International Field School on Algal Blooms

Biology 9439
Course Syllabus
Capacity: 20 students
Deadline to Apply: June 30, 2014

Apply to:

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Course Coordinators
Irena Creed (Canada) and Ann-Kristin Bergström (Sweden)

Course Description

The incidence of algal blooms is increasing globally. These blooms are often harmful, depleting water of oxygen and light, or toxic, producing noxious, inhibitory or toxigenic metabolites with potentially devastating consequences. We seek to find answers to the following unresolved questions:

First, "getting there" – what are the factors that allow potentially harmful algae to exist? Is it the stimulation of natural populations within the lake *or* the transfer ("invasion") of more prolific strains into the lake that out-compete the more moribund natural populations? What are the causative factors (e.g., climatic, atmospheric transport, boat and ballast water transport) that allows for the invasion of new "seeds" of an algal blooming population?

Second, "being there" – what are the factors that enable freshwater algal bloom species to dominate the pelagic waters of an ecosystem? Present dogma considers that high nutrient levels give rise to algal blooms, but our understanding of the mechanistic linkages is extremely weak at this point (e.g., N *vs.* P limitation debate). Indeed, rather than a direct causal agent, P is considered by some to be a strong risk factor with unknown intermediate factors linking P and cyanobacteria dominance of phytoplankton (e.g., the phosphorus-ferrous model). We will challenge competing conceptual models of light and macro- and micronutrient controls on algal blooms. Critical to resolving the debate is estimation of the concentration, speciation and stoichiometry of nutrient supply that lead to conditions favoring algal blooms. We will assess the relative importance of nutrients supplied from (a) the terrestrial contributing source areas to the lake *vs.* the lake itself and (b) epilimnetic *vs.* hypolimnetic sources in systems with a stable thermocline or sediment boundary layers in polymictic systems on algal cell nutrient quota and growth conditions. We will explore the changing nature of competition and predation pressures on algal bloom species. We will determine both the effects of algal blooms on food web structure, and in turn, the effects of food web structure on algal blooms.

Third, "staying there" – what are the factors that allow for the re-occurrence and persistence of cyanobacteria blooms? Does this process involve the production of toxins, allelopathic compounds and/or siderophores? It is a commonly held belief that the release of toxins produced within the cell occurs at the cessation of the algal bloom – a system that promotes the longevity of a bloom promotes the toxicity of the bloom. However, not all cells make toxins and more harmful algal bloom species biomass does not always result in more toxins. A critical need is the clarification of the physiological model of toxin production (toxin/cell) and the environmental loading of cyanotoxins (toxin/volume). We will explore the metabolic purpose of toxins, the transfer of cyanotoxins through the food chain and the potential risks for human exposure to toxins.

Fourth, "preventing them" – can we use our foundational understanding of the factors that allow cyanobacteria to "get there", "be there" and "stay there" to inform critical management initiatives that will result in successful prevention of cyanobacteria blooms? "Hard" ecological research is often deeply rooted in formulating a new conceptual understanding of naturally occurring processes with little success in communicating this "new knowledge" for management or prevention efforts. We will use our findings in response to the first three unresolved questions to effectively communicate management and prevention

suggestions to all levels of a "lake community" including lake managers, policy makers, stakeholders and community citizens.

Furthermore, broadening the geographic scope of the four foundational questions, we pose the question: to what extent does trophic status (i.e., from hyper-oligotrophic to hyper-eutrophic) dictate the potential for harmful algae to dominate algal biomass? How does DOC or salinity affect cyanobacteria bloom formation? We will explore the suite of algal toxins in a given system and specific toxins across systems that represent a range in trophic state to establish trophic state-dependency of specific toxins and their concentrations.

This 7-day intensive field school is the first in an anticipated annual series that will be rotated among North America, Europe, Asia and Africa. The field school is designed to facilitate interdisciplinary learning on the science of algal blooms, discussing theory, demonstrating techniques and comparing systems from participating countries. The field school is expected to be highly interactive, with discussions contributing to the project design of student research projects and highly collaborative providing opportunities for students to extend their research productivity.

This field school will be held at the Abisko Scientific Research Station, managed by the Swedish Polar Research Secretariat. Situated on the south shore of Lake Torneträsk, it is a unique, modern and comprehensive infrastructure situated about 200 km north of the Arctic Circle in Sweden (68º21'N, 18º49'E). It has international standard facilities that support a range of research from observation and monitoring to high-tech experimentation within terrestrial and freshwater environments. The surroundings are characterized by a high variability of topography, geology and climate.

Course Credits

Canada

Credit point: 0.5 FCE
Course code: Bio9439
Responsible department: Department of Biology
Main field of study: Ecology
Level: Master or Doctoral level
Specialization in relation to degree requirements: MSc/PhD
Grading scale: Percent, 0 to 100

Sweden

Credit point: 5.0 ECTS
Responsible department: Department of Ecology and Environmental Science
Main of field study: Earth Science/Physical Geography/Ecology
Level: Advanced level
Specialization in relation to degree of requirements: Doctoral level
Grading scale: Pass or Fail

Course Prerequisites

Successful completion of a Bachelor's of Science degree in Biology, Geography or Earth Sciences.

Course Format

In addition to field and laboratory work, the course also contains an individual student project where students with a high degree of independence compile, analyze and present orally and in written text relevant scientific literature within the theme of the course. The teaching includes lectures, seminars, laboratory and computer practices, presentations and excursions. Participation in all teaching components is compulsory. The main themes of the course include – recent trends in algal blooms, conceptual models of lakes, conceptual models of algal bloom triggers, algal taxonomy, algal physiology (and proteomics, metabolomics, genomics), algal toxins, external *vs.* internal loading of nutrients, nutrient limits to algal growth, nutrient regeneration up the food chain and cascading nutrient limitation (and toxin transfer) at higher trophic levels and bloom prevention management. For each theme, morning activities will include 3 hours of lectures, afternoon activities will include 3 hours of laboratory or field excursions and evening activities will include 2 hours of

seminars and discussions. The course format is designed is to give students exposure to contemporary theory and techniques focused on algae and its role in trophic food webs.

Course Instructors

Irena Creed is Canada Research Chair in Watershed Sciences, Professor of Biology, Geography, Earth Sciences, Western University. Her expertise is in hydrology, biogeochemistry and ecology. She studies the hydrological and biogeochemical triggers leading to the development of algal blooms in freshwater lakes. *Creed is Director of the NSERC Create Algal Bloom Abatement through Technology and Education (ABATE) Training Program.*

Ann-Kristin Bergström is Senior Lecturer in Aquatic Biogeochemistry, Umeå University, Sweden. She is a limnologist who studies the importance of nutrients for lake productivity and food webs.

Lewis Molot is Professor of Environmental Studies, York University. His expertise is in watershed and lake biogeochemistry. His research focuses on the role of iron in co-promoting freshwater harmful algal blooms in oligo-mesotrophic and eutrophic waters.

Charles Trick is Beryl Ivey Endowed Chair in Ecosystem Health, Professor of Biology, Pathology, Western University. He is a harmful algal bloom expert in physiology and biochemistry, environmental regulation of toxin production and ecosystem health. In addition to his work on fHABs in Canadian and African lakes, he is co-leader of an international training program on harmful algae and toxin analysis that focuses on capacity building of communities in Guatemala, Philippines, Indonesia, Cook Islands and Vietnam.

William Cochlan is Senior Research Scientist at the Romberg Tiburon Center at San Francisco State University. He is a biological oceanographer/marine microbial ecologist who addresses the fundamental question: "What factors control phytoplankton growth, their nutrition and distribution in the ocean?". More specifically, how do the multiple interactions of light, and macro- and micronutrients, affect the physiology of marine phytoplankton, and hence determine their growth rates, biochemical processes and distribution patterns in the sea from coastal to polar environments? He provides expertise in microbial ecology, bacteria and phytoplankton, the role of nitrogen in marine harmful algal blooms, and the use of isotopes in tracking marine microbial dynamics.

Beth Hundey is a recent PhD graduate from the Department of Geography and the Centre for Environment and Sustainability at Western University. Her graduate research focused on eutrophication and nitrogen cycling in high nitrogen environments using paleolimnological and limnological methods to understand changes in productivity over the past 200 years, sources of nitrate and altered lake ecology in the Uinta Mountains of Utah, USA.

Ryan Sorichetti is a recent PhD graduate from the Department of Biology and the Centre for Environment and Sustainability at Western University. His graduate research focused on the role of iron in regulating cyanobacteria biomass in nutrient-poor lakes using limnological and biogeochemical methods to understand how dissolved organic matter and iron-binding siderophores influence cyanobacteria proliferation in the Algoma Highlands of Ontario, Canada.

Course Evaluation

10% Laboratory/field work book (daily)
40% Individual seminar (evenings)
20% Group seminar (last day)
30% Participation (in lectures, seminars, lab and field)

Expected Learning Outcomes

Students will achieve competency in each of the following five categories needed for Job Readiness in the field of algal ecology and physiology:

(1) Scholar

- In-depth knowledge of the student's chosen field or sub-field and familiarity with the scientific literature in that field
- Interpretation and integration of published scientific literature

- Actively contribute qualified scientific viewpoints at seminar discussions
- Data acquisition – in laboratory or field, as appropriate
- Identify key algal species and estimate their biomass and biovolume
- Estimate catchment nutrient balances and nutrient loading to lakes
- Assess nutrient limitation and nutrient regeneration
- Data analysis and management (e.g., computational approaches, statistical analysis, statistical data transformations, handling and organizing large datasets)

(2) Collaborator

- Team and collaborative working environment
- Independent responsibilities in project progression
- Participation (where appropriate) with expanded research teams

(3) Communicator

- With a high degree of independence, both critically assess and present in written and oral form scientific literature within the main field of the course
- Communicate science to transdisciplinary groups (academics, policy makers, lake managers, citizens)
- Individual and group presentations

(4) Professional

- Participation in several activities of being an academic (research, integration of ideas, creation of research advancements, community outreach)

(5) Gatekeeper

- Critical thinking
- Evaluation and appreciation of science outside of the specialty

Course Materials:
A set of lectures will be prepared that cover three hour time slots and should include "fundamentals", "state of the practice in tools/techniques" and "state of the science, with insights from the front lines" – a "seminar" given by the instructor reflecting current relevant research activities. A digital library is being created with key papers; papers will include: classic papers; paradigm shifting papers; key papers related to algal bloom science will be included. A digital manual is being created to support lab/field activities. We will need to customize based on equipment available.

		Theme – lectures from fundamentals to advanced*, **	Lead Instructor
Saturday, Aug 16	Arrive	Introduction and tour of facilities and surroundings	Irena Creed and Ann-Kristin Bergström
Sunday, Aug 17	AM	LECTURE: Frontiers in algal bloom science, competing paradigms, global perspectives, Pasteur's Quadrant and scientific needs for effective management of algal blooms	All faculty
	PM	LAB/FIELD: Algal fundamentals (taxonomy, biomass, biovolume, occurrence)	Charlie Trick and William Cochlan
	Evening	SEMINAR: Getting to know each other's research interests	PDFs
Monday, Aug 18	AM	LECTURE: Conceptual models of lakes, lake morphometry, physical and chemical limnology, external *vs.* internal loading of nutrients to lakes	Irena Creed
	PM	LAB/FIELD: Tour of alpine, sub-alpine and boreal lakes – compare "catchment as a filter" along this gradient and gather physical and chemical data from lakes	Ryan Sorichetti and Irena Creed
	Evening	SEMINAR: "Getting there" student seminars and discussion	PDFs

Tuesday, Aug 19	AM	LECTURE: Principle of limiting factors and limits to algal growth (light, C:N:P, trace elements). A steady state mass balance model to show links between load and concentration, a demonstration of how phosphorus management has resulted in reduced P loading and therefore productivity in some lakes, but not other lakes, how some lakes still suffer from internal P loading and related algal blooms and a description of the P-Fe model that links P to anoxia, a critical examination of the P *vs.* N debate, and how the P-Fe model can be used to illustrate how N controls might work in some systems when N loads are high enough to significantly affect dissolved oxygen consumption	Lewis Molot
	PM	LAB/FIELD: Demonstration of historical (paleolimnology) and contemporary (bioassays) for assessing limiting factors across a gradient of lakes	Beth Hundey and Ann-Kristin Bergström
	Evening	SEMINAR: "Staying there" student seminars and discussion	PDFs
Wednesday, Aug 20	AM	LECTURE: Algal growth physiology, the role of N and Fe in toxin production. Developments of bioassays to detect toxin production in lakes.	Charles Trick
	PM	LAB/FIELD: Grow-outs, chemostats, mesocosms, ecostats and limitations of culturing methods (batch, serial dilution and continuous culture) to examine algal growth dynamics.	William Cochlan and Charles Trick
	Evening	SEMINAR: "Being there" student seminars and discussion	PDFs
Thursday, Aug 21	AM	LECTURE: Algal determinants of food web quantity/quality (who eats what and nutrient cascades (regeneration) up the food chain) and plasticity *vs.* homeostasis in food web stoichiometry	Ann-Kristin Bergström
	PM	LAB/FIELD: Analysis of phytoplankton *vs.* zooplankton species, use of C and N isotopes to track food web dynamics.	William Cochlan and Ann-Kristin Bergström
	Evening	SEMINAR: "Links between trophic status and toxins" student seminars	PDFs
Friday, Aug 22	AM	Recapping the frontiers in algal bloom science, priorities for future research needs and paradigms for future researchers	Group syntheses and highlights
	PM	Departure	

Scholastic Offences:
Scholastic offences are taken seriously and students are directed to read the policy at http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_grad.pdf

Course Component	Ontario Graduate Degree Expectations						ABATE Program Objectives					Professional Skills									
	Depth and Breadth of Knowledge	Research and Scholarship	Level of Application of Knowledge	Professional Capacity/ Autonomy	Level of Communication Skills	Awareness of Limits of Knowledge	Training Method	Knowledge is Constructed	Knowledge Needs to be Challenged	Transdisciplinary Thinking	Self Directed Learning	Leader	Creator/ Innovator	Critical Thinker	Project Coordinator	Code of Conduct/ Ethics	Communicator	Team Player	Inter-sectoral Competence	Inter-cultural Competence	Knowledge Translator
Scientific Theory Students will: 1) build a comprehensive understanding of lakes as "open systems" with inextricable linkages (water, nutrients and gasses) to terrestrial landscapes and the atmosphere 2) learn foundational conceptual models describing the biotic and abiotic processes that occur within the atmosphere, landscapes and lakes and how the processes are linked among these ecosystems 3) learn how the foundational conceptual models of biotic and abiotic processes are related to cyanoblooms and that there exists a need for current conceptual models to be challenged and/or revised 4) form an appreciation for the implications of climate change and human perturbance on the biotic and abiotic processes that regulate cyanoblooms in lakes 5) have the capacity to evoke educated and conceptually-derived descriptions of how future climate change scenarios will alter the spatial and temporal patterns of cyanobloom occurrence in lakes																					

Scientific Practice Students will: 1) develop a skill set of standard limnological methodology (physical, chemical and biological), in the field and in the laboratory, that will provide resources making them competitive in the job market (academia, government and industry) 2) learn water sampling techniques in lakes including water sample collection, sample processing (filtration and preservation) and water chemical analysis 3) learn phytoplankton taxonomic identification and be able to determine food web composition in lakes 4) develop ecotoxicology laboratory method skills (bioassays) with the ability to measure the cytotoxicity of lakes (cell line bioassays) and toxin concentrations in lakes (enzyme linked immunosorbent assay) 5) learn how to conduct historical lake reconstructions of phytoplankton community composition using paleolimnological research techniques (sediment cores) 6) learn to manage large datasets of physical, biological and chemical parameters commonly collected in limnological research campaigns, statistical methods appropriate for multivariate analysis of limnological data and how to effectively interpret these multivariate results in the context of lake biogeochemical nutrient processing and cyanobloom occurrence																					
International Experience Students will: 1) form relationships with an international network of aquatic science specialists 2) learn cutting edge scientific approaches that will allow them to increase the productivity of their research project																					
International Communication and Management Students will: 1) be able to describe and explain the complexities of lakes and lake management in regions within and outside of Canada																					