Name and Title: Brad Bass, Professor  
Department: School of the Environment

TITLE OF RESEARCH PROJECT: Building Virtual Laboratories: Studying Complexity in Natural Systems Through Simulation Models

OBJECTIVES AND METHODOLOGY:
To what degree can a virtual representation of a system complement lab work, field work and meta-analysis, methods that are common to all scientific disciplines? In this ROP, students will be tasked with expanding existing or developing new simulation models that will be used as virtual laboratories. Although students from any scientific discipline can be part of this ROP, in the past, students have come from life sciences (including psychology, ecology and chemistry), materials science, geography and environmental science. Students have used their simulation models as virtual laboratories, exploring ecosystem stability, soil phosphorus chemistry, suicide genes, Alzheimer’s disease, pre-synaptic and post-synaptic activity, epidemiology, virology and genetics.

Although students are given some opportunity to choose their own system of interest, one objective for the 2019-20 year is to continue with the development of a virtual representation of a designer ecosystem. Designer ecosystems are built to mimic some of the characteristics of ecosystems such as wetlands, but they can be broken up into separate components and built in a variety of spaces. For research, these systems are broken up into different tanks for purposes of observation and to improve our understanding of various ecological processes. Using existing designer systems as models, the objective is to build a virtual representation of one such designer ecosystem and assess the degree to which this “virtual lab” can inform research in this area. The ability to design ecosystems is not a new practice, i.e. many stormwater ponds function as wetlands, can enhance the use of green infrastructure to improve water quality and increase habitat as part of a biodiversity strategy.

Not all students will work in this area. In the past four years, students have completed simulations for vector-borne diseases, ecosystem toxicity and bioaccumulation, Alzheimer’s disease, soil-phosphorus chemistry and suicide genes. Some students will have the opportunity to continue with work in these areas, either as part of the main project or as a completely separate project. These projects enhance other projects through collaboration between students from disparate disciplines. Collaboration often
occurs in this ROP, following the philosophical approach of General Systems Theory\textsuperscript{1} and Cybernetics\textsuperscript{2} where a common set of principles underlie all of the simulation models. Thus, a model of the heart may inform a model of an ecosystem or a model of a city.

Models will be developed with COBWEB (Complexity and Organized Behaviour within Environmental Bounds – a software package, developed by Professor Bass and U of T students). COBWEB is an agent-based simulation model, meaning that the actions of each individual member of a population or component of a system can be represented in the model. Each member of the population can learn, and populations/systems can evolve novel strategies over time. Experiments are run in a two- or three-dimensional grid, and the outputs are downloaded into a spreadsheet for display and further analysis. The analyses range from visual description to statistical analysis to mathematical assessment of chaos, depending on the interests and experience of the student. Interested students may contact Brad Bass for a copy of the software.

**Why apply for this ROP:** An ROP provides an enhanced research experience, typically not available to second or third-year students, and often not available until graduate school. This ROP provides additional opportunities for cross-disciplinary work, teamwork and team leadership, transferrable software and skills to your specialist/major programs, opportunities for mentoring and opportunities for leading workshops. This ROP encourages cross-disciplinary collaboration as the processes being simulated in one field are often transferable to solve a problem in other areas of study. Students work in teams and there are opportunities to lead teams. As new students come into the lab from other courses, ROP students often provide the training and mentorship. The software used in the ROP is freely available for you to use at any time. We often receive requests to provide workshops for other groups, and ROP students have the opportunity to use these workshops to develop presentation and training skills.

**DESCRIPTION OF STUDENT PARTICIPATION:**

Students in this ROP will learn how to use COBWEB based on previous year’s start-up guides and may create start-up guides of their own. During the fall semester, each student will also write a literature review. Third-year students will develop a more focused topic and will be expected to utilize more articles. The literature will shape the specifics of the research that students will complete with their simulation models. The model development will also begin in the fall and is completed in January and February. Third year students will be expected to generate multiple outcomes from their models and are encouraged to use statistical, mathematical or other analyses to evaluate model output from COBWEB. Students will also participate in the ROP Poster Forum in March 2020. The latter part of the course is spent on preparing a poster and writing the final research report.

This research is intended for students in biology, ecology, chemistry, physics mathematics and environmental science but is open to students in any discipline with a genuine interest in simulation of


living/physical systems and/or designer ecosystems.

This ROP is also open to computer science students with programming experience in Java. Computer Science students have the option to expand the capabilities of either the 2D or 3D version of COBWEB. Computer Science students can work on agent behaviour, environmental characteristics, transmission between agents (currently toxins and diseases can be transmitted), visual representation, data collection and display, genetic algorithms or mobile applications. This is a process that begins with understanding the capabilities of the program, meeting with the users for to discuss future needs, updating the program, collaboratively testing the new code with the users, debugging the code and retesting it in collaboration with the users. The users are usually the other ROP students but may include students and faculty who are using COBWEB outside of this course. The difference in participation is that computer science students will begin coding their additions/changes to the software instead of developing simulations of different systems for research. Although, it may be possible to incorporate your modifications into the 2018-19 research program, most likely your changes will take effect in the following year.

**MARKING SCHEME** (assignments with weight and due date):
2-page write up of first analysis/annotated bibliography - Oct. 31, 2019  10%
Journal - Apr. 8, 2019  20%
Literature Review - Dec. 13, 2019  20%
Poster - Mar. 7, 2020  5%
Final Report - Apr. 3, 2020  40%
Participation - Ongoing  5%
RESEARCH OPPORTUNITY PROGRAM
299Y/399Y PROJECT DESCRIPTIONS 2019-2020
FALL/WINTER

Name and Title: Brad Bass, Professor
Department: School of the Environment

TITLE OF RESEARCH PROJECT: Encouraging Behavioural Change to Achieve Different Environmental Outcomes: Studying Behavioural Change Through Simulation Models

Number of 299Y Spots: 7                                  Number of 399Y Spots: 3

OBJECTIVES AND METHODOLOGY:
The objective of this research is to study different means of encouraging behavioural change in order to improve the environment through a reduction in pollution. Students will use the simulation model developed with the COBWEB software – Complexity and Organized Behaviour Within Environmental Bounds

New environmental policies often rely on regulations, guidelines or programs to achieve the intended outcomes. Economic incentives are another option. Incentives involve subsidies, costs or trading permits to pollute. The objectives of this ROP are to study the degree to which programs focused on outreach to potential users can influence the adoption of new modes of behavior in order to achieve a specific environmental outcome. Students will develop simulation models based on marginal utility functions, personality traits, the Prisoner’s Dilemma – a game used to analyze socio-economic interactions and group dynamics – the emergence of central places/retail clusters, or the trade-offs between housing and transportation costs within urban land use models. Students will also have the opportunity to develop models based on the social factors that influence change, whether including following early influential adopters, the influence of social networks and group dynamics.

Although students are given some opportunity to choose their own system of interest, one objective for the 2019-20 year is to continue with the development of a model of innovation. This model involves the use of microeconomics, social factors that influence change and the spatial context for the diffusion of innovations within the three-dimensional version of COBWEB.

Models will be developed with COBWEB (Complexity and Organized Behaviour within Environmental Bounds – a software package, developed by Professor Bass and U of T students). COBWEB is an agent-based simulation model, meaning that the actions of each individual member of a population or component of a system can be represented in the model. Each member of the population can learn, and populations/systems can evolve novel strategies over time. Experiments are run in a two- or three-dimensional grid, and the outputs are downloaded into a spreadsheet for display and further analysis. The analyses range from visual description to statistical analysis to mathematical
assessment of chaos, depending on the interests and experience of the student. Interested students may contact Brad Bass for a copy of the software.

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**DESCRIPTION OF STUDENT PARTICIPATION:**
The students will develop virtual labs with COBWEB. COBWEB offers opportunities for a very sophisticated simulation of the Prisoner’s Dilemma involving multiple agents, flexible rewards, multiple strategies, marginal utilities and the ability to restrict one-on-one interactions. COBWEB also has a module to study the emergence of retail clusters/central places with both producers and consumers. Although the central place model is based on Krugman’s work on spatial economics, it has been enhanced with the emergence of a market and the impact of urbanization on food production. COBWEB 3D allows students to work with specific functions for controlling production and consumption, all within an agent-based framework.

Students in this ROP will learn how to use COBWEB based on previous year’s start-up guides and may create start-up guides of their own. During the fall semester, each student will also write a literature review. Third-year students will develop a more focused topic and will be expected to utilize more articles. The literature will shape the specifics of the research that students will complete with their simulation models. The model development will also begin in the fall and is completed in January and February. Third year students will be expected to generate multiple outcomes from their models and are encouraged to use statistical, mathematical or other analyses to evaluate model output from COBWEB. Students will also participate in the ROP Poster Fair in March, 2020. The latter part of the course is spent on preparing a poster and writing the final research report.

This research is intended for students in the economics, political science, geography, social psychology, sociology, mathematics and environmental studies but is open to students in any discipline with a genuine interest in the issue.

This ROP is also open to computer science students with programming experience in Java. Computer Science students have the option to expand the capabilities of either the 2D or 3D version of COBWEB. Computer Science students can work on agent behaviour, environmental characteristics, transmission between agents (currently toxins and diseases can be transmitted), visual representation, data collection and display, genetic algorithms or mobile applications. This is a process that begins with understanding the capabilities of the program, meeting with the users for to discuss future needs, updating the program, collaboratively testing the new code with the users, debugging the code and retesting it in collaboration with the users. The users are usually the other ROP
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