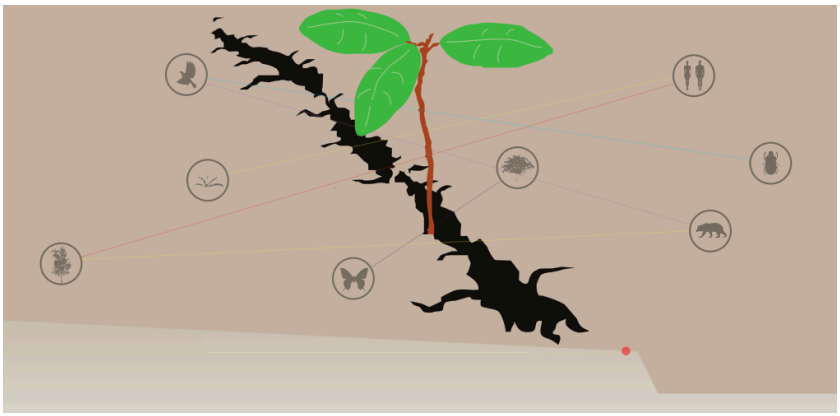
CONFERENCE PROGRAM

Living on the Precipice: Interdisciplinary Conference on Resilience in Complex Natural and Human Systems



UNIVERSITY OF WATERLOO

May 16-17, 2017

Hosted by the Waterloo Institute for Complexity and Innovation

WATERLOO INSTITUTE for COMPLEXITY & INNOVATION

with additional support from the Field's Institute for Mathematical Sciences and the Canadian Industrial and Applied Mathematics Society

FIELDS

SCM CAIMS I

Canadian Applied *and* Industrial Mathematics Society

Société Canadienne *de* Mathématiques Appliquées *et* Industrielles

WATERLOO INSTITUTE for COMPLEXITY & INNOVATION

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Conference Information

The resilience of complex systems to disturbances is a topic of longstanding and continuing interest in academic communities including applied mathematics, ecology, environmental sciences, and the social sciences and humanities, among others. Over the past few decades this research has led to both insights into real-world systems as well as policy improvements. However, significant theoretical and empirical challenges remain, as well as challenges in improving policy. This is particularly urgent for environmental systems where human influence is pervasive. This conference will bring together researchers and scholars interested in resilience in complex systems, with a special emphasis on natural, human, and coupled natural-and-human systems. The objective is to advance the field by bringing together individuals trained in disparate disciplines working on both qualitative and quantitative approaches, so they can benefit from interdisciplinary conversations. This conference will thereby deepen our understanding of resilience and help identify priority areas for future research.

Organizing Committee: Chris Bauch (Committee Chair, University of Waterloo), Madhur Anand (WICI Director, University of Guelph, University of Waterloo), Mark Crowley (University of Waterloo), Vanessa Schweizer (University of Waterloo), Kathryn Fair (University of Waterloo), Perin Ruttonsha (University of Waterloo), Yue Dou (Michigan State University), Andjela Tatarovic (University of Waterloo)

Assistant to Organizing Committee: Noelle Hakim-Valeriote (University of Waterloo)

Conference website: http://wici.ca/new/2016/12/wici-resilience-and-complexity-conference-may-16-17-2017/

Program for May 16 (Day 1)

Please see end of program for venue and campus maps. Any schedule changes will be posted each day on the Message Board located in the registration area. Please visit this area each day for the most up-to-date information about session changes and other conference news.

8.45-9.00	Welcome and opening comments from WICI Director Madhur Anand *Room SJ2 - 2002*
9.00-10.00	Plenary talk: Alan Hastings, University of California, Davis *Room SJ2 - 2002*
10.00-10.30	Coffee break *Atrium*
10.30-11.15	Invited speaker 1: Mark Constas, Cornell University *Room SJ2 - 2002*
11.15-12.00	Invited speaker 2: Matthew Bonds, Harvard University *Room SJ2 - 2002*
12.00-1.00	Lunch *St. Jerome's Servery*
1.00-1.45	Invited speaker 3: Ann Kinzig, Arizona State University *Room SJ2 - 2002*
1.45-2.30	Invited speaker 4: Vanessa Schweizer, University of Waterloo *Room SJ2 - 2002*
2.30-2.45	Coffee break *Atrium*
2.45-4.15	Parallel sessions Session 1: Human Behaviour Affects the Spread of Diseases, Ideas and Identities (*Room SJ2 - 2001*) Session 2: Sustainability and Coupled Human-Environment Mathematical Models (*Room SJ2 - 2003*) Session 3: Case Studies from Local to Global in Natural and Human Resilience (*Room SJ2 - 2007*)
4.15-4.30	Coffee break *Atrium*
4.30-5.15	Invited speaker 5: Simron Singh, University of Waterloo *Room SJ2 - 2002*
5.15-6.00	Invited speaker 6: Philip Beesley, University of Waterloo *Room SJ2 - 2002*
6.00-7.00	Reception *Atrium*

WATERLOO INSTITUTE for COMPLEXITY & INNOVATION

Program for May 17 (Day 2)

Please see end of program for venue and campus maps. On day 2, WICI conference events will be held in coordination with the BioM&S Symposium events (https://mathstat.uoguelph.ca/bioms) and registrants for either meeting will be able to attend events in both meetings. In the following schedule, light blue font is used to indicate BioM&S events. This year, the topic of the BioM&S Symposium is microbial ecology.

<table>
<tr><td>9.00-10.00</td><td colspan="3">BioM&S Plenary Talk #1: Jurek Kolasa, McMaster University
Room SJ2 - 1002</td></tr>
<tr><td>10.00-10.30</td><td colspan="3">Coffee break. WICI and BioM&S poster session.
Atrium</td></tr>
<tr><td>10.30-11.15</td><td colspan="3">WICI Invited speaker 7: Bridie McGreavy, University of Maine
Room SJ2 - 1002</td></tr>
<tr><td>11.15-12.00</td><td colspan="3">WICI Invited Speaker 8: Kevin McCann, University of Guelph
Room SJ2 - 1002</td></tr>
<tr><td>12.00-12.45</td><td colspan="3">Lunch
St. Jerome's Servery</td></tr>
<tr><td>12.45-1.30</td><td colspan="3">WICI and BioM&S poster session
WICI closing comments and awards
Atrium</td></tr>
<tr><td>1.30-2.00</td><td>MapleSoft Demonstration
Room SJ2 -2007</td><td>Workshop: What is Life? Socio-Ecological Resilience and Sustainability as Complex Adaptive Processes
Room SJ2-2001</td><td rowspan="2">BioM&S Plenary Talk #2
Ashton Lecture: Honzhe Li, University of Pennsylvania
Room SJ2-2002</td></tr>
<tr><td>2.00-2.30</td><td colspan="2">Workshop: What is Life?
Room SJ2- 2001</td></tr>
<tr><td>2.30-3.15</td><td colspan="2" rowspan="3">Graduate Student Workshop: Transdisciplinarity in Resilience Research: Formulating Diverse Conceptions of Complex Systems

KI studio (EV2-2069)</td><td>BioM&S Talk 1: Hong Gu, Dalhousie University
Room SJ2-2002</td></tr>
<tr><td>3.15-3.45</td><td>Coffee Break
Atrium</td></tr>
<tr><td>3.45-4.30</td><td>BioM&S Talk 3: Peter Kim, University of Guelph
Room SJ2-2002</td></tr>
</table>

4.30-5.15	See campus map	BioM&S Talk 4: Toby Kenney, Dalhousie University *Room SJ2-2002*
5.15-5.30		BioM&S Closing Comments *Room SJ2-2002*
5.30-6.30		

Plenary Talk Abstract

"**Management of ecological populations in time and space**"

Alan Hastings, University of California Davis

I will begin with several examples of ecological systems that raise important issues of management approaches: invasive species and coral reef ecosystems. I will then present general approaches that can be sued to address management problems for these systems as well as other systems. Themes will include the role played by simple models on the one hand, and, the importance of recognizing nonlinearities and the possibility of tipping points. An overall important theme will be the need to focus on appropriate biological time scales, and the limitations of management options available for ecological systems.

Invited Talk Abstracts

"Resilience and the Measurement of Recovery in Development Settings"

Mark Alexander Constas, Cornell University

There is wide agreement that the combined effect of climate change, ecosystem fragility, political instability, and economic volatility has generated a more pronounced set of risks for the world's poor. Viewed as both a strategic approach and as a programmatic objective to deal with an altered risk landscape, resilience has emerged as a popular concept among those who work to find solutions to the challenges of humanitarian aid and development assistance. Over the past few years, international agencies and the donor community have made large investments in resilience programming. The high levels of enthusiasm associated with resilience have been paralleled by a growing need for data on the success of related policies and interventions. Consequently, the need for resilience measurement has increased significantly. The purpose of the present paper is to describe the theoretical foundations and empirical requirements of a resilience measurement methodology designed for developing countries. Drawing on work undertaken as part of an ongoing effort sponsored by several United Nations agencies, this paper presents an approach to measure resilience that enables the analysis of dynamic relationships central to understanding recovery. An ongoing study that examines recovery trajectories following exposure to a catastrophic flood

is used as an empirical example of resilience measurement. Ideas related to the next generation of resilience measurement for development are also considered.

"Ecology of Poverty, Disease, and Health Care Delivery: A New Model District in Madagascar"

Matthew Bonds, Harvard University

Over the past two decades, the global health agenda has increasingly embraced the concept of sustainable development in pursuit of solutions at the "systems" level. A central challenge is that the relevant social, economic, and biophysical systems that influence human health and wellbeing operate at difference spatial and temporal scales and scopes of problem solving. I present mathematical and conceptual models to explore three interconnected self-reinforcing systems of central importance to planetary health: 1) the ecology of poverty, 2) the ecology of disease, and 3) systems of health care delivery. A new model health district in Madagascar is presented to demonstrate how interventions can be implemented and studied to a) create practical systems-level change at the ground level, and b) establish methods for evaluating that change and produce transferable knowledge for scaling or replication.

"Extending Resilience Beyond Small-Scale Natural Resource Systems: A Help or a Hindrance for Human Well Being?"

Ann Kinzig, Arizona State University

Crawford ("Buzz") Hollings seminal 1973 paper created a "paradigm shift" for how scholars thought about resilience in ecological systems. These insights were later extended to small-scale social-ecological systems, and the framework further developed by members of the Resilience Alliance, among others. More recently the resilience framework has been applied to larger-scale natural resource systems, cities, neighborhoods, disasters, and national security. How applicable is the resilience framework to these sectors and situations? This talk will look at the application of resilience beyond its original foundations of small-scale natural-resource systems, ask what has worked and what hasn't, and examine how the resilience framework may have to change to be more broadly applicable.

"System Collapse, Tipping Points and Complex Disasters: Nicobar Islands in the Aftermath of the 2004 Tsunami"

Simron Singh, University of Waterloo

By virtue of being close to the epicentre, the Nicobar Islands located in the Bay of Bengal was severely affected by the 2004 Indian Ocean tsunami. Overwhelming aid followed, and in a matter of months, transformed an indigenous community of hunters, gatherers and coconut growers into a consumer society. Based on several years of fieldwork, this paper describes the tsunami and its aftermath, the role of aid organizations, the media and the government in driving the islanders from a self-reliant to an aid dependent society, plagued with social conflicts. We call this a 'complex disaster', a situation that has fundamentally challenged the island socio-ecological system to reproduce itself, leading to a breakdown in society's metabolism to fundamentally alter society-nature interactions. In other words, a complex disaster results from inappropriate interventions following a "simple" disaster, affecting the social system's ability to regenerate, to govern its own recovery, by interfering with its cultural, economic and political regulation. This is, in effect, a situation more severe and longer lasting than what the disaster itself had accomplished. Using the case of the Nicobar Islands in the aftermath of the tsunami, and drawing on results from an agent-based model, the paper will elaborate on the phenomenon of a system collapse, tipping points and how this relates to the notion of complex disasters.

"**Investigating resilience and transformability in human systems**"

Vanessa Schweizer, University of Waterloo

"Resilience" and "transformation" have become hot topics in research on sustainability and the impacts of climate change. However, the meanings of these terms are contested, especially when applied to human systems. A challenge has been that many factors potentially relevant as drivers or indicators of resilience and transformability can be difficult to quantify. This has prevented advancements in clarifying how resilience and transformability in human systems can be studied systematically, let alone enhanced deliberately. This talk proposes that even with qualitative, case-specific understandings of interrelationships among difficult-to-quantify social factors, typical conceptualizations of resilience from the natural sciences, engineering, and mathematics – e.g., local stability, multiple equilibria, and structural stability – remain applicable and can provide clues for the transformability of human systems.

"New Sentient Architecture"

Philip Beesley, University of Waterloo

Can architecture come alive? Could future buildings think, and care? Researchers from the Living Architecture Systems Group are exploring these questions by designing new prototypes of experimental architecture. The Living Architecture collaboration includes architects, engineers and industrial designers from the University of Waterloo in Canada, with groups of re searchers in North America and Europe. Design methods from the Living Architecture group are now being used to train emerging generations of architects and engineers, providing them with the skills they need to work with complex interconnected sustainable environments.

These extremely lightweight, flexible structures are interwoven with miniature computers controlling mechanisms that can sense, react and learn from viewers. The work is organized the same as a coral reef or a swarm of insects, with large numbers of many individual parts. These systems are connected together, passing signals back and forth so that the entire environment works as a whole. Interconnected vessels contain a liquid synthetic biology that can absorb and exchange materials from the atmosphere. Digitally fabricated components make meshwork scaffolds with mechanical fronds that gently stir the air. Cricket-like acoustic mechanisms make constantly-shifting choruses of whisper sounds, responding to movement of viewers. Working together, these systems suggest new ways of building adaptive, sensitive buildings of the future.

"**Communicating resilience in coastal shellfish management: Insights from sustainability science to connect science with decision making and promote human well-being**"

Bridie McGreavy, University of Maine

Soft-shell clams, Mya arenaria, and the intertidal ecosystems in which clams grow are an important part of global coastal economies, environments, and cultures, but the resource is also among the most imperiled. The shellfish industry faces multiple stressors, many linked to climate change, such as increases in ocean temperature and invasive species populations as well as unsustainable land use and development. In the northeastern United States, Maine's shellfish resource has a long history of community-based co-management, where municipalities work with the Maine Department of Marine Resources (DMR) and other state agencies to manage the resource. Globally, community-based co-management arrangements that include fishermen have been shown to be a key factor in promoting the health and adaptability of fisheries, though relatively few studies have looked at clam fisheries and none have focused on understanding and enhancing communication within this context.

We conducted a four-year ethnographic and engaged communication research project within Maine's shellfish management which resulted in science-based

recommendations to managers and regulators to promote adaptive capacities in the face of rapid coastal change. Through participant observations at fifty meetings and in-depth interviews (n=41), we identified complex and intersecting socio-environmental problems. In light of these problems we also examined how people within the shellfish industry define success and how, through communication, we can strengthen the shellfish management program to help promote ecosystem resilience and human well-being. Working with representatives from DMR, the Maine Shellfish Advisory Council (ShAC), and shellfish committees from across the coast we developed five specific communication recommendations. These recommendations focus on conducting a yearly needs assessment with towns; building municipal partnerships; increasing information sharing; improving and leveraging the annual Maine Fishermen's Forum; and agency restructuring to prioritize shellfish science within DMR. We also discuss how this research produced an understanding of a particularly challenging social problem, namely substance use disorders and opiate addiction in the shellfishery, and its influence on socio-environmental sustainability. We conclude by describing how our recommendations have been incorporated into decision making within the municipal shellfish management system and reflect on how this approach may be adapted to other natural resource-based economies, communities, and co-management contexts to help build resilience to coastal change.

"Embracing Variability: On the Adaptive Capacity of Food Webs"

Kevin McCann, University of Guelph

Environments are changing at a rapid pace. Scientists are now tasked with anticipating a myriad of potential threats to the stability of single populations, multi-species communities and entire ecosystems. However, the across scale responses to environmental change, and the characteristics that allow ecosystems to respond flexibly to perturbations, have only recently been considered. Here, I begin to look at theoretical and empirical results that suggest that organismal responses to variation may be the real "structure" that governs stability and resilience of ecosystems. I argue that understanding an ecosystems "adaptive capacity" is central to the goal of developing more theoretically and evidence based conservation and management strategies in a changing world.

Contributed Talk Abstracts

Session 1: Human Behaviour Affects the Spread of Diseases, Ideas and Identities
Room SJ2 - 2001

2:45 – 3:00: **"Voluntary vaccination strategy and the spread of sexually transmitted diseases"**. Fei Xu, Wilfred Laurier University**.** Co-authors: Ross Cressman

In this work, we investigate the spread and control of sexually transmitted diseases when a game-theory based vaccination strategy is involved. An individual's decision on vaccination uptake may follow a cost-benefit analysis since the individual obtains immunity against the disease from the vaccination and, at the same time, may have some perceived side effects. Evolutionary game theory is integrated into the epidemic model to reveal the relationship between individuals' voluntary decisions on vaccination uptake and the spread and control of such diseases. We show that decreasing the perceived cost of taking vaccine or increasing the payoff from social obligation is beneficial to controlling the disease. It is also shown how the "degree of rationality" of males and females affects the disease spread through the net payoff of the game. In particular, individual awareness of the consequences of the disease on the infectives also contributes to slowing down the disease spread. By analyzing an asymmetric version of our evolutionary game, it is shown that the disease is better controlled when individuals are more sensitive to fitness differences when net payoff is positive than when it is negative.

3:00-3:15: **"A Mathematical model of radicalization".** Manuele Santoprete, Wilfred Laurier University. Co-authors: Connell McCluskey

Radicalization is the process by which people come to adopt increasingly extreme political or religious ideologies. In recent years radicalization has become a major concern for national security because it can lead to violent extremism. Governments and security services are making a substantial effort to better understand the radicalization process and to identify the psychological, social, economic, and political circumstances that lead to violent extremism. It is in this context that this talk attempts to describe radicalization mathematically by modelling the spread of extremist ideology as the spread of an infectious disease. This is done by using a compartmental epidemiological model. We try to use this model to evaluate the effectiveness of some strategies to counter violent extremism.

3:15–3:30: **"The effect of commonly shared modifiable group identities on the resilience of a social system".** Luca Rade, Princeton University

A resilient system is able to maintain its functional organization in the face of unexpected catastrophic risk. This involves a response system that is flexible and adaptive (Levin, 1998). One of the most notable characteristics of human societies is the existence of abstract, widely shared group identities. By setting up a simple model of agents interacting to produce a functional outcome and introducing a modifiable group identity, I show that this additional component increases the system's resilience to external shocks. More specifically, the group identity is an added variable to each agent's behavioral function and facilitates cooperation between previously non-interacting agents through similar mechanisms to those of foci (Feld 1981). Resilience is increased by allowing instantaneous costless diffusion of behavior change and easier rewiring between agents, enabling the system to continue achieving its functional outcome through flexible and rapid adaptation.

3:30-3:45: **"The Body of the Nation: A Cognitive-Affective Theory of National Identity".** Steve Mock, University of Waterloo

The interdisciplinary study of ethnicity and nationalism is rife with competing theories that explain the persistence and resilience of the nation as the dominant means of constructing identity and normative basis of political legitimacy in the modern world. Is the nation a wholly modern contrivance, or in continuity with pre-modern forms of cultural and political community? Does its efficacy lie in its ability to rationalize current dynamic social arrangements, or in providing its members with a sense of ultimate meaning grounded in primordial human needs? Is its symbolic and normative structure determined organically "bottom-up" by its members, or invented "top-down" by the state? Using a new method derived from the cognitive sciences for graphically representing the emotional content of belief systems, I show how these debates can be resolved through an approach that frames the nation as an emergent product of dense interaction between systems that operate at traditionally distinct levels of analysis: the individual-cognitive systems of the human mind, and the collective-social systems of the group.

3:45-4:00: **"Design for Resilience: Supporting Stakeholders in Systemic Transformations".** Goran Matic, Ontario College of Art and Design. Co-author: Ana Matic

A number of researchers have proposed important theoretical frameworks that reflect on the nature of the phenomena of resilience across various systemic scales (Bergström and Dekker 2014), human psychosocial contexts (Matin and Taylor 2015) and from the standpoint of social support (Sippel et al. 2015) as influenced by social systems (Almedom 2015). We look at the broadly shared characteristics that human participants ('stakeholders') might share within such transforming eco/systems, as an input for proposing a new kind of design practice - one that focuses on building stakeholder resilience by maximizing social coherence

(Antonovsky 1987, Keyes 1998) across systemic scales and levels of analysis (Marr 1982), optimizing for integrative complexity (Tadmor et al. 2009), and easing the perilous journey across the 'liminal spaces' (Van Gennep 1906, Turner 1987) that demarcate transformational journeys. We propose an integrative design process oriented towards building resilience, that can be utilized by multi-disciplinary practitioners during systemic transformations.

Session 2: Sustainability and Coupled Human-Environment Mathematical Models
Room SJ2 - 2003

2:45-3:00: **"Population dynamics in a changing environment: interactions and feedbacks".** Ivan Sudakov, University of Dayton

A multispecies population model surviving on distributed resources is considered. The basic model is demanded as Lotka-Volterra type and modeling the large ecosystem and the effect of climate is incorporated into the model by considering the effect of environmental temperature on the system dynamics. In particular, a feedback between species abundances and resources via environmental temperature factor is introduced. This model is apparently the first of its kind to include a feedback mechanism coupling climate and population dynamics. In case of a positive climate feedback loop we observe catastrophic bifurcations related to the extinction of all species.

3:00-3:15: **"Supply and demand drive a critical transition to dysfunctional fisheries".** John Fryxell, University of Guelph

There is growing awareness of the need for fishery management policies that are robust to changing environmental, social, and economic pressures. Here use conventional bioeconomic theory to demonstrate that inherent biological constraints combined with nonlinear supply-demand relationships can generate threshold effects due to harvesting. As a result, increases in overall demand due to human population growth or improvement in real income would be expected to induce critical transitions from high yield/low price fisheries to low yield/high price fisheries, generating severe strains on social and economic systems as well as compromising resource conservation goals. As a proof of concept, we show that key predictions of the critical transition hypothesis are borne out in oceanic fisheries (cod and pollock) that have experienced substantial increase in fishing pressure over the past 60 years. A hump-shaped relationship between price and historical harvest returns, well demonstrated in these empirical examples, is particularly diagnostic of fishery degradation. Fortunately, the same heuristic can also be used to

identify reliable targets for fishery restoration yielding optimal bioeconomic returns while safely conserving resource abundance.

3:15-3:27: **"Common Pool Resource Harvesting: Structural Similarities between Fisheries, Product Markets, and Bank Lending".** Michael Yodzis, University of Guelph

Harvesting a renewable resource involves a choice about sustainability: how large a profit does the harvester seek relative to the resource's capacity to regenerate, and are they planning for the short-term or the long-term? If in addition the resource belongs to a common pool that is drawn upon by a group of harvesters, the question of sustainability becomes a social coordination problem: how to satisfy the preferences of each harvester without descending to a state of competitive over-extraction, or a tragedy of the commons? Drawing on insights from mathematical models in ecological economics and evolutionary game theory, this talk will discuss the common pool attributes of fisheries that are found in other economic sectors, and will explore ways of viewing industrial organization and financial fragility in a common pool resource context.

3:27-3:40: **"Regime shifts in socio-ecological systems: Silent early warning signals in the natural subsystem".** Thomas Bury, University of Waterloo**.** Co-authors: Chris Bauch, Madhur Anand

Abrupt and often irreversible transitions can be observed in a wide variety of systems including ecological communities, complex disease and social networks. These so-called 'critical transitions' can be brought on by a gradual change in external conditions that quietly reduce the resilience of a system. Despite their seemingly unpredictable nature, generic early warning signals have been proposed which, once verified for a particular system, could provide the means for mitigating or even preventing unwanted transitions. However, not all state variables in complex systems guarantee early warning signals, even those that undergo significant change during the transition. We explain this 'silence' using theory from multi-dimensional stochastic processes, and show how one can infer which variables will exhibit traits of an upcoming transition. In applying this to generic socio-ecological systems, we demonstrate that signals in the ecological subsystem are often silent. Given the potential for drastic, long-lasting regime shifts in these systems, prediction of upcoming tipping points is of significant importance. Our work sheds light on the mechanisms that suppress / exemplify the proposed early warning signals, and suggests that monitoring shifts in human behaviour is vital for the sustainability of ecological systems.

3:40-3:52: "**Socio-ecological dynamics of Caribbean coral reef ecosystems and conservation opinion propagation**". Vivek Thampi, University of Waterloo. Co-authors: Madhur Anand, Chris T. Bauch

The Caribbean coral reef ecosystem has experienced a long history of deterioration due to various stressors. For instance, over-fishing of parrotfish - an important grazer of macroalgae that can prevent destructive overgrowth of macroalgae - has threatened reef ecosystems in recent decades and stimulated conservation efforts such as the formation of marine protected areas. Here we develop a mathematical model of coupled human-environment interactions between reef dynamics and conservation opinion dynamics to better understand how natural and human factors interact individually and in combination to determine coral reef cover. We find that the coupling opinion and reef dynamics generates complex dynamics. For instance, the system can oscillate between low and high live coral cover as human opinion oscillates in a boom-bust cycle between complacency and concern. Under some conditions, increasing the maximum possible fishing rate can stimulate a conservationist feedback response in human populations and thus lead to greater protection of the coral reefs. In contrast, raising awareness of coral reef endangerment avoids potentially counter-productive nonlinear feedbacks and always increases and stabilizes live coral reef cover. In conclusion, an improved understanding of coral reef dynamics under anthropogenic stressors is possible using coupled human-environment models, and such models should be further researched.

3:52-4:05: "**A non-equilibrium formulation of welfare resilience**". Matteo Smerlak, Perimeter Institute

Concepts like "resilience" play an important role in international development research and policymaking. Past experience, however, suggests that such concepts often degenerate into buzzwords—vaguely defined notions that yield little analytical insight. Resilience itself is currently at a familiar crossroads. Funding agencies will soon begin to tire of the cacophony of alternative conceptualizations if researchers and program implementers do not converge on clearly defined boundaries for theory, analysis, and use. Some of the most promising current approaches require assumptions that are difficult to empirically test. In this talk I will discuss on an intuitive, statistically simple alternative method which is useful in analyzing high-frequency time series datasets.

Session 3: Case studies from local to global in natural and human resilience
Room SJ2- 2007

2:45-3:00: **"Exploring Development Resilience Dynamics with Agent Based Models".**
Peter Deadman, University of Waterloo. Co-authors: Yue Dou, Marta Berbes

An agent based model was developed to explore the dynamics of development resilience in rural households living in the Amazon estuary of Brazil, near Belem. The model maps household livelihood activities to resilience in the face of economic and environmental shocks. Simulation results indicate that basins of attraction exist, including a chronic poverty zone and a non-poor zone. Analysis of the agents using principle components analysis identifies the household characteristics, including demographics, capital, and land resources, that contribute to resilience.

3:00-3:15: **"Revisiting Spatial Land Use Modelling with Agent-Based Simulation".** Brad Bass, Environment and Climate Change Canada

Spatial models of land use do not capture the dynamics of the complex urban economy and the interaction of multiple drivers for change. Two examples of agent-based spatial simulations are presented to illustrate the insights gained from re-examining two dominant spatial models: central place theory/Hotelling and land-use theory. In 1995, in his book *The Self-Organizing Economy*, Paul Krugman suggested a simple model to explain how the clustering of economic activity and central places could emerge from a limited set of initial conditions. This model was abstract in that it did not occur in a real place, and there were no requirements for resources to feed the entrepreneurs. This model has been programmed into an agent-based simulation model, COBWEB (Complexity and Organized Behaviour Within Environmental Bounds), which has been used in fields as diverse as retail clustering, group dynamics, urban land use, epidemiology, bioaccumulation of mercury and cancer therapy. In the most recent work, the clustering was tested in different sized domains with resources. The results indicate conditions under which the model will reproduce the expected theoretical outcomes, but also conditions where the model fails to stabilize around the central place "attractor" as hypothesized by Krugman. A second simulation of urban land use theory is also developed with COBWEB. These models reach a stable outcome in different zones based on assumptions of how housing and transportation costs vary with distance from the core. By relaxing some of the rigid assumptions required for these theoretical constructs, it is now possible to compare how housing prices and transportation costs drive changes in density with evolving consumer preferences. This presentation represents some of the modelling emerging from the University Research Program with Complex Systems with the School of the Environment at the University of Toronto.

3:15-3:30: **"Projected Dynamics of the Global Wheat Trade Network and Resilience to Shocks"**. Kathyrn Fair, University of Waterloo**.** Co-authors: Chris Bauch, Madhur Anand

The time evolution of the global wheat trade network is modelled dynamically to explore mechanisms of its formation and response to shocks. Shocks are applied to the evolving network and their impact gauged by network metrics. We compared attacks (outward edge removal on high degree nodes) and errors (outward edge removal on randomly selected nodes). We find that assuming preferential attachment and rewiring enables the best fit to the empirical network's dynamics over several decades. Shocks of similar sizes to those experienced by the real-world network alter the structure of the network considerably, increasing link diversity and causing long-term structural changes. Attacks have greater impact on network metrics than errors. If the network experiences sequential attacks, the resulting structural changes mean that each attack has a lesser impact the previous one, suggesting some robustness over time. We discuss the consequences of these findings in the context of resilience, observing that the wheat trade network is evolving to become less vulnerable to attacks. However, network resilience may remain low for a substantial portion of the 21st century. We conclude that dynamic models of multi-year, commodity-specific trade networks should be further developed to gain insight into possible futures of global agri-food trade.

3:30-3:45: **"What drives biodiversity and conservation in global biodiversity hotspots?"** Virginia Capmourteres, University of Guelph. Co-authors: Madhur Anand

The conservation of global biodiversity hotspots relies on our understanding of biodiversity responses to not only environmental but also socio-economic drivers. Here we use Structural Equation Modeling (SEM) to test hypotheses on the effect of such drivers on the conservation of species richness and primary (native) vegetation extent of hotspots. We construct four models with increasing complexity of environmental and socio-economic factors. First, we show that the plant richness in hotspots is neither explained by current hypotheses related to major latitudinal gradients (temperature, precipitation, radiation) or OCBIL theory (phosphorus retention potential), but responds simply to the remaining extent (area) of a hotspot. Second, we do not find a response of plant and vertebrate richness to major land uses (agricultural, livestock, urban), suggesting land use impact scenarios may be hotspot-specific. Third, we find evidence that vegetation loss contributes mainly to the endangerment of endemic birds and mammals and that protected areas solely protect mammalian species. Last, we find that the effectiveness of environmental policies is more important than income itself when it comes to the conservation of hotspots. We argue that key components of efficient environmental policies —social inclusion, equality, and better management in the public sector —must be enhanced

for more effective conservation of hotspots. Also, we suggest that while the two conservation value metrics that currently define hotspots —plant endemism and habitat loss—are closely related to other metrics (richness, land use, and species endangerment), they may not be sufficient to conserve all forms of biodiversity.

3:45-4:00: **"Integrative analysis of the Lake Simcoe watershed (Ontario, Canada) as a socio-ecological system".** Alex Neumann, University of Toronto

After two centuries of deforestation and urbanization, Lake Simcoe, Ontario, Canada currently experiences re-oligotrophication processes induced by an array of nutrient reduction activities in its catchment that targets phosphorus input of 42 TP tonnes/year by 2045. In this study, we present an integrative analysis of the Lake Simcoe watershed as viewed from the perspective of a socio-ecological system (SES). Key features of our analysis are (i) the equally weighted consideration of environmental (soil, land use types) and socioeconomic (population density, income) attributes and (ii) the identification of the minimal number of key socio-hydrological variables that should be included in a parsimonious watershed management framework, aiming to establish linkages between urbanization trends and nutrient export. Drawing parallels with the concept of Hydrological Response Units, we applied Self-Organizing Mapping subwatersheds clustering based on similarity of SES attributes, also referred to as Socio-Environmental Management Units (SEMUs). Our post-hoc analysis with structural equation modeling provides evidence of two SEMUs with contrasting features, the "undisturbed" and "anthropogenically-influenced", within the Lake Simcoe watershed. The "undisturbed" cluster occupies approximately half of the Lake Simcoe catchment (45%) and is characterized by low landscape diversity and low average population density <0.4 humans/ha and static nutrient export. By contrast, the socio-environmental functional properties of the "anthropogenically-influenced" cluster highlight the likelihood of a stability loss in the long run, as inferred from the distinct signature of urbanization activities on the tributary nutrient export, and the loss of subwatershed sensitivity to natural mechanisms that may ameliorate the degradation patterns.

Poster Abstracts

"Unfurling of An Expanding Space: Frameshifting Through Conceptual Complexity". Perin Ruttonsha, University of Waterloo

'Concept spaces' are ephemeral, however, their influence on cultural change and social complexity should not be understated. In some respects, conceptual

complexity can emerge with minimal footprint, which makes it especially interesting as a point of analysis when discussing transition along sustainability and resilience pathways. Of course, there are a number of means by which to obtain knowledge and refine our understanding of the world in which we live. The visual arts is one arena wherein we regularly navigate the deeper corners of concept spaces, and are granted considerable liberty in how we do so. Moreover, through arts-based practices, we can easily root our interpretations of reality in tacit, experiential, intuitive, and human-centred knowledge, lending a different style of analysis to sustainability and resilience problem spaces. This poster presentation illuminates how arts-based methods can be applied as a tool for inquiry and social change. Here, I share a preliminary body of visual artwork that illustrates themes of cultural change, cumulative complexity, and creative destruction.

"Hope for climate momentum? Applying critical transitions theory to energy decarbonisation". Yonatan Strauch, University of Waterloo.

In the discourse on the climate crisis and energy decarbonisation, two popular themes within theories change are "momentum shift" and overcoming the "lock-in" or resilience of carbon-base systems. However, too often, these themes are applied within analytic silos of jurisdiction, discipline or industry – when the messy reality may be that the key drivers of momentum-shift act across these silos. To address this limitation, this paper introduces a novel approach to assessing carbon lock-in and how it might be overcome, based on the complex adaptive systems theory of critical transitions – the first such application. Critical transitions theory describes how abrupt and comprehensive regime shifts come about in ecosystems: they are driven by runaway feedbacks, as systems move from one resilient (or locked in) states to another, across an unstable middle ground between them. The framework introduced in this paper applies this theory to analyse the potential for a rapid global shift from carbon lock-in to the lock-in of decarbonisation. This paper presents an interpretation of critical transitions which is more generalizable, beyond ecosystems and ecosystem management. It outlines how this interpretation is adapted to apply - in a transdisciplinary manner - to a very different system type with more socio-political and technological layers. Finally, it briefly illustrates an application of the resulting framework to assess the potential for a major energy-transition momentum shift. This paper demonstrates the potential of complexity-based approaches to generate more realistically-messy, yet systematic, analyses; ones which can provide more practical insight into how sufficient climate action might be catalysed, where the breaking point is for carbon-regime resilience, and how decarbonisation may set in more rapidly, and ratchet-in more powerfully, than most expect.

"Forest transitions, land use, and ecological thresholds: implications for forest resilience". Robert Gooding-Townsend, University of Waterloo. Co-authors: Chris Bauch, Madhur Anand

The forest transition refers to a shift from net deforestation to afforestation, which has occurred in tandem with agricultural intensification in many countries (Mather, 1992). Ensuring that forest cover does not continue to decline in countries that have not yet undergone a forest transition is key to protecting the ecological and economical value of forests, in addition to remaining within the ``safe operating space for humanity'' with respect to nutrient cycles, biodiversity, and land use (Rockström et al. 2009). However, human activities including agriculture, urban development, and lumber harvesting continue to encroach on forests (DeFries et al. 2010), which may face additional strains from climate change. Economic and geospatial models have been developed to predict future land use and define management strategies (Lambin & Meyfroidt, 2011; Pagnutti et al., 2013); however, these often neglect established findings showing feedbacks effects in forest cover (Scheffer et al. 2012, Van Nes et al. 2014). We develop and analyze a simple differential-equation model of land use, incorporating ecological threshold dynamics and time-varying land conversion rates, to investigate the effects of these feedbacks, the risk of forest collapse, and management strategies.

"Impacts of Global Warming on a Size-Structured Population". Xueqi Wang, University of Guelph. Co-authors: Gustavo Betini, John Fryxell

Climate is among the most important determining factors of the presence and distribution of species. As anthropogenic warming persists, organisms across all ecosystems have been observed to experience changes to their phenology, biogeographic ranges, and body size (Durant et al, 2007; Visser & Both, 2005; Gardner et al, 2011). When the unrivaled warming phenomenon results in a temporal mismatch or shortage of food abundance, organisms are found to suffer early life malnutrition, grow smaller and have reduced fitness (Gils et al, 2016). When rising temperatures are associated with increased resource abundance and/or prolonged growing seasons, organisms are often found to maintain their regular sizes and even grow due to the increase in resource acquisition and assimilation (Ozgul et al, 2010). Yet, how changes in temperature influence the effects of resource availability is still unknown.

Body size determines many physiological and ecological properties of species, such as survival, growth rate and reproductive output. Even though evidence gathered over several taxa suggests a negative correlation between growth and temperature, the degree to which body size is affected by temperature differs within and across the ecosystems. More importantly, the underlying cause of this response is unclear and whether change in body size is a direct effect of temperature or other

confounding attributes are undetermined. Therefore, to better understand and project the population consequences of anthropogenic climate change, my thesis will explore how global warming as an interaction of temperature and resource abundance affects population dynamics through changes in size-dependent vital rates in Daphnia magna.

My research will test a suite of related hypotheses: that (1) temperature and (2) resource abundance are limiting factors in population growth, (3) whether there is a synergistic interaction between resource and temperature effects on growth rates, and (4) whether parental status affects population growth. My objectives are (1) to understand how variation in temperature and resource abundance interact to influence growth rates by individuals, (2) to evaluate the effect of body size, temperature, and resource abundance on Malthusian fitness (survival and reproductive output) and (3) to analyze how size distribution and asymptotic population grown rate responds to changes in aggregate levels of vital rates (growth, survival and fecundity) at different levels of temperature and resource abundance. A size-structured integral projection model will be parameterized to link individual variations to a population level effect.

"The Two Sides of Delayed Dispersal in Metapopulation Dynamics". Jingjing Xu, Western University. Co-author: Geoff Wild

Metapopulations are collections of local populations connected by dispersal. They persist because local extinctions are counterbalanced by the recolonization that follows a dispersal event. Thus, the delays in natal dispersal seen in many species ought to impact the dynamics of metapopulations, and our goal is to assess that impact using an ODE model. More specifically, we seek to determine the mathematical and biological conditions under which delayed dispersal promotes persistence or extinction in a metapopulation. Our model assumes that delayed dispersal is associated with the inheritance of local breeding territories, which can be the case in nature. Keeping that assumption in mind, we find that when birth rates and/or mortality rates are sufficiently low, delayed dispersal could help metapopulations avoid extinction by reducing the occurrence of local extinctions. By contrast, when the birth rate and the mortality rates are both high the effect of delayed dispersal mainly leads to reduced overall recolonization rate by lowing down local recolonization rate, which is depending on a positive density dependent effect, or Allee effect, so delayed dispersal results in the extinction of metapopulations. We discuss the variable role of delayed dispersal in terms of conservation of metapopulation, and we speculate on the implications of our results for future models for the evolution of dispersal.

"Interaction of an explicit and an implicit time delay in a one predator–two prey system". Christopher Greyson-Gaito, University of Guelph**.** Co-authors: Kevin McCann

The stability of ecosystems is a highly important research topic due to our continued destruction of global biodiversity. Time delays occur in all ecosystems at multiple levels from cellular to landscape scales and have the potential to destabilize ecosystems. However, researchers have posited that careful positioning of time delays could stabilize an unstable system. Asynchronous populations have repeatedly been found to confer stability to ecosystems. Consequently, we posit that a time delay could create asynchrony, and thus stabilize a system. We compare two energetically similar models: a one resource – one consumer model and a two resources – one consumer model. We introduce and change an explicit time delay on the resource growth rate in both models, where the explicit time delay is on one of the resources of the two resources – one consumer model. We examine how the introduced explicit time delay interacts with the implicit time delay that occurs in all predator-prey dynamics, where the implicit time delay is the delayed peaking of the predator population after the prey population. As we increase the explicit time delay we compared the resultant bifurcations. Stability did appear to increase in the two resources – one consumer model as the consumer was bounded further from 0 for more values of the range of explicit time delay that we applied. The ubiquitous nature of time delays in ecosystems make time delays an integral area of study to examine the stability of ecosystems. Our study aims to address the present lack of time delay interaction research in ecology, adding another level to our understanding of ecosystem stability.

"Generalized simulated annealing algorithm applied to the patient zero inverse problem". Olavo Menin, University of Waterloo**.** Co-authors: Chris Bauch

Inferring the source of an epidemic outbreak ('patient zero') is an important issue that can help policy makers to adopt strategies that enhance the resilience of the population against some infectious diseases. Here, this problem is addressed by using the Generalized Simulated Annealing algorithm (GSA), a stochastic optimization method based on Metropolis criterion and the generalized Gaussian distribution visitation, which is controlled by the parameter $q\tilde{v}\in\mathbb{R}$. By adopting the optimization approach one must define and minimize an objective function which evaluates the discrepancy between two set of data, one measured experimentally and another predicted by a mathematical model. The disease natural histories susceptible-infected (SI), susceptible-infected-susceptible (SIS), susceptible-infected-recovered (SIR) and susceptible-infected-recovered-susceptible (SIRS) in a regular lattice are studied. Both the position of patient zero and its time of infection are considered unknown and must be retrieved. Computational experiments were performed to assess the GSA performance with respect to the generalization

parameter $q\tilde{}v$ and the fraction ρ of infected nodes for whom infection status can be ascertained. Results show that the algorithm is able to identify the location and time of infection of patient zero with good accuracy when it is possible to ascertain infection status in at least 10% (ρ=0.1) of the nodes, but not when only 1% (ρ=0.01) of nodes can be ascertained. However, our experiment outcomes show that GSA performs better for $q\tilde{}v \lesssim 0.3$, contrasting the findings reported in the literature.

"Climate change triggers non-linear responses in species interaction: evidence from a simple resource-consumer system". Gustavo Betini, University of Guelph**.**
Co-authors: Tal Afgar, Kevin McCann, John Fryxell

Although temperature is recognized as a major determinant of the type and strength of species interaction, it is still not clear whether temperature strengthen or weaken top-down control and how temporal and spatial variation in biotic and abiotic conditions interact to mediate this effect. One hypothesis is that temperature have concomitant effects on both resources and consumers, depending on their thermal tolerance and how temperature varies in space and time. Here we investigated this hypothesis using six large aquatic mesocosmos tanks, each filled with 26,000 L of water and inoculated with both the non-motile green algae C. vulgaris (resource) and the freshwater water flea Daphnia magna (consumer). Tanks were kept at different average temperature (15oC, 20oC and 25oC) and both resource and consumer densities were tracked in 18 different spatial positions in each tank, for 250 days. We found that the effect of the consumer on the resource depends non-linearly on both the temperature and the amount of the algae in the tanks. Daphnia suppress algal growth rate at intermediate temperature and when algal density is high, but not at the range of optimal growing conditions of the resource. These results suggest that the effects of temperature may intensify at thermal range boundaries, which can vary in space and time, and help to explain why temperature has been shown to both increase and weaken the strength of species interaction in natural systems.

"Spatial Correlation as an Early Warning Signal of a Critical Transition in a Multiplex Disease-Behaviour Network". Peter Jentsch, University of Waterloo.
Co-authors: Chris Bauch

Early warning signals of critical transitions are a widely studied phenomenon because they can provide the ability to quantify a system's proximity to a tipping point to a new and contrasting dynamical regime. However, this effect has been little studied in the context of the complex interactions between disease dynamics and vaccinating behaviour. Our objective was to determine whether critical slowing down (CSD) occurs in a multiplex network that captures opinion propagation on one network layer, and disease spread on a second network layer. We parameterized a network simulation model to represent a hypothetical self-limiting, acute, vaccine-

preventable infection with short-lived natural immunity. We tested five different network types: random, lattice, small-world, scale-free, and an empirically derived network. For the first four network types, the model exhibits a critical transition as perceived vaccine risk moves beyond a tipping point, from full vaccine acceptance and disease elimination to full vaccine refusal and disease endemicity. This critical transition is preceded by an increase in the spatial correlation in non-vaccinator opinions beginning well before the bifurcation point, indicating CSD. The early warning signals occur across a wide range of parameter values. However, the more gradual transition exhibited in the empirically-derived network underscores the need for further research before it can be determined whether trends in spatial correlation in real-world social networks represent critical slowing down. The potential upside of having this monitoring ability suggests that this is a worthwhile area for further research.

"Reality and illusion in the (post-normal) science and policy-making of resilience". Norman Kearney, University of Waterloo

Promoting the resilience of increasingly complex and globally interconnected social-ecological systems involves imagining, assessing, and managing risks and uncertainties. This task calls for rationality not only from scientists but also from policymakers and the publics that they serve. In 2016, in reference to the apparent wave of irrationality in the Brexit referendum and the US presidential election, the Oxford Dictionaries named "post-truth" the word of the year, and in 2017 "alternative facts" became a household term. Many have reacted with alarm to what has been deemed a sudden rejection of epistemic authorities and objective knowledge in favour of charismatic leaders who speak to personally felt subjective truths. While the danger of demagoguery cannot be dismissed, there is nothing new about this age-old tension between knowledge and belief. Drawing on the work of the existential psychoanalyst Otto Rank, Ernest Becker argues that mental health – and it can be argued, by extension, social welfare – depends on achieving an optimal balance between reality and illusion. To scientists, whose professional lives are dedicated to increasing what Norbert Elias calls "the social stock of reality-congruent knowledge," the word "illusion" is anathema. In this talk, I will draw on Rank and Becker's observations about human nature to justify the place of illusion in post-normal science and policymaking. Rank and Becker argued that the basic human condition is defined by two truths: we are torn between the need for complete surrender to mysterious and powerful forces that transcend us, and the need to expand and distinguish ourselves as heroic individuals. Recognizing that too much reality or too much illusion can be personally, socially, and we should add ecologically destructive, Becker called for the pursuit of better illusions that meet these twin needs. The best illusions, he argued, would offer the most freedom, dignity, and hope. While scientists and policymakers have a professional responsibility to search for and speak the truth, the existential nature of

sustainability challenges, especially climate change, means that they cannot avoid engaging with questions of illusion. This talk will explore the necessity for, difficulties of, and ethics of this engagement.

"On the brink: predicting population collapse in seasonal environments".
Joseph Burant, University of Guelph**.** Co-author: D. Ryan Norris

The detection of impending population declines remains one of the biggest challenges in the conservation of threatened species. Theoretical and experimental studies in aseasonal systems have demonstrated the use of population counts and early warning signals (EWS) to evaluate when a population is approaching a tipping-point. However, while virtually all species live in seasonal environments, seasonality has yet to be considered in the context of EWS. Using Drosophila melanogaster, we aim to explore how seasonal changes in environmental quality influence population declines and the detectability of signals predicting population collapse. We are using an established population of seasonally-reproducing individuals with non-overlapping generations to test the hypothesis that the statistical properties of abundance and other demographic data will reflect the period in which habitat deterioration occurred. This research attempts to identify generalizable statistical signatures of impending population declines in seasonal systems, which is especially pertinent given the ongoing widespread decline of seasonal populations due to habitat loss and global change.

"Agent Based Models of Economic Crisis: A Sketch of the State of the Art".
Kirsten Robinson, University of Waterloo**.** Co-authors: Andrea Scott, Paul Fieguth

From the tulip boom of 1663 to the dot-com crisis of 2001, economic bubbles and crashes have driven enormous creation and destruction of wealth. These phenomena are poorly explained by mainstream economic models, which typically focus on rational representative agents in a state of equilibrium. Bubbles and crashes, on the other hand, are inherently out of equilibrium phenomena, and increasing evidence suggests that they emerge from the non-linear interaction of heterogenous agents.

Since the economic crisis in 2007 made the limitations of simpler models apparent, a range of newer models and techniques, including agent-based modelling has made inroads into explaining the phenomena driving economic crises. This paper presents an overview of these new models, situates them within a broader history, and sketches prospects and challenges for new work.

These new models arise from established older models and authors made a compelling case that their models improve on their predecessors. The problem is that there are many competing models describing crisis phenomena. To understand

the state of the art, it is necessary to understand whether these models describe fundamentally different competing mechanisms, in which case we must find ways to determine which are acting in any given context, or whether they describe the same mechanism, in which case the new work is converging on a compelling new explanation of the world.

We illustrate this approach to comparing the extent to which models describe the same underlying phenomena by, looking at particular set of models where endogenous crises arise from one mechanism, asymmetries driving synchronization phenomena within systems of many interacting agents.

"**Competition Between Injunctive Social Norms and Conservation Priorities Gives Rise to Complex Dynamics in a Model of Forest Growth and Opinion Dynamics**". Ram Sigdel, University of Guelph. Co-authors: Madhur Anand, Chris Bauch

Human systems and environmental systems are often treated as existing in isolation from one another, whereas in fact they are often two parts of a single, coupled human-environment system. Developing theoretical models of coupled human-environment systems is a continuing area of research, although relatively few of these models are based on differential equations. Here we develop a simple differential equation coupled human-environment system model of coupled forest growth dynamics and conservationist opinion dynamics in a human population. The model assumes logistic growth and harvesting in the forest. Opinion spread in the human population is based the interplay between conservation values stimulated by forest rarity, and injunctive social norms that tend to support population conformity. We find that injunctive social norms drive the system to the boundaries of phase space, whereas rarity-based conservation priorities drive the system to the interior. The result is complex dynamics including limit cycles and alternative stable states that do not occur if injunctive social norms are absent. We also find that increasing the inherent perceived value of forests is the best way to boost and stabilize forest cover while also boosting conservationist opinion in the population. We conclude that simple models can provide insights and suggest patterns that might be harder to see with complicated, high-dimensional models, and therefore should be pursued more often in research on coupled human-environment systems.

Workshops and Special Activities

What is Life?
Socio-Ecological Resilience and Sustainability as Complex Adaptive Processes
With PhD Candidate, Perin Ruttonsha

1:30pm-2:30pm

Room SJ2- 2001

Resilience literature indicates that socio-ecological systems can oscillate through multiple states of equilibrium. What this implies, is that sustainability and resilience are not static end points, rather, are contingent on various, interdependent, dynamic factors. From the perspective of transition, we could say the context for transformation, itself, changes, and the means by which we pursue related goals should account for the circumstances in which they are implemented. Accepting that socio-ecological systems states can fluctuate widens the array of possibilities for sustainable and resilient futures. It also opens the boundaries of tolerance for diversity, conditions that deviate from standard expectations, or socio-political tensions that may emerge along the way. This workshop is grounded in ideas from complexity, systems, sustainability, and resilience discourses, which suggest that process-oriented, relational approaches are imperative when planning for transition.

From recent research on anthropogenic change, we might also gather that sustainability and resilience dilemmas arise primarily from human-in-environment interactions. Some resilience scholars have adopted the concept of 'dwelling' to characterize these relationships, and discuss the tacit or embodied connections that exist between people and their inhabited ecosystems. In this workshop, we will engage in an exercise of coarse-grained transdisciplinary scoping, to dissect the contents of 'dwelling', or human-in-environment interactions, as a distillation of basic human life routines. Doing so could lend clarification to the 'wickedness' of sustainability and resilience challenges, considering why and how social complexification has become strangely discontinuous from other biosphere processes. As an entry point, we will adopt the classic question posed by Schrödinger (1967[1944]), "*What is life?"*, along with Capra's (2002) extension, "*What are the defining characteristics of social reality?"*(p.3), to formulate the broadest possible interpretation of the complex socio-ecological dynamics that exemplify transition problem spaces. **To reserve a space in this workshop, please email pruttonsha@uwaterloo.ca**.

CONFERENCE STUDY

Transdisciplinarity in Resilience Research: Formulating Diverse Conceptions of Complex Systems

To accompany this conference, we are conducting a short study. In this research, we aim to capture the diverse perspectives of attendees and presenters, in order to deepen our understanding of resilience thinking, and identify opportunities and challenges for future work in the field. Results will be published online, as part of the WICI working paper series. This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee**.** The study consists of four components:

1. **Pre-Conference Survey**
   The online survey will take approximately 15 minutes of your time. To complete the survey, please upload the following link:
   https://www.surveymonkey.com/r/LKKDS8G

2. **Informal Activities**
   What Does Resilience Mean to You? (Tuesday, May 16, 10:00-10:30am)
   Resilience is commonly understood as a system's ability to respond effectively to disturbance; though, how we define, characterise, measure, or enable this capacity may vary by discipline. In this activity, we will bridge and blend our diverse conceptions using an arts-based approach. Upon registration, each conference attendee will receive a set of keywords. During the first morning coffee break, we will gather in small groups to create resilience haikus. These poems will be posted in the St. Jerome's atrium, and read aloud during the evening reception.

   Analogous, Distinct, or Complementary? (Tuesday, May 16, 4:15-7:00pm)
   Resilience thinking can be applied in the analyses of disparate or interconnected issues; in research and in practice; and, using qualitative, quantitative, or participatory methods. During the second afternoon coffee break and reception, on the first day, we will chart some of the similarities, differences and synergies between natural science, social science, policy-oriented, and community-based approaches. Activity charts will be located in the St. Jerome's atrium.

3. **Moderated Panel Discussions** (Tuesday, May 16, 2:45-4:15pm)
   In resilience thinking, it is recognized that cross-scale interactions are a factor in systems change, and that incremental impacts from various sources can instigate shifts towards critical thresholds. The challenge, then, is drawing appropriate boundaries to capture these complex dynamics, or perhaps integrating complementary studies to expand our range of analyses. To examine these challenges, each of the three parallel sessions will be

followed by moderated panel discussions, wherein we will compare and contrast the foci, methods, scope, and scales applied by the various presenters.

4. **Graduate Student Workshop** (Wednesday, May 17, 2:30-6:15pm)
Resilience is a term that is applied across diverse fields such as restoration ecology and community health. However, this does not mean that we have developed universal means of defining, characterising, measuring, and monitoring systems resilience and risks. Given the normality of interconnection between social and ecological factors in complex systems, the advancement of transdisciplinary approaches to resilience planning would seem appropriate. In this workshop, participants will collaborate, using case scenarios, to develop integrated concepts, methodologies, and frameworks for grappling with resilience challenges. The workshop will provide participants with an opportunity to share their perspectives on the future of resilience research, while also gaining insights from others on techniques for systems analyses. The workshop is being organized by and for graduate students, and will be guided by Dr. Vanessa Schweizer (University of Waterloo, http://wici.ca/new/2015/04/vanessa-schweizer/). Please note that workshop outcomes will be documented for research purposes and summarized in a short paper. To register for the workshop, please email Kathryn Fair (k3fair@uwaterloo.ca).

MapleSoft Demonstration

Title: **Overview of Maple**
Speaker: Dr. Jürgen Gerhard, Maplesoft
Time: Tuesday, May 17, 1.30-2.00
Location: *Room SJ2-2007*

Abstract: We will give a brief overview of the capabilities of Maple, including plotting, Math Apps, and differential equations, and also demonstrate how to use Maple for problems in environmental modeling.

Website: www.maplesoft.com

Bio: Maplesoft (http://www.maplesoft.com) is the leading provider of high-performance software tools for engineering, science, and mathematics. Maplesoft's flagship product, Maple, combines the world's most powerful mathematics engine with an interface that makes it extremely easy to analyze, explore, visualize, and solve mathematical problems.

Jürgen Gerhard holds a PhD from University of Paderborn, Germany. He has been with Maplesoft since 2003, and is currently Senior Director of Research. His areas of interest are symbolic computation and its applications in engineering, and he is coordinating research and consulting projects in these areas at Maplesoft.

Attendees who are interested to attend the MapleSoft demo can send an email to Jennifer Iorgulescu (jiorgulescu@maplesoft.com) indicating their interest to attend.

BioM&S Symposium Abstracts

"From Ecological Complexity through Simplicity to Felicity"
Jurek Kolasa, McMaster University
Authors: J Kolasa and MH Hammond

Starting with the premise that complex systems should be easier to manage and employ if they can be made to present themselves as simple. Wide-spread acceptance that ecological systems are complex defines the challenge. We use insights gained from attempts to construct functional indoor, aquaponics-like ecosystems to highlight promising features. To arrive at these insights, we propose that modularity, both conceptual and physical, can serve as a device to simplify a complex system without sacrificing richness of its components. The modularity can arise through internal processes that integrate components, containment by external constraints, or a combination of both. We use an experimental system to illustrate how modularity can help to construct a quasi-autonomous ecosystem that reproduces most functions observed in natural systems. We further show that, at a comparable scale, such a system has a potential to exceed natural systems' productivity, biodiversity, and resilience. We further note that when a modular system moves beyond intended bounds, modularity allows for a greater understanding of causes, better tractability of component behaviors, and facilitates human intervention in more effective ways than possible in non-modular systems. Finally, we comment on applicability of this general view of how complex systems can be simplified by applying it to examples of natural systems.

"Integrative Analysis for Incorporating the Microbiome to Improve Precision Medicine"
Hongzhe Li, University of Pennsylvania

The gut microbiome impacts health and risk of disease by dynamically integrating signals from the host and its environment. High throughput sequencing

technologies enable individualized characterization of the microbiome composition and function. The resulting data can potentially be used for personalized diagnostic assessment, risk stratification, disease prevention and treatment. In this talk, I will present several ongoing microbiome studies at the University of Pennsylvania and provide some empirical evidence of using microbiome in precision medicine. I will talk about some statistical issues related to species abundance quantification, compositional data regression and mediation analysis.

"Learning Microbial Community Structures with Supervised and Unsupervised methods"
Hong Gu, Dalhousie University

Learning the structure of microbial communities is critical in understanding the different community structures and functions of microbes in distinct individuals. We view microbial communities as consisting of many subcommunities which are formed by certain groups of microbes functionally dependent on each other. This talk covers several different methods for extracting the subcommunities from the data, including both OTU data and functional metagenomic data.

We will first review two Bayesian hierarchical model frameworks for inference of metabolic divergence among microbial communities and for inferring the structures of microbial communities. We then focus on a more recently developed likelihood based method utilizing Non-Negative Matrix Factorization (NMF) in finding biologically meaningful subcommunities. NMF is an unsupervised method which has been widely applied in many areas, such as image and natural language processing, and also has found many applications in computational biology. We explore the application of NMF to microbiome data to capture the subcommunity structure information and address the issues of heterogeneity among samples. We further develop a supervised version of NMF for identifying the discriminating microbial subcommunities between different classes of individuals. The relevance of the subcommunities identified by NMF is demonstrated by their excellent performance for classification. Through data examples, we demonstrate how to interpret the features identified by NMF to draw meaningful biological conclusions and discover hitherto unidentified patterns in the data.

"Microbial Communities *Clostridium difficile* Infection and Fecal Microbiota Transplantation"
Peter Kim, University of Guelph and McMaster University

The clinical data comes from a recently completed clinical trial where *Clostridium difficile* infection (CDI) was treated using fecal microbiota transplantation (FMT). CDI resolution following an FMT(s) has turned out to be an effective treatment alternative to traditional antibiotics. In brief following the last FMT, if the

patients CDI symptom does not recur following 7 days following their last FMT, that patient is deemed clinically cured. As part of the protocol every patient was monitored by the research staff. From this group a subset of patients stool samples were sequenced at four time points: pre-FMT; followed by day 10, week 5 and week 13 following their last FMT. A donor stool provided the material for the FMT and we paired the donors stool with the corresponding patients pre-FMT stool sample. The donor and pre-FMT CDI patient, along with the three followups, were simultaneously sequenced using the Illumina MiSeq platform. We note that not all FMTs were initially successful hence of particular interest is to try and understand the clinical outcome using metagenomic (bioinformatic) variables as covariates. Metagenomics bears a structural relationship between covariates. Bacteria exhibit a treelike relationship with each other. Thus their operational taxonomic unit (OTU) proxies, typically the 16S rRNA gene, also exhibit a treelike structure with patterns of cycles at deep taxon classification. Our resolution depends on the length of the 16S rRNA region, the degree of lateral gene transfer, and the reliability of the reads. In addressing any research question, particularly in terms of modelling, we require a means of selecting the OTUs having dominating roles in the microbial systems at hand. The relationship between OTUs is such that some of them may represent the same type of bacteria. Alternatively, some spurious OTUs are artifacts of the laboratory sequencing protocol. Thus, rather than selecting OTUs on their individual merits, we want to select them based on their group affiliations using machine learning algorithms which was developed. Some key genera were identified.

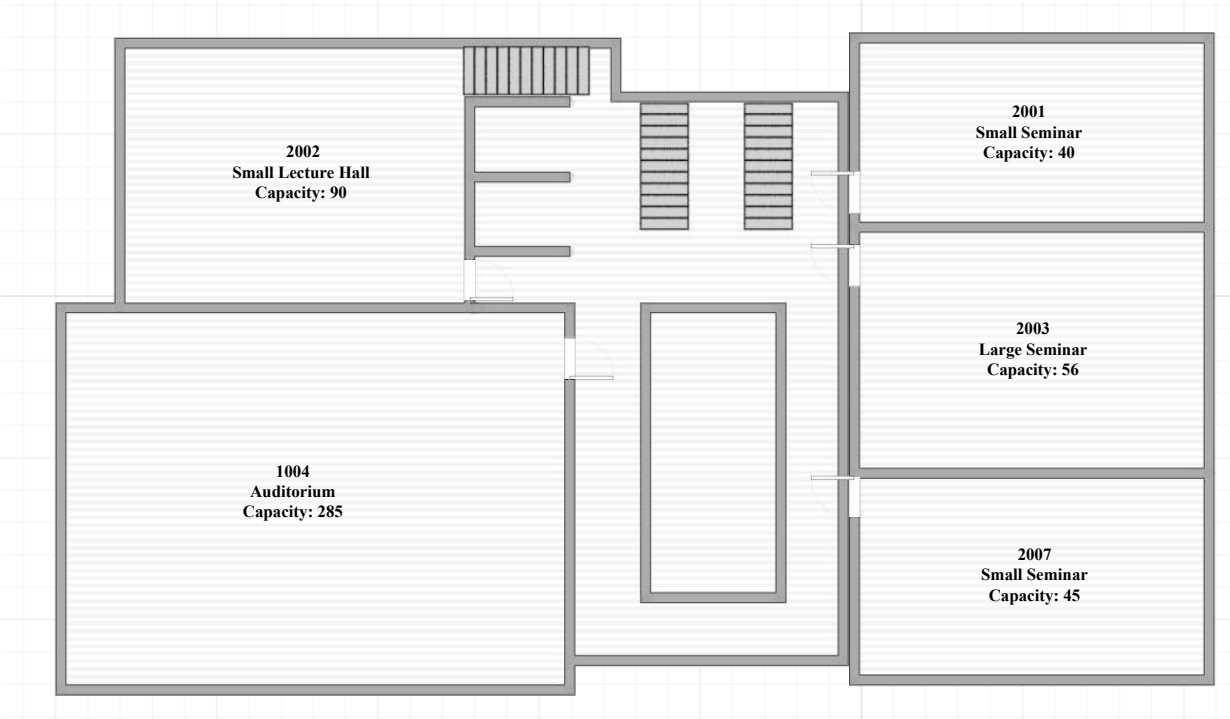
“Variable Selection in OTU Data”
Toby Kenney, Dalhousie University

OTU data are very high-dimensional, and there are often small sample sizes. To analyse such data, it is crucial to select a smaller number of variables to build a stable model. This variable selection is complicated further by the tree structure of the data | OTUs are organised into a tree structure, and the key variables might come from any level of the tree. We need a method that can penalise based on this tree structure to _nd the key variables at the right level. We present a new method (SuRF) which combines subsampling and forward selection to select the relevant variables. We are able to calculate p -values in the forward selection procedure using a permutation test. We demonstrate the performance of SuRF on several real-data analyses, and discuss challanges that need to be addressed to further improve the SuRF algorithm.

Venue and WIFI Information

St. Jerome's WIFI access:
User: sjuconf1@uwaterloo.ca
Password: Joy48(eight(

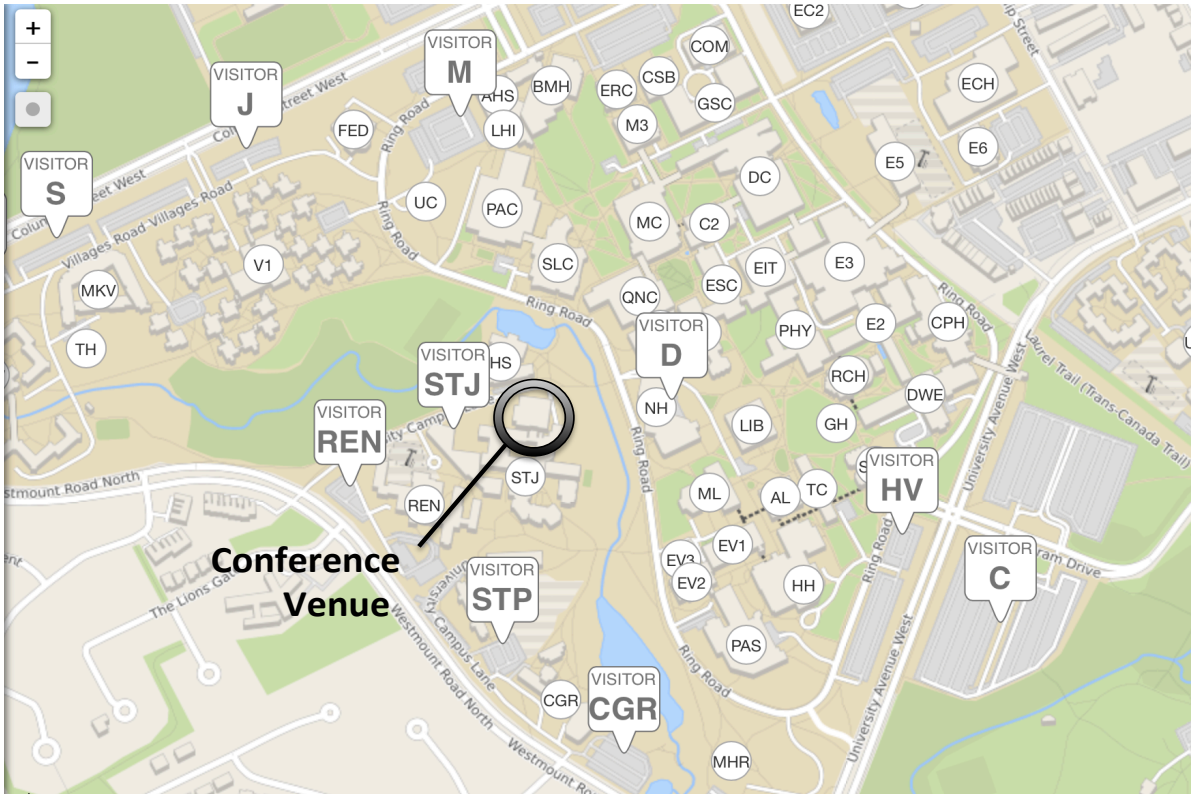
St. Jerome's 2nd Floor Layout:



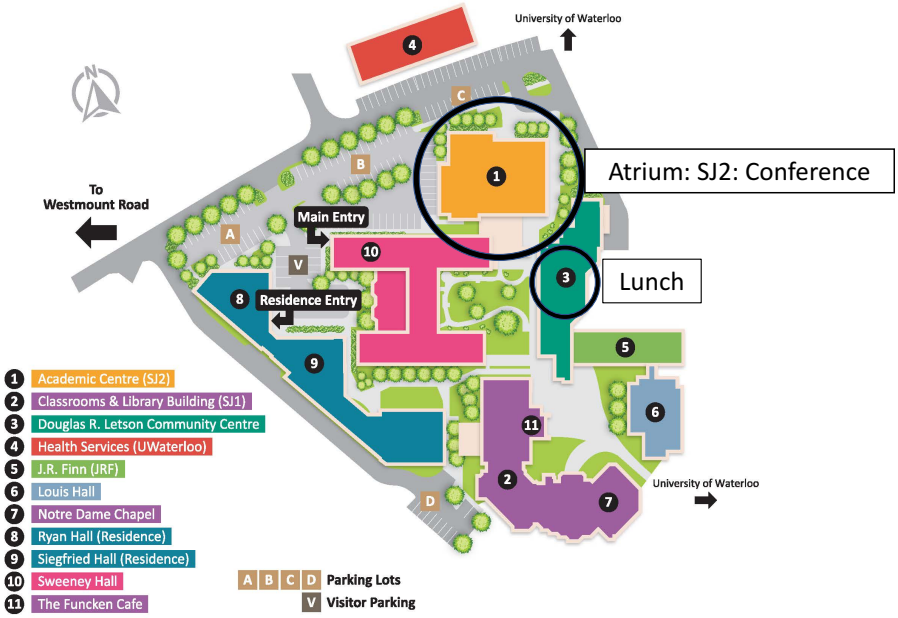
WATERLOO INSTITUTE
for COMPLEXITY & INNOVATION

University of Waterloo & St. Jerome's University Campus Maps

University of Waterloo/St. Jerome's University Map



St. Jerome's Campus Map



Parking

St. Jerome's University: 20 Parking spots are available in Lot A - $5/day
Additional Parking is also available at Renison University College [$6/day at entry] and Conrad Grebel University College [$9/day].
University of Waterloo Visitor Parking Lots [see above] have varying rates.

Transportation

Greyhound Bus: http://www.greyhound.ca/
VIA Rail: http://www.viarail.ca/en
Airways Transit: http://www.airwaystransit.com/door-to-door.shtml
GO Transit: http://www.gotransit.com/publicroot/en/default.aspx
Local City Bus: http://www.grt.ca/en/index.asp
Local Waterloo Taxi Services: http://waterlootaxi.ca/, http://www.citycabs.ca/ http://www.unitedtaxi.ca/

Accommodation

Main campus summer accommodations: https://uwaterloo.ca/summer-accommodations/accommodation-information

Short term accommodations near campus: https://uwaterloo.ca/housing/short-term-accommodations