Biogeoscience Institute of the Canadian Rockies and Foothills

2016 ANNUAL REPORT

Director's Message

The coming year will see exciting developments at both the R.B. Miller and Barrier Lake Field Stations. We have received considerable money from the Federal Government for infrastructure renovation. All the buildings at R.B. Miller were removed this fall except for the trailer. In the spring, one new building will be constructed which will be very energy efficient and with sustainable water, heating, and lighting. In the meantime, additional trailers will be provided for the 16 or so users, probably at the ranger station.

Temporary ATCO Trailer on site to provide kitchen and classroom facilities during 2017-2018 renovation

Barrier Lake construction will be only on the lodge and laboratory building. The lodge renovation is mostly to enlarge the kitchen to make it a more efficient work space. The laboratory building will have its interior, both in the basement and on the main floor, rearranged so we will have a research library, a wet laboratory, dry laboratory, a large basement laboratory, two upstairs lecture/work rooms, a computer room, three offices, and in the basement a combination laboratory/work room. This arrangement may change slightly as the plans solidify. Again, we will be providing alternative space during construction. Similarly, the kitchen will be replaced during construction by kitchen trailers and eating space. The duplexes and forestry buildings are not to be part of this renovation and so will still be available. We want to do everything we can to allow you to continue your research during this renovation. We of course were sorry to see the old R.B. Miller buildings go as they evoked many memories of other researchers who built most of them. However, the new building will be quite a showcase of sustainable building for field stations.

You will also find in this BGI report the stories of the research on small mammals by John (Jack) Millar, Emeritus Professor at Western University. Jack has carried out research at BGI longer than any other researcher in our 65-year history – more than 40 years. Jack is honoured in the Institute's Library by an example of his wooden walking sticks and by a large number of scientific papers and theses on small mammal populations. A life in research well spent.

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DIRECTOR

Edward Johnson, PhD
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Dr. E.A. Johnson is the Director of the BGI. In addition to this position, he is a Professor at the University of Calgary and involved with research programs at the BGI. 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."

ASSOCIATE DIRECTORS

Kathreen Ruckstuhl, PhD
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Dr. Kathreen Ruckstuhl is an Associate Director of the BGI with her primary role in the operation of the R.B. Miller Station. She is an Associate Professor at the University of Calgary with numerous projects within the BGI. Her research program focuses on mammalian social systems, parasite-host dynamics and foraging ecology. Her work includes both applied and fundamental research.

Yvonne Martin, PhD
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Dr. Yvonne Martin is an Associate Director of the BGI, assisting in the operation, maintenance, and strategic planning of the Institute. She is an Associate Professor in the Department of Geography at the University of Calgary and has numerous projects within the BGI. Her 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.

INSTITUTE PROFESSORS

Steve Dobson, PhD
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Dr. Steve 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.

Marco Festa-Bianchet, PhD
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Dr. Marco Festa-Bianchet's research explores the links between individual reproductive strategy, population dynamics, and wildlife conservation. Based mostly upon long-term monitoring of individually marked mountain ungulates, his program seeks to understand how selection for a conservative maternal reproductive strategy and strongly age- and phenotype-dependent male reproductive strategies affect age-specific survival in populations living in different environments, with spatial and temporal changes in population density, weather, predation, and age-sex composition. Accurate long-term data on population dynamics are also used to analyze the effects of population density, weather, age structure, and other factors on population growth.

Evolutionary ecology plays a central role in our understanding of animal behaviour and population dynamics, yet its applications in wildlife management are seldom recognized. By underlining the importance of artificial selection (such as that caused by trophy hunting) and of natural selection (such as density-dependent changes in relative allocation to maintenance and reproduction in both sexes) upon changes in population dynamics and population genetics, this research program examines how we can best use our knowledge of evolutionary biology for the conservation of living resources.

Specific research programs include long-term monitoring of the ecology, behaviour, and genetics of two populations of bighorn sheep and one of mountain goats in Alberta, as well as several populations of alpine ibex in Europe. Dr. Festa-Bianchet's interest in conservation is exemplified by his current position as Chair of the Committee on the Status of Endangered Wildlife in Canada.

Masaki Hayashi, PhD
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Canada Research Chair in Physical Hydrology
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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.

Shawn Marshall, PhD
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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 an Associate of the Canadian Institute for Advanced Research (CIAR) Earth System Evolution program and is a Fellow of the Royal Canadian Geographical Society. Dr. Marshall has served on the Council of the International Glaciological Society and as Chair of the American Geophysical Cryosphere Sciences group.

John W. Pomeroy, PhD
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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 the Centre for Hydrology at the University of Saskatchewan, an Honorary Professor of the Centre for Glaciology, Aberystwyth University, Wales, 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 American Geophysical Union and the Royal Geographical Society.

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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 landuse and environmental changes. Currently, his research group is focussing 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.

Susan Kutz, DVM, PhD
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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 interactions between sympatric bighorn sheep and cattle with respect to parasite diversity and abundance; and the use of long-term community-based monitoring of caribou and moose as a method for early detection of population changes.

Marc Macias-Fauria, PhD
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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).

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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.

Peter Neuhaus, PhD
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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.

John R. Post, PhD
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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.

Caterina Valeo, PhD
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Dr. Valeo's research focuses on pine beetle infestations and forest fires which are large-scale disturbances that impact watershed hydrology. This research develops and uses complex hydrological models to incorporate the pine beetle life cycle and forest infestation scenarios to predict resulting water yields in managed watersheds. These models are also used to determine amount of duff (organic layer) that is consumed during a forest fire in order to predict forest regeneration patterns. Our models provide highly distributed spatial predictions of consumed duff given hydrological conditions and canopy characteristics (provided by remote sensing). This research effort plays a necessary role in forest management.

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.

INSTITUTE PROFESSOR (EMERITUS)

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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. Recent studies have included both field and laboratory experiments to investigate the genetics of mating systems of wood rats, mice, and chipmunks using DNA fingerprinting, the energetics of mice using doubly-labeled water techniques, diet assessments of mice and red-backed voles using stable isotopes, and behavioural studies of mice, chipmunks, and wood rats using radio telemetry. His applied interests are in the effects of climate change on small mammals and alpine populations, and in the role small mammals play in the transmission of human pathogens. Recent studies have been conducted on *Giardia* and Lyme disease, and the role of mice as reservoirs for *Hantavirus*.

Jens Roland, PhD
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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.

OTHER PI`S & POST-DOC`S

Name	*Department*	*Title*	*Affiliation*
Bedard-Haughn, Angela	Department of Soil Science	Associate Professor	University of Saskatchewan
Boonstra, Rudy	Department of Life Sciences	Professor	University of Toronto
Cartar, Ralph	Department of Biological Sciences	Associate Professor	University of Calgary
Cully, Christopher	Department of Physics and Astronomy	Assistant Professor	University of Calgary
Eckert, Chris	Department of Biology	Professor	Queen's University
Erbilgin, Nadir	Department of Renewable Resources	Associate Professor	University of Alberta
Greene, David	Department of Geography, Planning and Environment	Professor/Department Chair	Concordia University
Harder, Lawrence	Department of Biological Sciences	Professor	University of Calgary
Helgason, Warren	College of Engineering	Assistant Professor	University of Saskatchewan
Hicks, Faye	Department of Civil and Environmental Engineering	Professor	University of Alberta
Husband, Brian	Department of Integrative Biology	Professor/Associate Dean	University of Guelph
Jardine, Tim	School of Environment and Sustainability	Assistant Professor	University of Saskatchewan
Judge, Kevin	Department of Biological Sciences	Assistant Professor	MacEwan University
Lafrenière, Melissa	Department of Geography	Assistant Professor	Queen's University
Lane, Jeff	Department of Biology	Assistant Professor	University of Saskatchewan
Lein, Ross	Department of Biological Sciences	Associate Professor	University of Calgary
Mayer, Bernhard	Departments of Geoscience and Physics and Astronomy	Professor	University of Calgary
Mori, Akira	Graduate School of Environment and Information Sciences	Associate Professor	Yokohama National University
Neilson, Scott	Department of Renewable Resource	Assistant Professor	University of Alberta
Richard Petrone	Geography and Environmental Management	Professor	University of Waterloo
Prescott, Cindy	Faculty of Forestry	Professor/Associate Dean	University of British Columbia
Reid, Mary	Department of Biological Sciences	Professor	University of Calgary
Skidmore, Mark	Department of Earth Sciences	Associate Professor	Montana State University
Sturdy, Christopher	Department of Psychology	Professor	University of Alberta
Vincent, Viblanc	Center for Functional and Evolutionary Ecology	Post-Doctoral Fellow	Auburn University
Vinebrooke, Rolf	Department of of Biological Sciences	Professor	University of Alberta
Wayand, Nic	Coldwater Centre	Post-Doctoral Fellow	University of Saskatchewan
Whitfield, Paul	Coldwater Centre	Senior Research Fellow	University of Saskatchewan

INSTITUTE OPERATING PERSONNEL

The BGI has a small dedicated group of individuals who keep the research and education programs operating all year round. The BGI would like to welcome new staff in 2016: Trevor Woods (Building Operator) and Melody Sproule (Sous chef)

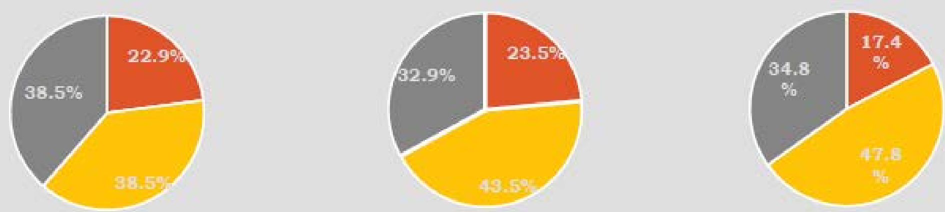
From left to right: Yves Levesque, Sue Arlidge, Savannah Steinhilber, Melody Sproule, Adrienne Cunnings, Brenda Simmons, Trevor Woods.

Biogeoscience Institute
User Days and Groups Report

ANNUAL USER DAY SUMMARY (April 1- March 31st)

	2013/2014	2014/2015	2015/2016
Research	5201	5227	4965
University Courses	3409	3344	2989
Education Groups	1813	1981	2212
Community and Conferences	2176	1648	2122
TOTAL	**12,599**	**12,200**	**12,288**

SUMMARY OF GROUP NUMBERS



	2013/2014	2014/2015	2015/2016
University Courses	19	20	16
Education Groups	32	37	44
Community and Conferences	32	28	32
Total	83	85	92

DETAILS

User days are calculated by the number of days each user stay at the field station.

RESEARCH UNIT

The research unit of the BGI consists of a Science Research Program to include individual scientists and groups of scientists within research clusters. There are five *Research Clusters* within the BGI and their associated research direction:

1. Animal Ecology and Wildlife Conservation Biology

- Interactions among domestic, non-native and native fauna.
- Long-term understanding of populations in changing environments.
- Ecological and evolutionary consequences of harvesting fish and wildlife.
- Species and environmental interactions with implications for function and structure of complex systems.
- Behavioural ecology, life-history trade-offs, and impacts of climate change on wildlife

2. Ecohydrology, Meteorology, and Watersheds

- Effects of climate warming on the hydrological, thermal, and chemical regimes in mountain watersheds.
- Coupling of hillslope and in-channel hydrological and geomorphological processes to terrestrial and aquatic ecosystems.
- The vulnerability of streams and lakes to tourism and development.
- Meteorological coupling to mountain ecohydrological processes.
- Biogeochemical processes in mountain terrestrial and aquatic systems.

3. Vegetation Dynamics and Forestry

- Interaction between disturbances, vegetation, and sediment movement on hillslopes to streams.
- Metapopulation dynamics of forest trees and implications for forest management and land use.
- Mountain treeline changes: causes and population and community responses.
- Ecosystem responses and landscape sensitivity to wildfire in mountain ecosystems.
- How invasive plants affect ecosystem processes.

4. Ecosystem Services and Environmental Economics

- Which strategies and policies can sustain and promote vulnerable populations, such as those at risk due to changing habitat, invasive species, wildfires, or disease?
- What are the requisite governance processes, information needs, and institutional arrangements that can protect and preserve key ecosystem processes and services?
- Which land use developments, policies, and controls can best sustain healthy ecosystems?
- What are the determinants of the values of ecosystem services and how should these values guide resource use decisions and investments?

5. Human, Domestic Animal, and Wildlife Disease Interactions

- The role of population genetics in wildlife disease epidemiology.
- Habitat alteration effects on transmission of disease and parasites between humans, domestic animals, and wildlife.
- Indirect effects of climate and weather on wildlife/human disease epidemiology.
- Ecotoxicology and ecosystem health.

These research clusters address long-term, complex, coupled environmental systems, each built around recognized geoscience and ecological processes. The nature of coupled environmental systems is that they are process driven. Different science disciplines are needed because of the coupled nature of the processes (e.g., ecological-hydrological models, microclimate-animal population models, and disturbance process-response models). Individual scientists represent the individual funded projects that the BGI has always attracted.

The BGI engages in an extensive science program to include independent scientists and research programs that involve multidisciplinary efforts within five research clusters. The strategic direction of the research clusters are described in the table below. Four basic research approaches are applied: (1) monitoring through long-term research projects to detect changes in earth and atmospheric systems and provide data for modeling and a context for process studies; (2) process studies to identify and understand important processes and functional responses; (3) retrospective studies to maximize use of existing long-term observational records, and (4) modeling to synthesize, extrapolate in time/space, test ideas, forecast future scenarios, and provide scientific advice for informed decision making.

PROMOTING SCIENCE UNIT

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

The programs foster scientific literacy through engagement of the community, and research/scholarship through publications, knowledge exchange, and education research networks. The section on PROMOTING SCIENCE describes the progress and development plans in detail.

Spring Naturalist Weekend: second weekend in June where the public are invited to learn and engage with Biogeoscience Researchers

SCIENCE RESEARCH PROJECTS

Selected Research Projects Highlights 2013-2016

Highlight 1: Climatic changes and impacts on the fitness of Columbian ground squirrels: more than simple global warming

Project Coordinator(s): F. Stephen Dobson and Jeffrey E. Lane

Introduction

There is no longer any question that the climate of our planet is changing at an unprecedented rate, at least within recorded human history, and that this change is largely due to human activities that result in the production of atmospheric hydrocarbons (Intergovernmental Panel on Climate Change 2007). Much of the change is described and monitored as a considerable warming during the past couple of decades. In fact, the "global warming" pattern has been considerably underestimated (Kintis 2014). Several studies of animal populations have reported an increase of about 2° C over the past 20 years (e.g., Inouye et al. 2000, Reale et al. 2003, Both et al. 2009). These latter studies examined the impacts of warming temperatures on the phenology, or lifecycle events, of species of birds and mammals (Parmesan and Yohe 2003). In general, the studies report earlier breeding as a response to warming temperature, with varying degrees of matching or mis-matching of the lifecycle, particularly the timing of breeding, to changes in food resources (Visser and Both 2005).

In results published in the journal Nature, we found that Columbian ground squirrels were emerging from their 8-9 months of hibernation significantly later over the past 20 years (Lane et al. 2012). Spring emergence and associated breeding dates have been delayed about half a day per year. This roughly 10-day delay is considerable for a species that is only active for about 100 days per year, one of the shortest activity periods of mammalian hibernators (Dobson et al. 1992). We examined changes in weather patterns, and found that the delay in spring emergence was associated with an increased number of late spring snow storms (snowmelt was delayed by almost 3 days per year) that resulted from increased humidity coming over the mountains from the Pacific coast. And surprisingly, associated temperatures were cooler, the reverse of the pattern of other terrestrial vertebrates (by about -2° C over the 20 years, but not statistically significant).

The change in the date of emergence of the ground squirrels from hibernation was also associated with the annual fitness of adult females (measured from survival and reproduction). Annual fitness declined significantly as spring emergence became later, and also declined significantly over the 20-year period of the study (Lane et al. 2012). Naturally, continued declines in fitness are incompatible with population viability, but late in the study period a slight resurgence of female fitness appeared to occur. In short, the correlative data seemed to indicate a substantial impact of spring snow and temperature conditions on the ground squirrel population. However, climatic changes and possible associations with fitness at other time of the year were not examined for this long-lived and annually breeding rodent (maximum age is 10 or 11 years; a single litter of about 3 pups is produced each year).

A complete study of the effects of climate change on wildlife species needs to do several things. First, a description of how climate is changing should be given for other periods during the annual cycle, not just for the spring breeding period. Other critical periods might be summer fattening for the long period of hibernation fast, when no food is consumed, and winter snow pack conditions that might influence survival (Dobson and Murie 1987). Second, potential responses of annual fitness to the identified aspects of climate change should be sought. And finally, responses in terms of animal fitness to climatic changes at different times of the year should be compared, so that the impacts of alternate seasonal aspects of climatic change can be compared for their influences on fitness. Thus, our present research tests for associations of fitness of Columbian ground squirrels with changes in climate in Kananaskis Country.

Methods

We studied Columbian ground squirrels near the R.B. Miller Biological Station (a field station of the Biogeosciences Institute) along the Sheep River in southwestern Alberta, from 1992 to the present day. For a given year, we measured annual fitness of reproductive adult female ground squirrels from their survival to emergence from hibernation in the following spring (1 if survived, 0 if not), augmented with 0.5 for each surviving offspring (thus a function of the number of offspring of the year and their survival to the following spring). We also checked the components of fitness, female annual survival, litter size, survival of juveniles, and number of surviving juveniles; but the annual fitness measure seemed to reflect the general pattern of all these fitness components. We used the yearling age group at spring emergence as the end point for offspring because the young stay near their mother until they are older than this, and reproduction of both males and females does not usually begin until ages 2 or 3.

Our climatic data came from the website of Canada's National Climate Archive, for the town of Okotoks, Alberta. While this weather station is 50 km East of the Miller Station, it is in the same weather track and should be sufficient for general climatic patterns over the years. For climatic changes over time, we looked for "climate windows" of 10-30 days, during which variables such as temperature, rainfall, snowfall, and snow pack had changed the most during the 21-year study period. In the computer software R, we regressed climate averages for windows of 10 to 30 days on the years of study, and retained the best "fits" (viz., greatest R^2 values) for rolling periods. We also looked at climate windows that best reflected changes in annual fitness. Finally, we compared climate variables in a standardized partial regression analysis, where the climate data were used to "explain" annual fitness. Because temperature and rainfall exhibited similar patterns of climate change in late June and early July, we combined their values in a Principle Components Analysis, where the scores on the 1st Principle Component reflect the combination of temperature and rainfall. The standardized partial regression analysis was used to compare the importance, or "effect size," of climatic changes at different times of the year on fitness.

Results

During the past 21 years, spring snowfall has increased significantly, as we found in our previous study (Lane et al. 2012). The change has been only about a 2 cm increase over 21 years (Table 1), but as we found before, the timing of late snowfalls is what is important. But there have been other changes too. In particular, early July temperature has increased and rainfall decreased significantly; basically, summers are getting hotter and drier. Winter snowfall and snowpack in early December have gotten significantly greater as well. Spring snowfall was examined before adult females produced litters, because it influenced the timing of reproduction. But we also examined spring snowfall ***after*** females reproduced, since this might influence the survival of mothers and their offspring to emergence from hibernation in the following year, when annual fitness was measured. Of course, this also increased significantly during the study.

Do any of these periods co-inside with periods of strong change in annual fitness? Cooler spring temperatures and late spring snow accumulation had a negative association with annual fitness (Table 2). Interestingly, snowfall after the year of reproduction also had a negative association, as one would expect if delayed emergence from hibernation were associated with poorer survival. Annual fitness was also positively associated with rainfall during the latter half of June and first half of July, a time when rainfall was significantly decreasing during the 21 years (Table 1). There were other strong associations of climate with fitness, including winter snowfall in January-March, but these latter patterns were not closely associated with directional changes in climate during the 21 years of study.

We compared aspects of climate that had changed during the 21 years of study for their potential influence on annual fitness of adult females with a standardized partial regression analysis. The regression coefficients of this analysis range from -1 to 0 to +1, so they can be used as a measure of association. The analysis shows that temperature and rainfall during the period of late June to mid-July has the strongest potential influence on annual fitness of female Columbian ground squirrels (Figure 1). Spring snowfall in the year that survivors (mother and offspring) are measured for the annual fitness measure shows a trend towards a negative influence, but this was not significant. There were two correlations of spring snowfall and subsequent December snowfall and snowpack, and these correlations did not bias the analysis (all variance inflation factors below 2.0).

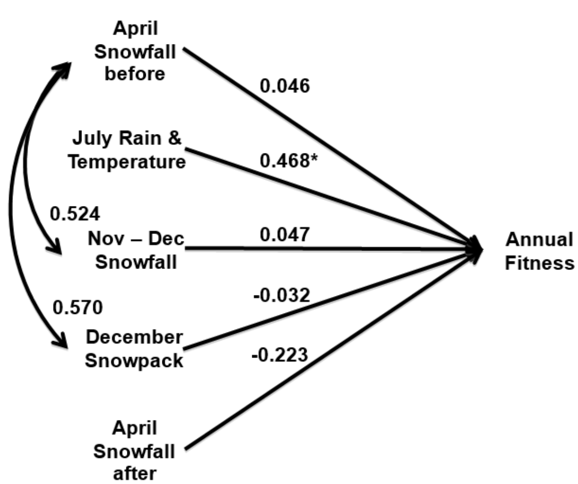


Figure 1. Standardized partial regression of the influence of climatic variables on Columbian ground squirrels. Two significant correlations among climatic variables are shown ($P < 0.05$, $N = 21$), other correlations among climatic variables were not significant and these correlations were included in the model but are not shown. July rainfall and temperature were combined in a principle components analysis, since they exhibited a significant negative correlation and occurred at the same time (see text). The only significant standardized partial regression coefficient is shown with an asterisk ($P < 0.05$).

Discussion

In our earlier study (Lane et al. 2012), we showed that late spring snowstorms were likely causing delayed emergence from hibernation and later breeding dates in adult female Columbian ground squirrels. We went on to show that delayed emergence from hibernation was associated with lower annual fitness for these females. While there appears to be a link between spring snowstorms and lower fitness (thought delayed emergence from hibernation and associated delays in breeding date), this was not the major influence of climate change on the ground squirrels. Rather, conditions during mid-summer appear to be changing ***and*** have major effects on fitness of the ground squirrels. Basically, summers are getting hotter and drier in southwestern Alberta. This is a time when the young of the year have been weaned, and both juveniles and adults are fattening up for an 8-9 month period of hibernation. Thus, it is a critically important period. Why does it matter if it's getting warmer and drier then? The quality of the food resources of the ground squirrels depends on rain for growth. When conditions are hot and dry, the vegetation likely dries out and provides poor nutrition and water for the ground squirrels.

For the ground squirrels, it is important to examine climatic changes throughout the year, not just at the time of emergence from hibernation and subsequent breeding. Breeding periods have likely been examined because many studies of climate change and animal phenology have been conducted on birds, and birds are most easily monitored in the spring. Nonetheless, examination of conditions throughout the year is extremely important. Ground squirrels are primary consumers, eating primarily plant materials. As such, they are a good indicator of how a food chain might be influenced by climate change. Further research on changes in vegetation would clearly be important, and might be expected to impact the phenology of other herbivores such as bighorn sheep. There may also be implications for species that prey on ground squirrels. As hibernators, the ground squirrels also allow testing of the importance of overwinter conditions on survival during their hibernation period. In our study, these conditions appeared much less important than conditions during summer activity.

It is somewhat surprising that we can see such dramatic directional changes in climate in a mere 21-year period. It's perhaps more surprising that it is possible to distinguish the footprint of this change on the phenology of a species of herbivore. An additional aspect of our study is that animal fitness responds significantly to several climate variables. Some aspects of climate appeared to be changing in a directional manner, but others did not. The abiotic environment clearly has some dramatic influences on this herbivore. Our study demonstrates the importance of considering all possible seasonal changes in both climate, as well as the animal responses to such changes.

Table 1. Associations of climatic variables and year for the Okotoks, Alberta, Environment Canada Weather Station. For each of the 21 years 1992-2012, the climatic variable was averaged over the specified dates. The final column shows the average projected change in the climate variable during the study, calculated from the regression slope.

Variable	**Dates**	**Days**	***R^2* with Year**	**F**	**P**	**Mean**	**Δ over 1992-2012**
Snowfall[1]	13 April – 28 April	16	0.459	16.1	<0.001	1.04 cm	2.09 cm
Temperature[2]	28 June – 18 July	21	0.423	14.0	0.001	16.5° C	4.4° C
Rainfall[2]	28 June – 11 July	14	0.278	7.3	0.01	2.52 mm	–3.69 mm
Snowpack[3]	5 Dec – 15 Dec	11	0.302	8.2	<0.01	6.52 cm	9.63 cm
Snowfall[3]	26 Nov – 10 Dec	15	0.292	7.8	0.01	0.57 cm	1.14 cm
Snowfall[3]	8 April – 30 April	23	0.360	10.7	<0.01	0.93 cm	1.36 cm

[1]Snowfall before annual fitness was estimated, reflects influence on the timing of reproduction.

[2]Summer mean annual temperature and mean annual rainfall (for the periods shown) were negatively associated over the years of study (***r*** = -0.593, P = 0.005, n = 21).

[3]Snowpack and snowfall after reproduction and in the year for which annual fitness was measured, reflects direct influence of snowfall on survival of mother

Table 2. Associations of climatic variables and mean annual fitness of Columbian ground squirrels. For each of the years 1992-2012, the climatic variable was averaged over the specified dates. "*r* with Annual Fitness" indicates the correlation of mean annual fitness on the mean daily value of the climatic variable for the 21 years of the study.

Variable	**Dates**	**Days**	***r* with Annual Fitness**	**P**
Temperature	30 April – 11 May	12	0.691	0.0005
Temperature	22 Aug – 1 Sept	11	-0.686	0.0006
Rainfall	10 June – 14 July	35	0.597	0.004
Rainfall	28 July – 13 Aug	17	-0.498	0.02
Snow Accumulation	27 April – 24 May	28	-0.515	0.02
Snowfall before[1]	14 Feb – 8 March	23	-0.665	0.001
Snowfall before[1]	30 April – 19 May	20	-0.442	0.04
Snowfall after[2]	19 Jan – 17 Feb	30	-0.581	0.006
Snowfall after[2]	26 April – 20 May	25	-0.513	0.02

[1]Snowfall before annual fitness was measured, reflects influence of the timing of reproduction.

[2]Snowfall after reproduction and in the year for which annual fitness was measured, reflects direct influence of snowfall on survival of mother and offspring.

References

Both, C., M. van Asch, R.G. Bijlsma, A.B. van den Burg, and M.E. Visser. 2009. Climate change and unequal phenological changes across four trophic levels: constraints or adaptations? *J. Anim. Ecol.* 78: 73-83.
Dobson, F.S., M.J. Badry, and C. Geddes 1992. Seasonal activity in the Columbian ground squirrel. *Can. J. Zool.* 70:1364-1368.
Dobson, F.S., and J.O. Murie. 1987. Interpretation of intraspecific life history patterns: evidence from Columbian ground squirrels. *Amer. Nat.* 129:382-397.
Intergovernmental Panel on Climate Change. 2007. *The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge Univ. Press.
Inouye, D.W, B. Barr, K.B. Armitage, and B.D. Inouye. 2000. Climate change is affecting altitudinal migrants and hibernating species. *Proc. Nat. Acad. Sci. USA* 97:1630-1633.
Kintis, E. 2014. Climate outsider finds missing global warming. Science 344:348.
Lane, J.E., L.E.B. Kruuk, A. Charmantier, J.O. Murie, and F.S. Dobson. 2012. Delayed phenology and reduced fitness associated with climate change in a wild mammal. Nature 489:554-557.
Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.
Reale, D., A. G. McAdam, S. Boutin, and D. Berteaux. 2003. Genetic and plastic responses of a northern mammal to climate change. *Proc. R. Soc. Lond.* 270:591-596.
Visser, M. E., and C. Both. 2005. Shifts in phenology due to global climate change: the need for a yardstick. *Proc. R. Soc. Lond.* 272:2561-2569.

Highlight 2: The effect of lodgepole pine cavitation emissions on female mountain pine beetle host choice

Project Coordinator(s): Mathias Kaiser and Mary L. Reid, University of Calgary
Collaborator(s): Jayne E. Yack, Carleton University
Student(s): Mathias Kaiser, Kate Greco, Robyn Rush

Introduction

Many insects use acoustic signals for mate finding and mate attraction (Gerhardt and Huber 2002) but other functions such as predator deterrence are also common (Masters 1979). Each function is often associated with a distinct signal type or calling structure and many species have diverse acoustic signalling repertoires (Kalmring and Elsner 1985) and various mechanisms to detect sound have evolved among insects (Fullard and Yack 1993). Species that are sensitive to acoustic signals from conspecifics may also be sensitive to other acoustic signals in their environment and use them as behavioural cues. One hypothesis of particular interest to this study is that insect herbivores may use acoustic signals related to drought stress from plants for host selection (Haack et al. 1988). In our study we tested this hypothesis for mountain pine beetles (MPB), *Dendroctonus ponderosae*, an acoustically active bark beetle species (Fleming et al. 2013) and their preferred host tree lodgepole pine, *Pinus contorta*.

In relation to climate warming (Carroll et al. 2006, Allen et al. 2010) MPB populations increased leading to unprecedented outbreaks with significant economic and ecological impact on Western North America (Axelson et al. 2009) over the past decades. MPB attack living pine trees which provide high quality food (fresh phloem) but also induce resinous defences in response to beetle attack (Safranyik and Carroll 2006). MPB may struggle to overcome such defences when populations are low (endemic) and trees cannot be mass attacked. Previous research found that females colonize trees with less defences during endemic population stages whereas almost any tree is attacked during an outbreak (Boone et al. 2011). It remains unclear which cues pioneering females (the first to colonize a tree) use to select suitable hosts.

Chemical cues accessible to females do not predict a tree's quality and its ability to induce defences (Raffa and Berryman 1982). Female MPB show behavioural responses to conspecific acoustic signals (Ryker and Rudinsky 1976) and they could possibly use acoustic emissions (AEs) produced by plants under drought stress as well. AEs occur as a result of photosynthetic activity when high hydraulic pressure on water conduits leads to cavitation of some xylem cells (Tyree and Dixon 1983). High numbers of water conduits are found along the trunk of lodgepole pines where female MPB initiate their attack and therefore AEs may be a readily available source of information to females. To test whether pioneering female MPB use acoustic emissions for host selection we first measured lodgepole pine AEs in the field and then used playbacks of these recordings in the lab to observe the effect on female host choice. We predicted that pioneering females prefer hosts under higher water stress that are characterized by high AE rates.

Methods

We used a self-designed acoustic measurement chain (Figure 1) to obtain field recordings of lodgepole pine acoustic emissions from three different sites around the Biogeoscience Insititute's Barrier Lake Field Station (Figure 2). A total of 108 trees were sampled during mid-July and mid-August 2012. Individual recordings lasted five minutes and were taken between 1 pm and 4 pm in the afternoon which corresponds to the time of mountain pine beetle peak host seeking activity (Safranyik and Carroll 2006). For each tree we determined the average acoustic emission rate and collected data on tree quality such as relative moisture content of the outer 5 mm of xylem. We combined all variables in a general linear model to evaluate whether emission rate was predicted by tree quality and water stress. In a lab experiment we directly tested whether host choice of pioneering female MPB was affected by continuous playback of lodgepole pine AEs at a rate of 30 emissions per minute. Each of 96 females was given 20 hours to choose between an acoustically treated and an untreated lodgepole pine log from the same tree. Females were tested individually, simulating an endemic population stage.

Results

We found three significant main effects on the acoustic emission rate of lodgepole pine trees (Table 1). 1. Rates were almost twice as high in mid-August as they were in mid-July (Figure 3). 2. Rates increased throughout the afternoon. 3. Trees with thicker phloem (higher amount of food for beetles) had lower emission rates. Within the same model acoustic emission rate was not affected by relative moisture content of the outer xylem ($p = 0.665$) which was lower in mid-August than in mid-July (Figure 3) but also depended on tree diameter and recent growth (Table 1). In the playback experiment pioneering female MPB tended to prefer logs that were treated with acoustic emissions over untreated ones for gallery initiation ($p = 0.07$, N=89). Seven females did not enter either log within the given amount of time.

Discussion

For the first time we showed that lodgepole pine trees emit acoustic signals within the frequency range of MPB signals that are related to presumed water stress (diurnal and seasonal) and tree quality (phloem thickness). Relative outer xylem moisture was not a good predictor for emission rate because it depended on individual tree characteristics such as recent growth rate (Table 1). We considered water potential measurements of mid-crown leaves as a more common measure for overall water stress of individual trees (Tyree and Ewers 1991) but the logistics to obtain this measure for a large number of tall trees were not feasible within this study. Female MPB appeared to be able to detect acoustic emissions from lodgepole pine and they tended to choose hosts with higher emission rates as we predicted. This could mean that pioneers attacking in low numbers sacrifice food quality (phloem thickness) for increased chances of successfully attacking a tree. More playback experiments need to be conducted to confirm this and also the relationship between drought stress and the ability to induce defences should be investigated in lodgepole pine to further improve our understanding of MPB host choice behaviour. This study found support for a host-selection cue of bark beetles that has been hypothesized for the last three decades. The ability of MPB to identify water-stressed trees may be critical to their success when populations are low.

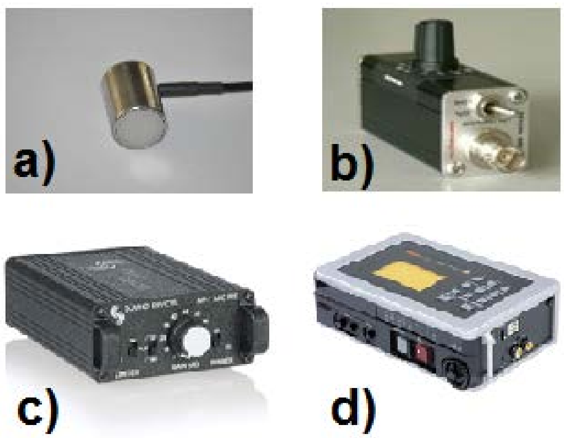


Figure 1. Devices used to obtain field recordings of acoustic emissions (AEs) from lodgepole pine. a) D9241A AE sensor chosen to record AEs within the frequency range of beetle signals.
b) Avisoft Charge Amplifier.
c) Sound Devices MP1 Preamplifier.
d) Fostex FR-2LE Field Memory Recorder. The sensor was pressed onto the xylem of the monitored tree with constant force (approx. 30N) using spring-based attachment clamps after removing a circular piece of bark and applying a thin layer of silicon grease for improved acoustic coupling to the sensor and the sapwood surface.

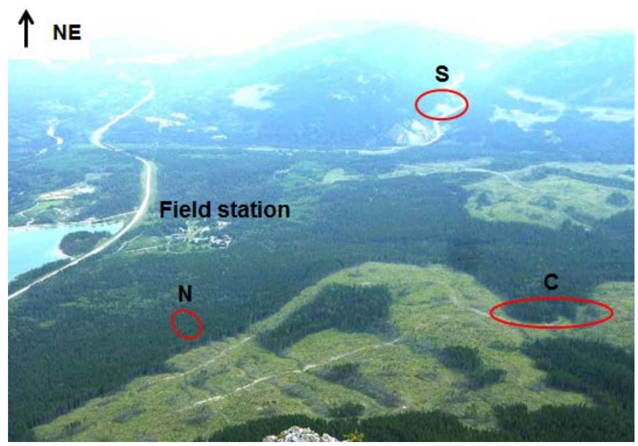


Figure 2. Image taken from the top of Mount Baldy showing the location of AE recording sites relative to the field station. Sites were chosen based on differences in expected moisture regimes to capture maximal natural variation of moisture stress within the area. S is located on a south-facing slope and expected to be dry, N is located on a north facing slope and expected to be wet, C is located along the edge of a clearcut.

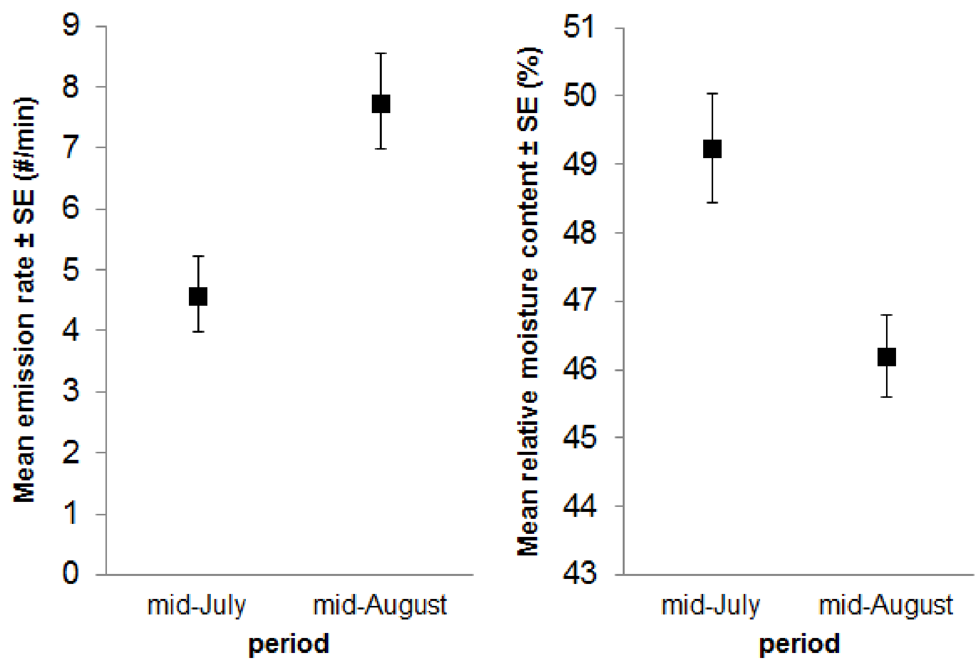


Figure 3. Mean AE rate and relative moisture content of outer 5 mm of xylem for the two time periods of acoustic sampling. Sample sizes were 42 and 66 for mid-July and mid-August respectively.

Table 1. Significant main effects of general linear models for a) ln(acoustic emission rate), df_{model} = 99 and b) relative moisture content of the outer 5 mm of xylem, df_{model} = 98.

	Effect	df_{par}, F	Effect size p	Effect direction
a)	Period	1, 7.892	0.006	Jul < Aug
	Time after noon	1, 7.151	0.009	+
	Phloem thickness	1, 5.954	0.017	-
b)	Site	2, 6.168	0.003	S > C
	Period	1, 7.055	0.009	Jul > Aug
	Diameter	1, 10.95	0.001	+
	Recent growth rate (5y)	1, 8.501	0.004	+

References

Allen, C. D., A. K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. (Ted) Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J.-H. Lim, G. Allard, S. W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259:660–684.

Axelson, J. N., R. I. Alfaro, and B. C. Hawkes. 2009. Influence of fire and mountain pine beetle on the dynamics of lodgepole pine stands in British Columbia, Canada. Forest Ecology and Management 257:1874–1882.

Boone, C. K., B. H. Aukema, J. Bohlmann, A. L. Carroll, and K. F. Raffa. 2011. Efficacy of tree defense physiology varies with bark beetle population density : a basis for positive feedback in eruptive species. Canadian Journal of Forest Research 41:1174–1188.

Carroll, A. L., J. Régnière, J. A. Logan, S. W. Taylor, B. J. Bentz, and J. A. Powell. 2006. Impacts of climate change on range expansion by the Mountain Pine Beetle. pp 1-20 In: Mountain Pine Beetle Initiative working paper. Canadian Forest Service.

Fleming, A. J., A. A. Lindeman, A. L. Carroll, and J. E. Yack. 2013. Acoustics of the mountain pine beetle (*Dendroctonus ponderosae*): sonic, ultrasonic, and vibration characteristics. Canadian Journal of Zoology 91:235–244.

Fullard, J. H., and J. E. Yack. 1993. Evolution of insect hearing. Trends in Ecology & Evolution 8:248–252.

Gerhardt, H. C., and F. Huber. 2002. Acoustic communication in insects and anurans: Common problems and diverse solutions. Chicago. University of Chicago press.

Haack, R. A., R. W. Blank, F. T. Fink, and W. J. Mattson. 1988. Ultrasonic acoustical emissions from sapwood of Eastern White Pine, Northern Red Oak, Red Maple, and Paper Birch : Implications for bark- and wood-feeding insects. The Florida Entomologist 71:427–440.

Kalmring, K., and N. Elsner. 1985. Acoustic and vibrational communication in insects. Berlin. Paul Parey Verlag.

Masters, W. M. 1979. Insect disturbance stridulation : Its defensive role. Behavioral Ecology and Sociobiology 5:187–200.

Raffa, K. F., and A. A. Berryman. 1982. Physiological differences between Lodgepole Pines resistant and susceptible to the Mountain Pine Beetle and associated microorganisms. Environmental Entomology 11:486–492.

Ryker, L. C., and J. A. Rudinsky. 1976. Sound production in Scolytidae: aggressive and mating behaviour of the mountain pine beetle. Annals of the Entomological Society of America 69:677-680.

Safranyik, L., and A. L. Carroll. 2006. The biology and epidemiology of the mountain pine beetle in lodgepole pine forests. pp 3–66 In: The Mountain Pine Beetle a synthesis of biology, management, and impacts on Lodgepole Pine.

Tyree, M. T., and M. A. Dixon. 1983. Cavitation events in *Thuja occidentalis L.*? Ultrasonic acoustic emissions from the sapwood can be measured. Plant Physiology 72:1094–1099.

Tyree, M. T., and F. W. Ewers. 1991. The hydraulic architecture of trees and other woody plants. New Phytologist 119:345–360.

Highlight 3: Meltwater Runoff from Haig Glacier

Project Coordinator(s): Alexandra Pulwicki and Shawn Marshall

Researchers from the University Of Calgary, Department Of Geography, have been studying glacier-climate processes and high-elevation snowpack and meteorological conditions at Haig Glacier since 2000. Haig Glacier is the main outlet of a small (~3.3 km2) icefield that straddles the continental divide in the Canadian Rocky Mountains, and is one of several glacierized headwaters catchments of the Kananaskis River.

The catchment is a tremendous snow pocket, receiving heavy precipitation from Pacific air masses in the winter months. Based on snowpit measurements from the site, the average winter (September to May) snowpack at the continental divide averaged 4.0 m from 2002-2013 (1700 mm water equivalent, (w.e.)), with an average glacier-wide winter snow accumulation of 3.2 m (1360 mm w.e.). An additional 50 mm w.e. of snowfall comes in the summer months. Measurements and modelling indicate that summer snow and ice melt averaged 2350 mm w.e. over this period, giving a mean glacier mass balance of −960 mm w.e. from 2002-2013. There has not been a positive mass balance year (net gain of snow/ice) during the study period. According to our estimates, Haig Glacier thinned by about 12.5 m from 2001 to 2013, releasing a large volume of stored ('fossil') water to the Kananaskis River. Here we describe measurements from summer 2013 examining the timing and extent of meltwater runoff from Haig Glacier.

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Meltwater runoff from Haig Glacier is of interest for understanding seasonal and interannual variability and long-term trends in glacier contributions to alpine stream hydrographs and Alberta river flows. Runoff data also provide an integrated measurement of snow and ice melt on the glacier, which supplements direct measurements of glacier mass balance and provides calibration data for our distributed glacier energy balance and melt models

Figure 1. The spring snow survey on Haig Glacier, May 2013. Photos from AP

In summer 2013 Alexandra Pulwicki (Environmental Sciences Program) received an NSERC Undergraduate Student Research Assistantship to join our group and set up stream gauging and preliminary water chemistry studies on Haig Glacier. Our aim is to better understand the hydrology of Haig Stream, a bedrock-channeled drainage outlet that funnels all of the runoff from the glacier (less any water losses to evaporation and groundwater infiltration).

We visited the site in early May for the annual snow survey, along with PhD student Wendy Wood and an undergraduate geography student RA, Pete MacLeod (Figure 1). There is good ski access to the glacier at this time of year, via French or Robertson Glaciers (Burstall Pass trailhead). The glacier snowpack was near normal for winter 2012-2013, and the stream was not yet running; there was still ~2 m of snow in the stream channel, so it was not possible to set up the stream gauge at this time. We planned to hike in again come late June to establish the stream instrumentation, but access to the site was unfortunately limited in early summer due to the June floods, which closed Kananaskis roads for an extended period and wiped out most of the bridges along the access trail.

It was late July by the time we got in, well into the glacier melt season. Hence our observations of stream runoff are limited to a 60-day period from July 24 to September 22 (Figure 3), during which time the glacier drainage system was well-established. Figure 3 is based on continuous pressure measurements from Haig Stream in combination with discharge measurements (velocity-profile method) to establish a stream rating curve (discharge, Q, as a function of water pressure). Discharge was measured on visits from July through September, including bihourly measurements over a diurnal cycle to capture high and low flows.

Figure 2. Pressure sensor for glacier stream discharge monitoring. Photo from AP

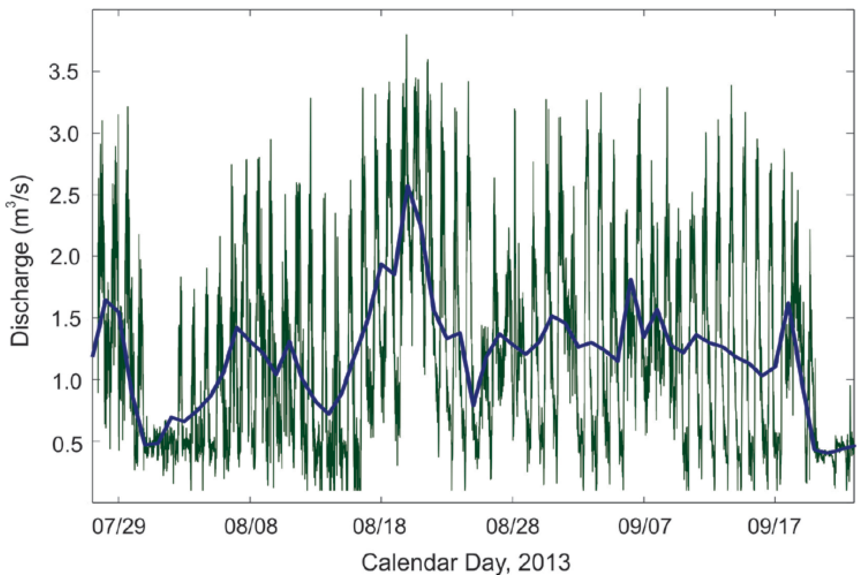


Figure 3. Haig Stream discharge, July 25 – September 22, 2013

The plot illustrates a strong diurnal discharge cycle, following insolation-driven daily melt cycles. Periods of extended high flows and higher overnight flows reflect either rain events or warm nights, when melting did not shut down on the glacier. The 'end of summer' is evident in the discharge record, with low flows commencing after Sept. 20. There was new snow cover beginning to accumulate on the glacier at this time; the baseflow recorded through this period presumably reflects residual summer meltwater that is still being evacuated through the subglacial drainage system, which includes both slow and fast pathways.

Lags and recession curves for the diurnal stream discharge are evident in Figure 4, which plots the modelled glacier melt (red line) and the observed stream discharge (blue) over an 8-day period in later summer. Peak runoff lags maximum snow/ice melt by an average of 3.5 hours over the summer, based on the time lag of peak correlation between the two time series. Runoff is more diffuse in general, with a broader daily peak. Modelled melt is strongly diurnal, shutting down on most nights (particularly in late summer, as in this image). This curve is generated from a distributed energy balance model applied to the entire glacier, with melting expressed as the average rate of snow/ice loss (with units mm w.e. melt per 30-minute period). The model is driven by meteorological data collected at the site.

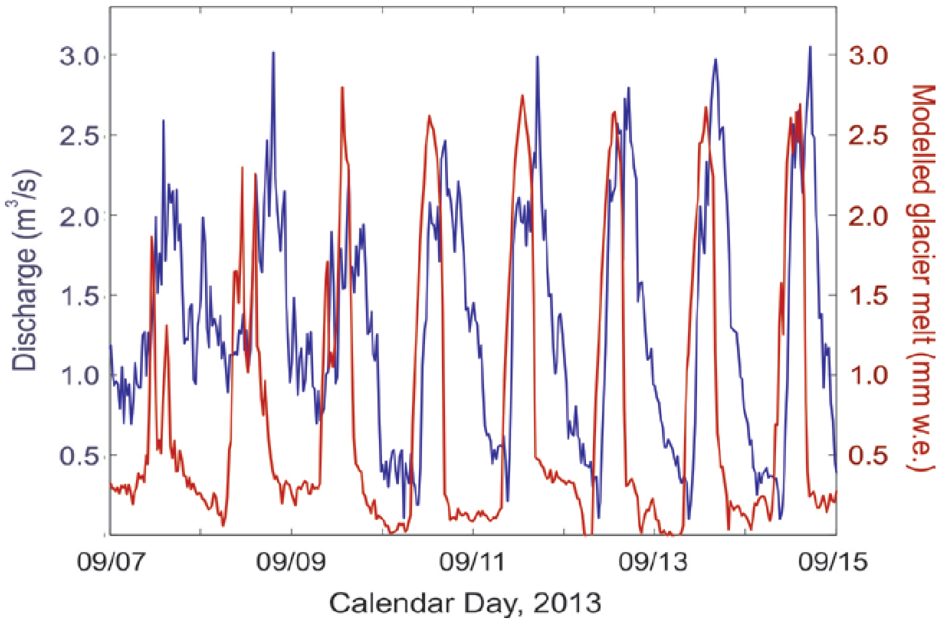


Figure 4. Haig Stream discharge (blue) and modelled glacier melt (red), Sept 7-15, 2013

The concentration of ions in Haig Stream also follows a diurnal cycle. Figure 5 shows the normalized concentration (concentration/maximum concentration of ion) of calcium, magnesium, and sulphate over the course of one day. Night time concentrations are stable and close to the maximum. The early morning decrease in concentration is due to dilution from newly melted glacial ice, which has a very low concentration of ions. The gradual increase in concentration during the day might be due to “flushing” of stored water along to glacial bed by high volumes of meltwater (indicated by large discharge volumes). Late in the day, the ion concentrations approach those of base flow (maximum concentration) and the stream discharge declines. Higher ion concentrations likely indicate a longer contact time with underlying bedrock and glacial till, although the source of sulphate is not clear. We also sampled the stream ion concentrations in September, when flow was very flow, and found that the concentration of these three ions was much higher.

Combined with water chemistry measurements from Haig Stream, discharge records and modelled runoff are providing a better understanding of delays and storage within the glacier system, along with variability in the amount and quality (e.g., ion chemistry) of glacier runoff feeding into the Kananaskis River system.

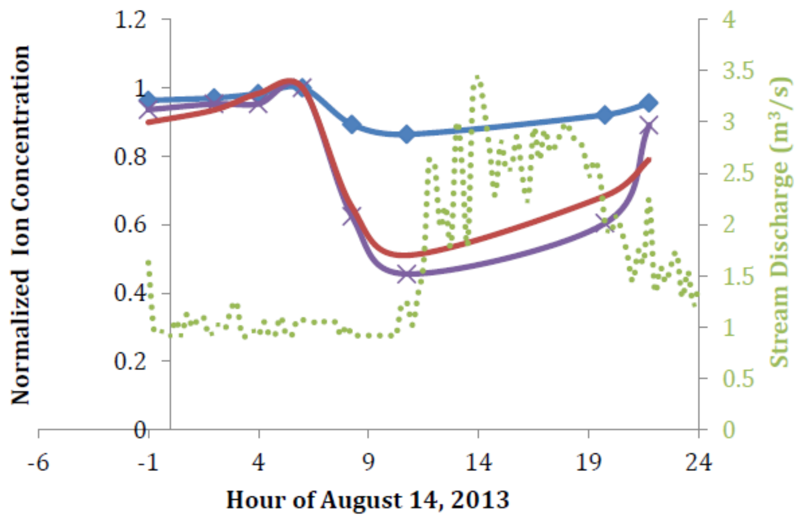


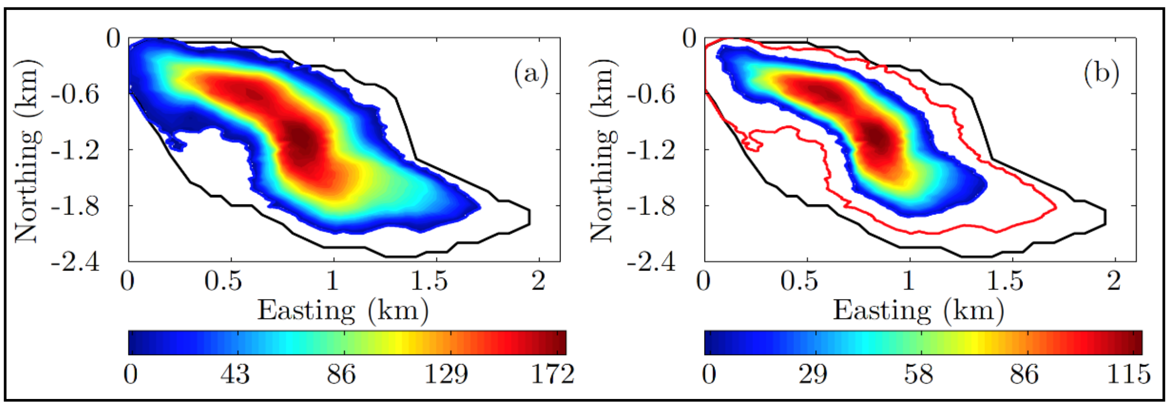
Figure 5. Normalized concentration of three dominant ions, calcium (blue), sulphate (purple), and magnesium (red), in Haig Stream. The stream discharge is plotted in green (dashed

BARRIER LAKE STATION PROJECT DESCRIPTIONS

University of Calgary

Future evolution of Haig Glacier (Adhikari, Surendra. PhD Student, Department of Geography, University of Calgary. Supervisor: Shawn Marshall)

Investigation of the future evolution of Haig Glacier under ongoing climate warming forms a part of my PhD research. I simulated a comprehensive 3-D Stokes flow model for Haig Glacier under three RCP (representative concentration pathways) future climate change scenarios. I found that the glacier is presently in a great degree of climatic disequilibrium: Even if the climatic conditions were to prevail as is (2001-2012 average), Haig Glacier will lose about 90% of its ice volume in the next 100 years. Under more realistic RCP scenarios, Haig Glacier is projected to be gone by 2080. The mode of the glacier shrinkage is interesting: in the 2030s, for example, glacier length has declined by less than 15% but the glacier has lost almost half of its present-day volume. Haig Glacier deflates more than it retreats upslope (see figure below: Black and red lines show present-day and 2025 glacier outlines, respectively).



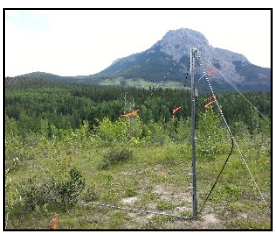
Fire Spread Model (Bakhshaii, Atoossa(Tessa). Post doctorate, Department of Biology, University of Calgary. Supervisor: Ed Johnson)

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.

<u>Characterizing hydrogeology of a first-order watershed in the Canadian Rocky Mountains</u> (Christensen, Craig. MSc Student, Department of Geoscience, University of Calgary. Supervisor: Masaki Hayashi)

Alpine watersheds in the Rocky Mountains are important stores for fresh water. Climate change is forecasted to modify the hydrology of these systems, yet their hydrogeology is poorly understood. Recent studies have successfully described flow regimes in a case-studies (notably, the Lake O'Hara Basin), but there is as of yet too few examples to adequately generalize how subsurface water in alpine zones behaves. My project aims to develop a conceptual model of groundwater flow in a first-order watershed with characteristics differing from previous studies. This will be achieved by combining flow monitoring, piezometric data, and multiple geophysical techniques.

<u>Array for Broadband Observations of VLF/ELF Emissions (ABOVE)</u> (Cully, Christopher. Assistant Professor, Department of Physics and Astronomy, University of Calgary)



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 BGI in summer 2013.

<u>A Window of Opportunity: the Influence of Zooplankton on Resuspended Sediments in Shallow Lakes</u> (Elgin, Erick. MSc Student, Department of Biological Sciences, University of Calgary. Supervisor: Leland Jackson)

Species interactions sometimes have drastic effects on ecosystem structure and function. In shallow lakes submersed aquatic vegetation (SAV) stabilizes the clear-water state in by enhancing water clarity via reduction of phytoplankton and prevention of sediment resuspension. However, SAV require sufficient water clarity in the spring to establish and grow. The relative contributions of different suspended particles and factors influencing water clarity over time are not well studied in freshwater lakes. I hypothesized that zooplankton grazing is one mechanism for reducing resuspended sediments and enhancing water clarity. I measured SAV biomass, phytoplankton, organic particles, mineral particles, and zooplankton at high temporal resolution in six shallow lakes from May-August. Preliminary results show maximum concentration of suspended particles in early spring during SAV germination, with non-phytoplankton particles as the dominant contributors to reduced water clarity. Later in the spring, we observed sharp declines in suspended solids in lakes with high *Daphnia* spp. density. The biomass of SAV in these same lakes then increased dramatically and became dominant for the remainder of the season. My results suggest that zooplankton grazing on non-plankton particles may facilitate the spring clear water phase. Thus management efforts that promote the presence of *Daphnia*, such as control of small fish, can help return lakes back to the more desirable clear-water state.

Long-term Interactions of Fire, Vegetation, and Climate (Hallett, Douglas. Biogeoscience Institute, University of Calgary)

The quantification and analysis of charcoal records archived in lake sediments soil, and peat deposits are being investigated. This information provides a deep time look at fire in the earth system and enhances the ability to forecast shifts in forest fire frequency, the global carbon budget, and risks to forest sustainability. Regional climate and dynamic vegetation models will be developed to be used to predict forest responses to climate change.

Lake O'Hara Hydrological Study (Hayashi, Masaki. Professor, Department of Geoscience, University of Calgary)

The overall goal of our research 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. The specific goals of the Lake O'Hara study are to quantify the spatial distribution and timing of water inputs in the form of glacier melt, snowmelt, and rain, and to examine the surface and sub-surface storage and release mechanisms. Results to date have confirmed the importance of groundwater processes. In 2015, we will continue to work on field-based process studies and also develop and test mathematical models of alpine watersheds.

Flow Monitoring and Modelling at Sulphur Mountain Thermal Springs (Hayashi, Masaki. Professor, Department of Geoscience, University of Calgary)

Spring flow rate (i.e., discharge) is a critical habitat parameter for the endangered Banff snail, *Physella johnsoni*. Long-term, systematic monitoring of discharge is essential for understanding the groundwater flow system and its response to climatic fluctuations. Despite its importance, there has been little or no systematic measurement of spring flow rates. The goals of this study are to: 1) establish the 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. On-going research activities continued in 2015 to monitor flow rates, temperature, and electrical conductivity (EC) of water at the Upper Hot Spring, the Kidney Spring, the Upper Middle and Lower Middle Springs, and the

Cave and Basin Spring Complex. In 2016, we will continue to monitor flow rates, temperature, and EC at the springs as well as snowmelt at the top of Sulphur Mountain to examine the correlation between snowmelt and spring flow rates and chemical compositions.

<u>Vegetation Dynamics</u> (Johnson, Edward. Professor, Department of Biological Sciences, University of Calgary)

The purpose of the research is to gain an understanding of the principal processes that influence forest dynamics at both local (hillslope) and landscape (basin) scale. Projects include: major biophysical forces that determine plant distribution and abundance, how wildfire creates the age mosaic on the landscape, and the metapopulation dynamics of the principal forest trees.

<u>Acoustics of Mountain Pine Beetle and Lodgepole Pine</u> (Kaiser, Mathias. MSc Student, Department of Biological Sciences, University of Calgary. Supervisor: Mary Reid)

This project aims to increase the knowledge about acoustic communication in mountain pine beetles and will elucidate to what extent acoustics play a role in their interactions with the environment. Acoustic cues will be investigated in the insect-plant interaction between mountain pine beetles and lodgepole pine. Trees under water-stress emit acoustic signals (acoustic emissions) that are caused by cavitation in the xylem. Water conducting cells may cavitate when the water tension inside them gets too high, making them unable to transport water. The lower frequency acoustic emissions of lodgepole pine are in the same frequency range as mountain pine beetle sounds, meaning that there is a good chance that beetles can hear these emissions. Measurements in the area around Barrier Lake will identify relationships between emission characteristics (e.g. rate, frequency, content) and tree traits (e.g. size, moisture stress) for lodgepole pine to understand what information about these trees is present in their emissions. The results may also inform insect-plant interactions more widely, as many phytophagous insects are associated with stressed hosts, which may be identified through the use of acoustic cues.

<u>Modelling Palaeohydrological Controls in Postglacial Mountain Drainage Basins</u> (Klassen, Peter. MSc Student, Department of Geography, University of Calgary. Supervisor: Yvonne Martin)

Quaternary glacial processes are a defining feature of the Canadian Rocky Mountains and have been a driving factor in the formation and continuing modification of the landscape. Once the ice retreats the landscape is left in disequilibrium and is dominated by paraglacial processes which have an immediate and strong role in creating and remobilizing sediment in the system. My research aims to better understand how glacigenic sediments affect surface and subsurface water flow. Using numerical landscape and hydrological models I hope to demonstrate how surficial deposits control stream flow response to precipitation and tie this to the paleoenvironment to understand paraglacial processes after glacial ice retreats.

Subsurface hydrological processes in alpine and lowland permafrost environments (Kurylyk, Barret. Postdoctoral Fellow (NSERC, Killam, and Eyes High), Department of Geoscience, University of Calgary. Supervisor: Masaki Hayashi)

My research is focused on subsurface heat transfer and hydrological processes in cold environments. In particular, I am using a finite element model of couple heat and water transfer to simulate the thawing of permafrost islands (peat plateaus) in a discontinuous permafrost region in southern Northwest Territories (Scotty Creek). I am also actively engaged in Dr. Hayashi's alpine research programs in Lake O'Hara, BC and Helen Creek, AB. Our objective is to investigate the hydrogeological functions of alpine landforms by integrating field-based studies with numerical modeling.

Determinants of individual foraging effort and colony success in wild bumble bees (Kutby, Rola. PhD Candidate, Department of Biological Sciences, University of Calgary. Supervisor: 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.

Studies of Song Variation in Birds (Lein, Ross. Associate Professor, Department of Biological Sciences, University of Calgary)

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.

Glacier-Climate Process Studies at the Haig Glacier (Marshall, Shawn. Professor, Department of Geography, University of Calgary)

We are working towards improving predictions of global-scale glacier and icefield response to climate change. This includes the development of simple models for snow and ice melt, snow distribution, and physically-based strategies for downscaling of large-scale climate fields. Haig Glacier field studies include measurement of glacier mass balance and meltwater discharge, and are designed to improve forecasting of water resource impacts with glacier decline in the eastern slopes of the Rockies. The current FCA/Haig team includes Terri Whitehead, Wendy Wood and Alex Pulwicki.

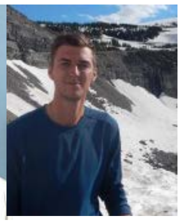
Role of Tree Population Dynamics and Wildfire in the Timing and Magnitude of Sediment Transporting Events (Martin, Yvonne. Associate Professor, Department of Geography, University of Calgary, Collaborative with Ed Johnson)

The impact of wildfire on a variety of sediment transporting processes in the Canadian Rockies is being examined, including soil erosion, tree throw, and mass wasting. The contribution of the 2003 wildfire to soil erosion was examined at Hawk Creek, Kootenay National Park. Soil erosion values in 2004 were very low despite significant rainfall events. We postulate that the likely cause of our low erosion rates relative to higher rates often reported for other regions is the notable duff coverage (fermentation and humus soil organic layers) remaining after the wildfire at our field site. Significant duff coverage remained above the mineral soil following the wildfire, with somewhat higher duff coverage found on the lower gradient slopes vs. steep slopes. Duff provides detention storage for rainfall input and enhances the ability of water to infiltrate into the underlying mineral soil. Furthermore, the duff layer provides a physical barrier to soil erosion. Post-fire soil erosion is most often studied and reported in regions where noteworthy erosion occurs. In many of these studies, it may be the case that the duff layer has been removed and a hydrophobic layer has developed, leading to significant soil erosion. However, results and inferences of such studies may not be representative of other regions. Rates of post-fire soil erosion often go unreported or are ignored when negligible amounts occur, meaning that the environmental scenarios leading to low soil erosion rates are often not documented.

Sediment transport due to tree throw events was also examined. As trees topple, large volumes of material attached to the roots are brought to the surface in the form of root plates, which eventually disintegrate and sediment drops to the forest floor, often leading to net downslope transport. The amount of sediment transported in this manner is dependent on tree characteristics, as trees smaller than certain threshold diameters uproot only negligible sediment while larger trees are associated with larger root plates. A model for tree population dynamics (driven by a stochastic wildfire algorithm) with sediment transport over time scales of ~10^3 years has been developed.

The final component of this research anticipates that the eventual decay of tree roots will lead to increased rates of shallow landsliding and debris flow activity in post-fire years. Net tensile root strength in post-fire years is determined by the interplay of decaying tree roots and establishment of new vegetation. Measurements are being undertaken of tree root decay in Kootenay National Park aiming to identify the period of significantly decreased net tensile root strength, during which the possibility of mass wasting increases. Numerical analysis will be undertaken to assess how root decay affects lateral reinforcement due to tree roots and slope stability along the eastern Rockies.

Hydrogen and Oxygen Isotope Composition of Wet Precipitation in the Kananaskis Valley (Mayer, Bernhard. Professor, Departments of Geoscience and Physics and Astronomy, University of Calgary; Scott Jasechko, Assistant Professor, Department of Geography, University of Calgary)



Precipitation is collected at the Barrier Lake Station and submitted to the Isotope Science laboratory at the University of Calgary for hydrogen and oxygen isotope ratio measurements. The obtained isotope ratios will yield a so-called local meteoric water line (LMWL), which is an important input parameter for hydrological studies using stable isotopes.

A detailed understanding of the temporary variations of the isotopic composition of precipitation will help researchers to trace the fate of rainwater and snowfall in watersheds located in the front ranges of the Rocky Mountains and the Foothills.

Effect of Tree Throw Bioturbation on the Critical Zone: Topographic Susceptibility to Wind Flow and Tree Uprooting, Kananaskis, Alberta (Momodu, Paul. MSc Student, Department of Geography, University of Calgary. Supervisor: Yvonne Martin)

The current study extends on earlier tree throw research by connecting tree throw processes to the driving force of wind. Strong winds blowing over the landscape may cause trees to upheave along with their root wad or the bole may break. When lateral forces on the crown and trunk exceed the ability of roots and soil to hold it in place, the tree upheaves. Although wind throw may occur in an instant, the sequence leading to this event unfolds over a longer period and involves the interaction of wind loading, resistance to breakage/overturning and applied force.

Objectives of the present study are: (i) collection of field data about forest characteristics in Kananaskis, AB for calibration of the wind flow model; (ii) analysis of meteorological data for input into the wind flow model; and (iii) utilization of the wind flow model, WindStation (Lopes, 2003), to identify topographic locations in mountainous landscapes that are most susceptible to tree root throw. WindStation is a numerical model based on 3D Navier-Stokes equations that simulates wind flow over complex topography. The model will be run for a DEM in Kananaskis, AB to analyze impactof topography, forest characteristics and wind storms of varying magnitude on wind flow and tree root throw.

<u>The Influences of Plant Characteristics on the Operation and Intensity of Sexual Selection in Angiosperms</u> (O'Donnell, Lisa. PhD Student, Department of Biological Sciences, University of Calgary. Supervisor: Lawrence Harder)

Understanding the contribution of sexual selection to the evolution of plant mating traits is being investigated. This project examines how characteristics of plants and their mating, such as 1) hermaphroditism, 2) immobility, 3) self-pollination, and 4) the spatial (herkogamy) and temporal (dichogamy) separation of sex function, influence the operation and intensity of sexual selection in flowering plants.

<u>Ecology of Mite Phoresy on Bark Beetles</u> (Peralta-Vazquez, Haydee. PhD Student, Department of Biological Sciences, University of Calgary. Supervisor: Mary Reid)

My research focuses on knowing if phoretic mite associates of pine engraver (*Ips pini*) and mountain pine beetles (*Dendroctonus ponderosae*) have negative or positive consequences on the dispersal and reproductive success of these beetle hosts. Currently, I am working on the mite identification and biology of pine engraver and mountain pine beetle phoretic associates found in Alberta (Kananaskis and Bragg Creek) and British Columbia (Yoho, Kootenay and Valemount).

<u>Interactions among Non-Native and Native Fishes</u> (Post, John. Professor, Department of Biological Sciences, University of Calgary)

The introduction of non-native species can have dramatic consequences for aquatic ecosystems. Ecologists have argued that species introductions have resulted in greater biotic impoverishment than any other single factor. Aquatic systems along the Rocky Mountains have been subject to stocking of non-native fishes for over a century. Experiences from biological invasions in ecosystems elsewhere suggest they lead to substantial negative effects on sustainability of native fishes. The mechanisms involved in the success and failure of these introductions are poorly known. Studies include: assessing spatial patterns of non-native invasions into the East Slopes region, a rehabilitation project in Quirk Creek in the Elbow River watershed, and planning experiments to understand the mechanisms of interactions between native and non-native fishes.

<u>Sustainable Exploitation of Freshwater Fisheries</u> (Post, John. Professor, Department of Biological Sciences, University of Calgary)

We are examining the biology and harvest dynamics in a number of western Canadian recreational fisheries including bull, lake, and rainbow trout. The Canadian Rockies National Parks and the eastern slopes are subjected to relatively heavy fishing pressure because of their proximity to large cities and heavy tourist visitation. Field data are used to assess biological productivity and creek census is used to measure harvest demand. Models are constructed to assess sustainable harvest and uncertainty related to data variance and process error. In particular, the bull trout population of Lower Kananaskis Lake and lake trout population of Lake Minnewanka are being analyzed in detail to develop models that can be applied to other populations.

<u>Tree Quality from a Bark Beetle's Perspective</u> (Reid, Mary. Professor, Department of Biological Sciences - Environmental Science Program, University of Calgary)

In lodgepole pine, we are investigating relationships between tree size, growth rate, defences and phloem nutrients to better understand host choice by bark beetles.

<u>Controls on Rockfall-Talus Process-Response Systems, Kananaskis, Canadian Rockies</u> (Thapa, Prasamsa. MSc Student, Department of Geography, University of Calgary. Supervisor: Dr. Yvonne Martin)

Rockfalls are major contributors to hillslope erosion and drainage basin development. Despite the importance of low-magnitude high-frequency rockfalls (<100 m3) in landscape development, few studies have documented rockfall rates over extended spatiotemporal scales. The objectives of my M.Sc. research are (i) to collect large inventories of talus deposits covering ~500 km^2 and investigate rockfall-talus processes by analyzing the association of these talus inventories with glacial topography and geological features; (ii) to analyze climatic control on frost cracking and its possible role in determining locations of rockfall-talus process in the Canadian Rockies; (iii) to estimate rockfall erosion rates and their contribution to drainage basin and mountain development in the Canadian Rockies. An inventory of talus deposits in fifth-order drainage basins was collected for Kananaskis, with rockfall erosion rates of 2.9 mm yr^{-1}. Results show a strong association of talus with faults and cirques. Although frost cracking is likely an important process leading to rockfall erosion, reconstructed temperature data suggests frost cracking alone is not the major determinant of locations of rockfall activity and talus deposition. Findings of this study provide important information on the contribution and controls of rockfall activity that can be utilized to better understand landscape evolution in mountainous regions.

<u>Geomorphological & Hydrological factors limiting forest encroachment into alpine meadows</u> (Toloui-Semnani, Moujan. MSc Student, Department of Biological Sciences, University of Calgary. Supervisor: Ed 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.

University of Alberta

<u>Information contained within a simple acoustic signal: The *fee-bee* song of the black-capped chickadee (*Poecile atricapillus*)</u> (Hahn, Allison. PhD Student, Department of Psychology, University of Alberta. Supervisor: Chris Sturdy)

While most songbirds produce short, simple calls and long, complex songs, black-capped chickadees produce a complex *chick-a-dee* call and a short and relatively simple *fee-bee* song. Using a variety of techniques including: operant conditioning, bioacoustic analyses, and immediate early gene (ZENK) expression, my research is examining potential cues within the *fee-bee* song that contain information regarding dominance, geographic origin, and sex.

<u>Pulsed Resources and the Nutritional, Movement, and Conservation Ecology of Grizzly Bears</u> (Lobo, Nikhil. Post-Doctoral Fellow, Department of Renewable Resources, University of Alberta. Supervisor: Scott Nielsen)

Buffaloberries (Shepherdia canadensis) are a critical component of the diet of grizzly bears during the late-summer period prior to hibernation. Buffaloberry crops can vary dramatically among years, and berry production has been implicated as the primary limiting factor of some bear populations, but little is known about the effects of inter-annual variation in berry production on the health, movement, and mortality of grizzly bears. These are important resource-consumer interactions to address, given the implications of bears' foraging patterns and habitat use to their survival, and the significance of buffaloberries to their late-season diet. My research will examine how the nutrition, health, demography, and habitat use of bears are related to within-season and inter-annual variation in buffaloberry production. I will also investigate the environmental factors that regulate buffaloberry production at multiple spatial scales, and how these factors relate to incidences of human-induced grizzly bear mortality.

<u>Assessing the Net Effects of Climate Warming and Invasive Trout on Fishless</u> Alpine Lakes (Loewen, Charlie. MSc Student, Department of Biological Sciences, University of Alberta. Supervisor: Rolf Vinebrooke)

Climate warming and biological invasions are among the most important stressors affecting freshwater biodiversity. Changing temperature regimes are expected to have pronounced effects on cold-adapted communities in mountain lakes and may facilitate the spread of exotic species by weakening the resistance of native communities. Exotic sportfish are already prevalent in our provincial and national mountain parks from historical stocking programs, and may considerably impact the composition and function of native freshwater communities.

As unforeseen synergistic or antagonistic interactions often complicate the net effects of multiple ecological stressors, we are conducting mesocosms experiments at the Barrier Lake Field Station to elucidate whether exotic sportfish and higher temperatures exert indirect rather than straightforward direct effects on native plankton communities. Our experiments also examine the potential for stress-tolerant colonists arriving from a regional species pool to functionally rescue stressed local communities from the effects of a novel predator and warmer summer heating events.

<u>Measurements of suspended frazil ice particles in Alberta rivers</u> (McFarlene, Vincent. PhD Student, Civil and Environmental Engineering, University of Alberta. Supervisors: Mark Loewen and 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.

<u>Winter stressors for fish in rivers: The effect of flow regulation</u> (Nafziger, Jennifer. PhD Student, Department of Civil and Environmental Engineering, University of Alberta. Supervisor: Faye Hicks)

Winter conditions can have significant negative effects on fish living in rivers. Regulated environments may mitigate or aggravate the negative effects that winter conditions have on fish survival. The presence of river ice, combined with water level regulation by hydroelectric generating stations, creates a poorly understood and complicated physical habitat for juvenile fish and eggs. Our study streams included both regulated and unregulated streams: four in Newfoundland (winter 2010-2011), three in New Brunswick (winter 2011-2013), and the Kananaksis River in Alberta (winter 2011-2014). Winter ice conditions were observed using remote cameras at all sites and water temperatures and levels measured throughout the winter at our New Brunswick sites. Additional data were also collected by our University of New Brunswick collaborators including dissolved oxygen concentration and salmonid winter egg survival. We aim to improve the understanding of the winter environment in small regulated streams and learn how it compares to that in small unregulated streams with the goal of characterizing the effect this environment may have on winter fish survival.

<u>A functional approach reveals zooplankton responses to environmental change in mountain lakes</u> (Redmond, Laura E. MSc Student, Department of Biological Sciences, University of Alberta, Supervisor: Rolf Vinebrooke)

Concern is increasing over the potential negative impacts of climate change on lakes and ponds, and alpine systems are especially susceptible to such changes.My research explores the factors that determine the community composition of zooplankton in the Canadian Rocky Mountains. By understanding the distribution of species, and the abiotic and biotic factors that contribute, we can gain insights and improve forecasts of ecological impacts of climate change on ecosystem function. With this new knowledge, it will be possible to identify indicator species for early signs of environmental change and initiate policy and management procedures to conserve these valuable ecosystems.

<u>Alpine Butterfly Population Dynamics</u> (Roland, Jens. Professor, Department of Biological Sciences, University of Alberta)

This project examines factors affecting the spatial and temporal dynamics of small populations of alpine butterflies. Factors such as habitat size, habitat quality and climate are examined using a combination of long-term monitoring of population size and distribution and of experimental manipulations.

<u>Neuroethology of Songbird Acoustic Communication</u> (Sturdy, Christopher. Professor, Department of Psychology, University of Alberta)

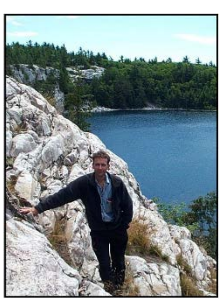
This research is aimed at understanding the cognitive, perceptual, evolutionary, developmental, and neural bases underlying chickadee acoustic communication. A variety of experimental techniques are used, including bioacoustic analyses, operant conditioning experiments, and *in vivo* electrophysiology and anatomy in several, related species of chickadees.

<u>Mountain Pine Beetles in Postburn Lodgepole Pine Forests</u> (Tabacaru, Crisia. PhD Student, Department of Renewable Resources, University of Alberta. Supervisor: Nadir Erbilgin)

The mountain pine beetle (MPB) (*Dendroctonus* ponderosae) is a significant threat to Alberta's lodgepole pine (*Pinus contorta*) forests. Prescribed fires are currently used in Alberta to kill potential host trees, thus slowing the spread of MPB. However, physiologically stressed trees are more susceptible to attack and fire poses the risk of leaving live, yet, partially burned – and therefore stressed – trees in its wake. Such trees may contribute to MPB population growth and allow the beetles to overwhelm otherwise healthy trees. An integrated approach addressing multiple scales over a longer term is needed to improve our understanding of MPB responses to fire-injured trees. In addition, it is necessary to determine which aspect of fire-injury supports or impedes reproductive success, as this can help in managing post-burn environments. Finally, the responses of local MPB natural enemies and competitors to prescribed fire are important factors as they can mediate MPB-fire interactions.

The broad objectives of this study are 1) to determine whether burned lodgepole pine stands will become ecological sinks or sources for MPB populations over the long-term in relation to a) host preference and b) reproductive success, and the aspects of fire-injury that support or impede these, 2) to provide ecologically meaningful explanations for overall MPB responses to fire, specifically in relation to natural enemies and competitors

<u>Ecological Surprises of Multiple Stressors in Mountain Lakes</u> (Vinebrooke, Rolf. Professor, Department of Biological Sciences, University of Alberta)



My research group is focusing on the cumulative impacts of multiple ecological stressors on mountain lake ecosystems. Currently, we are investigating the combined effects of invasive sportfish and climate change on planktonic diversity and function (e.g. primary productivity). Lake surveys along natural climatic/elevational gradients are used to generate hypotheses regarding how decades of introduction of exotic trout into mountain lakes have affected their responses to climate warming. These hypotheses are being tested through a series of mesocosm experiments, which are being conducted at the Barrier Lake Field Station.

University of British Columbia

<u>Decomposition of Coarse Woody Debris in Rocky Mountain Coniferous Forests</u> (Prescott, Cindy. Professor and Associate Dean, Faculty of Forestry, University of British Columbia)

This project was established in 1984 as part of my PhD research at sites in the Lusk Creek Valley. 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, and 21 years and the plan is to continue collection until 30-35 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 Rocky Mountain coniferous forests: 21-year results** *Canadian Journal of Forest Research 38:125-132* sensitivity analysis will be carried out in the study area.

<u>Linking Long-term Fluvial Morphologic Change with Mesoscale Aquatic Habitat Responses</u> (Tamminga, Aaron. PhD Student, Department of Geography, University of British Columbia. Supervisor: Brett Eaton)

My project focuses on comparing how long-term physical impacts of changing conditions (due to climate change or flow regulation for hydropower) relate to finer scale mesoscale aquatic habitat responses. The regulated Kananaskis River and the unregulated Elbow River (as a reference) will be studied, along with several other pairs of rivers across Canada. The research involves identifying long-term changes in mesoscale morphological units (pools, riffles, runs, glides) through sequences of historical air photos. These changes will be compared with mesohabitat classifications from high –resolution air photos taken with helicopters or unmanned aerial vehicles and ground surveys. This dataset will be used to determine underlying processes to link mesoscale morphodynamics to regime models of channel change.

<u>Physical Aquatic Habitat of Fish below a Hydropeaking Dam</u> (Winterhalt, Lesley. MSc Student. Department of Geography, University of British Columbia. Supervisors: Brett Eaton and Michel Lapointe)

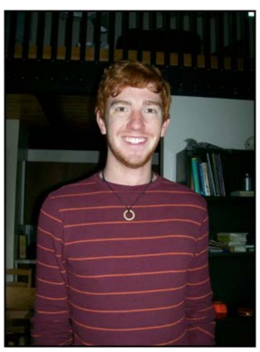
This project examines the impacts of a hydropeaking dam on downstream fish habitat. Specifically, the influences of tributaries and distance from the dam on flood pulse characteristics are investigated. The study site is the Kananaskis River below the hydropeaking Pocaterra dam. Seven sites downstream of the Pocaterra dam were established, and examined at high and low flow releases. Of primary interest is the variability in water depths and velocities on the Kananaskis River between high and low flow releases. Other factors under investigation include the variability in channel bed mobility, total suspended sediments and invertebrate community composition. By researching the tributaries and increased distance from a hydropeaking dam influences the Kananaskis River, a greater understanding may be achieved in terms of 1) the degree of river modification and 2) the spatial extent of these modifications progressively downstream from hydropeaking power facilities. This knowledge may enable more effective management of hydropower facilities for aquatic life.

University of Cincinnati

<u>Effects of Forest Encroachment for the Rocky Mountain Apollo Butterfly, *Parnassius smintheus*</u> (Matter, Stephen. Assistant Professor, Department of Biological Sciences, University of Cincinnati)

Treeline elevation is rising in alpine areas throughout the world. Encroachment of forest into alpine areas is predicted to isolate and reduce the area of habitats above treeline, such as mountain-top meadows. These changes potentially threaten organisms endemic to these habitats. However, not all area above treeline is necessarily suitable for forest. Since many of these areas contain resources necessary for endemic alpine species, there is the possibility that these species may be able to persist for considerable time, despite broad changes in the elevation of treeline. We will investigate encroaching forest and its effects on the Rocky Mountain Apollo butterfly, *Parnassius smintheus*, an alpine meadow specialist, at three sites in the front ranges of the Canadian Rocky Mountains that have experienced considerable forest encroachment over the last 60 years. Using a combination of aerial photography, habitat mapping, and tree ring dating, we will determine areas above treeline that are not subject to forest encroachment as well as a time frame over which such chnages may occur. We will parameterize and optimize metapopulation persistence models for the butterfly using 14 years of exisitng population and dispersal data and additional data collected during this study. Using habitat areas not subject to forest encroachment, these persistence models will allow us to predict if forest encroachment will impact *P. smintheus* and if so when populations will be affected.

<u>Modeling Forest Encroachment into Alpine Meadows along Jumpingpound Ridge</u> (Westbrook, Matt. MSc Student, Department of Biological Sciences, University of Cincinnati. Supervisor: Steve Matter)



Comparisons of aerial photographs from 1955 and 1993 indicate an estimated 75% decrease in alpine meadow habitat due to forest encroachment along Jumpingpound Ridge in Alberta, Canada. This encroachment is causing meadow fragmentation and is limiting dispersal of the Rocky Mountain Apollo butterfly (*Parnassius smintheus*). The immediate goal of this study is to predict where forest will continue to encroach and where the butterflies' habitat will remain, i.e. presence of both the host plant and nectar flowers of *P.smintheus*. Subsequent studies will test the persistence of this population given the refugia predicted by the habitat model.

University of Guelph

<u>Ecology and Evolution of Fireweed</u> (Husband, Brian. Professor, Department of Integrative Biology, University of Guelph)

Our research examines the process of whole genome duplication (i.e. doubling of chromosome number) as a potential mechanism of rapid adaptation and speciation. Many organisms, including vertebrates, have undergone such doubling in their evolutionary past; the phenomenon is especially common in plants. In fireweed, a common plant of the Canadian Rockies, polyploid individuals are produced on an ongoing basis and coexist alonside ancestral diploids, making this an ideal opportunity to study evolution in action.

<u>Non-climatic constraints to tree species distributions in the Canadian Rocky Mountains</u> (Emma L. Davis, PhD Candidate, Department of Geography, University of Guelph. Supervisor: 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.

Humboldt State University

<u>Reproductive Ecology of Conifers</u> (Greene, David. Professor, Forestry & Wildland Resources, Humboldt State University)

Conifer pollen production along an altitudinal gradient is being examined. In particular, we ask if seed production is pollen limited near treeline. Further, we ask whether the receptivity period is sufficiently brief – relative to the rate at which the anthesis isophene travels upslope – that trees at the lower and upper elevations have little gene exchange via pollen.

MacEwan University

Hybridization and the Breakdown of Species Isolating Mechanisms in Two Sexually Cannibalistic Insects (Cyphoderris spp.) (Judge, Kevin. Assistant Professor, Department of Biological Sciences, MacEwan University)

Hybrid zones - areas of geographic overlap between two species ranges where hybridization occurs - are important natural laboratories for testing fundamental theories about the origin and maintenance of biological diversity. We are utilizing the unique breeding biology of a group of sexually cannibalistic insects in the genus Cyphoderris and their recently discovered hybrid zone to test some of these theories. Our long term objectives include: 1) large scale mapping of the Cyphoderris hybrid zone to look for other areas of hybridization, 2) measuring the rate of gene flow between the two parent species of Cyphoderris, and 3) examination of the role of environmental disturbance and nutrient availability on the extent of hybridization. Populations of C. monstrosa at the BioGeosciences Institute are of interest because of their relative isolation from populations of its congener, C. buckelli, with whom it is thought to hybridize.

Montana State University

Robertson Glacier Historic Mass Balance Change (Scanlon, Ryan. MSc Student, Department of Earth Sciences, Montana State University. Supervisor: Mark Skidmore)

The goal of this project is to determine the historic mass balance of the Robertson Glacier. This will be accomplished by using detailed ablation and accumulation data collected in the field and then correlating it to weather data that is available dating back to 1887. This will give us an accurate estimate as to the way the glacier has changed over the past 125 years. In addition to historic weather data, this project will also incorporate historic aerial photographs to delimeate the glacier boundary so that area changes may be observed.

Methane Cycling in Subglacial Sediments (Skidmore, Mark. Associate Professor, Department of Earth Sciences, Montana State University)

Biological methane production and oxidation *in situ* in anaerobic sub-glacial sediments at ambient temperatures ~0 - 1˚C will be examined. Archaeal methanogens and methanotrophs catalyze the interconversion of C1 and C2 substrates to methane (CH_4); reactions which are considered to result in free energy near the thermodynamic limit for supporting life. Preliminary data from sub-glacial sediments from the Robertson Glacier, Peter Lougheed Provincial Park, Alberta, Canada, strongly point toward an active population of archaeal methanogens in these sediments. Given methane production, a logical progression is to understand the cycling of methane in the sub-glacial sediments and the flux to the atmosphere. A combination of biochemical, isotopic, and geochemical techniques will be employed to investigate the abundance and activity of archaea and bacteria involved in methane cycling in sub-glacial sediments collected from the Robertson Glacier.

An increased awareness of the tenacity of life on Earth has fueled speculation that sub-ice extraterrestrial environments such as on Europa or Mars may also be habitable by microbes due to the availability of liquid water in these systems. The cold, anoxic, sub-glacial terrestrial environment on present day Earth provides a potential model analog for these extraterrestrial that are also likely to have very low to no oxygen.

Queen's University

<u>Phenological and genomic determinants of elevational range limits in *Rhinanthus minor*</u> (Ensing, David J. PhD Candidate, Department of Biological Sciences, Queen's University, Supervisor: 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.

<u>Ecology and Evolution of Altitudinal Range Limits in *Rhinanthus minor*</u> (Hargreaves, Anna. PhD Student, Department of Biology, Queen's University. Supervisor: Chris Eckert)

All species are restricted in their geographic and altitudinal distribution, or range. We are exploring three emerging topics regarding the ecology and evolution of species' range limits: 1) the relative importance of abiotic and biotic factors in limiting range expansion at different locations on species' range margins (e.g. upper versus lower elevation limits), 2) the degree of local adaptation within the range and 3) the effect of gene flow in hindering or enabling expansion of range limits. The native, annual herb, *Rhinanthus minor* (yellow rattle), is the study species and two transects span the prairies to the alpine.

<u>Hydrology, Weathering, and Nutrient Dynamics in Glacial Alpine Catchments</u> (Lafrenière, Melissa. Assistant Professor, Department of Geography, Queen's University)

The aim of this research project is to conduct a multi-year investigation of the influence of climatic, hydrologic, and anthropogenic factors on the weathering processes, the deposition of sulphur and nitrogen, and the biogeochemistry of dissolved organic carbon (DOC) and nitrogen (N) in glacial and snow-covered (nival) alpine catchments in the Canadian Rocky Mountains.

<u>The influence of phenology on the elevational range limit of Yellow Rattle (Rhinanthus minor)</u> (Sora, Dylan. MSc Candidate, Department of Biology, Queen's University. Supervisor: 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.

University of Saskatchewan

<u>Investigating the turbulent transport and sublimation of snow in alpine terrain</u> (Aksamit, Nikolas. PhD Student, Centre for Hydrology, Department of Geography and Planning, University of Saskatchewan. Supervisor: John Pomeroy)

Wind driven redistribution and sublimation of snow is a natural phenomenon that has profound impacts on avalanche safety, cold climates engineering, and the yearly water budget. Wind-loading controls springtime snow depletion rates and acts as a large component of growth for most small mountain glaciers. Current approaches to modeling snow redistribution use mean wind speed over varying time scales and over simplify turbulent structures, especially in the mountains. The proposed research will investigate the influence of intermittent turbulence on non-steady blowing snow processes in alpine terrain, focusing on saltation initiation, transition to suspension, and sublimation.

<u>Atmospheric controls on snow energetics</u> (Conway, Jonathan. Post-Doctoral Research Fellow, Centre for Hydrology, Department of Geography & Planning, University of Saskatchewan. Supervisors: Warren Helgason and John Pomeroy)

My research uses a combination of in-situ micro-meteorological measurements and snowpack/ atmospheric models to understand the role of turbulent, sensible and latent, heat fluxes in surface energy exchanges over mountain snow and ice surfaces. These fluxes play a key role in determining snow and ice melt in many situations. However the mountain environment presents many challenges in understanding their magnitude as many of the assumptions used by standard theories are violated. I have two key sites – an extremely sheltered valley bottom clearing at Fortress Mountain Snow Laboratory, and the Athabasca Glacier, where the a persistent katabatic (downslope) wind prevails. In improving our fundamental understanding of atmosphere-snowpack exchanges we can have more confidence in how seasonal snow and glaciers has and will respond the changing climates.

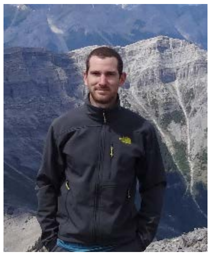
<u>Modelling of the soil freezing/thawing</u> (Demand, Dominic. Research Student, University of Freiburg. Supervisor: John Pomeroy)

The focus of my work was to improve a module of soil freezing and thawing to obtain better knowledge of the soil characteristics and associated hydrological processes. To model the freezing/thawing depth a modified 1D Stefan's equation (XG algorithm) developed by Changwei et al. (2013) was used, which calculates the freezing/thawing in a multi layered soil. The XG algorithm was validated with some datasets from Marmot Creek, Bad Lake and Wolf Creek. Also some methods for obtaining an appropriate soil surface temperature under snowcover as input for the model were tested.

<u>Sources and Transformations of Mercury in Beaver-influenced Mountain Streams</u> (Jardine, Tim. Assistant Professor, School of Environment and Sustainability, University of Saskatchewan)

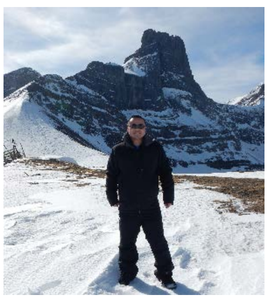
This project examines how beaver ponds alter riverine food web structure and contaminant availability. Nutrients, algal biomass, invertebrate standing crop, and mercury concentrations above and below ponds will be measured to determine how ecology and biogeochemistry if affected by these ecosystem engineers. Stable isotopes of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) are sued to follow the fate of mercury as it moves through food webs from biofilm to invertebrates and ultimately to fish. These results will help us understand the implications of increasing beaver populations in streams and wetlands as well as providing information on the influence of dams and natural floods on these processes in larger rivers.

<u>Fluxes in a melting alpine snow cover</u> (Leroux, Nicholas. PhD Student, Centre for Hydrology, Department of Geography and Planning, University of Saskatchewan. Supervisor: John Pomeroy)



My research focuses on improving the understanding of snowmelt processes in mountainous terrain. A physically based snow model will be developed to simulate changes in snowpack features and compute snowmelt from recorded meteorological data. My field sites are located in Marmot Creek and Fortress 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.

<u>Snow data assimilation in Canadian Rockies Mountains</u> (Lv, Zhibang. PhD Student, Centre for Hydrology, Department of Geography and Planning, University of Saskatchewan. Supervisor: 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).

<u>Ecohydrological Processes of Alpine Wetlands</u> (Mercer, Jason. MSc Student, Department of Geography and Planning, University of Saskatchewan. Supervisor: Cherie Westbrook)

My research focuses on alpine wetlands in recently deglaciated terrain. Wetlands have been establishing in areas recently occupied by glaciers in the Rockies. But we don't know much about these systems, such as the functions and ecosystem services they provide, what ecohydrological processes are driving their distribution or structure, or how persistent they will be as the climate continues to change. To better understand some of these issues I'll be examining the hydrology supporting these ecosystems.

<u>Spatially Distributed Modeling of Mountain Snow Hydrology</u> (Musselman, Keith. Post-doctoral Fellow, Coldwater Centre, University of Saskatchewan. Supervisor: John Pomeroy)

Experimental micrometeorological data are used to develop and drive sophisticated, fully distributed snow hydrology models to better understand headwaters basin response to changing climate and land use. Particularly, snow hydrology models are used to determine scale relationships, climate sensitivity, and landscape ecological sensitivity of snow hydrological processes in high mountainous environments. Models are driven and tested with data from instrumented experimental basins at Marmot Creek and the Peyto Glacier in Alberta.

Canadian Rockies Hydrological Observatory (Pomeroy, John. Professor, Centre for Hydrology, Department of Geography, University of Saskatchewan)

The Canadian Rockies Hydrological Observatory (CRHO) aims to improve the understanding of capacity to predict the changes in water yield from headwater basins where cold climate processes predominate. It will examine the water supply response to climate variability in a range of mountain headwater ecohydrological site types, incorporating the transient responses of both climate forcing and cryospheric and basin hydrological response. Particular attention will be paid to how snowpacks, glaciers, groundwater, wetlands, forests and frozen soils interact and modulate the response of water supply to variability in climate. An important component will be on downscaling climate model products over complex mountain terrain. The project will support improved water resource modeling and management over larger river basins such as the Saskatchewan River Basin by contributing advanced mountain headwater hydrological modeling capability and future flows under downscaled climate scenarios. It will do so by strengthening the hydrological and glaciological science foundation for estimating water resource impacts from future climate scenarios and by testing and improving hydrological models that can be used for current and future water resource assessments. The CRHO will also undertake a focused effort to communicate scientific findings and new methods useful to governments, communities, and industry and to train and develop the next generation of cold region hydrologists and glaciologists.

Questions:

1) How do mountain basin characteristics affect snow and ice systems to produce hydrological responses to precipitation and energy inputs on time scales from hours to centuries?
2) Do cold regions mountain hydrological systems enhance or dampen the effects of climate variability on water resources?
3) Are the Canadian Rocky Mountains a reliable future source of streamflow?

Specific Objectives:

1) Improve the understanding and description of the governing cold regions hydrological factors for mountain water supply through intensive process studies in representative headwater research sites,
2) Develop an improved cold regions hydrology model based upon improved numerical descriptions of processes and enhanced basin representation.
3) Use new scientific information and improved models to predict headwaters water resource sustainability in light of climate change and variability by:
   a) Downscale current meteorology and future climate scenarios to drive cold regions hydrology in light of concurrent ecohydrological dynamics
   b) Predict hydrological cycling and quantify uncertainty in these calculations in ungauged mountain basins
   c) Improve the coupling of the groundwater to the surface-atmosphere system

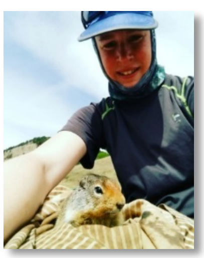
<u>Response of High Mountain Snow and Ice Hydrology to Changing Climate</u> (Pradhananga, Dhiraj. PhD Student, Centre for Hydrology, Department of Geography and Planning, University of Saskatchewan. Supervisor: John Pomeroy)

The role of snow and glacier melt on water availability under changing climate conditions in the Canadian Rockies is being investigated. An energy balance physically-based melt model coupled with a blowing snow redistribution and sublimation model within a mountain basin hydrology model using the Cold Regions Hydrological Model Platform (CRHM) is being applied. The research site is the Peyto Glacier in Banff National Park, Alberta. This project will both enhance our understanding of snow and glacier melting behavior and water availability and improve the hydrological modeling capacity in cold regions of high mountains.

<u>Sensitivity Analysis of Climate/Land-use Change Impacts on Permafrost Melt and Glacier Variability</u> (Rasouli, Kabir. PhD Candidate, Centre for Hydrology, Department of Geography, University of Saskatchewan. Supervisor: John Pomeroy)

The Cold Regions Hydrological Model will be assessed and applied for permafrost melt change analysis in the Wolf Creek Research Basin in Yukon, Canada. The observed data and re-analysis model outputs will be prepared and assessed. Climate change and related permafrost melt, glacier change and land surface change will be studied using the CRHM model.

<u>Annual Contributions to Fitness for Columbian Ground Squirrels Subject to Natural and Manipulated Environmental Conditions</u> (Rivet, Danielle R., PhD Candidate, Department of Biology, University of Saskatchewan. Supervisor: Jeff Lane)



All organisms must be able to synchronize the timing of events such as reproduction or emergence from hibernation with environmental conditions and cues in order to optimize fitness. A large body of literature suggests that natural selection favors earlier migration within avian species, extending the amount of time available for optimal fitness enhancement. However, with the increased rate of climate change, plants and animals are being forced to undergo rapid phenological shifts, or suffer population declines due to not shifting in sync with food resources or climatic delays. My study seeks to assess the effects of climate change on Columbian ground squirrel emergence date and torpor profiles at an individual level. Mainly, I seek to manipulate snow depth via the use of snow fences to expand upon the natural variation in emergence dates seen in early and late snow years, to analyze whether this has an effect on torpor profile patterns. A general torpor profile model will be created, including pre- and post-hibernation weights, torpor and arousal cycle duration and frequency, and hibernation and arousal metabolic rates. Based upon this model, I will be able to determine the effects of a late snowmelt year on Columbian ground squirrel torpor profiles.

<u>Beaver as a Soil-Forming Factor: Characterizing Peat Properties and Biogeochemical Processes in a Mountain Peatland</u> (Wang, Xiaoyue. PhD Student, Department of Soil Science, University of Saskatchewan. Supervisor: 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.

<u>Ecohydrology of Rocky Mountain Peatlands</u> (Westbrook, Cherie. Associate Professor, Centre for Hydrology, Department of Geography & Planning, University of Saskatchewan)

My research 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.

<u>Climate and Hydrology of the Canadian Rockies</u> (Whitfield, Paul. Senior Research Fellow, Centre for Hydrology, University of Saskatchewan)

My 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 inputing 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

University of Victoria

<u>Watershed Hydrology</u> (Valeo, Caterina. Associate Professor, Department of Mechanical Engineering, University of Victoria; Collaborative with Ed Johnson)

Pine beetle infestations and forest fires are large-scale disturbances that impact watershed hydrology. Complex hydrological models are used to incorporate the pine beetle life cycle and forest infestation scenarios to predict resulting water yields in managed watersheds. These models are also used to determine the amount of duff (organic layer) that is consumed during a forest fire in order to predict forest regeneration patterns.

University of Waterloo

<u>Seasonality of alpine forest water use and availability</u> (Langs, Lindsey, MSc student, Department of Geography & Environmental Management, University of Waterloo. Supervisor: Richard Petrone)

Our group's purpose in the Kananaskis region is to understand the importance of forest ecohydrological processes to mountain stream generation. Specifically, the micrometeorological and boundary-layer influences on evapotranspiration. My project in particular is focussed on understanding how alpine forests access and utilize the water available to them. In this study we will also be examining the hydrology of the alpine hillslope areas in which these forests reside aiming to understand the response of the groundwater to varying meteorological events and seasonality. My work will help to provide an understanding on how ecohydrological processes act under varying seasonal alpine conditions and their potential alterations due to climate change.

University of Western Ontario

<u>The Effects of Nutrition on Reproduction and Survival in Small Mammals</u> (Millar, John. Professor Emeritus, Department of Biology, University of Western Ontario)

Our research investigates variation in reproduction and survival of small mammals in environments with short growing seasons. Under such conditions, reproduction is constrained but survival rates are high, with considerable annual variation. Previous studies of the energetics of reproduction failed to explain annual variation in reproduction and our studies focus on nutrition, especially available protein. We are monitoring stable isotopes of carbon and nitrogen as indicators of diet in natural populations of deer mice and red-backed voles.

Yokohama National University

<u>Climate-Wildfire Relationships in the Canadian Rockies</u> (Mori, Akira. Associate Professor, Graduate School of Environment and Information Sciences, Yokohama National University)

In order to help forest management and forest-based sector adapt and mitigate to the challenges of changing climate, it is essential to have several options based on prediction scenarios to present to policymakers and managers. Climate change may affect probability of extreme events such as wildfires. Wildfires are one of the most important ecological processes in forest ecosystems, but large-scale fires are sometimes perceived as an environmental catastrophe. This study tries to infer several scenarios in forested ecosystems in the Canadian Rocky Mountains, which are prone to stand-replacing wildfires. These scenarios predict the probability of large-scale forest fires based on the hierarchical Bayesian model. The model is based on relationships between recorded wildfire activity and drought code at regional scale. The drought code is widely used by forest fire management agencies in the monitoring of wildfire risk. To calculate the future drought intensity, this study relies on different possible future circumstances of climate, which were provided by the Special Report on Emission Scenarios (SRES) of the Intergovernmental Panel in Climate Change (IPCC). The past variability in biomass burning and drought intensity are also evaluated based on paleoecological methods. By combining the reconstructed fire regime and vegetation model, this study aims to see climate-wildfire linkage at a local scale.

R.B. MILLER STATION PROJECT DESCRIPTIONS

University of Calgary

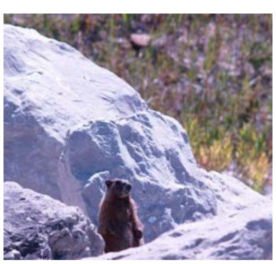
Ecology of Bumble Bees and Their Forage Plants (Cartar, Ralph. Associate Professor Department of Biological Sciences, University of Calgary)

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.

Wing Wear and Foraging behavior of Bumble Bees (Earle, Greg. MSc Student, Department of Biological Sciences, University of Calgary. Supervisor: Ralph Cartar)

This project is examining whether wing wear changes the ways in which bumble bees visit flowers (e.g. flower species, patch density, use of wings while foraging in patch) and their energetics of foraging. Bumble bee species will be surveyed (and individuals within those species) that differ in tongue length, and plant species that differ in their floral handling times. The hypothesis that wing wear changes the costs of wing use, and therefore causes wing-worn bees to forage in situations that reduce their wing use will be tested. Different behavioural responses to wing wear depending on body size and tongue length is predicted.

Intrinsic and extrinsic factors affecting dispersal and survival of yellow-bellied marmots *Marmota flaviventris* in southern Alberta (Holland, Berna-Dean. MSc Student, Department of Biological Sciences, University of Calgary. Supervisors: Kathreen Ruckstuhl and Peter Neuhaus)



The yellow-bellied marmot has been studied for decades in the US, in alpine habitats at elevations around 2900m. However, we know very little about their prairie-dwelling cousins in southern Alberta, living in coulees and river valleys at elevations between 800 and 1300m. There have been some documented sightings of yellow-bellied marmots in southern Alberta and although seemingly rare, their population status is currently designated as "secure". However, to date, no formal assessment of the behaviour or regional conservation status of yellow-bellied marmots has been conducted in this region.

To evaluate species' persistence in a disturbed and changing landscape, we need to investigate factors contributing to effective population sizes and gene flow such as mating skew, which is typically regulated by mating strategies and monopoly of some males over breeding females, along with life history characteristics such as age at first reproduction, immigration, recruitment, dispersal, birth and death rates. Although dispersal tendencies have been investigated for many mammal and bird species, tracking individual dispersal success is often difficult if not impossible. The yellow-bellied marmots in southern Alberta present a unique opportunity to look at mating strategies, behaviour, dispersal and reproductive fitness as they are occurring within a fragmented landscape, but are easy to track. Our research objectives include:

1) Investigate intrinsic and extrinsic factors affecting dispersal and survival of yellow-bellied marmots in southern Alberta and 2) Based on the findings of objective 1), determine whether the current conservation status is adequate in terms of present and future prospects for the persistence of yellow-bellied marmots in southern Alberta.

Given the lack of data on the behaviour of yellow-bellied marmots in southern Alberta, it is premature to formulate specific hypotheses on their dispersal patterns, mating strategies and viability. However, we predict this study will reveal how mating strategies and dispersal are interrelated and how the observed patterns influence population persistence and dynamics in this region. It is also unclear to what extent these marmots differ in their ecology from their alpine counterparts. We thus anticipate the findings of our study will begin to fill this regional knowledge gap.

Parasite Diversity and Abundance (Kutz, Susan. Associate Professor of Wildlife and Ecosystem Health Faculty of Veterinary Medicine, University of Calgary. Collaborative with Kathreen Ruckstuhl)

Interactions between sympatric bighorn sheep and cattle will be examined with respect to parasite diversity and abundance.

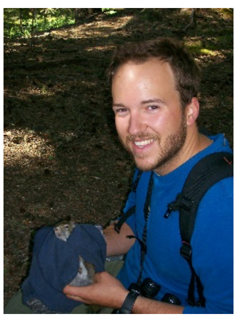
Attending to Attention: An Ethological Framework for Understanding the Mechanisms Underlying Attention Following (McDougall, Petra. PhD Student, Department of Biological Sciences, University of Calgary. Supervisor: Kathreen Ruckstuhl)

Attention can be costly in terms of time lost foraging or focusing attention on non-relevant aspects of the environment. Cues as to the object(s) of attention of another individual provide a means of focusing attention on potentially relevant stimuli. The ability to follow another's gaze has been intensely studied in human infants, and in our closest relatives, the non-human primates. However, little is known about the use of gaze following in non-primate species, or about how it might be used in a broader ethological framework (e.g. for anti-predatory or reproductive efforts). Gaze following behavior in free-ranging Bighorn Sheep (*Ovis canadensis*) is being examined to determine how, and in what context, they may use this ability in their natural setting, thereby providing information regarding how they learn about salient aspects of their environment, and how they utilize attentive information provided by other individuals (both within and across species).

Studies in Behavioural Ecology of Columbian Ground Squirrels (Neuhaus, Peter. Adjunct Professor, Department of Biological Sciences, University of Calgary)

In this research we look into the evolution of individual life-histories in Columbian ground squirrels. The main studies are: host-parasite interactions and the impact of parasites on reproductive success, mate choice, and life-history. Paternity analysis to look at reproductive success and the impact of MHC on mate choice is done in collaboration with Dr. David Coltman from the University of Alberta. Furthermore, we are collaborating with Katherine Wynne-Edwards on behavioural endocrinology with main emphasis on stress hormones and reproductive output. We also continue studies of behavioural syndromes (or animal personalities) in ground squirrels. Another project on the Columbian ground squirrels focuses on reasons, costs, and benefits of multiple mating in females and on the mechanisms leading to sex bias in dispersal of these animals. Finally we use the long-term data collected in the last two decades to understand an individual's impact on population dynamics.

<u>Patterns and Consequences of Parasitism in Small Mammals</u> (Patterson, Jesse. PhD student, Department of Biological Sciences, University of Calgary. Supervisor: Kathreen Ruckstuhl)



I am interested in the relationships between hosts and their parasites, and more specifically, in the role that parasites play in shaping host life-histories. A partial suite of small mammals (red squirrels, flying squirrels, chipmunks, ground squirrels, voles) available for study in the Kananaskis is used to approach the research questions, with most emphasis being on red squirrels. To establish the costs associated with parasitism, experimental removal of parasites are conducted to assess the effects of this treatment on adult body condition, reproductive success, survival, and behavior. Potential mechanisms (behavior, movements, hormones, host characters) behind observed patterns of parasitism in wild host populations are also being investigated. Work is also done with the Canadian Cooperative Wildlife Health Centre to monitor infectious diseases in this part of Alberta where rodents can serve as potential disease reservoirs with ectoparasite vectors (i.e. Lyme disease, plague). The hope is that this work will lead to improved wildlife management approaches and a better understanding of the factors that can lead to the pread and maintenance of disease. This project will also contribute to a more integrative understanding of the role of parasites in the evolution and expression of host life-history traits.

<u>Behavioural Ecology of Large Ungulates</u> (Ruckstuhl, Kathreen. Associate Professor, Department of Biological Sciences, University of Calgary)

My group's research focuses on the behavioural ecology of ungulates, particularly Rocky Mountain bighorn sheep and elk. Work on various topics ranges from how parasites affect mate choice, life-history traits, and how parasites and diseases are transmitted between individuals within social groups. Other research investigates parasites in urban coyotes in Calgary, how parasites affect life-history traits in red squirrels, and how/to what extent bighorn sheep and deer species use social cues and information to avoid predation. The study sites range from Sheep River Provincial Park (long-term focal study on bighorn sheep), north to Canmore (study on human disturbance and parasites on elk) and south to the border with Waterton National Park (study on Johnes disease and how it is transmitted between bighorn sheep). In all these studies, a behavioural ecology approach is used, in which we try and find answers to why animals behave the way they do.

Mate Choice in Rocky Mountain Bighorn Sheep (Ruckstuhl, Kathreen. Associate Professor, Department of Biological Sciences, University of Calgary)

The study is focused on mate choice behaviour in bighorn sheep. Emphasis will be placed on identifying whether or not bighorn mate choice is based on genes found within the major-histocompatibility complex.

Auburn University

The Behavioural Ecology of Columbian Ground Squirrels (Dobson, Stephen. Professor, Department of Biological Sciences, Auburn University)

The Columbian ground squirrel is an ideal model for studying a variety of questions central to the evolution of behaviour and life histories. There is a long-term study of a marked population that dates back to 1992. Along with microsatellite DNA analyses of paternity, there is a nearly complete pedigree that includes both known mothers and fathers that is now 6 generations deep and lifetime survival and reproduction for over 100 individuals. The fitness advantage of cooperation among females that are close kin (viz., genetic benefits of kin selection) and both selection on and heritability of the trade-off of offspring number and size are being studied. Sexual selection via measures of reproductive success of adult males and females is also being studied. Studies of evolution of life histories by natural selection are difficult in the wild, but because we can monitor the ground squirrels individually and closely, we are able to measure, for example, evolutionary responses to environmental factors like climate change.

The Presence and Influence of Incest on Fitness in Columbian Ground Squirrels (*Urocitellus columbianus*) (Klase, Carrie. MSc Student, Department of Biological Sciences, Auburn University. Supervisor: Stephen Dobson)

Columbian ground squirrels are unusual in that both immigrant and natal resident males are available to females as mates. With avoidance of inbreeding so ubiquitous among mammalian species, why do males of this species risk inbreeding by staying in the area of their birth when they are breeding adults? It is possible to ascertain rates of inbreeding in this species, measured in matrilineal and patrilineal pedigrees (the latter estimated via microsatellite DNA analyses). We compare actual rates of inbreeding to models based on alternative dispersal patterns and mating systems (the ground squirrels have multiple mating by both sexes, a condition termed "polygynandry"). This evidence should reveal the fitness costs for males that settle where they were born as adults, and thus have increased chances to breed with close female relatives.

To Breed, or Not To Breed? Early breeding and Population density and their effect on Individual fitness in Columbian Ground Squirrels (Rubach, Kristin. MSc Student, Department of Biological Sciences, Auburn University. Supervisor: Stephen Dobson)

One of the most fundamental principles of population ecology is that earlier breeding has a strong effect on population growth; this is called "Cole's principle" after its discoverer, Lamont Cole. In earlier work, Neuhaus and Dobson (BGI researchers) found evidence contrary to Cole's principles in Columbian ground squirrels. Now, in a more detailed examination, we are studying that application of Cole's principle: when it works and when it doesn't. The conditions under which Cole's principle fails to apply has far reaching implications for population management and conservation programs. Successful analysis of the operation of Cole's principle requires accurate measures of evolutionary fitness and long-term data. We are applying advanced techniques of matrix algebra to the analysis of population growth of Columbian ground squirrels, while continuing long-term monitoring of populations

University of Saskatchewan

<u>Evolutionary Ecology of Columbian Ground Squirrels</u> (Lane, Jeff. Assistant Professor, Department of Biology, University of Saskatchewan)

We are 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).

Université de Sherbrooke

<u>Comparative Population Dynamics and Life-History Strategies of Large Herbivores</u> (Festa-Bianchet, Marco. Professor, Départemente de biologie, Université de Sherbrooke; Collaborative with Ruckstuhl, Hogg, and Pelletier)

The results of the long-term monitoring of marked bighorn sheep at Sheep River, near the R.B. Miller Biological Station, are being increasingly used in conjunction with similar long-term programs at Ram Mountain, Alberta (bighorn sheep) and Caw Ridge, Alberta (mountain goats) and with other programs in Europe (roe deer, chamois, red deer) to examine the factors affecting population dynamics. In all cases, these unique high-quality data allow a complete breakdown of the relative contributions to population growth of each sex-age class, including their relative magnitude and the extent of year-to-year variability. Generally, this research shows that under different circumstances, different sex-age classes and different parameters (survival, reproduction) can be the main drivers of population growth. While small changes in the survival of adult females can have drastic effects on population growth, differences in juvenile survival have a relatively lower impact, although the latter in many cases is the main source of yearly changes in population growth rate. Presence or absence of predators and changes in weather can also affect population growth rate, often in interaction with population density.

Long-term monitoring of marked individuals allows us to examine how population density, age, and previous reproductive success affect the ability of individuals to contribute to recruitment. For males, recent research has shown the importance of social dominance in affecting both the individual reproductive success and the choice of mating tactics.

<u>The Evolutionary Consequences of Selective Hunting</u> (Festa-Bianchet, Marco. Professor, Département de biologie, Université de Sherbrooke)

Many large mammals are managed through trophy hunting, where males with large body size, horns, or antlers are the preferred target, creating an artificial selective pressure that is opposite to natural selection. Our work on bighorn sheep, for example, shows that a ram with rapidly-growing horns would enjoy a substantial mating benefit if it survived to 7-8 years of age and would become a dominant individual, but in hunted areas those large horns substantially increase its risk of being shot at 4-5 years of age. Because the 'cost' through hunting occurs earlier than the 'benefit' through matings, hunting favours the reproductive success of small-horned rams and eventually selects for small horns. Unfortunately, genetic correlations may result in artificial selection for low-quality individuals. Our work in collaboration with David Coltman at the University of Alberta suggests that large-horned rams also have genetic traits favouring large body size and higher reproductive success in their descendants of both sexes. We are currently pursuing this investigation through genetic rescue of the Ram Mountain population, which has undergone decades of artificial selection through trophy hunting, and several large-scale analyses of horn growth data under different management regimes.

Strasbourg, France

<u>Colombian Ground Squirrels and the Cost of Social Living</u> (Viblanc, Vincent. Permanent researcher, CNRS, IPHC, Department of Ecology, Physiology and Ethology, Strasbourg, France)

We study 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.

Research Publications

<u>2016</u>

N. O. Aksamit and Pomeroy, J. W., "**Near-surface snow particle dynamic from particle tracking velocimetry and turbulence measurements during alpine blowing snow storms**", *The Cryosphere*, 2016.

E. F. Baerwald and Barclay, R. M. R., "**Are migratory behaviours of bats socially transmitted?**", *The Royal Society*, 2016.

L. R. Bentley, Hayashi, M., Zimmermann, E. P., Holmden, C., and Kelley, L. I., "**Geologically controlled bi-directional exchange of groundwater with a hypersaline lake in the Canadian prairies**", *Hydrogeology*, 2016.

L. D. Harder, Aizen, M. A., Richards, S. A., Joseph, M. A., and Busch, J. W., "**Diverse ecological relations of male gametophyte populations in stylar environments** ", *American Journal of Botany*, 2016.

E. Johnson, Martin, Y**., "Coastal dunes and vegetation dynamics"**, In Johnson and Martin (eds) *Ecosystems: A Biogeoscience Approach*, Cambridge University Press, 2016.

E. Johnson, Martin, Y**.,** *Ecosystems: A Biogeoscience Approach*, Cambridge University Press, 2016.

T. M. J. Luszcz, Rip, J. M. K., Patriquin, K. J., Hollis, L. M., Wilson, J. M., Clarke, H. D. M., Zinck, J., and Barclay, R. M. R., "**A blind-test comparison of the reliability of using external morphology and echolocation-call structure to differentiate between the Little Brown Bat (Myotis Lucifugus) and Yuma Myotis (Myotis Yumanensis)**", *Northwestern Naturalist*, 2016.

D. A. Lyons and Vinebrooke, R. D., "**Linking zooplankton richness with energy input and insularity along altitudinal and latitudinal gradients**", *Limnology and Oceanography*, 2016.

A. Mozil, "**A Geophysical Investigation of a Rock Glacier in the Canadian Rockies**", 2016.

R. Rothwell, Hillman, G., and Pomeroy, J. W., "**Marmot Creek Experimental Watershed Study**", *The Forestry Chronicle*, vol. 92, 2016.

S. Strohm, Reid, M. L., and Tyson, R. C., "**Impacts on management on mountain pine beetle spread and damage: A process-rich model**", *Ecological Modelling*, 2016.

M. A. Walvoord and Kurylyk, B. L., "**Hydrologic impacts of thawing permafrost- a review**", *Vadose Zone Journal*, 2016.

X. Wang, Westbrook, C., and Bedard-Haughn, A., "**Effect of mineral horizons on spatial distribution of soil properties and N cycling in a mountain peatland**", *Geoderma*, 2016.

C. J. Westbrook and Bedard-Haughn, A., "**Sibbald Research Wetland: Mountain peatland form and ecohydrologic function as influenced by beaver**", *The Forestry Chronicle*, vol. Vol. 92, 2016.

K. L. Wilson, Cantin, A., Ward, H. G. M., Newton, E. R., Mee, J. A., Varkey, D. A., Parkinson, E. A., and Post, J. R., "**Supply-demand equilibria and the size-number trade-off in spatially structured recreational fisheries**", *Ecological Society of America*, 2016.

2015

Y. Alammari, Sanati, M., Freiheit, T., and Park, S. S., "**Investigation of boring bar dynamic for chatter suppression**", *Procedia Manufacturing*, 2015.

S. Bellaire, Jamieson, B., Thumlert, S., Goodrich, J., and Statham, G., "**Analysis of long-term weather, snow and avalanche data at Glacier National Park, B.C., Canada**", *Cold Regions Science and Technology*, 2015.

J. M. Bishop, Callaghan, M. V., Cey, E. E., and Bentley, L. R., "**Measurement and simulation of subsurface tracer of migration to tile drain in low permeability, macroporous soil**", *American Geophysical Union*, 2015.

A. P. Booterbaugh, Bentley, L. R., and Mendoza, C. A., "**Geophysical characterization of a undrained dyke containing an oil sands tailings pond, Alberta, Canada** ", *GeoScience World*, 2015.

J. M. Buttle, Allen, D. M., Caissie, D., Davidson, B., Hayashi, M., Peters, D. L., Pomeroy, J. W., Simonovic, S., St-Hilaire, A., and Whitfield, P. H., "**Flood processes in Canada: Regional and special aspects**", *Canadian Water Resources Journal*, 2015.

A. Cunnings, Johnson, E.A., Martin, Y**.**, **"Fluvial seed dispersal of riparian trees: transport and depositional processes**". *Earth Surface Processes and Landforms*, DOI: 10.1002/esp.3, 2015

S. Liccioli, "**Assessing individual patterns of Echinococcus multilocularis infection in urban coyotes: non-invasive genetic sampling as an epidemiological tool**", *Journal of Applied Ecology*, 2015.

S. Liccioli, Rogers, S., Greco, C., Kutz, S. J., Chan, F., Ruckstuhl, K. E., and Massolo, A., "**Assessing individual patterns of Echinococcus multiocularis infection in urban coyotes: non-invasive genetic sampling as an epidemiological tool**", *Journal of Applied Ecology*, 2015.

S. Liccioli, Bialowas, C., Ruckstuhl, K. E., and Massolo, A., "**Feeding Ecology Informs Parasite Epidemiology: Prey Selection Modulates Encounter Rate with Echinococcus multilocularis in Urban Coyotes**", *PLoS ONE*, 2015.

M. M. Maclennan, Dings-Avery, C., and Vinebrooke, R. D., "**Invasive trout increase the climatic sensitivity of zooplankton communities in naturally fishless lakes**", *Freshwater Biology*, 2015.

K. J. Painter, Westbrook, C. J., Hall, B. D., O'Driscoll, N. J., and D.Jardine, T., "**Effects of in-channel beaver impoundments on mercury bioaccumilation in Rocky Mountain stream food webs**", *Ecological Society of America*, 2015.

J. E. H. Patterson, Neuhaus, P., Kutz, S. J., and Ruckstuhl, K. E., "**Patterns of ectoparasitism in North American red squirrels (Tamiasciurus hudsonicus): Sex-biases, seasonality, age, and effects on male body condition**", *International Journal for Parasitology*, vol. 4, p. 301 to 306, 2015.

S. Raveh, Neuhaus, P., and Dobson, F. S., "**Ectoparasites and fitness of female Columbian ground squirrels**", *Philosophical Transactions B*, vol. 370, 2015.

S. Schindler, Gaillard, J., Gruning, A., Neuhaus, P., Lochran, W. T., Tuljapurkar, S., and Coulson, T., "**Sex-specificdemography and generalization of the Trivers-Willard theory**", *Nature*, 2015.

S. J. Schreiber, Rosenheim, J. A., Williams, N. W., and Harder, L. D., "**Evolutionary and Ecological Consequences of Multiscale Variation in Pollen Receipt for Seed Production.**", *The American Naturalist*, vol. 185, no. 1, p. E14 to E29, 2015.

C. A. Tabacaru and Erbilgin, N., “**Competitors and natural enemies may cumulatively mediate Dendroctonus ponderosae colonization of burned Pinus forests**”, *Forest Ecology and Management*, vol. 337, p. 98 to 109, 2015.

C. A. Tabacaru, McPike, S. M., and Erbilgin, N., “**Fire-mediated interactions between a tree-killing bark beetle and its competitors**”, *Forest and Ecology Management*, 2015.

Y. I. Takashi, Harder, L. D., and Kudo, G., “**The consequences of demand-driven seed provisioning for sexual differences in reproductive investment in Thalictrum occidentale (Ranunculaceae)**”, *Journal of Ecology* , vol. 103, p. 269 to 280, 2015.

A. Tamminga, Eaton, B. C., and Hugenholtz, C., “**UAS-based remote sensing of fluvial change following an extreme flood event**”, *Earth Surface Processes and Landforms*, 2015.

J. Telling, Boyd, E. S., Bone, N., Jones, E. L., Tranter, M., MacFarlane, J. W., Martin, P. G., Wadham, J. L., Lamarche-Gagnon, G., Skidmore, M. L., Hamilton, T. L., Hill, E., Jackson, M., and Hodgson, D. A., “**Rock comminution as a source of hydrogen for subglacial ecosystems**”, *Nature Geoscience*, 2015.

L. M. Wake and Marshall, S. J., “**Assessment of current methods of positive degree-day calculation using in situ observations from glaciated regions**”, *Journal of Glaciology*, 2015.

V. Wasiuta, Lafreniere, M. J., and Norman, A., “**Atmospheric deposition of sulfur ad inorganic nitrogen in the Southern Canadian Rocky Mountains from seasonal snowpacks and bulk summer precipitation**”, *Journal of Hydrology*, 2015.

V. L. Wasiuta, Lafreniere, M. J., and Norman, A. - L., “**Atmospheric deposition of sulfur and inorganic nitrogen in the Southern Canadian Rocky Mountains from seasonal snowpacks and bulk summer precipitation**”, *Journal of Hydrology*, vol. 523, p. 563 to 573, 2015.

C. S. Willisch, Biebach, I., Marreros, N., Ryser-Degiorgis, M. P., and Neuhaus, P., “**Horn Growth and Reproduction in a Long-Lived Male Mammal: No Compensation for Poor Early-Life Horn Growth**”, *Evolutionary Biology*, vol. 42, p. 1 to 11, 2015.

2014

R. Boonstra, “**Equipped for life in the boreal forest: the role of the stress axis in mammals**”, *Arctic*, 2014.

R. Boonstra, Mo, K., and Monks, D. A., “**Managing anabolic steroids in pre-hibernating Arctic ground squirrels: obtaining their benefits and avoiding their costs**”, *Biology Letters*, vol. 10, no. 11, 2014.

M. V. Callaghan, Cey, E. E., and Bentley, L. R., “**Hydraulic conductivity dynamics during salt leaching of sodic, structured subsoil**”, *Soil Physics*, 2014.

A. L. Hargreaves, “**Are Species' Range Limits Simply Niche Limits Writ Large? A Review of Transplant Experiments beyond the Range**”, *The American Naturalist*, vol. 183, no. 2, 2014.

A. L. Hargreaves, “**Evolution of dispersal and mating systems along geographic gradients: implications for shifting ranges**”, *Functional Ecology*, vol. 28, no. 1, p. 21, 2014.

A. A. Harpold, “**LiDAR-derived snowpack data sets from mixed conifer forests across the Western United States**”, 2014.

U. Hoffmann, Hoffmann, T., Johnson, E. A., and Kuhn, N. J., "**Assessment of variability and uncertainty of soil organic carbon in a mountainous boreal forest (Canadian Rocky Mountains, Alberta)**", *Catena*, vol. 113: 107-121, 2014.

J. L. Hood and Hayashi, M., "**Characterization of snowmelt flux and groundwater storage in an alpine headwater basin**", *Journal of Hydrology*, 2014.

Le. Lachowsky and Reid, M. L., "**Developmental mortality increases sex-ratio bias of a size-dimorphic bark beetle**", *Ecological Entomology*, 2014.

S. F. Lamoureux and Lafreniere, M. J., "**Seasonal fluxes and age of particulate organic carbon exported from Arctic catchments impacted by localized permafrost slope disturbances**", *Environmental Research Letters*, vol. 9, no. 10, 2014.

W. - J. Liao and Harder, L. D., "**Consequences of multiple inflorescences and clonality for pollinator behavior and plant mating**", *The American Naturalist*, vol. 184, no. 5, p. 580 to 592, 2014.

S. Liccioli, "**Spatial heterogeneity and temporal variations in Echinococcus multilocularis infections in wild hosts in a North American urban setting**", *International Journal for Parasitology*, 2014.

N. Lobo, "**Conifer seed predation by terrestrial small mammals: A review of the patterns, implications, and limitations of top-down and bottom-up interactions**", *Forest Ecology and Management*, vol. 328, p. 45 to 54, 2014.

C. E. Prescott, "**The scientific value of long-term field trials in forest soils and nutrition research: an opportunist's perspective**", *Canadian Journal of Soil Science*, vol. 94, pp. 1-8, 2014.

E. M. Quartero, Leier, A. L., Bentley, L. R., and Glomick, P., "**Basin-scale stratigraphic architecture and potential Paleocene distributive fluvial systems of the Cordilleran Foreland Bain, Albert, Canada**", *Sedimentary Geology*, 2014.

S. Raveh, Neuhaus, P., and Dobson, F., "**Ectoparasites and fitness of female Columbian ground squirrels**", *The Royal Society*, 2014.

M. L. Reba, Marks, D., Link, T. E., Pomeroy, J. W., and Winstral, A., "**Sensitivity of model parameterizations for simulated latent heat flux at the snow surface for complex mountain sites**", *Hydrological Processes* , vol. 28: 868-881, 2014.

A. W. R. Seddon, "**Looking forward through the past: identification of 50 priority research questions in palaeoecology**", *Journal of Ecology*, vol. 102: 256-267, 2014.

A. Tamminga, "**Hyperspatial remote sensing of channel reach morphology and hydraulic fish habitat using an unmanned aerial vehicle (UAV): A first assessment in the context of river research and management**", *River Research and Applications*, 2014.

J. Zhou, Pomeroy, J. W., Zhang, W., Cheng, G., Wang, G., and Chen, C., "**Simulating cold regions hydrological processes using a modular model in the west of China**", *Journal of Hydrology*, vol. 509: 13-24, 2014.

PROMOSCIENCE UNIT: EDUCATION PROGRAMS

The education program continues to strive 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 want to push participants to uncover links between scientific concepts and to bridge the gap between different disciplines, while learning research skills such as: formulating a good question, experimental design, data presentation, analysis, drawing results and identifying future research to pursue. We engage learners in an innovative inquiry program that allows participants 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; to develop and foster scientific literacy; 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 runs five main programs geared towards high school science. They focus on aquatic, forest and winter ecosystems, depending on the season.

Biology 20 Ecosystem Inquiry Research Program

- Students use an open inquiry model to investigate processes taking place in aquatic, forest or winter ecosystems. Briefly, students explore a novel environment, then develop and test a scientific question. 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 data and ultimately finish with a poster and/or paper outlining their research and conclusions.
  This program is geared towards International Baccalaureate (IB) or Advanced Placement (AP) students who are interested in careers in a scientific field. 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

These programs begin with fine-tuning students' ability to create *testable* scientific questions to investigate. 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.

AP Chemistry 20/30 Research Project

- A one-and-a-half-year science inquiry program beginning in AP Chemistry 20, spanning 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 environmental science programs was a student exchange between William Aberhart High School and two schools from the Netherlands. After participating in our field program, all of the students chose a topic of study related to freshwater. These students then presented at an international conference in Amsterdam: Water is Life.

Junior High Programs

BGI also offers three Junior High programs that introduce scientific concepts like ecosystems, biodiversity, and biomes. These programs integrate environmental science with outdoor experiences such as snowshoeing and snow studies, building snow shelters, and predator-prey simulations.

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 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 role-playing 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 and how they can affect/be affected by biological diversity.



Education Programs

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.

SEDV 625 Introduction to a Research Project

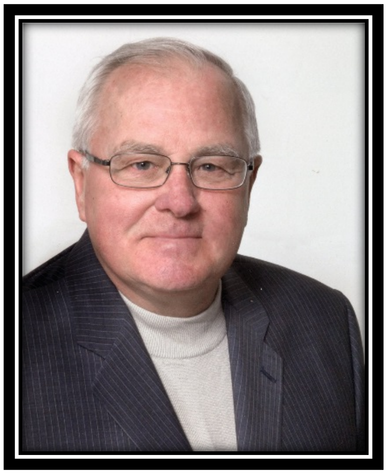
- A multi day seminar geared towards facilitating students’ research projects for the Sustainable Energy Development Masters Program. Because students in this program come from a range of educational backgrounds, this field trip was developed to ensure that every student is up to date on asking and testing 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 Field Weekend

- A field trip focusing on how to bring STEM concepts to your classroom. This field trip exposes beginning teachers to teaching in a laboratory and to 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 and school departments, Education staff have presented workshops at the Edmonton Public School Board's Career Pathways Learning Day and at the National Association of Biology Teachers (NABT) annual conference in Denver, Colorado. Recently, staff submitted an article about inquiry education for a special edition of the Alberta Science Education Journal. We are also working with staff from the *Understanding Science* team at the University of California, Berkeley's Museum of Paleontology, to submit an article for the Bulletin of the Ecological Society of America. As a part of this project, school program coordinator, Sue Arlidge, joined the advisory committee for a new Beta version of the *Understanding Science* model and the new *Understanding Global Change* model.

The renovations at BGI have provided an opportunity for the Education team to inventory and downsize from thirty years of education materials. 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.



Celebrating decades in the field: John (Jack) S. Millar

In the fall of 2015, the Barrier Lake field station had the privileged of hosting the "Mousers' Reunion". Twenty one of Dr. Millar's grad students, spanning from his first student in 1979 to his last student in 2013, attended the celebratory weekend.

REUNION LIST. Left to right: Name, degree, study location, year, (current address). Jennifer Smith, MSc, Kananaskis, 2008, (Montreal); Kristine Sare (nee Kasparian), MSc, Kananaskis, 2003, (Calgary); Dave Sare, MSc, Kananaskis, 2004, (Calgary); Crisia Tabacaru, MSc, Kananaskis, 2009, (Edmonton); Nikhil Lobo, PhD, Kananaskis, 2013, (Calgary); Emily Herdman, PhD, Kananaskis, 2005, (Edmonton); Dr. John Miller; Les Gyug, MSc, Heart Lake NWT, 1979 (Kelowna); Elissa Derrickson, PDF, Kananaskis, 1989, (Baltimore ML); David Ribble, PDF, Kananaskis, 1992, (San Antonio TX); Andrew McAdam, MSc, Kananaskis, 1998, (Guelph); Graham Hickling, PhD, Kananaskis, 1987, (Knoxville, TN); Laurel Duquette, PhD, Mexico, 1992, (Toronto); Jon Falk, MSc, Kananaskis, 1985, (Colorado); Richard Moses, PhD, Kananaskis, 1992, (Edmonton); Sean Sharpe, MSc, Kananaskis, 1985, (Smithers); Matina Kalcounis-Rueppell, PhD, Hastings CA, 2000, (Greensboro, NC); Jim Schieck, MSc, Kananaskis, 1984, (Vegreville); Albrecht Schulte-Hostedde, PhD, Kananaskis, 2001, (Sudbury); Neala MacDonald, MSc, Kananaskis, 1997, (Edmonton); Not pictured: Val Loewen, MSc, Kananaskis, 1985, (Whitehorse); Rick Harland, MSc, Ontario, 1978, (Calgary)

Dr. Millar spent over three decades on small mammal field research. His affiliation with the field statin began, in 1968, as a PhD. student at the RB Miller field station (University of Alberta) and continued with his distinguished field research at the Barrier Lake field station as a professor at Western University. Jack also taught one of the first field courses at the station, starting in 1979, called "Alpine Ecology" designed for 12 or 16 students. The course was one of Westerns offerings through the Ontario Universities Program in Field Biology (OUPFB) and had students from several Ontario universities each year. The course ran nearly continuously until 2011.

The Barrier Lake field station is pleased to house the compilation of Jack's trapping data and pass on the data to interested students or professors (contact the Research Coordinator). A summary of their findings can be found in the below article "Trapping Data for Mice and Voles, Kananaskis, Alberta".

Furthermore, Jack has provided a wonderful account of his many years in the field in the delightful article titled "My Last Field Season". In his retirement, Jack continues to visit the field each year to the delight of the field station staff. We sincerely appreciate his ongoing support, historic recollection of the field stations, and the endless stories that continue to amuse the staff.

TRAPPING DATA FOR MICE AND VOLES, KANANASKIS, ALBERTA

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Introduction

The eastern slopes of the Canadian Rocky Mountains are characterized by short summer seasons, relatively low precipitation in the rain-shadow of the main Rocky Mountains, and periodic winter thaws due to Chinook weather inversions. Within this zone, the Kananaskis Valley has a rich fauna due to diverse habitats over elevational gradients and post-glacier history. Eight species of mice and voles are found there. These and other small mammals in the Kananaskis Valley have been studied intensively for the past several decades, usually involving short-term projects to test specific hypotheses about life history strategies and behavioural ecology. Population-level studies have been conducted using accumulated data from multiple projects. In 2013 we initiated a compilation of trapping data from all mouse and vole projects 1983-2011 into a standard format. Here we present the results of that compilation.

Methods

Most grid were located along ephemeral stream beds with rocky substrates, prime habitats for deer mice (Millar et al. 1985); the Sibbald grid was the only one located in mature forest, the primary habitat for red-backed voles.Trapping protocols involved standard procedures; Longworth traps baited with oats and sunflower seeds on grids with 15 or 20m spacing. However, trapping frequencies were not typical of most small mammal studies. Rather than trapping for 2-3 nights on 3 or 4 week rotations as in most population studies, trapping was typically conducted for one night every 3-4 days. This permitted close monitoring of individuals and the construction of individual phenologies that could identify (within days) dates of parturitions for adult females, and dates of emergence and maturation of young.

Typically, only one species (the subject of the project) was tagged on each grid each year. Individuals were marked with two ear tags to track individuals that lost a tag. At capture, each tagged animal was weighed and sex, age (juvenile or adult), and reproductive condition noted. Grid coordinates were recorded for all captures. Non-target species were recorded, but only by species and grid coordinates. In all cases, grid sizes were calculated by the boundary strip inclusive method, adding one half trap spacing to all sides of each grid.

For this compilation, all data were organized into 3 files.

i. Live trapping files. The live trapping file includes all data recorded in the field for each trapped individual, including data for non-target (by-catch) species, for each day, grid, and year.

ii. Phenology files. The phenology files represent the compiled data for tagged individuals over each trapping season.

iii. Reconstructed files. Phenology data summed over all years for individuals.

Results

A summary of the data files is presented in Table 1. All publications are listed in Appendix I and all theses are listed in Appendix II. All theses are available in the Barrier Lake Field Station, Biogeosciences Institute, University of Calgary. Over all years, grids were located at 8 different locations, 1350-1650 m asl over 35 km in the valley. Number of grids trapped per year ranged from 2-5.The live trapping files include non-target by-catch species for most grid/years, except for those where the original live trapping data records were not available. In those cases, live trapping files were derived from phenology files and by-catch data are missing.

The majority of phenologies are for deer mice (*Peromyscus maniculatus*) (N=65 grid years) reflecting the primary focus on deer mice for most projects. Red-backed voles (*Myodes gapperi*) were tagged for only 27 grid years. By-catch data provide relative abundances of non-target mice and voles, including long-tailed voles (*Microtus longicaudus*), meadow voles (*Microtus pennsylvanicus*), heather voles (*Phenacomys intermedius*), jumping mice (*Zapus princeps*), as well as yellow pine chipmunks (*Eutamias amoenus*) and occasional other species.

Further insights

Besides standard population analyses, these data are suitable for documenting detailed life histories of individuals because of the frequent monitoring of individuals, including assigning emerged young to specific females in some cases (Millar and Derrickson 1992), estimating nest mortality (Millar et al. 1994), and estimating age at maturation (Teferi and Millar 1993, McAdam and Millar 1999). There is an art to making these determinations from trapping data, requiring a close examination of annual phenologies. The data files recorded here are raw files and have not been corrected to reconstruct detailed phenologies from the original data.

Growth rates: Another area for future examination involves growth of young in the wild. Condition of young at weaning is potentially an important indicator of their future success. Because we trapped every few days, and sometimes tracked females to their nest locations with intense trapping 3 weeks after parturition, we were confident that first captures of YY occurred very close to weaning, although some YY at first capture were too heavy to be placed in that category. Previously, based on growth rates in the lab and a maximum of about 12gm when feeding independently at about 18 days of age, we chose 12 gm or less at first capture to represent mass at weaning in the field and used this as a proxy for YY condition in the field. Those greater than 12 gm at first capture were considered to have missed capture when they first emerged from the natal nest.

However, an alternative use of the data is to examine growth rates per se as an indicator of condition. Towards this end, we selected 15 *Pm* and 9 *Mg* that were 12 gm or less at first capture and had 7 or more captures (range 7-19) over the summer, and calculated growth rates. These data were "clean" without obvious transcription errors and all regressions were significant. Average growth rates of *Pm* (0.123 g/day; range 0.04-0.19) were similar to average growth rates of *Mg* (0.125 g/day; range 0.04-0.0.25).

Linear regression best explained growth for 12 of 15 *Pm*, while log-log regression best explained growth for 7 of 9 *Mg*. Thus, either regression model is likely appropriate, with growth rates (linear) or intercepts (log-log) serving as a potential proxies for YY condition.

By-catch species: By-catch species were not tagged and the data are not suitable for standard population analyses. However, captures and releases were recorded and cumulative capture/releases over each grid year may provide a proxy for abundance. To pursue this idea, we examined cumulative captures vs Cormack-Jolly-Seber estimates of population abundance at the end of each season for deer mice over 15 grid/years. The correlation was high (R^2 = 0.82), supporting the idea. Hence it might be possible to investigate interactions between low-density species such as long-tailed voles and heather voles using cumulative capture/releases as a proxy for abundance.

Table 1. Summary of the Kananaskis data files. Some grid years were deemed unsuitable for most analyses (such as 2001 Sibbald) because trapping was sporadic. Such files are in the data but not included here.

Year	Grid	Grid Size	Species Tagged	By-catch
1985	Fortress	4.4	Pm	No
1985	Grizzly	2.6	Pm	No
1986	Fortress	4.4	Pm	No
1986	Grizzly	2.6	Pm	No
1987	Fortress	4.4	Pm	No
1987	Grizzly	3.8	Pm	No
1988	Fortress	4.4	Pm	No
1988	Grizzly	3.8	Pm	No
1989	Fortress	4.4	Pm	Yes
1989	Grizzly	3.8	Pm	Yes

1989	Mount Kidd	2.9	Pm	No
1989	Mouse Gulch	3.8	Pm	No
1990	Fortress	4.4	Pm	Yes
1990	Grizzly	3.8	Pm	Yes
1990	Mouse Gulch	3.8	Pm	No
1991	Fortress	4.4	Pm	Yes
1991	Grizzly	3.8	Pm	Yes
1991	Village	3.5	Pm	No
1992	Fortress	4.4	Pm	Yes
1992	Grizzly	3.8	Pm	Yes
1992	Mount Kidd	3.1	Pm	Yes
1992	Mouse Gulch	3.8	Pm	Yes
1992	Village	3.5	Pm	Yes
1993	Fortress	4.4	Pm	No
1993	Grizzly	3.8	Pm	No
1994	Fortress	4.4	Pm	Yes
1994	Grizzly	3.8	Pm	Yes
1995	Fortress	4.4	Pm	Yes
1995	Grizzly	3.8	Pm	Yes
1996	Fortress	4.4	Pm	Yes
1996	Grizzly	3.8	Pm	No
1996	Mount Kidd	3.1	Pm	No
1996	Village	3.5	Pm	No
1997	Fortress	4.4	Pm	No
1997	Grizzly	3.8	Pm	Yes
1997	Mount Kidd	3.1	Pm	Yes
1997	Village	3.5	Pm	Yes

1998	Grizzly	4.8	Pm	Yes
1998	Mount Kidd	3.85	Pm	Yes
1998	Village	4.2	Pm	No
1999	Mount Kidd	3.85	Pm	Yes
1999	Village	4.2	Pm	Yes
2000	Fortress	1.8	Mg	No
2000	Grizzly	4.8	Mg	No
2000	Mount Kidd	3.85	Pm	Yes
2000	Village	4.2	Pm	Yes
2001	Lorette	2.8	Pm	No
2002	Fortress	1.8	Mg	No
2002	Grizzly	1.68	Pm	No
2002	Lorette	2.8	Mg	No
2002	Sibbald	2.4	Mg	No
2003	Grizzly	1.68	Pm	No
2003	Lorette	2.8	Pm	No
2003	Sibbald	2.4	Mg	No
2004	Fortress	1.4	Pm	No
2004	Grizzly	1.68	Pm	No
2004	Sibbald	2.4	Mg	No
2005	Fortress	1.4	Pm	Yes
2005	Grizzly	1.68	Pm, Mg	Yes
2005	Sibbald	2.4	Mg	Yes
2006	Fortress	1.4	Pm, Mg	Yes
2006	Grizzly	1.68	Pm	No
2006	Sibbald	2.4	Pm, Mg	Yes
2007	Fortress	1.4	Pm, Mg	Yes

2007	Grizzly	1.68	Pm, Mg	Yes
2007	Sibbald	2.4	Pm, Mg	Yes
2008	Fortress	1.4	Pm, Mg	Yes
2008	Grizzly	1.68	Pm, Mg	Yes
2008	Sibbald	2.4	Pm, Mg	Yes
2009	Fortress	1.4	Pm, Mg	Yes
2009	Grizzly	1.68	Pm, Mg	Yes
2009	Sibbald	2.4	Pm, Mg	Yes
2010	Fortress	1.4	Pm, Mg	Yes
2010	Grizzly	1.68	Pm, Mg	Yes
2010	Sibbald	2.4	Pm, Mg	Yes
2011	Fortress	1.4	Pm, Mg	Yes
2011	Grizzly	1.68	Pm, Mg	Yes
2011	Sibbald	2.4	Mg	Yes

APPENDIX I: ALL PUBLICATIONS in chronological order

1. Millar, J.S. 1970. The breeding season and reproductive cycle of the western red squirrel. Can. J. Zool. 43:471-473.
2. Millar, J.S. 1970. Variations in fecundity of the red squirrel, *Tamiasciurus hudsonicus* (Erxleben). Can. J. Zool. 48:1055-1058.
3. Millar, J.S. 1970. Adrenal weights in relation to reproductive status in the pika, *Ochotona princeps* (Richardson). Can. J. Zool. 48:1137-1140.
4. Millar, J.S. and F.C. Zwickel. 1972. Determination of age, age structure and mortality of the pike (*Ochotona princeps* (Richardson)). Can. J. Zool. 50:229-232.
5. Millar, J.S. 1972. Timing of breeding in pikas in southwestern Alberta. Can. J. Zool. 50:665-669.
6. Millar, J.S. and F.C. Zwickel. 1972. Characteristics and ecological significance of hay piles of pikas. Mammalia 36:657-667.
7. Millar, J.S. 1973. Evolution of litter size in the pika. Evolution 27:134-143.
8. Millar, J.S. and S.C Tapper. 1973. Growth rates of pikas in Alberta. Canadian Field Naturalist 87:457-459.
9. Millar, J.S. 1974. Success of reproduction in pikas, *Ochotona princeps* (Richardson). J. Mammal. 55:527-542.
10. Millar, J.S. 1975. Tactics of energy partitioning in breeding *Peromyscus*. Can. J. Zool. 53:967-976.
11. Millar, J.S. and Iverson, S.L. 1976. Weight of the eye lens as an indicator of age in *Peromyscus*. Can. Field Nat. 90:37-41.
12. Millar, J.S. 1977. Adaptive features of mammalian reproduction. Evolution 31:370-386.
13. Millar, J.S. 1978. Energetics of reproduction in *Peromyscus leucopus*: the cost of lactation. Ecology 59:1055-1061.
14. Kiell, D.J. and J.S. Millar. 1978. Growth of juvenile arctic ground squirrels (*Spermophilus parryii*) at McConnell River, N.W.T. Can. J. Zool. 56:1475-1478.
15. Millar, J.S., F.B. Wille and S.L. Iverson. 1979. Breeding by *Peromyscus* in seasonal environments. Can. J. Zool. 57:719-727.

16. Millar, J.S. 1979. Energetics of lactation in *Peromyscus maniculatus*. Can. J. Zool. 57:1015-1019.
17. Harland, R.M., P.J. Blancher and J.S. Millar. 1979. Demography of a population of *Peromyscus leucopus*. Can. J. Zool. 57:323-328.
18. Innes, D.G.L. and J.S. Millar. 1979. Growth of *Clethrionomys gapperi* and *Microtus pennsylvanicus* in captivity. Growth 43:208-217.
19. Harland, R.M. and J.S. Millar. 1980. Activity of breeding *Peromyscus leucopus*. Can. J. Zool. 58:313-316.
20. Kiell, D.J. and J.S. Millar. 1980. Reproduction and nutrient reserves of arctic ground squirrels. Can. J. Zool. 58:416-421.
21. Newton, S.L., T.D. Nudds and J.S. Millar. 1980. Importance of aboreality in *Peromyscus leucopus* and *Microtus pennsylvanicus* interactions. Can. Field Nat. 94:167-170.
22. Gyug, L.W. and J.S. Millar. 1980. Fat levels in a subarctic population of *Peromyscus maniculatus*. Can. J. Zool. 58:1341-1346.
23. Gyug, L.W. and J.S. Millar. 1981. Growth of seasonal generations in three natural populations of *Peromyscus*. Can. J. Zool. 59:510-514.
24. Millar, J.S. 1981. Body composition and nutrient reserves of northern *Peromyscus leucopus*. J. Mammal. 62:786-794.
25. Millar, J.S. 1981. Prepartum reproductive characteristics of eutherian mammals. Evolution 35:1149-1163.
26. Innes, D.G.L. and J.S. Millar. 1981. Body weight, litter size and energetics of reproduction in *Clethrionomys gapperi* and *Microtus pennsylvanicus*. Can. J. Zool. 59:785-789.
27. Millar, J.S. and L.W. Gyug. 1981. Initiation of breeding by northern *Peromyscus* in relation to temperature. Can. J. Zool. 59:1094-1098.
28. Innes, D.G.L. and Millar, J.S. 1982. Demography of *Phenacomys intermedius*. Can. Field Nat. 96:307-311.
29. Millar, J.S. 1982. Life cycle characteristics of northern *Peromyscus maniculatus borealis*. Can. J. Zool. 60:510-515.
30. Kerr, D.C., C.D. Ankney and J.S. Millar. 1982. The effect of drying temperature on extraction of petroleum ether soluble fats of small birds and mammals. Can. J. Zool. 60:470-472.
31. Millar, J.S. and R.M. Zammuto. 1983. Life histories of mammals: an analysis of life tables. Ecology 64:631-635.
32. Millar, J.S. and D.G.L. Innes. 1983. Life cycle and demographic characteristics of montane *Peromyscus*. Can. J. Zool. 61:574-585.
33. Millar, J.S. 1983. Negative maternal effects in *Peromyscus maniculatus*. J. Mammal. 64:540-543.
34. Lightbody, J.P. and J.S. Millar. 1983. Morphological variation within populations of *Peromyscus maniculatus* from different geographic areas. Can. J. Zool. 61:934-936.
35. Vickery, W.L. and J.S. Millar. 1984. Energetics of huddling by endotherms. Oikos 43:88-93.
36. Moore, G.C. and J.S. Millar. 1984. A comparative study of colonizing and established eastern coyote populations. J. Wildlife Mgmt. 48:691-699.
37. Moore, G.C. and J.S. Millar. 1985. Food habitats and average weights of a fall-sample of eastern coyotes. Can. Field Nat. 100:105-106.
38. Zammuto, R.M. and J.S. Millar. 1985. A consideration of bet-hedging in *Spermophilus columbianus*. J. Mamm. 66:652-660.
49. Millar, J.S. 1985. Life cycle characteristics of *Peromyscus maniculatus nebrascensis*. Can. J. Zool. 63:1280-1284.
40. Millar, J.S., D.G.L. Innes and V.L. Loewen. 1985. Habitat use by non-hibernating small mammals of the Kananaskis Valley, Alta. Can. Field Nat. 99:196-204.
41. Schieck, J.O. and J.S. Millar. 1985. Alimentary tract measurements as indicators of diets of small mammals. Mammalia. 49:93-104.
42. Millar, J.S. and D.G.L. Innes. 1985. Breeding by *Peromyscus* over an elevational gradient. Can. J. Zool. 63:124-129.
43. Zammuto, R.M. and J.S. Millar. 1985. Life histories of ground squirrels over a climatic gradient. Ecology 66:1784-1794.
44. Millar, J.S. and J.O. Schieck. 1986. An annual lipid cycle in a montane population of *Peromyscus maniculatus*. Can. J. Zool. 64:1981-1985.
45. Millar, J.S., D. Burkholder and T. Lang. 1986. Estimating age at independence in *Peromyscus* populations. Can. J. Zool. 64:910-913.
46. Xia, X. and J.S. Millar. 1986. Sex related dispersion of breeding deer mice in the Kananaskis Valley, Alberta. Can. J. Zool. 64:933-936
47. Moore, G.C. and J.S. Millar. 1987. Observations on cranial differences between juvenile and adult eastern coyotes *Canis latrans*. Can. Field Nat. 101:461-463.

48. Schieck, J.O. and J.S. Millar. 1987. Can removal areas be used to assess dispersal of red-backed voles? Can. J. Zool. 65:2575-2578.
49. Green, D.A. and J.S. Millar. 1987. Changes in gut dimensions and capacity of *Peromyscus maniculatus* relative to diet quality and energy needs. Can. J. Zool. 65:2159-2162.
50. Millar, J.S. and D.A.L. Threadgill. 1987. The effect of captivity on reproduction and development in *Peromyscus maniculatus*. Can. J. Zool. 65:1713-1719.
51. Xia, X, and J.S. Millar. 1987. Morphological variation in deermice in relation to sex and habitat. Can. J. Zool. 65:527-533.
52. Innes, D.G.L. and J.S. Millar. 1987. Estimating number of litters per season in small mammal populations. J. Mamm. 58:675-678.
53. Falk, J.W. and J.S. Millar. 1987. Reproduction in female *Zapus princeps* in relation to age, size, and body fat. Can. J. Zool. 65:568-571.
54. El-Haddad, M., J.S. Millar and X. Xia. 1988. Offspring recognition by male *Peromyscus maniculatus*. J. Mamm. 69:811-813.
55. Xia, X. and J.S. Millar. 1988. Paternal behaviour by *Peromyscus leucopus* in enclosures. Can. J. Zool. 66:1184-1187.
56. Xia, X. and J.S. Millar. 1989. Dispersion of adult male *Peromyscus leucopus* in relation to female reproductive status. Can. J. Zool. 67:1047-1052.
57. Marinelli, L. and J.S. Millar. 1989. The ecology of beach-dwelling *Peromyscus maniculatus* on the Pacific Coast. Can. J. Zool. 67:412-417.
58. Millar, J.S. and W.D. Millar. 1989. Effects of gestation on growth and development in *Peromyscus maniculatus*. J. Mamm. 70:208-211.
59. Lusk, S.J.G. and J.S. Millar. 1989. Reproductive inhibition in a short-season population of *Peromyscus maniculatus*. J. Anim. Ecol. 58:329-341.
60. Grand, T.C. and J.S. Millar. 1990. The effects of intermittent dietary restriction on weight gain and body fat in white-footed mice, *Peromyscus leucopus*. Physiology and Behaviour 48:221-224.
61. Millar, J.S. and G.J. Hickling. 1990. Fasting endurance and the evolution of mammalian body size. Function Ecology. 4:5-12.
62. Innes, D.G.L. and J.S. Millar. 1990. Number of litters, litter size and survival in two species of microtines at two elevations. Holarctic Ecology 13:207-216.
63. Norrie, M.B. and J.S. Millar. 1990. Food resources and reproduction in four microtine rodents. Can. J. Zool. 68:641-650.
64. Mawhinney, K. and J.S. Millar. 1990. The effect of diet on lipid deposition in *Peromyscus maniculatus*. Can. J. Zool. 68:1473-1475.
65. Xia, X. and J.S. Millar. 1990. Sex-biased bot-fly infestations in *Peromyscus leucopus*. J. Mamm. 71:255-258.
66. Sharpe, S.T. and J.S. Millar. 1990. Relocation of nest sites by female deer mice, *Peromyscus maniculatus borealis*. Can. J. Zool. 68:2364-2367.
67. Millar, J.S. and Hickling, G.J. 1991. Body size and the evolution of mammalian life histories. Functional Ecology 5:588-593.
68. Millar, J.S., X. Xia, and M.B. Norrie. 1991. Relationships among reproductive status, nutritional status and food characteristics in a natural population of *Peromyscus maniculatus*. Can. J. Zool. 69:555-559.
69. Sharpe, S.T. and J.S. Millar. 1991. Influence on the variation in initiation of breeding in *Peromyscus maniculatus*. Can. J. Zool. 69:698-705.
70. Xia, X. and J.S. Millar. 1991. Genetic evidence of promiscuity in *Peromyscus leucopus*. Beh. Ecol. Sociobiol. 28:171-178.
71. Millar, J.S., E.M. Derrickson and S.T.P. Sharpe. 1992. Effects of reproduction on maternal survival and subsequent reproduction in northern *Peromyscus maniculatus*. Can. J. Zool. 70:1129-1134.
72. Ribble, D.O. and J.S. Millar. 1992. Intraspecific variation in testes size among northern populations of *Peromyscus*. Functional Ecology 6:455-459.
73. Hickling, G.J., J.S. Millar and R.A. Moses. 1991. Reproduction and nutrient reserves of bushy-tailed woodrats (*Neotoma cinerea*). Can. J. Zool. 69:3088-3092.
74. Millar, J.S. and E.M. Derrickson. 1992. Group nesting in *Peromyscus maniculatus*. J. Mamm. 73:403-407.
75. Moses, R.A. and J.S. Millar. 1992. Behavioral asymmetries and cohesive mother-offspring sociality in bushy-tailed woodrats. Can. J. Zool. 70:597-604.
76. Ribble, D.O. and J.S. Millar. 1992. Inbreeding effects among inbred and outbred laboratory colonies of *Peromyscus maniculatus*. Can. J. Zool. 70:820-824.

77. Millar, J.S. and T. Teferi. 1993. Winter survival in northern *Peromyscus maniculatus*. Can. J. Zool. 71:125-129.
78. Hanni, K.D. and J.S. Millar. 1993. Fall molt and lipid storage in raccoons (*Procyon lotor*). Can. J. Zool. 71:634-637.
79. Teferi, T. and J.S. Millar. 1993. Long distance homing by the deer mouse (*Peromyscus maniculatus*) in the Kananaskis Valley, Alberta. Can. Field-Nat. 107:109-111.
80. Teferi, T. and J.S. Millar. 1993. Early maturation by northern *Peromyscus*. Can. J. Zool. 71:1743-1747.
81. Innes, D.G.L. and J.S. Millar. 1993. Factors affecting litter size in *Clethrionomys gapperi*. Ann. Zool. Fenn. 30:239-245.
82. Teferi, T. and J.S. Millar. 1994. Effect of supplemental food on the dispersal of young *Peromyscus maniculatus*. Ecoscience 1:115-118.
83. Innes, D.G.L. and J.S. Millar. 1994. Reproduction in laboratory colonies of *Clethrionomys gapperi* and *Microtus pennsylvanicus*: A comparison between species and among populations. Can. J. Zool. 72:995-1001.
84. Moses, R.A. and J.S. Millar. 1994. Philopatry and mother-daughter associations in bushy-tailed woodrats: space use and reproductive success. Behav. Ecol. Sociobiol. 35:131-140.
85. Innes, D.G.L. and J.S. Millar. 1994. Life histories of Clethrionomys and Microtus (Microtinae). Mammal Review 24:179-207.
86. Millar, J.S. 1994. Senescence in a population of small mammals? Ecoscience 1:317-321.
87. Duquette, L.S. and J.S. Millar. 1995. The effect of supplemental food on life-history traits and demography of a tropical mouse *Peromyscus mexicanus*. J. Animal Ecol. 64:348-360.
88. Duquette, L.S. and J.S. Millar. 1995. Reproductive response of a tropical mouse, *Peromyscus mexicanus*, to changes in food availability. J. Mamm. 76:596-602.
89. Innes, D.G.L. and J.S. Millar. 1995. Correlates of life-history variation in *Clethrionomys* and *Microtus* (Microtinae). Ecoscience 2:329-334.
90. Moses, R.A., G.J. Hickling, and J.S. Millar. 1995. Variation in sex ratios of offspring in wild bushy-tailed woodrats. J. Mamm. 76:1047-1055.
91. Topping, M.G. and J.S. Millar. 1996. Home range size of bushy-tailed wood rats in southwestern Alberta. Can. Field Nat. 110:351-353.
92. Ribble, D.O. and J.S. Millar. 1996. The mating system of northern populations of *Peromuscus maniculatus* as revealed by radio telemetry and DNA fingerprinting. Ecoscience 3: 423-428.
93. Topping, M.G. and J. S. Millar. 1996. Foraging movements of female bushy-tailed wood rats (*Neotoma cinerea*). Can. J. Zool. 74: 798-801.
94. Topping, M.G. and J.S. Millar. 1996. Spacial distribution in the bushy-tailed wood rat (*Neotoma cinerea*) and its implication for the mating system. Can. J. Zool. 75: 565-569.
95. Havelka, M.A. and J.S. Millar. 1996. Multiple nest boxes per station in the study of *Peromyscus leucopus*. Am. Midl. Nat. 135: 376-380.
96. Havelka, M.A. and J.S. Millar. 1997. Sex ratio of offspring in *Peromyscus maniculatus borealis.* J. Mammal. 78: 626-637.
97. Topping, M.G., J.S. Millar and B.E. Woolfenden. 1997. Unsuccessful colonization of a naturally depopulated area by the deer mouse, *Peromyscus maniculatus.* Can. Field Nat. 111:466-468.
98. Woolfenden, B.E. and J.S. Millar. 1997. Effects of salt on the growth and timing of reproduction of the deer mouse, *Peromyscus maniculatus.* Can. J. Zool. 75: 110-115.
99. Topping, M.G. and J.S. Millar. 1998. Mating patterns and reproductive success in the bushy-tailed woodrat (*Neotoma cinerea*) as revealed by DNA fingerprinting. Behav. Ecol. Socio. 43: 115-124.
100. Duquette, L.S. and J.S. Millar. 1998. Litter sex ratio in a food supplemented population of *Peromyscus mexicanus.* Can. J. Zool. 76: 623-629.
101. Topping, M.G. and J.S. Millar. 1999. Mating success of male bushy-tailed woodrats: when bigger is not always best. Behav. Ecol. 10: 161-168.
102. McAdam, A.G. and J.S. Millar. 1999. Breeding by young-of-the-year female deer mice: Why weight? Ecoscience 6: 400-405.

103. McAdam, A,G. And J.S. Millar. 1999. The effects of dietary protein content on growth and maturation in deer mice. Can. J. Zool. 77: 1822-1828.
104. McAdam, A.G. and J.S. Millar. 1999. Dietary protein constraints on age at maturity: an experimental test with wild deer mice. J. An. Ecol. 68: 733-740.
105. Topping, M.G., J.S. Millar and J.A. Goddard. 1999. The effects of moonlight on nocturnal activity in bushy-tailed woodrats (*Neotoma cinerea*). Can. J. Zool. 77: 480-485.

106. Schulte-Hostedde, A.I. and J.S. Millar. 2000. Measuring sexual size dimorphism in the yellow-pine chipmunk (*Eutamias amoenus*). Can. J. Zool. 78: 728:733.
107. Hubbs, A.H., J.S. Millar and J.P. Wiebe. 2000. Effect of brief exposure to a potential predator on cortisol concentrations in female Columbian ground squirrels (*Spermophilus columbianus*). Can. J. Zool. 78: 578-587.
108. Havelka, M.A. and J.S. Millar. 2000. Use of artificial nest sites as a function of age of litter in *Peromyscus leucopus.* Am. Midl. Nat. 144: 152-158.
109. Schulte-Hostedde, A.I., H.L. Gibbs and J.S. Millar. 2000. Microsatellite DNA loci suitable for parentage analyis in the yellow-pine chipmunk (*Tamias amoenus*). Molecular Ecol. 9: 2180-2181.
110. Millar, J.S. and A.G. McAdam. 2001. Life on the edge: the demography of short-season populations of deer mice. Oikos 93: 69-76.
111. Schulte-Hostedde, A.I., J.S. Millar and G.J. Hickling. 2001. Sexual dimorphism in body composition in small mammals. Can. J. Zool. 79: 1016-1020.
112. Schulte-Hostedde, A.I., J.S. Millar and G.J. Hickling. 2001. Evaluating body condition in small mammals. Can. J. Zool. 79: 1021-1029.
113. Schulte-Hostedde, A.I., H.L. Gibbs and J.S. Millar. 2001. Microgeographic genetic structure in the yellow-pine chipmunk (*Tamias amoenus*). Molecular Ecol. 10: 1625-1632.
114. Millar, J.S. 2001. On reproduction in lemmings. Ecoscience 8: 145-150.
115. Kalcounis-Rueppell, M.C., A. Patrick and J.S. Millar. 2001. Effect of fluorescent powder marking of females on mate choice by male white-footed mice (*Peromyscus leucopus*). Amer. Midl. Nat. 146: 429-433.
116. Schulte-Hostedde, A.I. and J.S. Millar. 2002. "Little chipmunk" syndrome? Male body size and dominance in captive yellow-pine chipmunks (*Tamias amoenus*). Ethology 108: 127-137.
117. Kalcounis-Rueppell, M.C. and J.S. Millar. 2002. Resource partitioning along space, food, and time axes of syntopic *Peromyscus boylii* and *P. californicus.* J.Mammal. 83:614-625
118. Schulte-Hostedde, A.I. and J.S. Millar. 2002. Effects of body size and mass on running speed of male yellow-pine chipmunks (*Tamias amoenus*). Can. J. Zool. 80: 1584-1587.
119. Kalcounis-Rueppell, M.C., J.S. Millar and E.J. Herdman. 2002. Beating the odds: effects of weather on a short-season population on deer mice. Can. J. Zool. 80: 1594-1601.
120. Schulte-Hostedde, A.I., J.S. Millar and H.L. Gibbs. 2002. Female biased sexual sizedimorphism in the yellow-pine chipmunk (*Tamias amoenus*): sex specific patterns of annual reproductive success and survival. Evolution 56: 2519-2529.
121. Schulte-Hostedde, A.I., J.S. Millar and G.J. Hickling. 2003. Intraspecific variation in testes size of small mammals: implications for muscle mass. Can. J. Zool. 81: 591-595.
122. Schulte-Hostedde, A.I., J.S. Millar and H.L. Gibbs. 2004. Sexual selection and mating patterns in a mammal with female-biased sexual size dimorphism. Behav. Ecol. 15: 351-356.
123. Schulte-Hostedde, A.I. and J.S. Millar. 2004. Intraspecific variation in testis size and sperm length in the yellow-pine chipmunk (*Tamias amoenus*): implications for sperm competition and reproductive success. Behav. Ecol. And Sociobiol. 55: 272- 277.
124. Havelka, M.A. and J.S. Millar. 2004. Maternal age drives variation in litter size of *Peromyscus leucopus*. J. Mammal. 85: 940-947.
125. Kasparian, K. and J.S. Millar. 2004. Diet selection by red-backed voles *Clethrionomys gapperi.* Acta Theriologica 49: 289-300.
126. Millar, J.S., M.A. Havelka, and S. Sharma. 2004. Nest mortality in a population of small mammals. Acta Theriologica 49: 269-273.
127. Kasparian, K. and J.S. Millar. 2004. Effects of extra food on nestling growth and survival in red-backed voles. Can. J. Zool. 82: 1219-1224.
128. Millar, J.S. and E.J. Herdman. 2004. Climate change and the initiation of breeding by deer mice in the Kananaskis Valley 1985-2003. Can. J. Zool. 82: 1444-1450.
129. Schulte-Hostedde, A.I., J.S. Millar, and G.J. Hickling. 2005. Condition dependence of testis size in small mammals. Evol. Ecol. Res. 7: 143-149.

130. Schulte-Hostedde, A.I., B. Zinner, J.S. Millar, and G.J. Hickling. 2005. Restitution of mass-residuals: validating body condition indices. Ecology 86: 155-163.
131. Sare, D.T., J.S. Millar, and F.J. Longstaffe. 2005. Tracing dietary protein in red- backed voles (*Clethrionomys gapperi*) using stable isotopes of nitrogen and carbon.Can. J. Zool. 83:717-725.
132. Sare, D.T., J.S. Millar, and F.J. Longstaffe. 2005. Nitrogen- and carbon-isotope fractionation between mothers and offspring in red backed voles (*Clethrionomys gapperi*). Can. J. Zool. 83: 712-716.

133. Sare, D.T., J.S. Millar, and F.J. Longstaffe. 2005. Moulting patterns in *Clethrionomys gapperi.* Acta Theriologica 50: 561-569.
134. Hwang, Y.T., S.L. Gardner and J.S. Millar. 2007. *Hymenolepus horrida* (Cestoda: Hymenolepididae) and *Catenotaenia peromysci* (Cestoda: Anoplocephalidae) in voles from the Canadian Rockies. Journal of Comparative Parasitology 74: 160-163.
135. Millar, J.S. 2007. Nest mortality in small mammals. Ecoscience 14: 286-291.
136. Weber, D.M., J.S. Millar and B.D. Neff. 2007. Male reproductive success and female mate choice in bushy-tailed woodrats (*Neotoma cinerea*): Do females prefer males in good physical condition? Can. J. Zool. 85:169-176.
137. Hwang, Y.T., J.S. Millar and F.J. Longstaffe. 2007. Do ^{15}N and ^{13}C values of feces reflect the isotopic composition of diets in small mammals? Can. J. Zool. 85: 388-396.
138. Miller, J.F., J.S. Millar and F.J. Longstaffe. 2008. Carbon and nitrogen-isotops tissue-diet discrimination in deer mice, *Peromyscus maniculatus.* Can. J. Zool. 86: 685-691.
139. Lobo, N., M. Duong, and J.S. Millar (2009) Conifer-seed preferences of small mammals. Can. J. Zool. 87: 773-780.
140. Hwang, Y.T., S.L. Gardner, and J.S. Millar. (2010) Responses of endoparasites in small mammals to natural forest fires. J. Wildlife Diseases 46: 146-150.
141. Smith, J.J. , J.S. Millar, F.J. Longstaffe, and R. Boonstra. (2010) The effect of metabolic rate on stable carbon- and nitrogen-isotope compositions in deer mice, *Peromyscus maniculatus.* Can. J. Zool. 88: 36-42.
142. Lobo, N., A.B. Geary, and J.S. Millar. (2010) Intraspecific behaviour of Heather Voles. The Northwest Naturalist 91: 165-171.
143. Tabacaru, C.A., J.S. Millar, F.J. Longstaffe, and A.K. Ansell. 2010. Seasonal breeding in relation to dietary protein in deer mice (*Peromyscus maniculatus*). Can. J. Zool. 88: 520-526.
144. Lobo, N. and Millar, J.S. (2010). Photographic evidence of Bobcats, *Lynx rufus*, in the Kananaskis Valley in Southwestern Alberta. Can. Field-Nat. 124: 260-262
145. Miller, J.F., J.S. Millar and F.J. Longstaffe. (2011). Stable nitrogen and carbon isotope discrimination between juveniles and adults in an income breeding small mammal. Mammalian Biology 76: 563-569
146. Lobo, N. and J.S. Millar. (2011). The efficacy of conifer seeds as major food resources to deer mice (*Peromyscus maniculatus*) and red-backed voles (*Myodes gapperi*). Mammalian Biology 76: 274-284.
147. Tabacaru, C.A., J.S. Millar and F.J. Longstaffe. (2011) Seasonal moulting in deer mice (*Peromyscus maniculatus*) in the Rocky Mountains. Can. Field-Nat. 125: 126-131.
148. Lobo, N. and J.S. Millar (2013) Indirect and mitigating effects of pulsed resources on the population dynamics of a northern rodent. J. Anim. Ecol. 82: 814-825.
149. Lobo, N. Green, D.J. and Millar, J.S. (2013) Effects of seed quality and abundance on the foraging behavior of deer mice. J. Mamm. 94: 1449-1459.
150. Lobo, N. and Millar, J.S. (2013) Summer roadside use by White-tailed Deer and Mule deer in the Rocky Mountains, Alberta. Northwest Naturalist 94:137-146.
151. Lobo, N. 2013. Conifer seed predation by terrestrial small mammals: A review of the patterns, implications, and limitations of top-down and bottom-up interactions. Forest Ecology and management 328: 45-54.

OTHER PUBLICATIONS: (Symposia, etc.)

1. Millar, J.S. 1976. Evolution of litter size in the pika. pp.215-224. <u>In</u>: Selected readings in mammalogy (J.K. Jones, S. Anderson, and R.S. Hoffmann, eds.). Mus. Nat. History. University of Kansas.
2. Millar, J.S. 1982. Evolution of litter size in the pika. pp.39-48. <u>In</u>: Wildlife Population Ecology (S.S. Walkeley, ed.). Penn. State University Press.
3. Millar, J.S. 1984. Reproduction and survival of *Peromyscus* in seasonal environments. <u>In</u>: Winter Ecology of Small Mammals (J.F. Merritt, ed). Spec. Publ. 10: Carnegie Museum of Natural History, 253-266.
4. Millar, J.S. 1984. The role of design constraints in the evolution of mammalian reproductive rates. Ann. Zool. Fenn. <u>171</u>:133-136.

5. Millar, J.S. 1987. Energy reserves in breeding small rodents. <u>In</u>: Reproductive Energetics in Small Mammals. (A.S.I. Loudon and P.A. Racey, eds.). Symp. Zool. Soc. London. <u>57</u>:231-240.
6. Millar, J.S. 1988. The role of reproduction and life histories in models of small rodent population dynamics. Oikos <u>52</u>:212-214.
7. Millar, J.S. 1989. Reproduction and development. <u>In</u>: Advances in the study of *Peromyscus* (Rodentia). (G.L. Kirkland and J.N. Layne, eds.) Texas Tech Univ. Press. 200p.
8. Millar, J.S. and G.J. Hickling. 1992. The fasting endurance hypothesis revisited. Functional Ecology <u>6</u>:496.

9. Hickling, G.J. and J.S. Millar. 1993. The fasting endurance model: a testable hypothesis. Functional Ecology 7:134-135.
10. Millar, J.S. and H. Ylönen. 2007. Mammalian life histories: The basics revisited. Ecoscience 14: iv

APPENDIX II: ALL THESES in chronological order

1. Jim Bailey, M.Sc. 1976. (Interim supervisor) The ecology of white-tailed deer on Long Point.
2. Dave Kiell, M.Sc. 1978. Energy strategies of arctic ground squirrels (*Spermophilus undulatus)* at McConnell River, N.W.T.
3. Richard Harland, M.Sc. 1978. Activity of breeding *Peromyscus maniculatus.*
4. Duncan Innes, M.Sc. 1978. The reproductive tactics of two sympatric microtines.
5. Doug May, M.Sc. 1979. Demographic adjustments to length of the breeding season in *Peromyscus.*
6. Les Gyug, M.Sc. 1979. Reproduction and development in *Peromyscus.*
7. Gary Moore, M.Sc. 1981. A comparative study of colonizing and longer established eastern coyote (*Canis latrans*) populations.
8. Richard Zammuto, Ph.D. 1983. Effects of a climatic gradient on columbian ground squirrel (*Spermophilus columbianus*) life history.
9. Duncan Innes, Ph.D. 1984. The life history tactics of the voles, *Clethrionomys gapperi* and *Microtus pennsylvanicus,* at two elevations.
10. Jim Schieck, M.Sc. 1984. Movement and dispersal of the red-backed vole.
11. Jon Falk, M.Sc. 1985. Reproduction in relation to age, size, and body composition in *Zapus princeps.*
12. Val Loewen, M.Sc. 1985. Life history of the long-tailed vole, *Microtus longicaudus* in southwestern Alberta.
13. Graham Hickling, Ph.D. 1987. Seasonal reproduction and group dynamics of bushy- tailed wood rats, *Neotoma cinerea.*
14. Stewart Lusk, M.Sc. 1987. Reproductive inhibition of females in natural populations of *Peromyscus.*
15. Sean Sharpe, M.Sc. 1987. Correlates of asynchronous initiation of breeding by female deer mice, *Peromyscus maniculatus,* in the Kananaskis Valley, Alberta.
16. Luis Marinelli, M.Sc. 1987. The ecology of insular *Peromyscus maniculatus.*
17. Krista Hanni, M.Sc. 1990. Fall molt and lipid storage in raccoons.
18. Xuhua Xia, Ph.D. 1990. The mating systems of natural populations of *Peromyscus leucopus.*
19. Laurel Duquette, Ph.D. 1992. The effect of supplemental food on the life history traits and demography of a population of *Peromyscus mexicanus.*
20. Richard Moses, Ph.D. 1992. Intrasexual competition and reproductive success in female bushy-tailed wood rats.
21. Monika Havelka, M.Sc. 1993. Facultative manipulation of offspring sex ratio in *Peromyscus maniculatus borealis.*
22. Em Hofstede, M.Sc. 1993. Dispersal in an unmanipulated population of *Peromyscus maniculatus.*
23. Taye Teferi, Ph.D. 1993. Philopatry and dispersal by the deer mouse, *Peromyscus maniculatus borealis,* in the Kananaskis Valley, Alberta.
24. Spencer Seiler, M.Sc. 1994. The microhabitat associations of a subalpine small mammal community in the Kananaskis Valley, Alberta.
25. Bonnie Woolfenden, M.Sc. 1995. The effect of salt on the growth and timing of reproduction of *Peromyscus maniculatus borealis.*
26. Mike Topping, Ph.D. 1996. Male reproductive success and the mating system of bushy- tailed wood rats.
27. Neala MacDonald, M.Sc. 1997. The effect of 6-methoxy-2(3)-benzoxaolinone on the reproductive ecology of *Peromyscus maniculatus borealis.*
28. Andrew McAdam, M.Sc. 1998. Dietary protein limitation of growth and maturation in female *Peromyscus maniculatus borealis.*
29. Anne Hubbs, Ph.D. 1999. Effects of predator simulations on Columbian ground squirrels.
30. Matina Kalcounis-Rueppell, Ph.D. 2000. Activity of syntopic monogamous and promiscuous *Peromyscus.*
31. Albrecht Schulte-Hostedde, Ph.D. 2001. Sex-specific patterns of reproductive success and survival in relation to body size in the yellow-pine chipmunk (*Tamias amouenus*).
32. Susan Robinson, M.Sc. 2002. Sexual size dimorphism and resource competition in bushy-tailed wood rats, *Neotoma cinerea.*
33. Julie Desjardins, M.Sc. 2002. Effects of supplemental food on deer mouse populations.
34. Monika Havelka, Ph.D. 2002. Optimal litter size and reproductive tactics of *Peromyscus leucopus.*
35. Kristine Kasparian, M.Sc. 2003. Effects of extra food on nestling survival in red-backed voles, *Clethrionomys gapperi.*

36. David Sare, M.Sc. 2004. Tracing dietary response in red-backed voles (*Clethrionomy gapperi*) using stable carbon and nitrogen isotopes.
37. Emily Herdman, Ph.D. 2005. Activity and metabolism in deer mice.
38. Dawn Weber, M.Sc. 2005. Female mate choice in bushy tailed wood rats.
39. Johnston Miller, M.Sc. 2006. Age and tissue variation in deer mouse (*Peromyscus leucopus*) stable carbon- and nitrogen-isotope compositions.
40. Khahy Ho. M.Sc. 2007. The effect of ectoparasite removal on *Peromyscus maniculatus* nestlings: body condition and survival.
41. April Ansell. M.Sc. 2007. Isotopic variation in deer mouse diets: inferences about habitat quality.
42. Jennifer Smith. M.Sc. 2008. Isotopic variation in relation to metabolism in deer mice.
43. Crisia Tabacaru. M.Sc. 2009. Seasonal isotope variation in deer mice.
44. Lindsey Valliant. M.Sc. 2013. The effect of dietary protein on the initiation of spring breeding in the deer mouse (*Peromyscus maniculatus*).
45. Nikhil Lobo, PhD 2013. Small mammal foraging and population responses to northern conifer mast.

POST DOCTORAL FELLOWS

D. Morris	(1982)
P. Koteja	(1988)
E. Derrickson	(1989)
D. Ribble	(1992)
Y.T. Hwang	(2007)

"MY LAST FIELD SEASON……"

Well, it's not quite my last field season.

My first field season was when I was turned loose to poke around outdoors when I was about 3 years old, so I suspect that my last field season will be when I die. However, this year is my final **formal** field season as an academic and my "field work" will mostly involve cleaning up the last of the leftover research equipment from the storeroom at the Barrier Lake Field Station. I didn't have a research crew on site in 2012, but it takes a long time to throw out 30 years' worth of accumulated crap! So far the earliest "archeological treasure" is a storage box belonging to Les who graduated in 1979. Les didn't even work at Kananaskis and I have no idea how his box got there.

Anyhow, once upon a time field studies were done under much more rustic conditions than today. There were very few field stations and people working in the bush just stayed in the bush. In my case, my first formal field seasons were during my M.Sc. program in 1966-7 when I studied red squirrels on Vancouver Island and in the interior of BC. My "field station/lab" consisted of a Volkswagen Beetle. Anyone familiar with the Beetle might wonder how accommodation and a lab might fit, but space can be freed up if the passenger and back seats are removed and replaced with a plywood floor cut to fit. That provides enough space to put a sleeping bag length-ways on the passenger side, with room behind the driver's seat for a one burner optimus stove and a cooler for food.

Research equipment was also rustic, consisting of a shotgun and 0.22 calibre rifle for collecting specimens and a jug of formaldehyde in the trunk for preserving samples until I got back to campus to process them.

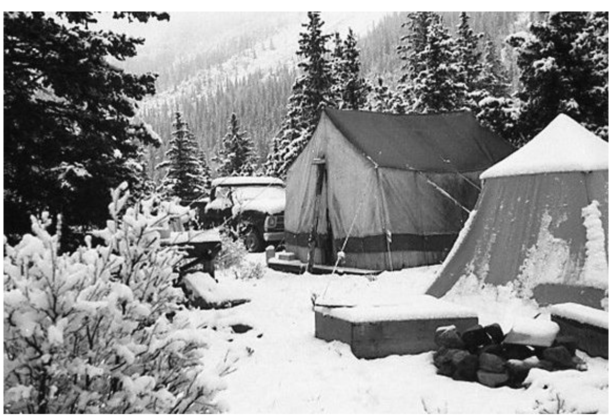
Transport/ lodging/ lab 1967

Field-work conditions improved considerably when I started my PhD research in 1968 because the University of Alberta had money. They had a university fleet of vehicles and every year I could sign out a new pick-up truck, at no cost to me complete with a credit card for gas. However, they were basic two-wheel drive trucks and tended to get stuck in mud and slide off the road.

U of A “field vehicle”. Not good in foothills mud, 1969

When things got really bad I used my Volkswagen Beetle because it had relatively big tires and the engine in the back for ballast. It could navigate anywhere! Typically, the pick-up trucks were no longer “new” when they were returned at the end of the summer, but there was always another one available the next year.

Accommodation was potentially better too. The Gorge Creek Station (now R.B. Miller Station) had rustic but permanent bunk houses and a kitchen cabin, hydro, and running water but, unfortunately, we were not permitted to stay there because the station had a “no-wives” policy. There had been problems with wives in the past. With husbands in the field all day wives were bored in camp and tended to squabble among themselves, causing tensions among the residents of the station. The station was off-limits to us, but we could still visit for a hot shower once in a while and store equipment there. Our real accommodation was a summer tent site west of Gibraltar Mountain, near the headwaters of the Sheep River. Our camp had a tent with a wooden floor and a Mighty Midget wood stove with a 3 inch stove pipe for heat. We had a storage tent and a covered kitchen area for cooking on a Coleman stove. We also had a garbage can in the ground as a “refrigerator” for fresh food, but our water came from the river and the bathroom was a hole in the ground.



Sheep River accommodation and storage 1968

Sheep River kitchen 1968

Moving to Western in 1971, research could only be done locally because my first research grant was only $2,000.00 (about $11.000.00 today) and everybody had to live at home. By the mid 1970s we had sufficient funds to work elsewhere and, from then on, research was done at field stations. The first location external locations in the 1970s included the AECL nuclear research station at Pinawa, Manitoba, where they had an environmental monitoring program and there were regular dormitory rooms for visiting scientists. The second location was at Heart Lake, NWT, where Bill Fuller had permanent buildings for his boreal forest studies on small mammals. Everybody at the U of A had a private research station in those days.

Finally, we set up shop at the U of C Field Station at Kananaskis where dorm rooms, duplexes, and 3 bedroom ATCO trailers were available, along with a permanent kitchen and kitchen staff. Duncan was the first to work at Kananaskis in 1978 and he was able to hire a summer assistant, lease a vehicle for the summer, stay in the dorm and eat in the dining room because he had a substantial research grant from the Canadian Sportsman Show. His grant was for only two years and the Sportsman Club research program was canceled in favor of more boat shows, never to return. Things got tighter for Duncan after that and he had to buy his own truck. Every year since, the Kananaskis research crew has stayed in rental accommodation where they did their own cooking.

For most years, one of the 3 bedroom ATCO trailers (Trailer B) served as Mousecrew Headquarters, but the trailers were condemned as unfit for human habitation in 2008, after which a 2 bedroom duplex served that same purpose. Invading mice, squirrels, and woodrats were always a problem in the trailer, but the last time I looked in the woodrats had made it their personal turf, complete with decorative rat crap piles. The trailers are now scrap, but the university will not pay for their removal, leaving a near-by source of woodrats which now have ready access to the other buildings. Woodrat studies could be done on-site today, instead of hiking up to bluffs in the dark.

Mousecrew Hotel 2008

Delux Accommodation?

Somehow, living in a duplex didn't seem quite the same as living in the trailer in the good old days.

Matina probably had the best-ever accommodation for her mouse studies at the Hastings Reserve in California. There she lived in a real house, complete with hydro, running water, and real bedrooms. Muddy boots stayed at the door.

Laurel probably had the most rustic accommodation for her mouse studies in Mexico. Her "field station" at Catemaco, was a home-made cabin with no hydro or running water.

Laurel's "house" and kitchen, Catemaco, 1989

Laurel also had the most rustic research vehicle, consisting of a bicycle. For local transit she had the back of an open crowded truck held together with duct tape, and for limo service to the airport in Vera Cruz she had the back of an open crowded truck held together with duct tape going very fast down the highway.

Having research vehicles at Kananaskis was always an important part of any field season because trapping sites were mostly remote. In the early days there was a lot of freedom as to where study sites could be located and when they could be accessed, but vehicle availability severely restricted our work.

NSERC funds could not be used to purchase vehicles, on the philosophy that such vehicles might be used for personal travel. That meant that students had to own their own vehicles to work there. Many students owned vehicles in those days, mostly clunkers, but sufficiently sound enough to drive to Alberta in the spring, access study sites all summer, and return to Ontario in the fall. And students knew how to fix and maintain them because they were personal vehicles. Still, some didn't survive the summer. Jim knew how to keep a vehicle operational, but even he couldn't do miracles. Val remembers riding in his car when the floor boards were so rusted out that there was nowhere to plant her feet. His car died in the summer of 1982 and even he, being mechanically inclined, couldn't fix it. We towed it to the Canmore dump where he rescued all the parts worth salvaging. I have no idea how he got the spare parts back to Ontario.

Jim's research vehicle, 1982

Other personal research vehicles met sad fates without even being on site. Graham had his ratmobile on site in 1985 and it gave him a lot of trouble, including a leaky radiator that required a 5 gallon can of water for outgoing trips to study sites so the radiator had enough coolant for the return trip. Sometimes it was a close call.

Graham's leaky ratmobile, 1985

The next year Graham decided to give his vehicle a rest for the summer so he could get a last trip to the Maritimes out of it before moving home overseas. He left it in the parking lot of his apartment block for the summer and used our “regular” vehicles for research in Alberta Unfortunately, folks in his apartment block in London assumed his car was abandoned and stripped it of all useable parts before his return in September. I recall taking him to Denzel, my tame car salesman at the time. He spotted one with a list price of $2,500.00. Denzel asked him how much money he had. Maybe $2,300.00. As I recall, Denzel gave it to him for $2,000.00. There is value added in tame mechanics and used car salesmen and I trust them over new car salesmen every time! Graham got his trip to the Maritimes, but in his newly purchased clunker. As I recall, it made the round trip OK….

Over time, fewer and fewer students could afford their own vehicles, but the cost of buying air fares to Alberta and leasing vehicles for the summer would have killed whatever salary and food budget I could provide for the summer. To alleviate the problem, I personally bought a used 9 passenger van, and paid it off by charging mileage to my research grant (claiming mileage was OK with NSERC). Every spring we packed up the van and drove to Alberta. By alternating drivers the trip could be done in 2-3 nights on the road, depending on head-winds or tail-winds on the prairies. It was a bonding experience for all involved. I participated in those drives for quite a few years until we had a big enough grant for me to send the students off on the road trip, after which I would fly out to meet them upon their arrival.

Alternate drivers on the way to Alberta, April 1983

In the late 1980s NSERC decided that a research vehicle a valid piece of field research equipment, opening up the chance to apply for one through an equipment grant. It took me 4 tries to receive funds for our first NSERC vehicle, and only after I tried to meet every single one of their criteria. Eventually I met all their preferred criteria (made in Canada, economical, to be used in Canada, no bells and whistles, etc.) and we got our very first research-funded vehicle. It was a basic Jeep Cherokee with enough space for 4 passengers and some storage, but hardly suitable as a field vehicle. It lasted only a few years.

Jim and Stewart discussing who will drive the Mousevan, 1983

After a while, most students did not own personal vehicles and many who had never owned a vehicle had never maintained one. Some had never driven more than a few hundred km on any trip and the crew always had someone who had never driven on a gravel road.

From the early 1990s we always two mousecrew vehicles, a primary one being relatively new and sound, and the secondary one bought from a used car lot. Secondary vehicles were often nicknamed “Boogermobiles” so, after the first (Booger I), we had many others.

Secondary vehicles in particular required frequent maintenance and, prior to spring departure to Alberta, I would have all vehicles fully serviced by Bill Hudson, my tame mechanic at Ballymote Auto, with instructions to fix anything that might break down during 4 months of abuse. Every spring Bill would do a thorough tune-up for the season, often a $1,000.00 investment per vehicle to make sure everything was OK. I then instructed new members of the crew about how to keep an eye on things. “Here’s how you check tire pressure, here’s the spare tire, here’s the window-washer fluid tank, here’s the radiator tank, here’s the oil dipstick”, etc. Unfortunately, some students thought that car maintenance involved taking it through a car wash, and all of this was beyond their comprehension, which lead to some hilarious (but potentially fatal!) situations.

This required some rules for drivers, as indicated by this late-era vehicle-use policy:

MOUSE CREW RESEARCH VEHICLE USE POLICY

Our research vehicles were purchased with NSERC funds, and therefore are regulated by NSERC and UWO policies which include the following:

Only approved UWO students and employees may drive these vehicles. Otherwise, the liability insurance is null and void.

NSERC dictates that the use of these vehicles is restricted to research purposes only. Use for personal trips is not permitted. Having said this, we recognize that these are the only vehicles available to our summer crew and there may be occasions when people have personal obligations in town. In such cases, the trip should be used to fulfill research requirements as well. For

example, if an airport pick-up is required, combine the trip with buying bait from the feed store, picking up supplies from U of C, or buying groceries. If you must use a vehicle for a personal trip, please pay for the gas.

An entry in the log book must be made for every trip.

Use of the vehicles among study sites should be planned efficiently. For example, if work is needed at both Grizzly Creek and Fortress, use one vehicle trip for both rather than driving vehicles independently to both sites. Similarly, trips for supplies should be combined with purchasing groceries or gas in order to minimize the number of trips needed.

Vehicles require regular maintenance. Oil and fluids should be checked regularly and topped up as needed. Also tire pressure. Each vehicle should be taken to the garage for an oil change and check-up every 5,000 km.

Alas, vehicles have problems from time to time. Here is the policy on problems:

If a vehicle gets stuck, the driver is in charge of getting it unstuck.

Similarly, you break it, you get it fixed.

IF YOU PRANG A BIG ROCK OR RUN INTO SOMETHING, DON'T IGNORE IT. GET IT CHECKED OUT. PAYING A BIT TO GET IT CHECKED IS A LOT LESS EXPENSIVE THAN ENDING UP WITH A SEIZED ENGINE!

In case of an accident, get a police report. DO NOT CALL THE INSURANCE COMPANY BECAUSE UWO HANDLES ITS OWN CLAIMS. In case of an accident, call Mary Dillon (519 661 2111 ext. 83154). If no answer, call Sherri Waring (ext. 86464) and she will relay the message.

Finally, all speeding tickets and other traffic infractions are the responsibility of the driver.

These instructions were stored in every vehicle, along with insurance and ownership papers. The instructions still look pretty clear to me, but were apparently not clear enough for everybody.

1. Drivers are responsible for all tickets received.

This was just a note of warning to encourage students to drive safely and avoid paying fines. After all, an extra night on the road was covered by the summer budget, right? I rarely heard about traffic offenses but I think they occurred regularly. I recall one return trip from Kananakis in my van, with a summer assistant behind the wheel in northern Ontario. She was driving well over the speed limit entering Dryden and got a speeding ticket. We stopped for gas in town and then she got another speeding ticket from the same cop on the way out of town. That cost her a few bucks! I know this for sure because I was trying to nap in the back seat and the police sirens kept waking me up.

2. If you get it stuck, get it unstuck.

Quite a few folks will remember digging out of ditches while their mousecrew mates stood around watching. I have too many pictures to include them here but you can check my truck picture from 1969 in case you forgot.

3. If you prang something, go to the garage and get it checked.

This was based on the simple idea that a repair bill is a lot cheaper than a replacement vehicle. There were many such instances, but the best one is from when we had a project in Kootenay sponsored by the G8 Legacy Fund. We had a 1990 Oldsmobile (the Booger Ark) dedicated to the daily trip from Kananaskis to Kootenay and back. When new, the Ark was a luxury car with plush seats and power everything and, although it had well over 300,000 km on the odometer when we bought it in the mid-1990s, it was in good shape. In 2005, Yeen Ten was in charge of the Kootenay Burn project and Michelle was her summer assistant. Johnston remembers what happened.

One day early in the summer, Michelle drove back to the field station and the car wasn't sounding so good. I asked if anything happened and she said no. It was due for an oil change, so I took it into Canmore, told them it had been sounding a little weird I came back an hour later and they told me the car was a write off. The entire under-carriage had been really beaten up. They asked if we had hit anything and I, having just driven it across the country alone, was wracking my brain trying to come up with any scenario that could explain this. I was able to drive it back to the field station and take a look at it for myself there, and sure enough, the oil pan had a crater in it the size of a bread plate, and the exhaust system was beat all to hell. When Michelle came back that day she fessed up and said that she hit a rock while driving. Eye witness accounts have her being a bit of a tunnel-vision driver, and this rock was in the middle of the road and visible from a long distance away. Apparently she hit the rock, and it clanged around underneath the car for a while until it got stuck and she just dragged it for a while. After finally stopping, they got out and took a look at the damage, at which point a ranger came by and helped them remove the rock. It is a minor miracle that they got the car back to the field station.

No mechanic would fix the car because there were no oil pans available for a vehicle of that vintage in Alberta. Jack found one in Ontario, shipped it out, and I replaced it myself (the most hands on mechanic thing I've ever done), but before we could get the exhaust system fixed, the torrential rains of 2005 washed away the road between the trailer and the exit, so we had to abandon the car above the wash-out for most of the field season. Later in the summer, the driveway was fixed and we got the exhaust fixed and the car made the trip back across the country.

The Booger Ark lasted another 2 field seasons. In the spring of 2008 our tame mechanics refused to work on it on the grounds that it would cost $3,000-4,000 to fix and they couldn't guarantee it would last the summer. So they sold us a Booger GrandAm for $5,000 and it earned a story of its own that same summer.

4. If you crash

The instructions are pretty clear on this and were usually followed: Don't call me. Call the police. Then call the office. When I arrived at Kananaskis the day before the start of my field course in August 1994, there was a scrap of paper on the kitchen table in the trailer.

"*Jack I think I did a bit of damage to the Jeep. I'm OK but have gone to the clinic for a check up anyhow I'll call the police Jamie*"

As it turns out, Jamie had rolled the Jeep off Powder Face Trail and it was toast. He claimed he was driving only 25 km/hr, but one wonders….. Anyhow, he got the police report and the insurance paid enough for a second-hand replacement for the next season.

“A little bit of damage”, by Jamie 1994

Sometimes people who knew how to follow the instruction ran into unexpected difficulties. Albrecht was always an assertive student, always aiming to be “first”. It was not uncommon for him to grab a vehicle early in April and drive across the US to get to the field station first. This resulted in him driving non-stop for 4,000 km, after which he aimed to beat his previous time record the next year. I was always concerned that he would end up dead or in a US jail, but he always made it OK. In 1998, Albrecht planned a bit of a holiday for the trip home. His fiancé, Bridget, flew west to join him for a leisurely Trans-Canada drive back to Ontario. He even arranged to take the Ford Taurus, our newest vehicle at that time. They loaded it up and departed in good spirits. Albrecht recalls the rest of the trip.

The car stalled out on us on the Trans Canada near Brooks. We had all the gear in the car and were stuck in the middle of nowhere. Eventually the car started and we took off, but man we were worried about the rest of the trip. Later, we stopped to get gas, and Bridget went to the washroom. She left her wallet in the stall by accident, and a young woman of dubious quality went in afterward. Bridget finally retrieved her wallet to find her cash gone. A confrontation at the gas pumps with the woman and her shirtless boyfriend led us to simply take the experience as a lesson learned. That night, west of Regina we slammed into a deer. Three males ran across the TransCanada from left to right, and I clipped the last one in the rear. It swung around and smashed the passenger side window over Bridget. (Deer) blood dotted the dash. We did a 180 on the highway, ending up on the shoulder. The transport truck behind us took care of the deer. A Doug Morris look-a-like took care of us. A burly, mustachioed gentleman checked the car (and us) and sent us on our way. In Regina, we filed a police report, and the next day I called Jane Sexsmith to tell her what happened. We drove all the way back without a passenger side window. Because Bridget was not insured to drive, she had to sit in the wind for 2 days. It drove her crazy. When we got back, I took the car to get fixed. I then heard, from Jack, that an administrator tried to get me removed from the university insurance policy.

Bridget married him anyhow.

Sometimes students panicked and forgot all about the crash policy. Neala was driving home with the mousecrew in September 1996 when I got a frantic phone call from somewhere west of Sudbury. “We creamed a moose!!!” With visions of a moose coming through the windshield I asked if everybody was OK. “Yes.” I asked if the car could be driven. “Yes.” So I told her to get a police report and contact the office when she got back. When she returned to campus she reported that the police laughed at her and refused to issue a report. So I went to the parking lot to check it out for myself. It had a broken headlight. No other damage.

And sometimes things that might have gone wrong just didn’t happen. Mike recalls the best of these from 1993 when he had the use of the Booger Mark II station wagon for the summer.

The comfort of driving out West was best described as 'surfing with the boog', since once you hit a bump, the whole car would bounce up and down for an alarming period of time. I always thought that this was due to the age of the Booger and dodgy shocks, but it would stay with you so that when you crashed for the night somewhere on the prairies, you would still be 'surfing' even when lying down. The best part about this was when we got back to London, we were informed by your 'tame' mechanic that the car was not actually attached to the frame at the back end, and had it not been for the weight of the field equipment, the whole back end may have come loose.

Finally, there are some accidents just waiting to happen. Eddie was a summer assistant in 2008. A pre-med student who spent his spare time studying for his entrance exam, he was often distracted or unfocussed. Nikhil nominates Eddie as the worst driver ever, and I’m inclined to agree. Eddie drove our “new” GrandAm in 2008, and here is Nikhil’s report.

Eddie had trouble with reverse and forward on the gear shift and frequently went the wrong way into a ditch. Even when he went in the intended direction he could go off course and he had problems, like knocking off the driver’s side mirror by clipping Sequoia’s truck while trying to look cool reversing down the road from the trailer at full speed. Once he tried to pass a school bus on Hwy 40 that was slowing down because 3 deer were crossing the road in front of us….he stopped just short of smoking one in front of the kids. And then there was the time he went out on a "scouting mission" for locations to put out some traps to catch jumping mice. He took the GrandAm one afternoon and was only supposed to be away for a couple of hours. He showed up back at the trailer almost 5 hours later, his boots and legs covered in mud...stupid fellow tried to take a sedan off-road from the Powderface Trail and got stuck in the mud on an abandoned seismic trail almost right away. After many attempts at driving out of it (invariably making things worse), he managed to flag down some good Samaritans who helped him push it out. I couldn't stay pissed off at him for too long b/c it was just so silly.

Imagine that guy as your physician...

PS. Eddie was accepted into Medical School. We can only hope his specialty does not require driving anywhere, or dealing with anything mechanical.

Normal maintenance

This only makes sense, eh? Well, not always.

One spring, a new graduate student and a new assistant (I don't recall the names or the year) were driving west on the Trans-Canada route. The vehicle had a full tune-up and 4 new tires prior to departure and I gave them the maintenance instructions. Somewhere in northern Ontario they decided that the radial tires looked soft, so they found an air hose and pumped the tires up nice and round. They didn't check the pressure, but it was probably over 60 lb pressure when 32 lb is recommended. All 4 tires were ruined when they arrived in Alberta and the trip must have felt like they were driving on ping-pong balls! They were damned lucky to make it all the way!

On another occasion, I had a new student who drove a Booger to Alberta OK and was having a successful field season. After 4000 km to get there and another 3 months of driving around the mountains, she had driven safely for about 15,000 km. I arrived in early August to see how things were going, and casually asked about the last oil change on the Booger. Oil change? What's that? So I explained to her about oil changes and dip sticks and sent her out to check it. She came back and happily reported that everything was OK because there was no oil on the stick! Sigh……..

In the mid 2000s, NSERC changed the rules for equipment grants and split the equipment budget for the Ecology and Evolution GSC between "lab" and "field" studies. Applications for vehicles were no longer in competition with applications for lab equipment, making funds for vehicles readily available. For decades our 2 research vehicles were the only ones in the parking lot during winter. All of a sudden, the department was paying insurance on 19 vehicles, ranging from ATVs to honking big 4X4 trucks. Virtually every ecologist now owns a truck, whether they really need one or not.

But the good times are over. NSERC cancelled its Equipment Grant Program last year and none of those trucks will be replaced using NSERC funds. Meanwhile, we had a good run with research vehicles, with access to them improving slowly but surely over the years. And the last two vehicles? The Ford Taurus and the GrandAm sat in the UWO parking lot last summer so I decided to sell them. Because they were owned, licensed, and insured by the university we had to sell them through Assets Disposal. The university mechanics deemed them unfit to drive and they went to the scrap yard.

Hell, I'm sure we could have gotten another couple of field seasons out of them!

So why quit now? After all, I still have research funds and could finance a few more field seasons. The answer is quite simple. After more than 40 years in the business our accommodation has never burned down and there have been no fatalities. I think it's a good idea to quit while I'm ahead. Besides, with no obligations or responsibilities, I can poke around outdoors any time I want.

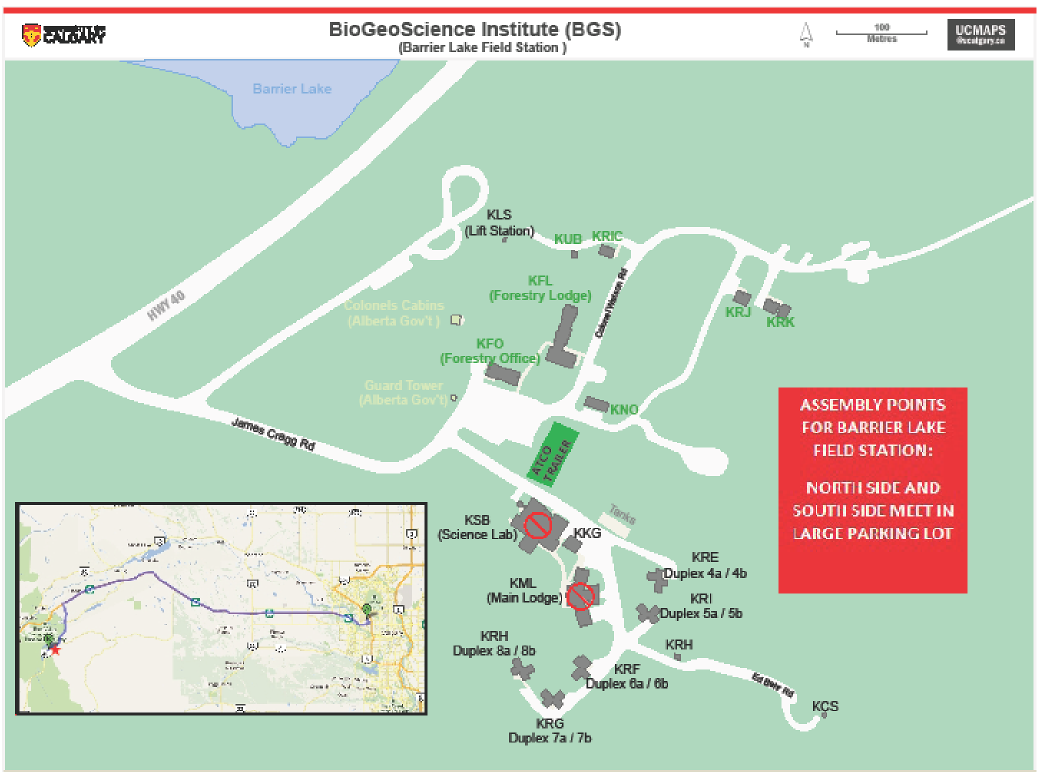
Jack Millar, April 19, 2013

BIOGEOSCIENCE FACILITIES

The BGI is an Institute of the University of Calgary consisting of two field stations. The Barrier Lake Station (built in 1967) is located in the Kananaskis Valley 80 km west of Calgary, and the R.B. Miller Station (founded in 1950) is located in the Sheep River Provincial Park 110 km southwest of Calgary. Both stations are located in Kananaskis Country in the front ranges of the Canadian Rockies.

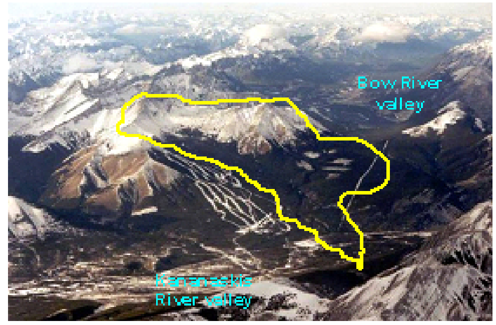
Barrier Lake Station operates year-round, providing users with research and teaching facilities. Currently under renovation, the main lodge with a 26-person dormitory and dining facilities, a forestry lodge with a 33-person dorm and cooking/dining facilities, laboratory/office building, five duplex units, two houses (2-4 bedrooms), one cabin, three mobile homes, workshop, garage, and storage buildings. The science lab building is also undergoing major renovations in 2017-2018 with funding provided by the federal and provincial governments, along with contributions from the UofC.

MAP OF BGS INSTITUTE - DURING CONSTRUCTION PERIOD

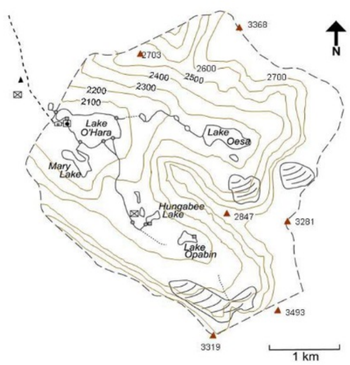


The R.B. Miller Field Station is also undergoing major renovations with the removal of all buildings and construction of a new research cabin in summer of 2017.

RESEARCH SITE MANAGEMENT

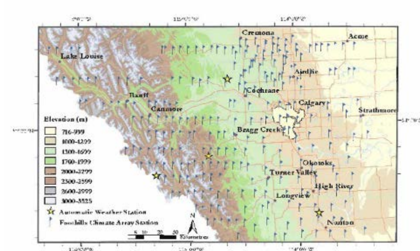


The Marmot Creek and Lake O'Hara watersheds are the only research watersheds in the Canadian Rockies. Marmot Creek Research Basin is located in the Kananaskis River Valley at 1450-2886 m a.s.l. Its terrain is alpine, subalpine, and montane with > 600 mm precipitation, 70% snowfall, and 50% runoff annually. Nine hydrometeorology stations have been installed by the University of Saskatchewan and Environment Canada in level, north facing, east facing, and south facing pine forests; a hay meadow; an alpine ridge top; a high elevation clearcut; a small clearing; and a high elevation spruce forest. Measurements of snowfall and rainfall, evaporation, soil moisture, soil freezing, snowmelt, radiation, wind speed, air temperature and humidity, and surface temperatures are being taken every 15 minutes at these sites.



The Lake O'Hara watershed is situated in the upper Cataract Brook Valley in Yoho National Park, British Columbia. Lake O'Hara is at an elevation of 2015 m a.s.l. The surrounding peaks reach heights over 3000 m. The terrestrial vegetation zones range from subalpine forests, dominated by spruce and fir trees, to heath tundra meadows and rock fields, dominated by lichens and mosses. Two weather stations, numerous streamflow gauging stations, water level devices, and shallow groundwater wells are installed at the site. Water, soil, aquatic plant, and invertebrate samples are collected as well.

BGI has researchers and collaborators involved with maintaining a meso-grid of backcountry weather stations in the southern Alberta foothills. This mountain-foothills climate array (FCA) will provide an unprecedented dataset of mesoscale meteorological variability in complex terrain.



Scientists from BGI and other collaborators have been conducting research in Sheep River Provincial Park in Kananaskis Country and on Ram Mountain (close to Rocky Mountain House) for well over 30 years, with sheep censuses being conducted at Ram Mountain since 1971 and at Sheep River since 1986. All resident bighorn sheep in Sheep River and Ram Mountain are marked and their population continues to be monitored for survival, predation events, individual reproductive success/tactics, relatedness and gene flow between populations, habitat use/health, animal health, and population trends.

Long-term studies have focused on behavioural ecology, life histories, and population dynamics of Columbian ground squirrels, with research programs going back to the 1970's. These programs form the basis for intensive monitoring that began in 1992 and is now addressing the influence of climate change on phenotypic and genetic characteristics of populations in natural alpine and subalpine environments.

Small mammal monitoring has been conducted since the 1970's at Fortress Mountain and Grizzly Creek. These populations have been studied and monitored to investigate the evolution of life history strategies and tactics in mammals living in short-season environments. Field studies begin early May to late August every year. The small mammal populations continue to be studied using both field and laboratory techniques (i.e., stable isotope).

The observation and monitoring of golden eagles migrating in the spring and fall near Mount Lorette by volunteers of the Rocky Mountain Eagle Foundation (RMERF) have been carried out since 1993. Researchers at BGI have been working with the group to understand the population dynamics of the golden eagle.

ENVIRONMENT CANADA VISIBILITY MONITORING SITE – KANANASKIS

Visibility is the primary means by which the general public judges air quality. While assessment of visibility conditions has taken place in urban areas of Canada, minimal information is available on the extent to which visibility is affected by air quality in rural and wilderness regions. Under a national visibility pilot monitoring study, Environment Canada is establishing air quality visibility monitoring capacity in rural/wilderness regions of Canada. Establishment of such monitoring capacity will allow assessment of the spatial and temporal trends of visibility degradation caused by air pollution. In addition, it will help fulfill Canada's responsibilities under the 1991 Canada-United States Air Quality Agreement (AQA), which is the primary mechanism for bi-national cooperation in addressing transboundary air pollution issues, and recognizes "the importance of preventing significant air quality deterioration and protecting visibility, particularly for international parks, national, state, and provincial parks, and designated wilderness areas".

Through a site selection process, the region of the Rocky Mountain parks was selected as a priority wilderness region to host a pilot visibility monitoring pilot site. Given its location away from significant sources of air pollution, on-site infrastructure, and year-round access, the University of Calgary Biogeoscience Institute Barrier Lake Field Station in Kananaskis Country was chosen as the monitoring site to represent this region. In cooperation with the University of Calgary, a monitoring site was established at the Barrier Lake Field Station in January 2011 and continues to run at present.

In order to ensure trans-boundary comparability of data, sampling taking place on site follows the United States Interagency Monitoring of Protected Visual Environments (IMPROVE) program protocols. The IMPROVE program manages visibility monitoring sites in 110 national parks and wilderness areas throughout the USA (http://vista.cira.colostate.edu/improve/Default.htm). In addition to these 110 sites, there are over 50 IMPROVE Protocol sites, including the new site at Barrier Lake Field Station and one in Egbert, Ontario, which has operated since 2005.

Instrumentation on site at Barrier Lake includes a nephelometer to measure atmospheric scattering by particles and an aerosol sampler which collects particulate matter on filters every third day. Subsequent analysis of the filter samples from the aerosol sampler at a laboratory to determine the composition of the particulate matter allows for the quantification of species known to be responsible for visibility impairment, from which the level of visibility degradation can be calculated. Particle composition data can also be used to infer which source categories are responsible for impairment of visibility. In addition to nephelometer and aerosol measurements, basic meteorological measurements are collected and there are plans for a digital camera to be installed to record information on visual air quality. Data collected from the monitoring site (BALA) will be available as the study progresses:

http://views.cira.colostate.edu/web/Default.aspx

Visibility Monitoring Site at Barrier Lake Field Station

Biogeoscience Institute

Barrier Lake / RB Miller Field Stations

2016-2017 Rates

	University Field Courses/BGS Education	Self-directed School Groups/ Universities/ Government Agencies	Non profit workshops/ conferences
Daily Costs (Per Person)			
Breakfast	$8.50	$10.00	$11.00
Lunch	$10.50	$12.50	$13.50
Dinner	$13.50	$15.00	$17.00
Linens	$2.50	$3.00	$4.00
Overnight	$17.50	$21.50	$31.00
Facility Fee	$7.50	$8.00	$8.50
Total cost (Before Tax)	$60.00	$70.00	$85.00
GST	$3.00	$3.50	$4.25
Tourism Levy	$0.70	$0.86	$1.24
Total cost with GST	**$63.70**	**$74.36**	**$90.49**

Addional Charges (Per Person)			
Snacks	$2.00	$2.50	$3.00
Single Room Rate (+ to overnight cost)	n/a	$10.00	$10.00
Classroom or Library Day Rate	n/a	$100.00	$150.00

MonthlyRentals			
Duplex -1 Bedroom	$550.00	$650.00	$850.00
Duplex -2 Bedroom	$650.00	$750.00	$1,000.00
Facility Fee - Weekly	$30.00	$45.00	$60.00
Facility Fee - Monthy	$60.00	$80.00	$100.00
RBMILLER			
Facility Fee - weekly	$15.00	n/a	n/a
Facility Fee - monthy	$35.00	n/a	n/a

School Groups	Day Trip	Two Days	Three Days
Students			
Meals	n/a	$32.50	$65.00
Accomodation	n/a	$25.00	$50.00
Education Fee	$35.00	$67.50	$95.00
Total cost (Before Tax)	$35.00	$125.00	$210.00
GST	$1.75	$6.25	$10.50
Tourism Levy	n/a	$0.70	$1.40
Total cost with GST	**$36.75**	**$131.95**	**$221.90**
Leaders			
Meals	n/a	$32.50	$65.00
Accomodation	n/a	$25.00	$50.00
Total cost (Before Tax)	$0.00	$57.50	$115.00
GST	$0.00	$2.88	$5.75
Tourism Levy	n/a	$0.70	$1.40
Total cost with GST	**$0.00**	**$61.08**	**$122.15**

*** Minimum Booking Numbers Apply To All Group Bookings ***