Banff International Research Station

for Mathematical Innovation and Discovery

Impact of climate change on biological invasions and population distributions
13-17 May, 2013

MEALS

*Breakfast (Buffet): 7:00 – 9:30 am, Sally Borden Building, Monday – Friday
*Lunch (Buffet): 11:30 am – 1:30 pm, Sally Borden Building, Monday – Friday
*Dinner (Buffet): 5:30 – 7:30 pm, Sally Borden Building, Sunday – Thursday
Coffee Breaks: As per daily schedule, in the foyer of the TransCanada Pipeline Pavilion (TCPL)
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in the lecture theater in the TransCanada Pipelines Pavilion (TCPL). An LCD projector, a laptop, a document camera, and blackboards are available for presentations.

SCHEDULE

Sunday

16:00	Check-in begins (Front Desk – Professional Development Centre - open 24 hours)
17:30-19:30	Buffet Dinner
20:00	Informal gathering in 2nd floor lounge, Corbett Hall (if desired) Beverages and small assortment of snacks are available on a cash honor system.

Monday

7:00-8:45	Breakfast
8:45-9:00	Introduction and Welcome by BIRS Station Manager, TCPL
9:00-10:00	Henri Berestycki, Ecole des Hautes Etudes en Sciences Sociales **- Can a species keep pace with a changing climate ?**
10:00-10:30	Odo Diekmann Mathematisch Instituut - Universiteit Utrecht & Laurent Desvillettes, Ecole Normale Supérieure de Cachan - **Can climate change lead to gap formation?**
10:30-11:00	Coffee Break
11:00-12:00	Ehud Meron, Ben-Gurion University **- Pattern formation - a missing link in the study of ecosystem response to climate change**
11:30-13:00	Lunch
13:00-14:00	Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
14:00-14:15	Group Photo; meet in foyer of TCPL (photograph will be taken outdoors so a jacket might be required).
14:15-15:10	Chris Cosner, University of Miami **- Challenges in Modeling Biological Invasions and Population Distributions in a Changing Climate**
15:10-15:30	Coffee Break
15:30-16:30	Alan Hastings, University of California, Davis **- Issues related to regime shifts and invasions**
16:30-17:00	Mary Lou Zeeman, Bowdoin College **- Resilience thinking in models**
17:00-17:30	Christina Cobbold, University of Glasgow **- Modelling the role of temperature in insect development and adaptation**
18:00-19:30	Dinner Free Time

Tuesday

7:00-8:30 Breakfast
8:30-9:30 Brett Melbourne, University of Colorado **- Spatial spread in invasion and climate change: stochastic models and biological experiments**
9:30-10:00 Amy Hurford, Memorial University of Newfoundland - **Parameterization of a mechanistic model for species spread under climate change and the implications for 12 North American butterfly species**
10:00-10:30 Coffee Break
10:30-11:30 William Fagan, University of Maryland **- Phenologically explicit models for population dynamics and species interactions under climate change**
11:30-13:30 Lunch
13:30-15:00 Break-out sessions/collaboration time
15:00-15:30 Coffee Break
15:30-17:00 Break-out sessions/collaboration time
17:30-19:30 Dinner
19:30-20:00 Alex Kiselev, University of Wisconsin **- Role of chemotaxis in enhancement of biological reactions**
20:00-20:30 Lionel Roques, INRA**- The dynamics of the genetic structure of range-expanding populations**
20:30-21:00 Francois Hamel, Universite d'Aix-Marseille & Institut Universitaire de France **- Inside structure of pulled and pushed fronts**

Wednesday

7:00-8:30 Breakfast
8:30-9:30 Luca Rossi, Università degli studi di Padova **- Fisher-KPP propagation in the presence of a line with fast diffusion**
9:30-10:00 Kim Cuddington, University of Waterloo **- Suboptimal conditions, stochasticity and probability of establishment**
10:00-10:30 Coffee Break
10:30-11:30 Yuan Lou, Ohio State University **- Evolutionarily stable strategies for dispersal in heterogeneous environments**
11:30-13:30 Lunch
Free Afternoon recommended--Hike or group activity
17:30-19:30 Dinner
Free Time

Thursday

7:00-8:30 Breakfast
8:30-9:30 Michael Bonsall, University of Oxford **- Noise, demographic sampling and population dynamics: implications of climate change.**
9:30-10:00 Claire Dooley, University of Oxford **- Spatial Patterns in Population Dynamics of the Large Skipper Butterfly**
10:00-10:30 Coffee Break
10:30-11:30 Péter Molnár, Princeton University **- Metabolic approaches to predicting ecological impacts of climate change: parasites, polar bears and other arctic critters**
11:30-13:30 Lunch
13:30-15:00 Break-out sessions/collaboration time
15:00-15:30 Coffee Break
15:30-17:00 Break-out sessions/collaboration time
17:30-19:30 Dinner
19:30-20:00 Jimmy Garnier, The French National Institute for Agricultural Research (INRA) **- Effect of climate niche shifting on the genetic diversity**
20:00-20:30 Rebecca Tyson, University of British Columbia Okanagan **- The Effect of Extreme**

Temperature Events on Developmental Dynamics

20:30-21:00 (Joy) Ying Zhou, University of Washington - **Niche deficits in varying climate warming scenarios: will the deficit go through the roof?**

Friday

7:00-8:30 Breakfast

8:30-9:30 Huaiping Zhu, York University - **Modeling Mosquito Abundance and West Nile Virus Risk Using Weather and Environment Conditions in Southern Ontario**

9:30-10:30 Paul Moorcroft, Harvard University - **Ecosystem futures: predicting the fate of Amazonian forests over the coming century**

10:30-11:00 Coffee Break

11:00-11:30 Mark Lewis, University of Alberta - **Mathematical challenges for modelling range boundaries and invasions in the context of climate change**

11:30-13:30 Lunch

Checkout by 12 noon.

** 5-day workshop participants are welcome to use BIRS facilities (BIRS Coffee Lounge, TCPL and Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

Abstracts to follow

Name of 2013 5-day Workshop
Date of 2013 5-day Workshop

ABSTRACTS

(in alphabetic order by speaker surname)

Speaker: Henri Berestycki, Ecole des Hautes Etudes en Sciences Sociales
Title: **Can a species keep pace with a changing climate?**
Abstract: Reaction-diffusion equations with heterogeneous terms can be used to describe biological populations whose range is dependent on climatic conditions. Time dependent versions of these equations, and in particular equations with an environment subject to translation with an exogenously given velocity provide simple models to represent the effect of a changing climate on a biological population. I will first describe such a model that we studied with O. Diekmann, K. Nagelkerke and P. Zegeling. We discuss the distribution of the population under a climate translation and examine the influence of various factors. I will review some extensions and further effects within this type of framework. This talk is intended to engage discussions about: 1) the relevance of the results from an ecological point of view, or what other properties should be looked for, 2) what are further effects to be included and how to enrich this type of model, and 3) what alternative models could be used.

Speaker: Michael Bonsall, University of Oxford
Title: **Noise, demographic sampling and population dynamics: implications of climate change**
Abstract: Climate change is expected to influence species phenologies, distributions and abundances. In many ways, this will be reflected in how variability in species traits (e.g., birth, death and/or dispersal rates) translates into affecting population-level patterns. I will present work on our approaches for understanding population and metapopulation dynamics. In particular, the emphasis will be on how we link theory and data and how best to appreciate how noise affects our understanding of the distribution and abundance of populations. Based on studies from laboratory microcosms, contemporary long-term field surveys and historical paleo-ecological records, the importance of demographic sampling, environmental noise and deterministic dynamics on the occurrence of a range of ecological processes such as Allee effects, alternative dynamics, spatial dynamics and trophic interactions will be highlighted. The implications for climate change on dynamics will be discussed.

Speaker: Christina Cobbold, University of Glasgow
Title: **Modelling the role of temperature in insect development and adaptation**
Abstract: Ecotherms rely on environmental heat sources to control their body temperature and as such temperature can play an important role in determining the development time and phenology of the organsim. Insects are an example of ectotherms, and the details of their phenology can have wide ranging consequences for population outbreaks and pest management, survival of consumers reliant on the insects

as food sources and the spread of insect-borne zoonotic diseases such West Nile virus.
The focus of my talk will be to examine how insect populations might adapt to changes in temperature. I will give an overview of some approaches for integrating climatic information into models of insect phenology. I will then explore how developmental rate curves may evolve in response to temperature and similarly how cold tolerance, the ability to survive winter freezing, my also adapt and discuss the population consequences of these adaptations.

Speaker: Chris Cosner, University of Miami
Title: **Challenges in Modeling Biological Invasions and Population Distributions in a Changing Climate**
Abstract: Classical models for dispersal and invasion typically assume that the underlying environment is fixed in size, shape, and location. They also typically focus on a single species or a pair of interacting species, with fixed attributes and interactions. In the presence of climate change and other anthropogenic changes to the environment those assumptions often will not be valid. In a changing climate the structure and properties of the underlying environment will change with time, which by itself poses modeling challenges. Climate change could shift the timing of events such as flowering, migration, or emergence from hibernation in different ways for different species, thus changing the interactions experienced by any particular focal species. To account for that, models would have to explicitly include parameters describing the timing of events. Climate change could also shift the ranges of species in space, which could also change species interactions and could cause niches to open up because the species occupying a particular niche has shifted its range and left that niche empty in some locations. To account for that, models would have to include multiple species. Finally, both climate change and the invasion process itself may impose novel selection pressures, so the attributes of a species invading a new region while the climate is changing are not likely to remain fixed. To address that would seem to require building some evolutionary processes into invasion models. This talk will discuss those issues and suggest some modeling approaches and ideas that might be relevant to addressing them.

Speaker: Kim Cuddington, University of Waterloo
Title: **Suboptimal conditions, stochasticity and probability of establishment**
Abstract: Environmental stochasticity has large impacts on the probability that an endangered population will go extinct, or that a newly introduced non-native species will establish and become invasive. Climate change will alter the intra- and inter-annual variance of environmental conditions, but in addition, recent work suggests that the autocorrelation signature of environmental signals may also change. We explore the impact of changes in variance and autocorrelation on establishment probability using both modeling and experimental approaches. We find that where variance is high and the geometric mean of the population growth rate is low, autocorrelation increases the risk that a population will pass an upper threshold density. That is, increased autocorrelation of environmental signals can increase the invasion risk for low risk populations.

Speaker: Odo Diekman Mathematisch Instituut - Universiteit Utrecht &
Laurent Desvillettes, Ecole Normale Supérieure de Cachan
Title: **Can climate change lead to gap formation?**
Abstract: Consider the situation that spatial heterogeneity creates a gradual shift in dominance of two competing species. Now assume that, due to

climate change, the environmental profile moves with constant speed in space. We show, in the context of a caricatural competition-diffusion model, that when the speed at which the environmental condition shifts exceeds the Fisher invasion speed of the advancing species, an expanding gap will form.
Joint work with Henri Berestycki

Speaker: Claire Dooley, University of Oxford
Title: **Spatial Patterns in Population Dynamics of the Large Skipper Butterfly**
Abstract: British butterfly life cycles and population dynamics are greatly influenced by a number of different weather variables. Butterfly species are not only ectothermic but are also highly sensitive to rainfall. I show for the large skipper butterfly *Ochlodes sylvanus* that responses in population growth to weather factors varies qualitatively across the different regions within its British range. My study also reveals a spatial variation in the importance of density dependence versus the importance of weather factors. Population dynamics in coastal regions in East England were significantly influenced by density dependence but not at all by weather factors, whereas weather appeared to be more influential on population dynamics than density dependence in regions clustered in North Wales and North-West England. My work highlights the need to develop our knowledge of spatial variation (including possible gradients) in the impact of weather factors on population dynamics, an area of research essential to predicting the consequences of potential increases in weather variability.

Speaker: William Fagan, University of Maryland
Title: **Phenologically explicit models for population dynamics and species interactions under climate change**
Abstract: Supported by extensive empirical data, issues of phenology (i.e., the timing of biological events such as budbreak, flowering, egg hatch, and metamorphosis) take center stage in discussions of the ecological consequences of climate change. However, classical modeling approaches in theoretical ecology do not take phenology into account, and instead focus on the dynamics of models that are time-independent. I will discuss how systems of non-autonomous ordinary differential equations can be used to explore the ecological consequences of phenological variation among individuals and shifts in phenology. I also discuss how non-autonomous partial differential equations can be used to study spatial phenomena such as critical patch size dynamics and species invasions that appear sensitive to phenology. Collectively, these 'phenologically explicit' models have substantial relevance biologically because they can be structured to allow parameterization from exactly the kinds of empirical data that are available from field studies of biological timing. Mathematically, these models are intriguing because they provide novel routes by which density dependent processes may introduce Allee effects, bifurcations, and complex dynamics. I draw on biological examples and data for populations of butterflies and moths, plant-pollinator systems, and plant-herbivore systems to motivate and parameterize the models.

Speaker: Jimmy Garnier, The French National Institute for Agricultural Research (INRA)
Title: **Effect of climate niche shifting on the genetic diversity**
Abstract: In this talk, I will analyze the genetic consequences of a climate change. As a result of climate change, a lot of species have seen their climatic niches shifted upward or poleward. Many populations have managed to track this moving

environment and they have expanded their range. But from a long-term prospective, it is not obvious if these populations can maintain a sufficient genetic diversity at the leading edge to tackle founder effects.
I will use a reaction-diffusion model with an heterogeneous environment which is moving with a constant speed in a particular direction to take into account the climate change. I will extend the analysis of inside dynamics of traveling waves to assess the effect of climate shifting on the dynamics of the genetic diversity of these expanding populations.
Then, I will use this analysis to describe the suitability of a climate change for a species.

Speaker: Francois Hamel, Universite d'Aix-Marseille & Institut Universitaire de France
Title: **Inside structure of pulled and pushed fronts**
Abstract: This talk will be focused on some mathematical aspects of a model for gene surfing along an invasion front. This model describes the dynamics of components inside a front. From a mathematical point of view, it corresponds to a reaction-diffusion equation with a forced speed. I will discuss the case of monostable, bistable or ignition reactions. In the monostable case, the fronts are classified as pulled or pushed ones, depending on the propagation speed. It will be shown that any localized component of a pulled front converges locally to 0 at large time in the moving frame of the front, while any component of a monostable pushed, bistable or ignition front converges to a well determined positive proportion of the front. The results give a more complete interpretation of the pulled/pushed terminology, which can be extended to the case of general transition waves.
This talk is based on some joint works with J. Garnier, T. Giletti, E. Klein and L. Roques.

Speaker: Alan Hastings, University of California, Davis
Title: **Issues related to regime shifts and invasions**
Abstract: I will review issues related to the existence and detection of regime shifts with special attention to the dynamics of invasions, both in spatial and nonspatial contexts. I will emphasize open questions, in particular ones related to the use of ideas of early warning signs to study the dynamics of invasive species.

Speaker: Amy Hurford, Memorial University of Newfoundland
Title: **Parameterization of a mechanistic model for species spread under climate change and the implications for 12 North American butterfly species**
Abstract: We apply a mechanistic spatial theory of species' range shifts under climate change (Potapov and Lewis 2004) to empirical data for 12 North American butterfly species to illustrate the potential use of the theory for global change biology. This theoretical framework explicitly defines the ecological processes that contribute to species range shifts via biologically meaningful dispersal, reproductive, and climate envelope parameters. We present methods for estimating the parameters of the model with widely available species occurrence and abundance data. The model predicts species persistence in light of current climate change and habitat loss. On average, we estimate the climate envelopes of our study species are shifting north at a rate of 3.25 km/yr (± 1.36 km/yr) and that our study species produce 3.46 viable offspring per individual per year (± 1.39). Based on our parameter estimates, we are able to predict the relative risk of our 12 study species lagging behind changing climate. This theoretical framework improves predictions of global change outcomes by facilitating the

development and testing of hypotheses, providing mechanistic predictions of current and future range dynamics and encouraging the adaptive integration of theory and data.
This presentation describes joint work led by Shawn J. Leroux and in collaboration with Maxim Larrivée, Véronique Boucher-Lalonde, Juan Zuloaga, Jeremy T. Kerr, and Frithjof Lutscher.

Speaker: Alex Kiselev, University of Wisconsin
Title: **Role of chemotaxis in enhancement of biological reactions**
Abstract: We discuss a system of two equations involving two diffusing densities, one of which is chemotactic on another, and absorbing reaction. The problem is motivated by modeling of coral life cycle and in particular breeding process, but the setup is relevant to many other situations. The models built on diffusion and advection alone, seem to under predict the success rate in coral reproduction. We show that presence of chemotaxis can significantly increase model reproduction rates. On mathematical level, the first step in understanding the problem involves derivation of sharp estimates on rate of convergence to bound state for Fokker-Planck equation with logarithmic potential in two dimensions.

Speaker: Mark Lewis, University of Alberta
Title: **Mathematical challenges for modelling range boundaries and invasions in the context of climate change**
Abstract: In this talk, I will try to outline the major developments and challenges arising from the BIRS workshop.

Speaker: Yuan Lou, Ohio State University
Title: **Evolutionarily stable strategies for dispersal in heterogeneous environments**
Abstract: From habitat degradation and climate change to spatial spread of invasive species, dispersal plays a central role in determining how organisms cope with a changing environment. How should organisms disperse “optimally” in spatially heterogeneous environments? I will discuss some recent development on the evolution of dispersal via reaction-diffusion-advection models.

Speaker: Brett Melbourne, University of Colorado
Title: **Spatial spread in invasion and climate change: stochastic models and biological experiments**
Abstract: I will describe an approach to studying spatial spread, including responses to climate change, that tightly links stochastic models with biological experiments. We derive mechanistic stochastic models at the population and landscape levels by scaling up from stochastic processes at the level of individuals. These models are tailored to highly replicated experimental microcosms using the red flour beetle, Tribolium castaneum. I will discuss experiments including spread into a novel habitat, spread in spatially heterogeneous landscapes, range limits on environmental gradients or environmental boundaries, and shifting habitats as expected under climate change. An advantage of this approach is the ability to control demographic, genetic, and environmental factors, and to closely track population and genetic changes through time. A further advantage is that we can study variance in spread generated by biological processes, essential for understanding uncertainty in model predictions.
Collaborators: Alan Hastings (University of California, Davis), Ty Tuff (University of Colorado, Boulder), Ruth Hufbauer (Colorado State University), Marianna Szucs (Colorado State University), Patrik Nosil (University of

Sheffield, UK).

Speaker: Ehud Meron – Ben-Gurion University
Title: **Pattern formation - a missing link in the study of ecosystem response to climate change**
Abstract: Self-organization processes leading to pattern formation phenomena are ubiquitous in nature. Cloud streets, sand ripples, stone patterns and animal-coat patterns are a few examples. Intensive theoretical and experimental research efforts during the past few decades have resulted in a mathematical theory of pattern formation whose predictions are well confirmed by controlled laboratory experiments. There is increasing observational evidence that pattern formation also plays an important role in shaping water-limited landscapes. Depending on the rainfall regime, self-organized vegetation patchiness in the form of nearly periodic spot, stripe and gap patterns has been reported. Supporting these observations are studies of spatially explicit vegetation models that have reproduced many of the observed patterns. In this talk I will review the state of art in studies of vegetation pattern formation, and delineate manners by which pattern formation processes can affect ecosystem response to environmental changes. The latter include gradual and incipient regime shifts induced by droughts and disturbances, the possible emergence of unexpected resonant patterns in water-harvesting practices of vegetation restoration, and mechanisms of species coexistence in stressed environments.

Speaker: Péter Molnár, Princeton University
Title: **Metabolic Approaches to Predicting Ecological Impacts of Climate Change: Parasites, Polar Bears and Other Arctic Critters**
Abstract: Climate change is affecting ecosystems worldwide. Predictive models for future impacts are needed but often remain elusive due to ecosystem complexity and a lack of data to parameterize models. Here, I argue that most impacts can be understood using bioenergetic approaches. Two major frameworks – the Metabolic Theory of Ecology (MTE) and Dynamic Energy Budget Theory (DEB) – have emerged in recent years, and I will discuss how these can be used to predict climate change impacts. For illustration, I focus on arctic ecosystems, which – due to a strong climate signal and relatively low complexity – are particularly suitable to develop and test predictive models. First, I link MTE with host-macroparasite models, an approach that allows addressing some of the central questions concerning climatic impacts on host-parasite systems, such as which systems are the most sensitive to change, or at which locations climate change will have the greatest impact. The framework allows integrating multiple nonlinear environmental effects to predict parasite fitness under novel conditions, and can, for example, be used to determine whether climate change will lead to range contractions, shifts, or expansions. Applying the models to seasonal environments, I show that climate warming can split previously continuous spring-to-fall transmission seasons into two separate transmission seasons with altered timings. Further, I show that parasites with an indirect life cycle may adapt more easily to warmer climates than parasites with a direct life cycle, in contrast to commonly prevailing assumptions. Model predictions conform closely with empirical data for several helminth parasites, indicating broad model applicability. Second, I discuss DEB-models for polar bears, which capture the functional dependence between energy availability and physiological processes to predict survival and reproduction under future environmental conditions. Finally, I highlight potential alleys to link MTE- and DEB-approaches to develop a unifying mechanistic, bioenergetic framework for understanding

climatic impacts on ecosystems. Throughout, I will place particular emphasis on the usefulness of bioenergetic approaches for estimating model parameters *a priori*, even in data-poor systems. This ability could help resolve prevailing problems of data scarcity and thus provide a framework for understanding and predicting climate change impacts worldwide.

Speaker: Paul Moorcroft, Harvard University
Title **Ecosystem futures: predicting the fate of Amazonian forests over the coming century**
Abstract: A number of existing predictions for the fate of Amazon forests over the coming century imply a threshold-type in which the ecosystem changes abruptly response to anthropogenic climate change. In this study, we investigate the fate of the Amazon forest using a terrestrial biosphere model that incorporates fine-scale ecosystem heterogeneity. The model reproduces observed patterns of spatial variability in above-ground biomass and associated changes in forest composition and canopy dynamics with increasing dry season length. Analysis shows that that these patterns are linked to water limitation operating at the scale of individual plants. As dry season length increases, heterogeneity in soil texture gives rise to varying levels of water limitation within the plant canopy, which gives rise to increasing spatial heterogeneity in above ground biomass and accompanying shifts in forest composition and structure. We then show these findings have important implications for the temporal response of Amazon ecosystems to anthropogenic climate change. Specifically, in contrast to the existing predictions of threshold-type behavior, our analysis implies that there will be immediate responses of Amazon forests to changes in climate characterized by a gradual, heterogeneous transition from high biomass moist tropical forests to seasonally dry and transitional forest types.

Speaker: Lionel Roques, INRA
Title: **The dynamics of the genetic structure of range-expanding populations**
Abstract: Scalar reaction-dispersion equations are widely used for the description of the spatio-temporal dynamics of a population. It is often useful to be able to distinguish between different subclasses in the population. These subclasses correspond, for instance, to genetic fractions. A usual way to introduce diversity in these models, avoiding the use of complex systems with several equations, is to introduce a variable corresponding to the position in the set of subclasses, e.g. a quantitative phenotypic trait. Here, we propose a totally different approach, which aims at being easily adaptable to a large class of models. The idea is to decompose the solution of the global model as the sum of subclasses. We give several applications of our approach to the study of the dynamics of genetic diversity in range-expanding populations. In particular, we investigate the role of the Allee effect and the existence of a non-reproductive juvenile stage."

Speaker Luca Rossi, Università Degli Studi di Padova
Title: **Fisher-KPP propagation in the presence of a line with fast diffusion**
Abstract: We propose a new system to describe the influence of a "road" with fast diffusion on biological invasions. Outside of the road a classical Fisher-KPP propagation with a different diffusion takes place.
It is found that the asymptotic speed of propagation in the direction of the road is enhanced if the ratio between the two diffusivities is above some threshold.
In such case, the speed of propagation in a given direction depends on the angle formed with the road. It turns out that there is a critical angle passed which the

enhancement does not occur.
This is a joint work with H. Berestycki and J.-M. Roquejoffre.

Speaker: Rebecca Tyson, University of British Columbia Okanagan
Title: **The Effect of Extreme Temperature Events on Developmental Dynamics**
Abstract: Extreme temperature events such as sudden and brief periods of warm temperatures during an otherwise cold season potentially have a strong effect on the developmental dynamics of insects that depend on temperature cues for development. We present a model for insect development based on the work of Powell et al., and investigate how the stable annual oviposition date and insect mortality are affected by extreme temperature events. Our work is motivated by the case of a biocontrol agent released in the foothills of the Rocky Mountains in southern Alberta where extreme temperature events called Chinooks are common in the wintertime. R.C. Tyson, G. Culos and R. DeClerke-Floate

Speaker: Mary Lou Zeeman, Bowdoin College
Title: **Resilience thinking in models**
Abstract: We will follow up on Alan's talk about issues related to regime shifts, to explore how similar ideas can be used as a framework for thinking about resilience in dynamical models, and discuss open questions related to finding proxies for modelling the role of temperature in insect development and adaptation resilience.

Speaker: (Joy) Ying Zhou, University of Washington
Title: **Niche deficits in varying climate warming scenarios: will the deficit go through the roof?**
Abstract: Rapid climate warming has caused species across the globe to shift their geographic ranges in recent years. This phenomenon has inspired us to consider an integrodifference equation (IDE) model for a single-species population whose suitable spatial range changes over time. The model is very versatile when it comes to prescribing spatially-heterogeneous recruitment rates, dispersal patterns (through an integral kernel), and varying speeds of climate warming. Although the IDE is non-autonomous in general, when the speed of warming is constant, we can peel off the time dependence to reveal its autonomous nature. It follows that, depending on the dominant eigenvalue of a linear integral operator, the population may persist (population distribution converge to a traveling pulse solution) or go extinct (population distribution converge to the trivial solution). Calculation of this dominant eigenvalue usually requires numerical methods, but there is a special example where an analytic result is available. This analytic example provides important insights, both for the constant-speed warming scenario and other scenarios such as accelerated warming. For example, it demonstrates how climate warming outruns the shifting population distribution. I will use the term "niche deficits" to refer to the distance that the population lags behind. The accumulation of niche deficits is shown to be drastically different between the constant-seed warming case and the accelerated-warming case.

Speaker: Huaiping Zhu, York University
Title: **Modeling Mosquito Abundance and West Nile Virus Risk Using Weather and Environment Conditions in Southern Ontario**
Abstract: In this talk, I will present modeling studies of mosquito abundance and West Nile virus risk in Southern Ontario, Canada. By using surveillance data, weather data

and land use information in the regions of Ontario, we develop both statistical and dynamical models incorporating weather conditions and land use information for the vector-mosquitoes abundance and risk assessment of West Nile virus. I will also present our weekly forecasting practice of the mosquito abundance and West Nile virus risk in the regions of Ontario, a collaborative effort with health regions of Ontario and Public Health Agency of Canada.