Special Topics in Freshwater Ecology: Freshwaters in the Anthropocene
BIOL 6064
Spring 2015

"To develop a world-wide accepted strategy leading to sustainability of ecosystems against human-induced stresses will be one of the great future tasks of mankind, requiring intensive research efforts… An exciting, but also difficult and daunting task lies ahead of the global research and engineering community to guide mankind towards global, sustainable, environmental management"
-Paul J. Crutzen & Eugene F. Stoermer 2000; IGBP no. 41, p. 18

TIME & ROOM
Mondays and Wednesdays, 9:05 - 9:55 AM
Derring Hall 1065

INSTRUCTOR
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COURSE OVERVIEW
Humans are modifying freshwater ecosystems across the globe. In this course, we will investigate the effects and interactions of altered climate, eutrophication, invasive species, and unsustainable withdrawal on the ecology and ecosystem services of lakes and streams. The course will be centered on reading discussions, supplemented by modeling exercises and lectures. The capstone of the course will be writing an independent research proposal exploring the fate of freshwaters in the Anthropocene.

LEARNING OBJECTIVES
- Describe how freshwater ecosystems have been altered by human activities, and how they are predicted to change in the future
- Understand concepts of resilience, stable states, tipping points, and feedbacks
- Interpret primary literature on coupled natural-human system interactions
- Analyze different management strategies and approaches to mitigating and adapting to future risk
- Write a compelling research proposal that examines a question related to your research interests and the Anthropocene, provides sufficient background material, and lays out a comprehensive research plan
- Use a coupled hydrodynamic-water quality model to manipulate climate scenarios and examine the effects on water quality

COURSE POLICIES

Your success in this course is dependent on your participation. You will be expected to regularly attend class, complete all of the readings beforehand, ask questions, provide feedback, and contribute to discussion. Being successful in science requires the communication of ideas verbally. Therefore, students are required to engage in discussion throughout the course and lead discussions. Classes are structured around discussion and analysis of the reading materials, and you will often be asked to work in teams to make mini-presentations. Please let me know beforehand if you will miss a class period for research or personal reasons. If you feel that you are falling behind, I encourage you to seek help from your peers and from me- I love to talk about freshwater ecosystems and the Anthropocene and don't bite, I promise. I am invested in your success in this class and will do everything in my power to help you if you pull your weight in the course. Please schedule a meeting with me through email or by talking after class.

The capstone of this course is a research proposal modeled on an National Science Foundation Doctoral Dissertation Improvement Grant (NSF DDIG); see: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5234. These are 24-month grants for dissertation research, with a maximum funding level of $13,000 per grant. The proposal should include a brief description of your overall graduate research project, including its design, scientific significance, and how it provides a context for the new work to be supported by the DDIG. It should then provide a detailed description of the question(s) to be addressed by the proposed new research, what new data would be collected, and details on experimental design, analysis and interpretation. The proposal must contain, as a separate section within the narrative, a discussion of the broader impacts of the proposed activities.

Successful examples of funded DDIGs from current and alumni Virginia Tech graduate students will be posted on Scholar for you to peruse. It is highly recommended that you look at these example proposals early in the semester to guide your writing and idea development. DDIG formatting specifies that the proposals can have a *maximum* of 8 single-spaced pages with 12-point Times New Roman font and 1 inch margins on all sides. There is no page limit on your cited references list. Any included figures and tables must fit within these page limits. These formatting guidelines will be strictly adhered to, as proposals at the real NSF DDIG panel are immediately rejected without review if not formatted properly.

It is my hope that your proposal for this class can be reused for an actual DDIG submission, or recycled into an NSF Graduate Research Fellowship application, Department of Energy fellowship application, EPA Star Award, dissertation/thesis prospectus, or other proposal. It takes several weeks to write a compelling proposal, and you will receive feedback from me and your peers during both a presentation of your proposal outline before spring break as well as through a mock review panel at the end of class.

At the end of the semester, copies of your proposal will be distributed to three to four of your classmates, who will write a max 1-page review of your proposal evaluating its intellectual merit and broader impacts. Your proposal will then be discussed at a mock review panel in class. It is expected that everyone will participate in the panel in a conscientious and respective manner, especially because everyone is working together to provide critical feedback on each other's work.

Even if you are not eligible to apply for a DDIG or have no interest in submitting a DDIG, it is highly likely that you will be doing some type of grant or proposal writing in your future career. Scientists at federal and state agencies, NGOs, consulting firms, and at academic institutions are usually responsible for writing several grant applications or proposals per year. Clear, persuasive writing is an extremely valuable skill and highly advantageous to develop *now*.

R and GLM: We will be using a new hydrodynamic-water quality model, the General Lake Model (GLM), to explore the effects of different climate scenarios on lake ecosystem function. GLM is an open-source model developed by my collaborators in the Global Lakes Ecological Observatory Network (GLEON). You can read more about GLM here: http://aed.see.uwa.edu.au/research/models/GLM/. Because GLM can sometimes be computationally intensive and can only run on Windows or Linux platforms, we will be using software developed to run on the R statistical program so that you can run GLM without having to download the actual Fortran model. You will need to download R, an open-source scripting language software program, from www.cran.r-project.org onto your laptop. R is an extremely valuable tool for data management and analysis, and I highly encourage you to check out the many R resources on the web. We will only spend approximately three class periods using R and GLM, so do not worry if you are not familiar with this software; everyone will get to work with a partner and I will do my best to help. This will be the first class (graduate or undergraduate) that I am aware of in the world that will be using the R GLM tools for teaching purposes, so I am anticipating that there may be some glitches and ask for your patience in advance.

ASSESSMENT

Assessment of student performance will be based upon the traditional A-F plus/minus grading scale. Assessment will be based on the following assignments:

Assignment	**Percent of final grade**
Group presentations: Debate, Literature Blitz, GLM analysis	10
Independent presentations: Literature Blitz, EU Water Framework Directive national analysis	10
Discussion leading and class participation	30
Research proposal: outline and presentation	5
: written proposal	30
: reviews of other proposals	10
: participation at review panel	5

Students are expected to abide by the principles of the Virginia Tech Honors System. The Virginia Tech Honor Code can be found at: http://www.honorsystem.vt.edu. You may work together on the presentations, GLM analysis, literature blitzes, and debate preparation but you are expected to individually complete your research proposal.

IMPORTANT DATES & DEADLINES

February 2: In-class debate: Does the Anthropocene exist, and if so, when did it begin?

February 18: Feel-good freshwater stories. A lot of what we are learning about in this class involves scary (and downright terrifying) changes occurring on the globe. We will take a break mid-semester to think about some positive outcomes occurring in freshwater research and conservation before we dive back into the IPCC.

February 23: No class

March 2: Written outlines of your proposals are due at the beginning of class. Your research question(s), hypotheses, motivation, proposed research plan, and broader impacts should be explicit in the outline, even if your document is in bullet points, not prose.

March 2 & 4: We will dedicate these two class periods to brief presentations that give an overview of your proposal outline. The purpose of this presentation is to solicit helpful feedback from your peers before you start writing the proposal in earnest.

March 9 & 11: Spring break- no class.

March 16 & 18: Literature blitzes. Each student will individually choose one paper from Figure 3-2 in the IPCC WG2's 2014 Freshwater Resources chapter and prepare a 10

minute presentation (7 minutes of presentation, 3 minutes for questions) on how the changing climate is altering fresh water quality.

March 25, March 30, April 1: GLM activities in class. You will need a working laptop with R software already downloaded in class.

April 15: Literature blitz. With a partner, present one peer-reviewed paper that gives a case study of how management has either been used successfully *or* unsuccessfully (and why) in a freshwater ecosystem. The presentation should be 10 minutes (7 minutes of presentation, 3 minutes for questions).

April 20: The final version of your written proposal is due at the beginning of class.

April 22: Proposals will be submitted to the reviewers at the end of class; each student will present a brief synopsis of how their chosen EU country has fulfilled (or not!) their EU Water Framework Directive responsibilities and tasks.

April 27: Max 1-page proposal reviews are due at the beginning of class.

May 4 & 6: Proposal review panel

TOPIC OUTLINE

Note: The topics covered and timing are subject to change

Week	Month	Day	Class plan	Theme
1	Jan	21	Introduction and overview (Ch. 1, Water Resilience)	Overview of course
2		26	Discussion of Steffen et al. 2011 *Roy. Soc. A* AND Smith & Zeder 2013 *Anthropocene*	History and development of Anthropocene research
		28	Discussion of Ch. 2, Water Resilience: Human modification of the Earth system (p. 44-67) and http://climatedata.us maps	Overview of Interacting anthropogenic drivers, impacts, and feedbacks
3	Feb	2	Debate: Does the Anthropocene exist, and if so, when did it begin?	History and development of Anthropocene research
		4	Discussion of Ch. 3, Water Resilience: Regime shifts (p. 69-84: stop at section 3.6) AND Carpenter 2003 (p. 8-17, 22-26 only)	Regime shifts, resilience, and ecological surprises
4		9	Murray-Darling Case Study	Feedbacks between natural and human systems
		11	Discussion of Ch. 4, Water Resilience: Global water system (p.	Human dependence on the global water system and risks for

			103-120: stop at section 4.3.4)	ecosystem services
5		16	Discussion of WG2, 5th Assessment Report of IPCC 2014, Ch. 3: Freshwater Resources (p. 229-240: stop at 3.3)	Observed impacts of climate change on freshwaters
		18	Feel-Good Freshwater Stories	Positive outcomes of freshwater conservation
6		23	No class	
		25	Guest lecture: Overview of Earth System modeling	Uncertainty and prediction of global climate using models
7	March	2	Proposal outline presentations and feedback	Written outlines due at beginning of class
		4	Proposal outline presentations and feedback	Chose which paper you would like to present your literature blitz on from Figure 3-2 in the IPCC chapter
8		9	Spring Break: NO CLASS	
		11	Spring Break: NO CLASS	
9		16	Literature blitz (independent): 10 minute presentations of IPCC water quality papers from Figure 3-2	Observed impacts of climate on water quality in lakes, streams, wetlands, and groundwater
		18	Literature blitz (independent): 10 minute presentations of IPCC water quality papers from Figure 3-2	Observed impacts of climate on water quality in lakes, streams, wetlands, and groundwater
10		23	Discussion of WG2, 5th Assessment Report of IPCC 2014, Ch. 3: Freshwater Resources (p. 240-253: stop at 3.6)	Future predictions of climate change, and climate impacts on freshwater resources
		25	Introduction to GLM using R (github.gleon.io/inspire.html)	Using a 1-D hydrodynamic-water quality model to examine the effects of climate forcing
11		30	Class exercise: Internal lake forcing in GLM 1	Using a 1-D hydrodynamic-water quality model to examine the effects of climate forcing
	April	1	Class exercise: Internal lake forcing in GLM 2	Using a 1-D hydrodynamic-water quality model to examine the effects of climate forcing
12		6	Discussion of WG2, 5th Assessment Report of IPCC 2014, Ch. 3: Freshwater Resources (p. 253-259: stop at 3.6) AND Brookes et al. 2014 ES&T	Adaptation and managing risks
		8	Discussion of Ch. 1, Water	Planetary boundaries

			Resilience (p. 19-33) AND Ch. 4, Water Resilience (p. 125-133)	
13		13	Discussion of Ch. 8, Water Resilience (p. 227-249)	Governance and adaptive management
		15	Literature blitz (group): 10 minute presentations of freshwater management case studies	Governance and adaptive management; pick one country for EU analysis
14		20	Discussion of WFD Articles 1-26 (p. 8-27 + relevant annexes)	Managing and legislating freshwaters across international borders; Proposals due at the beginning of class
		22	Discussion of WFD report on implementation of river basin management plans 2012 AND pick one EU country to evaluate its progress (http://ec.europa.eu/environment/water/water-framework/impl_reports.htm#third)	Evaluation of WFD and its challenges to implementation; Proposals handed out to reviewers at end of class
15		27	Discussion of Hering et al. 2010 AND Moss 2007	Academic critiques of WFD; Proposal reviews due at the beginning of class
		29	Catch-up: TBD	
16	May	4	Proposal review panel	
		6	Proposal review panel/conclusion	

READINGS

I will post most readings listed in the table above in Scholar and let you know beforehand if you will need to find materials elsewhere. The three pillars of this course will be:

1) A new textbook developed on freshwater sustainability that is targeted for graduate students:
Rockström, J., Falkenmark, M., Folke, C., Lannerstad, M., Barron, J., Enfors, E., Gordon, L., Heinke, J., Hoff, H., Pahl-Wostl, C. 2014. Water Resilience for Human Prosperity. Cambridge University Press. Cambridge, UK.

2) The IPCC chapter on freshwater from WG2's 2014 report
Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, and S.S. Mwakalila, 2014. Freshwater resources. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on

Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, UK, pp. 229-269.

3) And the European Water Framework Directive:
Directive 2000/60/EC of the European Parliament of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. OJ L 327, 22.12.2000 (Amended by: 2000L0060 — EN — 16.12.2001 — 001.001 — 1)