Global Change in Freshwater Ecosystems
Graduate level (3 credit hours)
Meets Tuesday periods 3 and 4 (9:35 -11:30) and Thursday period 3 (9:35-10:25)

Prerequisites: 2 semesters of undergraduate general biology coursework

Professor: Dr. Lindsey Reisinger
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(352) 294-1355
Office hours: by appointment

Text: Readings will consist of peer reviewed papers. There is no book for this course.

Course Description:
This course is designed to provide students with an understanding of human impacts in freshwater ecosystems and challenges and approaches for conserving freshwater diversity and ecosystem services.

Objectives:
At the end of the course, students will be able to:

- Describe the major drivers of global change in freshwater ecosystems (water availability and flow, pollution, land use, browning, overexploitation, biological invasions, and climate change) as well as how these drivers interact
- Describe how drivers of global change are currently being studied and the management efforts that may mitigate their effects
- Find and summarize scientific research related to global change in freshwater ecosystems
- Effectively present scientific information
- Critically evaluate scientific literature focused on global change in freshwater ecosystems

Class Format:
The class will be structured around reading and discussion of the primary literature on different topics surrounding global change in freshwater ecosystems. Readings each week will include one review paper that summarizes current knowledge on a topic as well as two original research papers. Reading and discussing the original research papers will be important for critically evaluating scientific evidence on the topic.

Discussion of the readings will begin online before each class. A computer with internet connection is required. The UF Canvas E-Learning site can be accessed at http://elearning.ufl.edu/ using your Gatorlink account. Online discussion will focus on the review paper assigned each week. Students will post their thoughts and questions about the review paper and respond to questions provided by the instructor.

In addition, students will answer summary reading questions on each of the two original research papers assigned each week. These questions will focus on the major questions and findings, how the paper fits in with other research, and the quality of the evidence. Class discussions will focus on the original research papers.

Each student will lead three discussions in person during the semester to learn to effectively present scientific material and gain a deeper understanding of the topic. When leading a discussion, students will prepare a presentation (15 minutes) that introduces additional material on the topic of the day. Students will also prepare questions to stimulate class discussion. Students will meet with the professor prior to the class to go over their plan for the presentation and leading the discussion.

Assignments/ Evaluation of Student Learning:

Assignments will be described in class, and grading rubrics will be provided.
Participation in class discussion (25%)
Summary reading questions (15%) and online discussion (15%)
Presentation 1 (5%) and leading class discussion 1 (5%)
Presentation 2 (10%) and leading class discussion 2 (5%)
Presentation 3 (15%) and leading class discussion 3 (5%)
Grade point allocation: A 94-100%; A- 90-93; B+ 86-89; B 83-85; B- 80-82; C+ 76-79; C 73-75; C- 70-72; D+ 66-69; D 63-65; D- 60-62; E <60%

Schedule of Class Topics:

Week	Topic	Reading
1	Biodiversity and drivers of change	Dudgeon et al 2006*, Jonsson & Malmqvist 2000
2	Biodiversity and drivers of change	Carpenter et al. 2011* Capps et al. 2015, Downing et al. 2014
3	Water availability	Baron et al. 2002* Aroviita & Hamalainen 2008, Galbraith et al. 2010
4	Flow modification	Poff & Hart 2002* Carlisle et al. 2011, Kelly et al. 2017
5	Pollution – Nutrients	Smith et al. 1999* Abell et al. 2010, Negishi et al. 2019
6	Pollution – Organic chemicals and metals	Bernhardt et al. 2017* Malaj et al. 2014, Hudelson et al. 2019
7	Pollution – Pharmaceuticals, salt, microplastics	Richmond et al. 2017* McCormick et al. 2016, Dugan et al. 2017
8	Land use change	Bernhardt & Palmer 2011* Roy et al. 2006, Fierro et al. 2019
9	Browning	Creed et al. 2018* Craig et al. 2017a, Hessen et al. 2017
10	Overexploitation	Allan et al. 2005* Estes et al. 2011, Taylor et al. 2006
11	Invasion – Vectors and drivers of success	Vander Zanden et al. 2010* Gherardi 2006, Davis & Darling 2017
12	Invasion – Impacts	Poulin et al. 2011* Neill et al. 2014, Walsh et al. 2017
13	Climate change	Knouft & Ficklin 2017* Kraemer et al. 2017, Till et al. 2019
14	Combined stressors	Craig et al. 2017* Nelson et al. 2009, Frenken et al. 2016
15	Combined stressors	Vaughn 2010* Schafer et al. 2016, Gutowski et al. 2019

*review paper

Reading:

1. Biodiversity and drivers of change
   - Dudgeon, D., A. H. Arthington, M. O. Gessner, Z.-I. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, A.-H. Prieur-Richard, D. Soto, M. L. J. Stiassny, and C. A. Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews 81:163.
   - Jonsson, M., and B. Malmqvist. 2000. Ecosystem process rate increases with animal species richness: evidence from leaf-eating, aquatic insects. Oikos 89:519–523.

2. Biodiversity and drivers of change continued
   - Carpenter, S. R., E. H. Stanley, and M. J. Vander Zanden. 2011. State of the world's freshwater ecosystems: physical, chemical, and biological changes. Annual Review of Environment and Resources 36:75–99.
   - Downing, A. L., B. L. Brown, and M. A. Leibold. 2014. Multiple diversity – stability mechanisms enhance population and community stability in aquatic food webs. Ecology 95:173–184.
   - Capps, K. A., C. L. Atkinson, and A. T. Rugenski. 2015. Implications of species addition and decline for nutrient dynamics in fresh waters. Freshwater Science 34:485–496.

3. Water availability
   - Baron, J. S., N. L. Poff, P. L. Angermeier, C. N. Dahm, P. H. Gleick, N. G. Hairston, R. B. Jackson, C. A. Johnston, B. D. Richter, and A. D. Steinman. 2002. Meeting ecological and societal needs for freshwater. Ecological Applications 12:1247–1260.
   - Aroviita, J., and H. Hamalainen. 2008. The impact of water-level regulation on littoral macroinvertebrate assemblages in boreal lakes. Hydrobiologia 613:45–56.
   - Galbraith, H. S., D. E. Spooner, and C. C. Vaughn. 2010. Synergistic effects of regional climate patterns and local water management on freshwater mussel communities. Biological Conservation 143:1175–1183.

4. Flow modification
   - Poff, N. L., and D. D. Hart. 2002. How dams vary and why it matters for the emerging science of dam removal. BioScience 52:659.
   - Carlisle, D. M., D. M. Wolock, and M. R. Meador. 2011. Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. Frontiers in Ecology and the Environment 9:264–270.
   - Kelly, B., K. E. Smokorowski, and M. Power. 2017. Impact of river regulation and hydropeaking on the growth, condition and field metabolism of Brook Trout (*Salvelinus fontinalis*). Ecology of Freshwater Fish 26:666–675.

5. Pollution – Nutrients
   - Smith, V. H., G. D. Tilman, and J. C. Nekola. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution 100:179–196.
   - Abell, J. M., D. Özkundakci, and D. P. Hamilton. 2010. Nitrogen and phosphorus limitation of phytoplankton growth in New Zealand lakes: implications for eutrophication control. Ecosystems 13:966–977.
   - Negishi, J. N., A. Hibino, K. Miura, R. Kawanishi, N. Watanabe, and K. Toyoda. 2019. Coupled benthic–hyporheic responses of macroinvertebrates to surface water pollution in a gravel-bed river. Freshwater Science 38:591–604.

6. Pollution – Organic chemicals and metals
   - Bernhardt, E. S., E. J. Rosi, and M. O. Gessner. 2017. Synthetic chemicals as agents of global change. Frontiers in Ecology and the Environment 15:84–90.
   - Malaj, E., P. C. von der Ohe, M. Grote, R. Kühne, C. P. Mondy, P. Usseglio-Polatera, W. Brack, and R. B. Schäfer. 2014. Organic chemicals jeopardize the health of freshwater ecosystems on the continental scale. Proceedings of the National Academy of Sciences 111:9549–9554.

Hudelson, K. E., D. C. G. Muir, P. E. Drevnick, G. Köck, D. Iqaluk, X. Wang, J. L. Kirk, B. D. Barst, A. Grgicak-mannion, R. Shearon, and A. T. Fisk. 2019. Temporal trends, lake-to-lake variation, and climate effects on Arctic char (*Salvelinus alpinus*) mercury concentrations from six High Arctic lakes in Nunavut, Canada. Science of the Total Environment 678:801–812.

7. Pollution – Pharmaceuticals, salt, and microplastics

Richmond, E. K., M. R. Grace, J. J. Kelly, A. J. Reisinger, E. J. Rosi, and D. M. Walters. 2017. Pharmaceuticals and personal care products (PPCPs) are ecological disrupting compounds (EcoDC). Elementa Science of the Anthropocene 5:5–8.

Mccormick, A. R., T. J. Hoellein, M. G. London, J. Hittie, J. W. Scott, and J. J. Kelly. 2016. Microplastic in surface waters of urban rivers: concentration, sources ,and associated bacterial assemblages. Ecosphere 7:1–22.

Dugan, H. A., S. L. Bartlett, S. M. Burke, J. P. Doubek, F. E. Krivak-tetley, N. K. Skaff, J. C. Summers, K. J. Farrell, I. M. Mccullough, A. M. Morales-williams, D. C. Roberts, Z. Ouyang, F. Scordo, P. C. Hanson, and K. C. Weathers. 2017. Salting our freshwater lakes. Proceedings of the National Academy of Sciences 114:4453–4458

8. Land use change

Bernhardt, E. S., and M. A. Palmer. 2011. River restoration: the fuzzy logic of repairing reaches to reverse catchment scale degradation. Ecological Applications 21:1926–1931.

Roy, A. H., M. C. Freeman, B. J. Freeman, S. J. Wenger, J. L. Meyer, and W. E. Ensign. 2006. Importance of riparian forests in urban catchments contingent on sediment and hydrologic regimes. Environmental Management 37:523–539.

Fierro, P., C. Valdovinos, I. Arismendi, G. Díaz, A. Jara-flores, E. Habit, and L. Vargas-chacoff. 2019. Examining the in fluence of human stressors on benthic algae, macroinvertebrate, and fish assemblages in Mediterranean streams of Chile. Science of the Total Environment 686:26–37.

9. Browning

Creed, I. F., N. B. Grimm, C. G. Trick, D. O. Hessen, J. Karlsson, K. A. Kidd, E. Kritzberg, D. M. Mcknight, E. C. Freeman, O. E. Senar, A. Andersson, J. Ask, M. Berggren, M. Cherif, R. Giesler, E. R. Hotchkiss, P. Kortelainen, M. M. Palta, T. Vrede, and G. A. Weyhenmeyer. 2018. Global change-driven effects on dissolved organic matter composition: implications for food webs of northern lakes. Global Change Biology 25:3692–3714.

Craig, N., S. E. Jones, B. C. Weidel, and C. T. Solomon. 2017a. Life history constraints explain negative relationship between fish productivity and dissolved organic carbon in lakes. Ecology and Evolution 7:6201–6209.

Hessen, D. O., J. P. Håll, J.-E. Thrane, and T. Andersen. 2017. Coupling dissolved organic carbon, CO_2 and productivity in boreal lakes. Freshwater Biology 62:945–953.

10. Overexploitation

Allan, J. D., R. Abell, Z. Hogan, C. Revenga, B. W. Taylor, R. L. Welcomme, and K. Winemiller. 2005. Overfishing of inland waters. BioScience 55:1041–1051.

Estes, J. A., J. Terborgh, J. S. Brashares, M. E. Power, J. Berger, W. J. Bond, S. R. Carpenter, T. E. Essington, R. D. Holt, J. B. C. Jackson, R. J. Marquis, L. Oksanen, T. Oksanen, R. T. Paine, E. K. Pikitch, W. J. Ripple, S. A. Sandin, M. Scheffer, T. W. Schoener, J. B. Shurin, A. R. E. Sinclair, M. E. Soule, R. Virtanen, and D. A. Wardle. 2011. Trophic downgrading of planet earth. Science 333:301–306.

Taylor, B. W., A. S. Flecker, and R. O. Hall. 2006. Loss of a harvested fish species disrupts carbon flow in a diverse tropical river. Science 313:833–836.

11. Invasions – Vectors and drivers of success

Vander Zanden, M. J., G. J. A. Hansen, S. N. Higgins, and M. S. Kornis. 2010. A pound of prevention, plus a pound of cure: early detection and eradication of invasive species in the Laurentian Great Lakes. Journal of Great Lakes Research 36:199–205.

Gherardi, F. 2006. Crayfish invading Europe: the case study of *Procambarus clarkii*. Marine and Freshwater Behaviour and Physiology 39:175–191.

Davis, A. J. S., and J. A. Darling. 2017. Recreational freshwater fishing drives non-native aquatic species richness patterns at a continental scale. Diversity and Distributions 23:692–702.

12. Invasions - Impacts

Poulin, R., R. A. Paterson, C. R. Townsend, D. M. Tompkins, and D. W. Kelly. 2011. Biological invasions and the dynamics of endemic diseases in freshwater ecosystems. Freshwater Biology 56:676–688.

Neill, D. B., J. T. A. Dick, M. C. Emmerson, A. Ricciardi, H. J. Macisaac, M. E. Alexander, and H. C. Bovy. 2014. Fortune favours the bold: a higher predator reduces the impact of a native but not an invasive intermediate predator. Journal of Animal Ecology 83:693–701.

Walsh, J. R., R. C. Lathrop, and M. J. Vander Zanden. 2017. Invasive invertebrate predator, *Bythotrephes longimanus*, reverses trophic cascade in a north-temperate lake. Limnology and Oceanography:2498–2509.

13. Climate change

Knouft, J. H., and D. L. Ficklin. 2017. The potential impacts of climate change on biodiversity in flowing freshwater systems. Annual Review of Ecology, Evolution, and Systematics 48:111-133.

Kraemer, B. M., T. Mehner, and R. Adrian. 2017. Reconciling the opposing effects of warming on phytoplankton biomass in 188 large lakes. Scientific Reports 7:1–7.

Till, A., A. L. Rypel, A. Bray, and S. B. Fey. 2019. Fish die-offs are concurrent with thermal extremes in north temperate lakes. Nature Climate Change 9:627–641.

14. Combined stressors

Craig, L. S., J. D. Olden, A. H. Arthington, S. Entrekin, C. P. Hawkins, J. J. Kelly, T. A. Kennedy, B. M. Maitland, E. J. Rosi, A. H. Roy, D. L. Strayer, J. L. Tank, A. O. West, and M. S. Wooten. 2017b. Meeting the challenge of interacting threats in freshwater ecosystems: a call to scientists and managers. Elementa Science of the Anthropocene 5:2–15.

Nelson, K. C., M. A. Palmer, J. E. Pizzuto, G. E. Moglen, P. L. Angermeier, R. H. Hilderbrand, M. Dettinger, and K. Hayhoe. 2009. Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options. Jounral of Applied Ecology 46:154–163.

Frenken, T., M. Velthuis, L. N. De Senerpont Domis, S. Stephan, R. Aben, S. Kosten, E. Van Donk, and D. B. Van De Waal. 2016. Warming accelerates termination of a phytoplankton spring bloom by fungal parasites. Global Change Biology 22:299–309.

15. Combined stressors continued

Vaughn, C. C. 2010. Biodiversity losses and ecosystem function in freshwaters: emerging conclusions and research directions. BioScience 60:25–35.

Gutowsky, L. F. G., H. C. Giacomini, D. T. De Kerckhove, R. Mackereth, D. Mccormick, and C. Chu. 2019. Quantifying multiple pressure interactions affecting populations of a recreationally and commercially important freshwater fish. Global Change Biology 25:1049–1062.

Schafer, R. B., B. Kuhn, E. Malaj, A. Konig, and R. Gergs. 2016. Contribution of organic toxicants to multiple stress in river ecosystems. Freshwater Biology 61:2116–2128.

Students Requiring Accommodations

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment."

The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conducthonor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor of this course.

Counseling and Wellness Center

Contact information for the Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc/, (352) 392-1575
Contact information for University Police Department:
(352) 392-1111 or 9-1-1 for emergencies.