it is imperative to conduct research that will contribute to a climate adaptation strategy that focuses on enhancing the natural resilience of ecosystems. Since beaver (Castor canadensis) are common in this region and known ecosystem engineers, their ability to store water and slow runoff may prove vital to the future hydrology of the Rockies. This research involves investigating the dynamic nature of beaver ponds in the Kananaskis area of Alberta. The data collected will be used to explore the role beaver may play in future climate change adaptation.

Dynamical processes for atmospheric convection at the lee side of the Canadian Rocky Mountains
Lucia Scaff, PhD Student
School of Environment and Sustainability, Supervisor: Dr. Yanping Li

A large fraction of summer storms in the lee side of the Canadian Rockies is associated with convective precipitation that can produce extreme events, such as intense rainfall and flash floods. When and where these storms are initiating? This is one of the challenges for the weather forecast. Recent advances in regional climate modelling can better reproduce convection, and thus improve the understanding of summer storms. We study the performance of these models and the atmospheric characteristics that dominates the initiation of convection in the past and in a warmer future projection for the end of this century.

Exploratory methods for remote sensing of snow
Jacob "Cob" Staines, MSc student
Department of Geography and Planning, Supervisor: Dr. John Pomeroy

The purpose of my research is to explore the use of novel ground-based and airborne sensors and sensing techniques for the measurement of snow mass and energy fluxes in complex terrain, and in the presence of dense vegetation. Spatial heterogeneity in terrain and vegetation results in variations in snowpack energy and mass fluxes across the length scales of such features. There are significant limitations to both the scaling-up of point measurements, and scaling down of low resolution satellite remote sensing products to estimate distributions at the scale of such features. The development of methods for measuring snow distributions at the scale of forest stands to catchment will facilitate a deeper understanding of the processes driving snow accumulation and ablation at these scales. This work aims to facilitate decision-making and further research at the intersection of hydrological modeling, land and water management, ecology, and climate change.

Beaver as a Soil-Forming Factor: Characterizing Peat Properties and Biogeochemical Processes in a Mountain Peatland
Xiaoyue Wang, PhD Student
Department of Soil Science, Supervisor: Dr. Angela Bedard-Haughn

Current and future research includes: 1) to develop a better understanding of the role of beaver as a soil forming factor; 2) to analyze the biogeochemical processes and soil nutrient dynamics in the main layers of beaver meadow and adjacent peatland not affected by beaver's historic activity in changing climate; 3) to provide insight into how beaver activity influences the microbial community responsible for carbon and nitrogen cycling in a changing climate.

Phenological and genomic determinants of elevational range limits in *Rhinanthus minor*
David Ensing, PhD Student
Department of Biological Sciences, Supervisor: Dr. Chris Eckert

Nearly all species have range limits, indicating a limit to adaptation by natural selection at the range margin. This poses a fundamental problem for evolutionary ecology and despite a long history of inquiry and a more recent resurgence of interest, the mechanisms constraining adaptation at range margins remain unclear. The objective of my PhD studies is to test how phenology, via tradeoffs in time to / size at reproduction and individual fitness, contributes to elevational range limits in yellow rattle (*Rhinanthus minor*), an annual plant with a distinct elevational distribution in the Rocky Mountains of Alberta. Using regular visits to natural populations, transplant experiments and landscape and population genomics I will determine how tradeoffs due to phenological traits may limit this species' range. My work will provide a useful case study for populations of any species at their range margin, particularly for those species whose ranges are subject to shifts under climate change.

The influence of phenology on the elevational range limit of Yellow Rattle (Rhinanthus minor)
Dylan Sora, MSc Student
Department of Biology, Supervisor: Dr. Chris Eckert

No species has a worldwide distribution, and while some species ranges are limited by a physical barrier such as an ocean many species distributions end across seemingly continuous habitat gradients. Range limits across continuous habitat gradients offer and opportunity to ask ecological questions such as what factors cause the range limit? We can also ask evolutionary questions like what prevents the species from adapting to conditions beyond the current range? To answer these questions we use the annual plant *Rhinanthus minor* (or yellow

rattle) as it as an elevational range limit of approximately 2300m even though habitat appears to continue on beyond that. Using several years of natural population surveys and reciprocal transplants across the species range we hope to determine if early phenology (the timing of major life history events) at high elevations restricts the adaptive potential to move beyond the range. This work can provide valuable insight into how populations may adapt, particularly at range margins, as species move northwards and to higher elevations under a warming climate.

Microclimate influences on the ecohydrological conditions of an alpine wetland
Dylan Hrach, MSc Student
Department of Geography and Environmental Management, Supervisor: Dr. Richard Petrone

Topographic aspect is an important control on radiation, the microclimate, and hydrothermal processes present in alpine environments. My research site is located at the base of a tall, steep headwall that provides shade, sediment erosion debris, and avalanche inputs to a first-order watershed wetland. Anticipated future climate variability may impact the snowpack characteristics, terrigenous inputs, and vegetation growth patterns in these systems. This is important because they play a significant role in the general ecosystem functionality of mountain landscapes and provide important hydrological and ecological functions to nearby lowlands. My project aims to better understand the water use efficiency of this alpine wetland and how a unique microclimate may influence its ecohydrological conditions. This will help determine their response to climate trends and predict their vulnerability or resilience to future climate scenarios.

Investigating the seasonality of alpine forest water and availability
Lindsey Langs, MSc student
Department of Geography & Environmental Management, Supervisor: Dr. Richard Petrone

Our group's purpose in the Kananaskis region is to understand the importance of forest and wetland ecohydrological processes on mountain water security and resiliency. My project in particular is focussed on understanding how alpine forests access and utilize different water sources in remote mountain environments. Sap flow instruments monitoring hourly water use and hydrological instruments measuring environmental conditions provided insight to tree water use behaviours during pre, during and post growing season. Stable water isotope analysis is also being used to understand and trace water sources used by the monitored tree species, Engelmann Spruce and Subalpine Fir. This work will help to provide an understanding of the hydrological stresses on alpine forests during varying seasonal alpine conditions, and potential impacts to these forests under climate change.

Vegetation diversity of valley bottom peatlands in the upper Bow River basin in Alberta, Canada

Calvin Lei, MSc Student
Department of Biology, Supervisor: Dr. Rebecca Rooney

Valley bottom peatlands located in the Rocky Mountains of the upper Bow River Basin are under-studied and have never been mapped, let alone characterized by the province. I am particularly interested in using these peatlands as model systems to learn more about vegetation communities and assembly rules, and detection probabilities of plants. By characterizing the vascular plants and bryophytes, I will produce a detailed inventory illustrating the plant species and functional trait diversity of these peatlands. Not only will my study contribute to basic research, but these inventories can potentially benefit future vegetation studies in the area and be applied in practical applications like land use management and disturbance studies.

Modeling avian community composition and species richness in mountain peatlands
Jordan Reynolds, MSc Student
Department of Biology, Supervisor: Dr. Rebecca Rooney

I am interested in bioacoustics and how it can be used to determine bird community composition and species richness in mountain peatlands in the Upper Bow Basin, Alberta. Peatlands are ecologically valuable ecosystems to both our society and the environment. Although, mountain peatlands have been quantified in some areas, mountain peatland biodiversity is severely under studied worldwide. In Alberta, mountain peatlands are currently not mapped or identified in the Alberta Wetland Inventory. To characterize bird communities and species richness in mountain peatlands I use autonomous recording units and bird surveys during the breeding season. With this research I look to quantify mountain peatland bird biodiversity, a stepping stone towards understanding the ecological value of mountain peatlands in Alberta.

Sub-alpine hydrology
Jessica Williamson, MSc. Student
Department of Geography and Environmental Management,
Supervisor: Dr. Richard Petrone

This research project focuses on studying the controls on the spatial variability in evapotranspiration on a hill slope consisting of krummholz and tree islands. Feedback relationships will be assessed between vegetation structures and their dominant controls in order to determine how krummholz and tree islands may be affected as climate change threatens alpine systems.

The effect of habitat connectivity on genetic rescue potential in the alpine butterfly Parnassius smintheus Doubleday (Lepidoptera: Papilionidae)

Andrew Chaulk, PhD Student
Department of Biology, Supervisor: Dr. Nusha Keyghobadi

My research focuses on the effects of habitat connectivity on gene flow, specifically how differing levels of connectivity can affect how genetic variation is distributed within and among natural populations. A metapopulation of the alpine butterfly *Parnassius smintheus* inhabits ridgetops throughout the Kananaskis region and is known to undergo punctuated population (demographic) bottlenecks related to poor winter weather conditions. These events dramatically alter the amount and distribution of genetic variation within and among populations (i.e. resulting in a genetic bottleneck). One predicted result of a severe reduction in population size is an increase in inbreeding as the probability of the coupling of genes that are identical by descent increases due to decreased mate availability. Using population and landscape genomic techniques I am exploring how punctuated weather-driven demographic bottleneck events affect this metapopulation and what role population connectivity may play in alleviating the effects of inbreeding within populations.

BARRIER LAKE EDUCATION PROGRAMS

2018 marks thirty years of BGI school and teacher education programs! Rough estimates indicate we've taught well over 100,000 students and teachers different ways of researching and understanding the natural world. The education team continues to offer dynamic, rigorous, cutting-edge, field research experiences in the science, technology, engineering and math (STEM) fields. A BGI field trip is a fully immersive scientific encounter. We facilitate experiences for participants to explore links between scientific concepts and to bridge the gap between different disciplines, while learning research skills such as: formulating questions, experimental design, data presentation, data analysis, drawing results and identifying future research to pursue. We engage learners in inquiry programs allowing them the freedom to explore interests while also giving them an authentic taste of the scientific process.

The goals for education programs are three-fold: to hone critical thinking skills in an experimental education milieu; to develop and foster scientific literacy, by exposing students and teachers to current science and research scientists; and to provide a wider context for the understanding of science and the non-linear nature of investigating scientific questions.

High School Programs

BGI currently offers five core programs geared towards the Alberta Program of Studies for high school, covering topics such as biodiversity, biomes, environmental chemistry, ecosystems and integrated science research projects. The programs, operating year round, access multiple field sites within Kananaskis to research aquatic, forest and winter ecosystems. While many of our programs already exist, we are always keen to develop new programs to tailor meet a school's request.

> ***Biology 20 Ecosystem Inquiry Research Program*** • students are led through a guided exploration of a novel environment, then develop and test a scientific question of their own choice. Students connect with current research scientists, have access to current research posters, and utilize scientific equipment to conduct an investigation from start to finish. Students learn how to construct a question, conduct background research, revise their question, collect data, synthesize and analyse data and create a poster and/or paper outlining their research and future areas of consideration. This program is geared towards International Baccalaureate (IB) or Advanced Placement (AP) students who are interested in careers in STEM fields. Students leave with a stronger appreciation for the 'nature of science' and a deeper understanding of processes involved in developing and conducting a scientific investigation.

Specialty Programs, ie: Saskatoon Outdoor School; Girls on Ice, Canada • these programs begin with fine-tuning students' ability to create testable scientific questions. Many of the students participating in these programs have already attended BGI's Ecosystem Inquiry Research Program and already have a grasp of the basis of inquiry. With guidance from BGI Education staff and their instructor, students design appropriate methods to conduct their research. During data collection outings, students often go through a few iterations of their original question – an important step in understanding the dynamic nature of science. A review of current peer-reviewed articles gives students background on their topic and shows them how to identify a credible source; it also helps them develop important skills for critical examination of information. Students are encouraged to connect with scientists in the field to gain insight on their project. Reflection is a large component of these projects, which allows for deeper learning and understanding, not only of their topic but also of the nature of science. Students have ownership of their project from start to finish. Ultimately, the product will be a scientific paper and a presentation outlining their research question, methods and findings. Importance is placed on connecting their research to the 'real-world' i.e.; why does your research matter? This is also an opportunity to explore careers in the STEM fields.
The Girls on Ice, Canada program is a joint venture with Inspiring Girls Expeditions whereby BGI staff work with closely with their team of female guides and glaciologists to provide a one of a kind, ten day field research experience for high school girls. We assist with research project development and data analysis, with the project ending at BGI with public presentations of the research projects.

AP Chemistry 20/30 Research Project • this sixteen month long science inquiry program begins in AP Chemistry 20 and spans through to AP Chemistry 30. This program is very open-ended to allow students' curiosity to take their project in many directions. Personal reflection on revisions, failures, and successes throughout the project help guide both students and teachers through the cycles of addressing a scientific question. After critically examining their own experience, students in this program act as mentors for new students beginning their projects. This project includes five field visits and includes site visits to explore the impacts of industry on environmental chemistry.

AP Environmental Science Program • students hike to the toe of the Rae Glacier, at the headwaters of Elbow River. Along the way, students are introduced to geology, geomorphology, soil profiles, and soil characteristics; they also learn field techniques for examining groundcover biodiversity, soil profiling and soil chemistry, and other abiotic data. In the lab, students use the Simpson Biodiversity index to compare their higher altitude data to data collected on site at BGI. Geology and glacial history of the area is the theme for this program. After this field visit, BGI staff work with students to create their own research question to investigate for the remainder of the semester. At the end of the semester, students present their research to their peers, with BGI staff and teachers acting as reviewers, to mimic an undergraduate-style research project. • One of our recent environmental science programs includes a student exchange between William Aberhart High School and schools from the Netherlands. After participating in our field program, the students chose a topic of study related to freshwater. These students then present at an international student conference in Amsterdam.

Bio 20 Aquatic or Terrestrial Ecosystems • this program sequence works well to teach concepts of deductive vs constructive reasoning. The programs are less open inquiry style and more traditional field study where students are taught specific methods of data collection and analysis. For the aquatic program, students learn the River Continuum Conceptual model. They measure depth, velocity, width, chemistry (pH, nitrite/nitrate,

phosphate, dissolved oxygen, conductivity) substrate size, and sample aquatic plants/algae and invertebrates to examine under microscopes/dissecting scopes in the lab. They compare their results to the expected results from the model and are taught to analyze their data against the expected results to look for areas of disconnect. Instructors explicitly teach how to use this method to lead to novel research areas.
The terrestrial program takes the opposite approach; students are taken into two adjacent forests of different species. Using the null hypothesis, students collect data (tree species distribution, STEM plot data, soil profiles, soil pH and moisture, tree age, air temp and moisture, light readings, etc.) to determine the key factors in forest distribution. Back in the class, with the aid of air photos, long term data sets, vegetation inventory models and small scale maps, students create generalized forest distribution models.

Junior High Programs
BGI offers three Junior High programs that introduce scientific concepts like ecosystems, biodiversity, and biomes. The programs typically take place over two and a half days, but we can create day trips out of any component. These programs integrate environmental science with outdoor experiences such as snowshoeing and snow studies, building snow shelters, and predator-prey simulations. Social studies is also covered with a slide presentation on the human use of the Barrier Lake station, from first nations to prisoners of war.

Science 7 - Intro to Ecosystems • Students are introduced to the idea of an ecosystem, with the focus on the question: “How do plants survive in the winter?” A mix of science and fun to introduce many concepts of experimental design to budding young scientists.

Science 8 - Freshwater Ecosystems • Students examine freshwater systems from the perspective of a Bull Trout. Students are introduced to a human perspective on water by participating in a ‘water auction’ - a roleplaying activity focused on how we value water resources.

Science 9 - Freshwater Biodiversity • This program focuses on the chemical and physical differences between two freshwater bodies (ie: pond vs stream) and how they can affect/be affected by biological diversity. We have an alternate terrestrial program where

students create a hypothesis about the relationship between tree diversity (above ground) and invertebrate diversity in the soil (below ground).

Professional Education
Teacher Professional Development • Professional development workshops for teachers of all faculties at a junior high or high school level. The focus is inquiry - how to ask questions and how to set up learning opportunities where the teacher is not the content area expert. The importance of immersive, outdoor experiences is highlighted with ideas on how science/ecology/nature can be incorporated into the classroom. We assist with finding field scientists who can bring teachers into their area of research, or come speak with classes.

SEDV 625 Introduction to Research • A multi day seminar geared towards facilitating students' research projects for the Sustainable Energy Development Masters Program. Because students in this program come from a range of professional and educational backgrounds, this field trip was developed to ensure that every student is up to date on asking and testing scientific questions. The Nature of Science, choosing a good research topic, local ecology and integrating multi disciplines into the final project are the focus of this course.

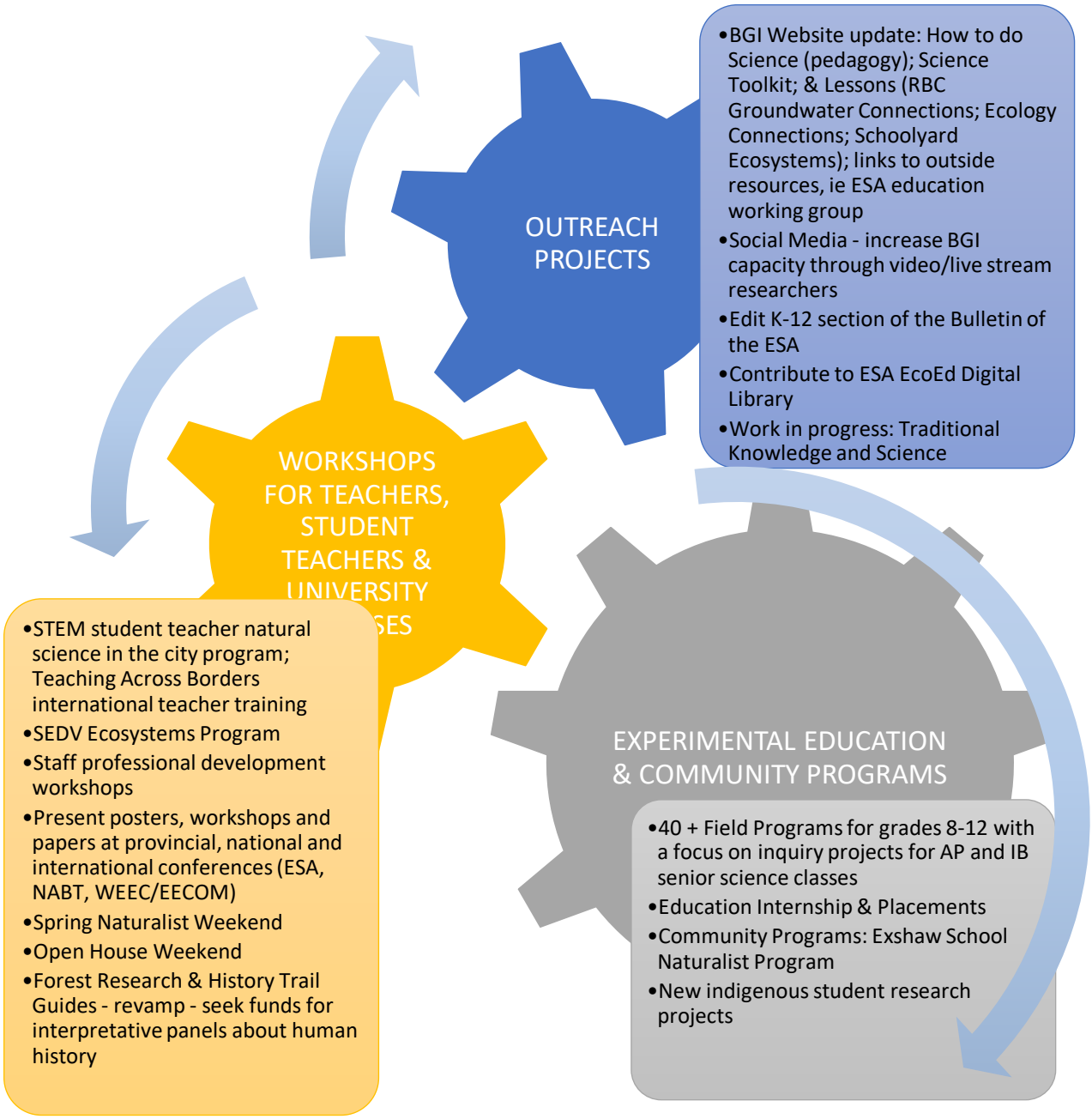
EDUC 427.03 STEM Field & Werklund School's Teaching Across Borders, Queensland University • These field trips focus on how to bring STEM concepts to your classroom. We expose beginning teachers to concepts such as open exploration, principles of moving from guided to open inquiry, group management outside, teaching in a laboratory (using different types of scopes, etc.) and designing immersive, outdoor experiences for students. Student teachers learn how to ask and test questions and explore how the nature of science can be taught in conjunction with subject area content.
As well as providing specific on-site workshops for teachers, non-formal educators and school departments, since the last annual report, BGI Education staff have presented workshops at the Edmonton Public School Board's Career Pathways Learning Day; the National Association of

Biology Teachers (NABT) annual conference in Denver, Colorado and at the Ecological Society of America's annual meeting in Portland, Oregon.
Recent publications from BGI education staff include:
Corbett, L., Arlidge, S., Poirier, S. and Johnson, E. *Guiding Students Toward Open Inquiry in a Novel Outdoor Setting* Alberta Science Educator Journal, Vol 45, 2, 2018
Arlidge, S., Thanukos, A., and Bean, J. *Using the Understanding Science Flowchart to Illustrate and Bring Students' Science Stories to Life* The Bulletin of the Ecological Society of America, Vol 98, 3, 2017

Another milestone to note was the full circle adventure we've had with one of our learners. We first met Travis as a grade ten student who came here on a field trip from Robert Thirsk High School. He then spent nearly two years in our first long term Chemistry inquiry cohort, where he was generous in his reflections of his experience and how we could make it better in the future. Travis and a few peers from the AP Chemistry project were interviewed by the Calgary Board of Education's assessment team, who have since used our project extensively in training high school science teachers about integrated inquiry projects. Well, he hadn't had enough! This past summer, Travis was the BGI's Student Intern – where he was able to get even more hands on experience with summer field researchers from hydrologists to invasive species ecologists. Now in his second year of science at U of Calgary, we're excited to see where Travis goes...you just never know what a field trip might inspire.

The renovations and move to new labs at BGI provided an opportunity for the Education team to inventory and downsize from thirty years of education materials!! We rediscovered some real gems and paired down our extra goodies. We worked closely with our contacts in schools and other educational agencies to donate a large amount of surplus curriculum materials, scientific glassware, tree cookies, and outdoor gear. The recipients were all very grateful for the donations and we saved a substantial amount of materials from the landfill.

Our focus for 2019/2020 includes:



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