DALHOUSIE UNIVERSITY

Syllabus:

Hacking the blue planet: the scientific and social dimensions of ocean fertilization

MARI/OCEA 4665 BIOL/OCEA 5665
T/R 1:05-2:25 pm LSC 234

Instructor: *Erin Bertrand* erin.bertrand@dal.c*a* *office: 902- 494-1853* *LSC BIOL 5076B*

Lectures: *Three lecture hours per week*

Office Hours: By appointment; email to arrange anytime

Course Description

This course explores the biology, ecology, biogeochemistry and ethical and legal dimensions of purposeful ocean fertilization. Through lectures, discussion, case studies, and group projects, students consider the biological and oceanographic basis of ocean fertilization and its use as a 1) scientific tool and 2) controversial geoengineering strategy for climate change mitigation.

In the 1980's, the scientific community began discussing the possibility that purposeful ocean fertilization could cause large-scale phytoplankton blooms with the potential to influence climate. Open ocean iron fertilization experiments began in the early 1990's and have continued into the current decade. These iron additions often resulted in large phytoplankton blooms, but the fate of the resulting biomass remained unclear. Ocean fertilization has been surrounded by scientific, ethical and legal controversies. It has received attention as a potential climate change mitigation strategy, a tool for basic oceanography research, and even as a method for revitalizing fish stocks. In this class, ocean fertilization will be used as a starting point from which to teach concepts including ecological stoichiometry, planktonic ecosystem structure and function, as well as order of magnitude calculations. The course will then bridge from biophysical sciences into the social realm, and students will use the knowledge they've gained about relevant biology and oceanography to evaluate various claims about ocean fertilization as a climate and fisheries engineering strategy. Through case study discussions, the class will explore the ethical and legal dimensions of such engineering strategies. This course will expose students to structured reading, discussion and synthesis of primary literature and will provide opportunities for improving cross-disciplinary communication, writing, and critical thinking skills.

Course Prerequisites

For 4665.03: one of the following: BIOL 3101.03, OCEA 2000X/Y.06, ERTH 3601.03, BIOL 3060.03 or Instructor's permission
For 5665: Instructor's permission

Key knowledge or skills expected of students coming into the course
Students will be expected to have a very basic understanding of planktonic marine ecosystems. This class, however, will be suitable for students with a wide range of backgrounds since it explores inherently interdisciplinary topics.

Course Objectives:

Students will come away from this class being able to discuss:

- *The roles of ocean biology in shaping global climate*
- *The concept of ecological stoichiometry and its implications for marine sciences*
  Ecological stoichiometry: the notion that observed patterns in biochemical use of elements at the molecular level may be directly connected with phenomena at the ecosystem or even global level
- *The nature of conflicts that arise at the intersection of basic research and applied science*
- *Ethical, legal, and policy implications of ecosystem and geoengineering schemes*

Students will have gained practical experience in:

- *Synthesizing and interpreting primary literature*
- *Making order of magnitude calculations and estimations to arrive at approximate solutions to complex problems*
- *Writing, peer reviewing, and presenting a formal research proposal*
- *Working in interdisciplinary teams*

Course Materials

All materials will be made available via the course Brightspace page. These include primary literature and perspective pieces from scientific journals as well as select chapters from textbooks including:

- *Sterner and Elser, Ecological Stoichiometry*
- *Harte, Consider a Spherical Cow*
- *Frausto da Silva and Williams, Biological Chemistry of the Elements*
- *Libes, Marine Biogeochemistry*

Readings for each class will be available two weeks ahead of time on the course Brightspace page.

Course Format: In general, Tuesdays and the first half of Thursday classes will be comprised of lecture and group activities led by the Instructor. The second half of Thursday classes will be student-led discussions, with two Peer Discussion Leaders designated. These will focus on 2-3 readings from primary literature, review articles, or opinion pieces from the literature.

Discussion leader responsibilities: Peer discussion leaders should come to class prepared to co-lead discussion on the assigned readings for the week for the last 30 minutes of class on their assigned days. This could consist of preparation of slides to highlight key figures or points, discussion questions, or prepared activities. Leaders for each day should get together to discuss and plan ahead of class such that each co-leader participates. Suggested approaches for discussion leading are provided on the Brightspace page

Course Content and Schedule

(schedule is subject to change; consult Brightspace regularly for updates)

Sept 5, 7: History of ocean fertilization, climate crisis context. Course overview, research proposal and critical literature summary introduction

Sept 12, 14, 19, 21: Phytoplankton physiology, ecological stoichiometry, and nutrient acquisition

Sept 26, 28; Oct 3, 5: Microbial loop, biological pump, unintended consequences, and the paleo-oceanographic perspective

Oct 10, 12, 17, 19: Writing and reviewing research proposals; results of iron fertilization experiments to date, and other related geoengineering schemes

Oct 24, 26: **Case Study 1**: LOHAFEX

Oct 31, Nov 2: Ethics, law and policy surrounding Ocean Fertilization

Study break

Nov 14, 16: **Case Study 2**: Haida Salmon Restoration Corporation

Nov 21: **Case Study 3**: Oceaneos in Chile, planned experiments

Nov 23, 28, Nov 30: **Proposal Presentations**

Course Assessment

Component	Weight (% of final grade)	Due Date
Problem Set 1	20%	Friday Oct 13th (Assigned Sept 28th)
Problem Set 2	20%	Monday Nov 13th (Assigned Oct 26th)
Weekly Critical Summaries	15%	Summaries Due Sept 14, 21, 28; Oct 5, 12, 19, 26; Nov 2, 16, 21
Worksheets, discussion-leading and class participation	15%	In class
Research proposal	30%	Final draft: Dec 15th (see other deadlines below)

Problem Sets (40%) Two equally weighted take-home problem sets including calculations and short answer questions on the following topics:

1. Phytoplankton stoichiometry, microbial loop, biological pump
2. Synthesis: where natural science meets policy, legal, and ethical dimensions of eco- and geoengineering schemes

Problem set policies: Students are free to work together and to use any lecture, course or other resources to work on these problems. If you work with another student or receive help from some other living resource, *include their name at the top of your problem set*. Problem sets will be assigned two full weeks before they are due but should not take you more than 8h total to complete. Problem sets will consist of five questions. Graduate students will answer five and undergraduates may choose four. Show all your work in submitted documents.

Weekly Critical Summaries (15%) 300-500 word critical summaries of the week's reading assignments. Examples of critical summaries will be discussed in the first week of class.

Final marks for these will also include assessment of class participation, duties as discussion leader, and worksheet contributions (15%) as described in the rubrics below.

Weekly summaries and participation evaluation rubric UNDERGRADUATE STUDENTS:

Criteria	**Indicators**
Critical summaries	The student demonstrates that they: • have completed the assigned reading (60%) • have developed an understanding of how these readings relate to broad themes in the course (30%) • identify key weaknesses or raise insightful questions when readings include primary scientific literature (10%) • Note that each critical summary is equally weighted.
Worksheets, discussion leading and participation	
Discussion leading (30%)	The student came well-prepared to lead discussion at the allotted time and effectively facilitated an active discussion
Frequency of participation in discussions (20%)	The student is actively engaged in class discussion at all times.
Quality of contributions (30%)	The student's comments are constructive and relevant; comments reflect a considered understanding of the week's reading materials and course aims.
Worksheets (20%)	Group worksheets completed in class are turned in at the end of class, and the student participates in worksheet discussions actively in small groups

Weekly summaries and participation evaluation rubric GRADUATE STUDENTS:

Criteria	**Indicators**
Critical summaries	The student demonstrates that they: • have completed the assigned reading (40%) • have developed an understanding of how these readings relate to broad themes in the course (30%) • identify key weaknesses or raise insightful questions when readings

	include primary scientific literature (30%) • Note that each critical summary is equally weighted.
Worksheets, discussion leading and participation	
Discussion leading (30%)	The student came well-prepared to lead discussion at the allotted time and effectively facilitated an active discussion
Frequency of participation in discussions (20%)	The student is actively engaged in class discussion at all times.
Quality of contributions (30%)	The student's comments are constructive and relevant; comments reflect a considered understanding of the week's reading materials and course aims.
Worksheets (20%)	Group worksheets completed in class are turned in at the end of class, and the student participates in worksheet discussions actively in small groups

Research Proposal (30%) Undergraduates in groups of 2-3 students, or graduate students as individuals: propose a research project to answer what you perceive to be a remaining key question about ocean fertilization, another aspect of ecological stoichiometry, or geoengineering more generally. The question can be a basic science question or one that bridges the social and natural sciences. Proposals will be 7-10 pages single spaced including figures and tables, and excluding references. Each student will individually review one other draft proposal. Each proposal will also be presented and defended in a 15-minute oral presentation with 5 minutes for questions. Principles of peer review and proposal writing will be discussed in class.

Proposal Due Dates and Marking Scheme:

5% Proposal topic and one-paragraph summary due Oct 10th
15% 1st draft of proposal Due Oct 31st
20% Peer review of other group's proposals due Nov 14th
20% Presentation- Nov 23, Nov 28, or Nov 30th
40% Final proposal due Dec 15th

Draft Proposal Marking Rubric

Criteria	**Indicators**
Format (20%)	Follows page length, spacing guidelines. Citations are properly formatted and consistent. Students may choose any citation format employed by a journal they cite in their proposal.
Clarity (30 %)	The proposal should be written for a scientifically- literate but non-specialist audience. The writing style is clear, focused and does not employ large amounts of technical jargon.

Innovation (30%)	The proposal identifies an outstanding problem or question and articulates a useful and innovative approach to solving that problem or answering that question.
Support (20%)	The proposal cites and synthesizes appropriate literature to support the topic choice and effectively places the proposal topic in context with current knowns and unknowns while avoiding plagiarism.

Final Proposal Marking Rubric

Criteria	**Indicators**
Format (15%)	Follows page length, spacing guidelines. Citations are properly formatted and consistent. Students may choose any citation format employed by a journal they cite in their proposal.
Clarity (25 %)	The proposal should be written for a scientifically- literate but non-specialist audience. The writing style is clear, focused and does not employ large amounts of technical jargon.
Innovation (25%)	The proposal identifies an outstanding problem or question and articulates a useful and innovative approach to solving that problem or answering that question.
Support (15%)	The proposal cites and synthesizes appropriate literature to support the topic choice and effectively places the proposal topic in context with current knowns and unknowns while avoiding plagiarism.
Revision (20%)	Productively incorporates constructive criticism given by instructor and peer reviewer into an improved final proposal submission.

Peer Review Marking Rubric

Criteria	**Indicators**
Format (25%)	Adheres to the guidelines and evaluation criteria provided.
Constructive feedback (75%)	Clearly and constructively identifies areas in which the proposal can be improved, either in content or in presentation.

Presentation Marking Rubric

Criteria	**Indicators**
Format (25%)	Adheres to time limit guidelines for both presentation and question and answer period.
Clarity of oral presentation (25%)	Presents the problem/ question, its significance, the approach taken and the expected outcomes clearly for a scientifically literate but non-specialist audience.
Clarity of slides (25%)	Effectively uses figures, images, and minimal text on slides for the purpose of enhancing the clarity of the presentation.
Responses to questions (25%)	Demonstrates a clear understanding of the topic of discussion in responses to questions.

Conversion of numerical grades (%) to Final Letter Grades follows the Dalhousie Common Grade Scale

A+	(90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A	(85-89)	B (73-76)	C (60-64)	F (<50)
A-	(80-84)	B- (70-72)	C- (55-59)	

NOTE THAT GRADUATE STUDENTS REQUIRE A B- (70%) OR BETTER TO PASS

Evaluation Definitions and Schema: In addition to the rubrics provided above, which articulate the criteria evaluated in each assignment, students should be aware of the definitions and evaluation schema that will be used for assigning numerical grades to written assignments and presentations:

Grade	Point	%	Definition	Notes
A+	4.3	90-100	Exceptional	Exceptional work- exceeds expectations; high order, original thinking, research, critical evaluation skills; extraordinary analysis and synthesis skills; excellent grasp of subject matter and command of relevant literature
A	4.0	85-89	Excellent	High order, original thinking, research and critical evaluations skills; excellent analysis and synthesis skills; excellent grasp of subject matter and command of relevant literature
A-	3.7	80-84	Very Good	Evidence of strong original thinking, research and critical evaluations skills; very good analysis and synthesis skills; very good grasp of subject matter and command of relevant literature
B+	3.3	77-79		
B	3.0	73-76	Good	Evidence of some original thinking, research and critical evaluations skills; sufficient analysis and synthesis skills; good grasp of subject matter and command of relevant literature
B-	2.7	70-72		
F	0	0-69	Failure	Insufficient evidence of original thinking, research and critical evaluations skills; poor grasp of subject matter and command of relevant literature or failure to complete assignments on time or according to course specification
INC			Incomplete	Extensions available only in exceptional circumstances
ILL			Illness, compassionate reasons	Documentation must be submitted to instructor within one week of due date
W			Withdrew after deadline	Registrar assigns this

Course Policies

Complete attendance of all lectures is highly recommended, and class participation is key.

Late assignments: 10% reduction in grade for every day an assignment is late. Extenuating circumstances will be considered; contact the instructor as soon as possible, within one week of the assignment due date.

Assignment submission: Assignments should be submitted via Brightspace by midnight on the due date with the following file naming format: Jane Doe, problem set 1, submission date Sept 27th 2016: File name: JDoe_PS1_20160927

Brightspace will be used for regular updates and announcements; students are responsible for regularly monitoring this space.

University Policies, Statements, Guidelines

This course is governed by the academic rules and regulations set forth in the University Calendar and the Senate. https://academiccalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog

Academic Integrity

At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect (*The Center for Academic Integrity, Duke University, 1999*). As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity.
http://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Advising and Access Centre and the Student Success Centre (Agricultural Campus) serve as Dalhousie's centres for expertise on student accessibility and accommodation. Our work is governed by Dalhousie's Student Accommodation Policy to best support the needs of Dalhousie students. Our team work with students who request accommodation as a result of: disability, religious obligation, an experienced barrier related to any other characteristic protected under Canadian Human Rights legislation. https://www.dal.ca/campus_life/academic-support/accessibility.html)

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/student-life-policies/code-of-student-conduct.html

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported. http://www.dal.ca/cultureofrespect.html

Recognition of Mi'kmaq Territory

Dalhousie University acknowledges that the University is located on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel and support. Visit the office in the McCain Building (room 3037) or contact the programs at elders@dal.ca or 902-494-6803 (leave a message).

University Policies and Programs

- Important Dates in the Academic Year (including add/drop dates) http://www.dal.ca/academics/important_dates.html
- University Grading Practices: Statement of Principles and Procedures https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html
- Scent-Free Program http://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html