Physical & Environmental Sciences
UNIVERSITY OF TORONTO
SCARBOROUGH

WINTER 2022
GRADUATE COURSE OUTLINE

EES1118H Fundamentals of Ecological Modelling
Monday 10:00-13:00 [Online Synchronous/in-person (TBA)]
Instructor: Yuko Shimoda
Email: yuko.shimoda@utoronto.ca
Office hours: Tuesday 2:00 – 5:00 pm, and by appointment for online meeting

COURSE DESCRIPTION

Mathematical (process-based) models have been widely used as a powerful instrument in science, as well as a management tool to support policy decision-making processes. This graduate course introduces the rapidly growing field of ecological/environmental modelling, which comprises fundamental theory and the practicum that provides hands-on exercises in the development and application of models.

COURSE OBJECTIVES

This course will provide a comprehensive overview of ecological/environmental modelling which includes a presentation of various model types, theories, and their application of the models. Students should become familiar with most of the basic equations used to represent ecological processes in the population dynamics models; prey-predator, resource competition, and physical, chemical, and biological processes described in the biogeochemical/eutrophication models. Emphasis will be placed on the rational model development, objective model evaluation and validation, selection of the optimal complexity from complex ecological processes, explicit acknowledgment of the uncertainty in ecological forecasting and its implications for environmental management. The practical training includes the development of models, model calibration and validation, compilation and interpretation of model outputs using excel, programming language, and modeling software. Students will develop his or her own model of intermediate complexity, calibrate the model and assess the goodness-of-fit against observed data, identify the most influential model parameters (sensitivity analysis), and present their results as a final project.

SCHEDULE

Jan 10 **ORIENTATION**
Course Outline; Lecture Schedule
INTRODUCTION
Models as a Management and Scientific Tool
Modelling Elements and Procedure
Model Types, Selection of Model Complexity and Structure
Conceptual Models
Evaluation of the Current State of Mechanistic Aquatic Biogeochemical Modelling

Jan 17 **MODELLING POPULATION DYNAMICS (PART I)**
Basic Concepts
Growth Models in Population Dynamics
Single Population Growth Model
Interaction between Populations: Lotka-Volterra Equations
Interspecific Competition, Prey-Predator Models

Jan 24 **MODELLING POPULATION DYNAMICS (PART II)**

Mathematical Models in Conservation Biology
Introduction to modelling software
Minimal Models for Solving the "Paradox of Plankton"

Jan 31 **MODELLING ECOLOGICAL SYSTEMS - PHYSICAL PROCESSES**

Space and Time Resolution
Mass Transport
- Advection, Diffusion & Turbulent Diffusion, Dispersion
- Mass Transfer at a Two-Phase Interface

Mass and Energy Balance
- Mass Balance for a Well Mixed System: Continuous Stirred Tank Reactor Model
- Mass Balance for a Non-Well Mixed System

Feb 7 **MODELLING ECOLOGICAL SYSTEMS - CHEMICAL PROCESSES**

Chemical Reactions
- Reaction Kinetics
- Enzymatic Reactions

Continuous Stirred Tank Reactor Model
Characterization of External Forcing and Response Patterns

Feb 14 **CATASTROPHIC SHIFTS IN ECOSYSTEMS**

Theoretical Framework: Ecosystem Response to Gradually Changing Conditions
Catastrophic Shifts in Ecosystems, Implications for Management
- Modelling Catastrophic Shifts in Ecosystems

Feb 21 **Reading Week**

Feb 28 **MODELLING ECOLOGICAL SYSTEMS - BIOLOGICAL PROCESSES (PART I)**

Aquatic Biogeochemical/Eutrophication Model
- Algal Growth
- Zooplankton Growth
- Phosphorous Cycle

Modelling Fish Growth as Biomass and Population

Mar 7 **MODELLING ECOLOGICAL SYSTEMS - BIOLOGICAL PROCESSES (PART II)**

Description of Aquatic Biogeochemical/Eutrophication Modelling Project
- Model Parameterization
- Data Description for Model Calibration
- Scenario implementations

Mar 14 **BASIC MATHEMATICAL TOOLS**

Truncation Errors and the Taylor Series
Error Propagation and Total Numerical Error
Ordinary Differential Equations
Euler's Method-Runge Kutta Methods

Mar 21 **UNCERTAINTY ANALYSIS OF MATHEMATICAL MODELS**

Equifinality and Uncertainty in Mathematical Models:
A Comparative Analysis of the Generalized Likelihood Uncertainty Estimation and Markov Chain Monte Carlo Methodologies

Mar 28 **SENSITIVITY ANALYSIS & OPTIMIZATION**

Sensitivity Analysis
- First-Order & Monte Carlo Analysis

Constrained Optimization
- One-dimensional Unconstrained Optimization, multi-dimensional Unconstrained Optimization

Apr 4 **GUEST LECTURE & WRAP-UP**

Guest Lecture: Watershed, Hydrodynamic modelling, ensemble modelling (TBA)

Course wrap-up

- Pointers for presentation
- Tips for final modelling project

EVALUATION

Modelling Project Proposal	**20 %**	**Due: Feb 7**
Mid-Term Modeling Project	**20 %**	**Due: Mar 7**
Final Oral Presentation (20%) and Final Modeling Project (30%)	**50 %**	**Due: Apr 11 & 13**
Participation	**10%**	

The evaluation will be carried out in accordance with the Graduate Grading and Evaluation Practices Policy (and how that policy is interpreted and applied in this Dept.)
http://www.governingcouncil.utoronto.ca/Assets/Governing+Council+Digital+Assets/Policies/PDF/grading.pdf

VERIFICATION OF ILLNESS

During the COVID-19 pandemic, the University is temporarily suspending the need for a doctor's note or a ***Verification of Illness*** for absences from academic participation; students should use the Absence Declaration tool on ACORN to declare an absence if they require consideration for missed academic work; students are responsible for contacting instructors to request the academic consideration they are seeking; students should record each day of their absence as soon as it begins, up until the day before they return to classes or other academic activities.

EMERGENCY PLANNING

Students are advised to consult the university's preparedness site (http://www.preparedness.utoronto.ca) for information and regular updates regarding procedures relating to emergency planning.

ACCESSIBILITY NEEDS

The University of Toronto is committed to accessibility. If you require accommodations for a disability or have any accessibility concerns about the course, the classroom or course materials, please contact the UTSC Accessibility Services as soon as possible: http://www.utsc.utoronto.ca/~ability/
We also suggest you also refer to the following University of Toronto Scarborough Library link:
http://utsc.library.utoronto.ca/services-persons-disabilities

PLAGIARISM

University of Toronto Code of Behaviour on Academic Matters states that "it shall be an offence for a student knowingly: to represent as one's own any idea or expression of an idea or work of another in any academic examination or term test or in connection with any other form of academic work, i.e., to commit plagiarism."
The University of Toronto's Code of Behaviour on Academic Matters outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences.
For accepted methods of standard documentation formats, including electronic citation of internet sources please see the UofT writing website at http://advice.writing.utoronto.ca/using-sources/documentation.

WRITING AND ENGLISH LANGUAGE

As well as the faculty writing support, please see English Language and writing support at University of Toronto or the Centre for Teaching and Learning at UTSC.

The following is also useful:
Sylvan Barnett, *A Short Guide to Writing About Art*. 5-7th edition (New York: Harper-Collins, 1997)
William Strunk Jr., E.B. White. The Elements of Style (New York: MacMillan Publishing)

LATE WORK
All assignments are due in class at the specified time and date. Please see the information under the ***Verification of Illness***, in the case of illness or other special circumstances.

READINGS:
The required textbook for this course is**:**
Fundamentals of Ecological Modelling. 2001 (3rd Edition). S.E. Jorgensen and G. Bendoricchio; Elsevier Science Ltd: 530 pp.

Specific readings will also be given out during the lecture and/or practical sessions.

FINAL EXAM DATE
The final exam (oral presentation a modelling project, no written exam) will be held on April 11th Monday, 2021 (Tentative).