Climate Change *vs.* Everything Else Causing Ecosystem Impairments: *What is driving global change?*

Syllabus of June 21, 2022
Fall 2022 - EAS 519 (2 credit hrs) *Section 001 "in-person"* *Section 003 "remote"*
Wed 5:30 – 7:10 pm
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Rationale

This course tackles the oft' ignored reality that while ecosystems are being subjected to climate change-related impacts (e.g., increases in droughts, wildfires, flooding, heat), there remain a plethora of co-occurring physical, chemical and biological stressors. *How is climate change affecting these unknown and well-known stressors? What role do 1) land use and habitat degradation, 2) societal and political norms and media biases, 3) economic constraints, 4) environmental justice, 5) chemical pollution, 6) the sensitivity and resilience of local/regional ecosystems, and 7) ecosystem context have in this issue?*

All ecosystem stressors vary in severity across geographies and as system drivers. As environmental managers, assessors, educators and stewards, it is critical to have an understanding how these issues are intertwined in the face of climate change. Many corporations and governmental agencies are now mandating that plans to manage or restore sites have climate change contingencies included, in the event of flooding, drought, wildfires, etc.

Examples of common-place stressors in human-dominated systems include: *Excess nutrients; Harmful algal blooms; Habitat alteration (e.g., erosion and turbidity, siltation, loss of riparian vegetation and trees, flows, channelization); Toxic chemicals such as metals, methyl mercury, pesticides, PFAS, PCBs, pharmaceuticals and personal care products); Macro- and microplastics; Water withdrawals for irrigation and fracking; Untreated sewage with viral, bacterial and fungal pathogens; Parasites; and Invasive species.*

Climate change is exacerbating the effects of virtually all these stressors, including altering biodiversity; yet environmental managers and assessors have been remiss in considering the role climate change on common and traditional stressors of focus. Traditional regulatory approaches for water, air, soil and wildlife management no longer are adequate. Traditional stressors tend to be addressed in a piece-meal, "silo" approach due to regulatory frameworks and the challenge of implementing interdisciplinary frameworks.

*This class will **not focus** on the sources of greenhouse gases or approaches to manage them*.

Class Learning Objectives

The Teaching Goals of all my classes are:

- Develop an awareness of primary issues: interdisciplinary ecosystem elements, chemical/physical/biological stressors, sociological and economic and justice drivers, regional political drivers;
- Understand a systems approach of issues and their interactions and relationships;
- Understand the trigger points of systems that initiate change;
- Developing solutions and rank them using Weight-of-Evidence based approaches;
- Understanding of what is involved in solution facilitation along with associated impediments; and how to rank them in a strategic manner for decision-making;
- Maintaining improving action inertia with adaptation; and
- Understand how to evaluate outcomes: Is positive change occurring? Is it sustainable? How can it be improved/optimized? How can impediments be minimized/circumvented?
- *Understand and commit to always continuing to grow in knowledge and wisdom – throughout life – to stay abreast of rapidly evolving interdisciplinary sciences in order to improve life and ecosystems.*

More specifically, the learning objectives for this class are for students to develop an understanding of the relative importance and interactions of physical, chemical and biological stressors in the face of climate change, across a range of ecoregions and hydrology types. Students will also generally consider the role of land uses, societal and political norms, economic and justice constraints and disease outbreaks (such as COVID-19); and how these may affect priority setting on ecosystem restoration actions and the ranking of stressors.

An important focus will be understanding how regional ecosystems along with geopolitical boundaries vary in their sensitivity to stress and subsequent resilience to resist impairments. These considerations should drive the development of pragmatic approaches for ranking and managing the most important stressors in the face of climate change. This allows for science-based decision making addressing appropriate restoration and remediation strategies that are place specific.

Specifically, students should achieve the following learning outcomes from this course:

- An understanding of likely ecosystem stressors typical of a range of regions, land uses and hydrologic systems; while considering their context in a range of societal, justice and economic conditions (resource rich to resource poor countries);
- An understanding of how stressors may interact with each other, ecosystems and human populations;
- An understanding of the role climate change may have on human-dominated ecosystems, in the face of co-occurring stressors; and
- An understanding of how to make science-based decisions for improved restoration and remediation strategies by prioritizing adaptation and stressor management.

Student Skill Requirements

This course is open to any SEAS, CEE, ClaSP, SPH, EES, Urban Planning or EEB graduate student. Exceptional circumstances will be considered. No specific course background is needed other than being associated with these (or similar) graduate programs at the University of Michigan.

Class Format and Pedagogical Tools

The class will consist of two separate formats using in-person lectures (Section 001) and remote learning (Section 003) using live lectures and class discussions that are during the in-person class real time. All lectures are recorded for later viewing. At the beginning of each class, relevant news/publications from the previous week will be covered with a brief discussion. In addition to lecture questions, there will be the following requirements:

1. A project required of each student (or pair of students) to rank stressors at a site impacted by multiple anthropogenic stressors considering major climate drivers such as heat, flooding, sea level rise, and droughts.
2. Participation in class and/or discussions on Canvas.

All class materials are on Canvas for access by enrolled students. Announcements, assignments and grades will be communicated via Canvas and lectures. Non-video Powerpoint files (.ppt) of lectures will also be placed on Canvas each week. "Live-capture" lectures will also be available for later viewing.

Office Hours are 4:00 – 5:00 Tuesday, Wednesday and Thursday with flexible availability on Zoom between 8:00 and 6:00 M-F, as long as prescheduled.

Reading Materials

Thousands of recent (2020-2022) climate publications exist. A substantial subset of journal papers, chapters, reports and news releases are located in folders on Canvas to support lectures and provide options for your reading. Recent **keystone** papers and reports are also included, such as IPCC and UN reports. These will be amended *each week* from current press and publication releases. The reading materials cover all SEAS Sustainability Themes and Focus Areas, such as emerging climate and global change issues dealing with extreme events, multi-stressor interactions with climate, urban growth, resource extraction and scarcity, biodiversity loss, human health, human migration, environmental justice, vulnerable populations, adaptive management, solutions and good news. Sources and reduction strategies for greenhouse gases (GHG) are only covered peripherally.

Class Topics

Students will be assigned 4 questions following each lecture that they will answer and submit via Canvas. On the homework submissions, students may suggest discussion topics for class or on the Canvas Discussion platform.

The first class will consist of reviewing the Syllabus and an overview of common ecosystem stressors in human-dominated systems. We'll also briefly discuss the class problem assignment – *Ranking Multiple Site Stressors for Restoration.*

We have the flexibility to discuss a wide variety of climate-related issues and their interaction with common physical, chemical and biological stressors; many of which are listed below. ***Student interests and their questions will drive which topics are discussed.***

- Overview of common stressors in human-dominated systems, such as: human-dominated land uses, habitat, flow, nutrients, dissolved oxygen, invasives/introduced species, temperature, pesticides, metals, synthetic organics, pharmaceuticals and personal care products.
- How do physical, chemical and biological stressors vary by ecoregion, hydrologic type, and political-socio-economic status?
- Overview of known climate change impacts, such as heat, extreme events (e.g., wildfires, drought, flooding, severe storms), food-web collapse, glacier and polar ice melt, pathogens, pests, invasive and introduced species, seasonal changes affecting reproduction and behavior, species loss and biodiversity declines.
- Where are climate-change hot spots? What are the indirect effects of climate-change on human populations, public health, environmental justice, pandemics, and economies and how might these affect regional ecosystems?

- How will ecosystem stressors likely be influenced by climate change? How will this vary across ecoregions?
- How should local to regional ecosystems be better managed and restored in the face of climate change and other stressors? Which stressors should be targeted first in a restoration or protection program? What are key considerations?

Grading

1. At the end of each lecture there will be 4 questions on content to answer. (4 points each x 10 wks) = 40 points
2. The Project will **only** consist of a Powerpoint presentation (30 slides maximum) on *Ranking Multiple Site Stressors for Restoration* (details below) = 50 points.
3. Participation (discussions, emails, *time spent* on Canvas) = 10 points
4. BONUS POINTS (15 max):
   - Volunteer and present your project in-person during the last 2 class periods (15 min) = +5 points.
   - Up to 10 summaries (150-200 words) of journal papers or chapters/reports from Canvas folder selections. Pre-approved articles may also be substituted for those on Canvas (1 point each) = 10 points max
5. Final Projects not submitted on-time (December 9, 5:00pm) will be penalized one letter grade per day.

* *As graduate students, you should understand the more you put into a course, the more you increase your expertise and benefit professionally. A plethora of recent readings are provided which are not required – but will benefit your understanding of this subject. Materials submitted will be checked for plagiarism; but, other than that, the learning is up to you.*

Chronological Lecture Topic Summary (*subject to revision)*

1. Review syllabus. Discuss the challenge of being a scientist or "expert" in this rapidly changing and growing field. Begin with an overview of pollutants and ecosystem stressors, with interactions of political, social and economic drivers, including environmental injustice. Which stressors identified by USEPA are worst on aquatic systems? Multiple stressors exposures are the norm in human-dominated ecosystems. How does one know which stressors are most important? Which ecosystems are most sensitive?
2. Major climate change drivers: temperature, drought, wildfires, ice melt, ocean acidification, extreme events. Intergovernmental Panel on Climate Change (IPCC) findings. Recent changes and literature support. Number of natural disasters increasing. Major climate change events cont'd. IPCC best/worst case predictions for biota (temp, acidification, sea rise).
3. Which regions are most vulnerable? IPCC predictions on regional impacts to physical, biological and human systems. Global changes by humans causing expanding land use changes for urbanization and agriculture, habitat degradation and fragmentation, excess nutrients, resource extraction, air pollution, water scarcity, altered flows, disease-pathogens-pests, contaminants and biocides, plastics, and introduced and invasive species. These impact ecosystems, human health, environmental justice and vulnerable human populations and climate migration.
4. Critical direct and indirect impacts to humans and ecosystems and linkages to other stressors: migration, economies, geopolitics, flooding, hurricanes, dam breakage, food and water scarcity, livestock vs GHG. Unknown unknowns.
5. Studies showing the linkages of environment and human activities: Living Planet 2020 report. Planetary Boundary and tipping points. How do climate and non-climate stressors interact

(physical, chemical, biological, ecological – examples with drought, flooding, wildfire. Global risk rankings and interactions. Ecosystem vulnerability ranking for each stressor.
6. Great Lakes multi-stressor evaluation by the International Joint Commission.
7. Ranking system drivers: Regional characteristics, Quality of life, Economies and GDP drivers (e.g., agriculture, industry, mining, tourism), Racism and EJ, Stakeholder power, Societal values
8. Management issues: Now vs. future drivers, Conservation vs. political priorities, National alliances, Technological advances, Popular opinions, Education, etc.
9. Class project (see below)

Recommended Readings

Numerous high quality, peer-reviewed publications are ***released each day*** *addressing climate and global change which are directly relevant to this class.* The sciences comprising this interdisciplinary field are growing rapidly, which is both wonderful and daunting when it comes to staying abreast of the science. Given the range of student interests in this class, I will attempt to broadly identify the most important and current science as it relates to both ecosystems and human populations and make these publications (or links) available on Canvas *each week*. **Students are encouraged to read as many articles as possible on your particularly area of specialization.** Due to the rapidly growing body of literature, only a few examples of excellent resources are provided below:

- Global efforts to protect biodiversity fall short. Sci 369:6510 2020
- Past perspectives on the present era of abrupt Arctic climate change. Nature Climate Change 10:714 2020
- An evaluation of stressor interactions in the Great Lakes. IJC. 2020
- Assessing the U.S. Climate in September 2020. NOAA.
- Increased extinction in the emergence of novel ecological communities. Sci 370:220. 2020
- Global Climate Change: Scientific consensus: Earth's climate is warming. NASA.
- Rising seas and agriculture created wetlands along the U.S. east coast. EOS. 2020.
- World Economic Forum. The global risks report 2020.
- World Wildlife Fund Living Planet Report. 2020
- Observed impacts of anthropogenic climate change on wildfire in California. AGU`00. 2019.
- Persistent quaternary climate refugia are hospices for biodiversity in the Anthropocene. Nature Climate Change. 2020
- IPCC reports (most recent Feb 28, 2022)

Class Project: *Ranking Multiple Site Stressors vs. Climate Change for Restoration*

Each student (or pair of students) will prepare Powerpoint presentation which can be presented to the class for 5 bonus points. The Powerpoint should be 30 slides maximum.
The project will show how you would rank (worst to least harmful) stressors, based on their likely degree of ecosystem impairments in a specific ecoregion (of your choosing) that is subject to climate change drivers*. Two or three examples of student projects from Fall 2021 will be provided on Canvas to assist you. Note there is no one right way to do this*. As a foundation for your project, you may pick a State in the U.S. and google its 303d report. For example, "Michigan 303d report". These are usually presented as integrated reports addressing 303(d), 305(b) and 314 sections of the Clean Water Act. Look at the most recent report – likely 2020. Go to the Appendix and find a tabular listing of all impaired waterways (separated as rivers,

lakes, reservoirs, wetlands, or coastal areas). These may be listed in a table as sites for "TMDL" studies (Total Maximum Daily Loadings). Look at some of these impaired waterways and note the "Causes" of impairment the State has listed, such as PCBs, Dissolved Oxygen, Siltation. These are the "traditional" stressors which are the focus of state, provincial and federal governments and subject to regulatory actions. How will climate affect these?

For students who are not primarily residents of the United States, you may pick a waterway in your home country where adequate data exist, rather than a U.S waterway.

1. Pick a region and site with climate change issues.
2. Now, investigate the site's watershed and surrounding land uses noting likely sources of impairments other than those identified by the State.
3. Describe how relevant climate change drivers for your site (such as drought, heat, wildfires, flooding, sea level rise) are likely to interact with dominate and traditional site stressors (non-climate).
4. Show how you would rank stressors and their interactions with climate in human-dominated systems.
5. Describe all major stressors, ecological services, and likely societal group interactions/linkages and show these in a Conceptual Model diagram.
6. Show how, as a restoration manager, you would decide which stressors to target for restoration, considering the cost to benefit ratio at your project site. How are the stressor rankings and restoration approaches affected by political, societal, justice and economic traits of your ecoregion? Show how climate change affects your restoration strategy. Suggest adaptive management strategies for dealing with climate and non-climate stressors.

*Grading Rubric (50 points)**

a) Conceptual model showing stressors, stressed systems, and linkages. 15 points
b) Stressors ranked considering magnitude, frequency and duration. Additional stressor ranking criteria described and logical. 15 points
c) Stressor interactions with climate/global change, in future scenarios 10 points
d) Stressors linkages to political-socio-economic issues noted 5 points
e) Decision-making framework for stressor and restoration decisions 5 points

Students working in pairs will each receive the same grade. Students presenting their projects in one of the last 2 class periods will **not be graded on presentation style and may use my critiques to revise their powerpoint before final submission.*

Other Considerations

- The project should provide an example to be used by Site Managers, Consultants or Regulators to guide decisions on the most efficient and effective restoration approach, considering climate/global change interactions in the next 10 years.
- Show how you would rank (most to least harmful) stressor (not to exceed 5), based on their likely contribution to ecosystem impairment (such as failing fish populations) at a site in a human-dominated watershed or coastline. Examples of non-climate stressors: Toxic chemicals, habitat degradation, excess nutrients, altered flows, invasive species, pathogens, pests, resource extraction, over-harvesting, etc.
- Which species/populations/communities are most vulnerable? Does their impairment cause secondary effects (i.e., cascading effects) to other species or ecosystem components?

- For the stressor ranking, have an explanation of the weighting/scoring rationale

Examples of possible stressor ranking indices and considerations

- ***Here is a ranking method example***: Assign values (0-5 = from no worries to high concern) to each stressor in a weight-of-evidence based ranking. Sum all indices and rank stressors by severity, with and without climate change.
- What is the degree of stressor exposure? Measured by magnitude, frequency of occurrence, and duration of exposure.
- To what degree is the stressor connected to other stressors? For example, farming is linked to habitat alteration, nutrients, HABs, pesticides, and soil erosion. Among connected stressors – which dominates? Is this ecoregion dependent?
- Is the non-climate stressor likely to grow in magnitude due to climate change? How likely will the stressor appear and increase its exposure impact in the next 10 years? For example, increasing extreme events can degrade habitat and transport pathogens and chemicals downstream.
- Examples of climate stressor interactions/linkages: Such as additive, synergistic or antagonistic responses that can be direct or indirect effects. For example – Warmer temperatures melt Arctic ice, thus increasing UV absorption and further water warming, thereby altering major ocean currents, thereby impacting aquatic life, terrestrial wildlife and societies.
- Relationship of stressor vs. political-socio-economic status of residents in the area affected. What percentage of the population is most affected (e.g., environmental justice and vulnerability consideration). For example: Lawn care fertilizer and pesticide applications in high socio-economic residential areas versus litter and engine oil dumping in low socio-economic areas. Lower income homes are more likely in flood zones with exposure to industrial emissions.

Submit via Canvas under “Assignments” by December 9 at 5:00 pm. During the last 2 class periods, volunteers will present their project and I will critique in class. These critiques may assist you in optimizing your project.