GSD 6481/OEB 218: Ecosystem Restoration

Coastal restoration with *Spartina* on the coast of North Carolina
Credit: Ecosystem Restoration and Management)

Schedule: Friday 9am to 11.45pm

Location: Gund 510

Main instructor: David Moreno-Mateos (dmoreno@gsd.harvard.edu)

Teaching Assistant: Joe Kennedy (jkennedy@gsd.harvard.edu)

Office hours: Wednesday 9.30-1.30. Book here: https://calendly.com/dmorenomateos-gsd/ecosystem_restoration_2023

Course description

Given the current speed of habitat and species loss caused by human development, the restoration of degraded ecosystems is one of the greatest challenges humankind is facing. For this reason, the United Nations declared the current decade (2021-2030) as the UN Decade on Ecosystem Restoration. This global effort will require experts on ecosystem science, management and design. This holistic approach will allow for a deeper understanding of how ecosystems recover from human disturbance and how we can use this knowledge to increase the currently limited performance of restoration practice. This course is particularly suited for students with interests in the natural component of landscape architecture, conservation, ecological engineering, or ecosystem management in a broad sense. This course is cross-listed with the Department of Organismal and Evolutionary Biology, which will allow students from both disciplines to exchange their knowledge in a multidirectional learning environment where we all will address real world restoration cases. We will learn how ecosystems recover from human disturbance to apply that knowledge to a real restoration project that students will develop. We will have key inputs from guest lectures coming from environmental consultants with many years of experience restoring ecosystems worldwide. They will help us to find targeted tools to support, design, and monitor ecosystems in both urban and natural environments. We will have field trips to restored sites where we would discuss with local managers or practitioners the outcomes of restoration practice. At least one previous course in ecology or a similar topic is required. This course will arm you with one of the most important tools to work with and for nature in the coming decades.

Syllabus disclosure

This syllabus aims to provide guidance to the students about the Restoration seminar. *Its contents may vary* throughout the semester according to the needs of the students and the evolution of the class.

Learning outcomes

1. Gain understanding about ecosystem restoration in three areas:
   a. The importance of restoration in the global context of anthropogenic degradation of nature.
   b. The recovery process of ecosystems degraded by human disturbances from a scientific perspective to then design tools for restoration.
   c. Current knowledge on the science and practice of ecosystem restoration.
2. Based on that knowledge, increase the ability of students to create and design tools for the research and practice of ecosystem restoration.
3. Develop the abilities to write real restoration projects including ecological, social, economic, engineering, and policy aspects.
4. Develop students' ability to work in multidisciplinary teams, particularly in teams formed by landscape architects, environmental scientists/engineers, and biologists.

Course components

The course has two kinds of deliverables (capstone assignment and field trip reports) and weekly readings and videos.

1. *Capstone assignment:* Develop a restoration project on a forest, wetland or coastal ecosystem anywhere in the world (see *Project Guidelines* in a separate document on Canvas). The project should have a strong support from the scientific and practice evidence we will gain through the semester. For the purpose of the project, we will divide the class in multidisciplinary teams of three people, so each team will work on an independent project. Each team member will bring its own expertise to the project (e.g. ecology, design, planning, or engineering). The deliverables will be a written document and a presentation due at the end of the semester.
2. *Field trip reports:* We will visit three restored sites near the Cambridge area and discus with local managers or practitioners what worked and did not worked to help us make better decisions (see *Field trip guidelines* document on Canvas). All field trips are subjected to weather conditions.
3. *Readings:* Thera are two kinds of readings, *required readings*, they are the key material for in-class discussion, and *optional readings* to deepen in specific aspects you are interested. The

required readings are a mix of chapters and case studies for the *Primer on Ecosystem Restoration* (Holl 2020) book (available at the Harvard Coop, https://tinyurl.com/Order-Spring-23-materials-here copy and paste it in your browser, and select Department OEB, course 218, and many other places, price $26 - $32), journal articles, book chapters, and restoration projects. Please, buy or order the textbook as soon as you can after you select the course! If students have problems getting the textbook on time, please contact the TA. Non textbook readings will be available on Canvas. To fully participate in discussion, students need to complete the readings and any associated assignments by the assigned date. Students have online access to the scientific journals *Restoration Ecology, Ecological Restoration,* and many other journals with relevant articles through the Harvard libraries (Hollis).

4. *Class participation:* Class will consist of lectures by David Moreno-Mateos, Veronica Cruz and guest speakers mixed with discussions and interactive activities drawing on readings and assignments. We hope that students engage in discussions about the readings, reviews of case studies, ideas about student's projects, new trends found in restoration science, practice and policy, or any other topics that emerge during the semester.

Course structure

The course includes two or three asynchronous hours of readings and videos to read and watch before the class. The classes will have four main components:

1. In-class *lectures and discussion* based on the readings and videos. This will include occasional breakout rooms that will then share agreed points, spontaneous comments and concerns, polls, or other approaches to facilitate the understanding of the concepts and applications of the course. Each week, we will have specific readings related to the discussion that we will have in the class that week. Students are expected to complete the readings and any associated assignments by the assigned date so that they can participate fully in discussions. Students will have access to all the readings for each week through the instructors or the Harvard library. Please, read carefully the *Scientific reading guidelines* posted on Canvas.

2. In-class work on the *restoration project* in breakout rooms to discuss in depth specific aspects related to the project or to the application of restoration concepts to restoration projects. This will allow you to build a complete toolkit of restoration actions and approaches and to reinforce your skills to identify which actions or approaches can be integrated in your future projects. Please, read carefully the *Project guidelines* posted on Canvas.

3. *Guest lectures* either in class or via Zoom. Guests will come to give 40 minutes talks and then will stay with us to discuss their ideas and their use in restoration.

4. Two or three *fieldtrips* (depending on weather conditions) to nearby restored locations. We will meet with managers or practitioners at the visited location to discuss the restoration project. Students will submit a field trip report after each field trip. Please, read carefully the *Field trip guidelines* posted on Canvas.

Guidelines

The course has the following three documents **uploaded to Canvas** to help students understand the assignments:

1. *Project guidelines*. Describes the goals, required contents, and deliverables expected from the project in coordination with Core Studio III. Includes the requirements for mid-term and final reviews.
2. *Field trip guidelines*. General description of the field trip and structure of the required field trip reports.
3. *Scientific reading help*. Describes the key points to read scientific papers, what to read, and what to skip, to save you time and focus on the core messages.

Grading and deadline policy

Grading

1. **Restoration project**, 15% midterm and 30% final: **45%**
2. **Field trip reports**, 15% each, total: **45%**
3. **In-class participation** in discussion based on readings and videos: **10%**

Deadline policy

The deadlines for the various assignments are absolute. Assignments submitted late will be subjected to a 10% deduction in grade for each day late. No credit will be given beyond 4 days of the due date. If extenuating circumstances occur, contact the professor BEFORE the due date.

Class conduct

1. Students are expected to adhere to the Harvard policy on academic integrity (https://handbook.fas.harvard.edu/book/academic-integrity). All assignments should be created individually and be original works for this class. All academic integrity violations (e.g. plagiarism, cheating, multiple submissions, facilitating dishonesty) will be prosecuted if encountered.
2. During on-line classes, student should have their cameras on unless conflicts exist. Conflicts could be weak internet connection, lack of private space, or other issues derived from the online learning condition.
3. I aim to provide an environment conducive to learning for all students. When students arrive late or talk to their neighbors, it is distracting to both me and other students. Therefore, students are requested to arrive on time and share comments or questions with the entire class. If a student repeatedly chooses not to respect this request they will receive a reduced class participation score.
4. Computers, phones, and other electronic devices may be used exclusively for note taking and responding to quizzes and questions in class. Please silence devices before class starts and use electronic devices for class activities only.

Schedule and contents

In the previous days to each class, the students will receive a *detailed schedule* for that particular day.

Deadline brief:

Date	Assignment
Feb 3	Project site selected
Mar 3	Field trip or case study report 1 (trip on Feb. 24)
Mar 10	Project mid-term reviews
Apr 14	Field trip report 2 (trip on Mar. 31)
Apr 28	Field trip report 3 (trip on Apr. 14)
May 3-5	Final reviews

Color codes: green – in-class, purple – no class, blue – field trip, orange – reviews.

Jan. 27. *Why restoring ecosystems?*

Restoration is today a global tool to reduce the daunting **loss of biodiversity** and ecosystem benefits to humanity. Many international programs and strategies are promoting it, including the UN Decade on Ecosystem Restoration. We will discuss about some of these strategies to understand why restoration is critical today.

We will talk about the restoration project that you will work on through the end of the semester. Please, this is the day to bring your questions about the course after **reading the course documents**!

Readings:

1. *Course documents*: Syllabus.
2. Ch. 1 Why restore ecosystems? (Holl 2020)
3. IPBES 2018. Assessment on Land Degradation and Restoration (pp. 20 to 43)
4. Ecosystem Restoration Decade Strategy 2020 (pp. 1 to 18)

Optional: Read the rest of readings 2 and 3.

Feb. 3. *What is ecosystem restoration? And tropical forest restoration*

Restoration has been defined in many different ways. We will go through several ways to understand restoration. There is now a hot debate on what the global restoration strategies that we saw last week will do for restoration. Most of the real efforts happening on the ground are quite limited to planting trees.

In the second hour, we will have our first **guest lecture** from *Leighton Reid* (Professor at Virginia Tech). He will join us to talk about his work on strategies for tropical forest restoration.

Readings:

1. Ch. 2. Defining restoration (Holl 2020)
2. Gann *et al.* 2019. International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology* 27. SECTIONS 1, 2 and 5

3. Reid, J. L., Fagan, M. E., Lucas, J., Slaughter, J., & Zahawi, R. A. (2019). The ephemerality of secondary forests in southern Costa Rica. *Conservation Letters*, *12*(2). https://doi.org/10.1111/conl.12607

Case study: Atlantic Forest restoration (Brazil)

Feb. 10. *Planning and monitoring* – Site selection deadline

We will discuss key points related to project planning including stakeholder engagement, reference models, goal setting, analysis of existing conditions, writing a design plan, permits, timelines, and contingency plans. We will also work on the adaptive management cycle and best practices for developing a rigorous monitoring plan.

We will **work on projects** to select the site.

Readings:

1. Ch. 3. Project Planning (Holl 2020).
2. Ch. 4. Monitoring and Adaptive Management (Holl 2020).
3. Gann *et al.* 2019. International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology* 27. SECTIONS 3 and 4.
4. Camarretta, N., P. A. Harrison, T. Bailey, B. Potts, A. Lucieer, N. Davidson, and M. Hunt. 2020. Monitoring forest structure to guide adaptive management of forest restoration: a review of remote sensing approaches. *New Forests* 51:573–596.

Feb. 17. *The physical dimension of restoration, e.g. stream restoration*

In the first part of the class, we will focus on the basic physical components of restoration, the land, the soil and the water. This is an essential part of the restoration process that will set the baseline for any other action that will happen in the biological dimension.

In the second part, we will have a **guest lecture** by *Joe Berg*, Senior Ecologist at Biohabitats, Inc, focusing on stream restoration that will show us the last approaches to restore a natural hydrology.

Readings and videos:

1. Ch. 6. Landform and hydrology (Holl 2020).
2. Ch. 7. Soil and water (Holl 2020)
3. Wohl. 2019. Forgotten Legacies: Understanding and Mitigating Historical Human Alterations of River Corridors. *Water Resources Research* 55, 5181–5201.
4. *Case study*: Bacon Ridge Restoration Plan
5. Video: Bacon Ridge branch restoration

Feb. 24. *Field trip to Tidmarsh Restoration project.* From 8am to 4 pm.

This is a difficult semester for field trips, but if the weather allows it (temperature >40 °F), we will have a morning visit to the Tidmarsh Restoration project to evaluate the state of the restoration of the cranberry bog and the surrounding habitat. This is one of the oldest peatland restoration projects in Massachusetts where we will hopefully meet with the manager of the project.

Readings: TBD.

If it is too cold, we will explore critical ecological concepts in the context of restoration. In particular, we will dig into the restoration of genetic diversity an aspect of critical importance when selecting plants and other organism for use in restoration. We will apply these and other concepts seen so far to the case study Alewife Brook Restoration.

In the second part, we will **work on projects**.

Readings:

1. Ch. 5. Applying Ecological Knowledge to Restoration (Holl 2020).
2. Richards *et al.* 2016. Population and Ecological Genetics in Restoration Ecology. In: *Foundations of Restoration Ecology*. Island press.
3. *Case study*: Alewife Brook Restoration Plan.

Mar. 3. *Restoring aboveground – Plant communities*

We will work on plants in restoration (from revegetation to plant biotic interactions) and how to deal with invasive species. Plants are along with soils the most critical structural and functional elements of most terrestrial ecosystems. Understanding how to help them establish is one of the critical, still unresolved question in restoration ecology.

We will have a **guest lecture,** Liz Koziol (Kansas University) in plant-mycorrhizal fungi associations in the context of grassland restoration in the US prairie region.

Readings:

1. Ch. 8. Invasive species (Holl 2020)
2. Ch. 9. Revegetation (Holl 2020)
3. Zirbel et al. 2017. Plant functional traits and environmental conditions shape community assembly and ecosystem functioning during restoration. *Journal of Applied Ecology* 54:1070-1079.
4. Weidlich, E. W. A., F. G. Flórido, T. B. Sorrini, and P. H. S. Brancalion. 2020. Controlling invasive plant species in ecological restoration: A global review. *Journal of Applied Ecology* 57:1806–1817.

Case study: Removal of invasive plants (Purple loosestrife in Massachusetts).

Mar. 10. *Project mid-term reviews*

Mar. 17. *Spring recess*

Mar. 24. *Restoring belowground – Soil microbes and plants*

We will focus today on multiple mechanisms to restore the soil and all its biotic (e.g. fungi, bacteria) and abiotic (e.g. organic matter, nutrients) components. We will put particular emphasis on fungi. Specifically, the interactions between plants and fungi and how these critical interactions can be facilitated through restoration. This is a key element for any terrestrial restoration project and, in particular, forest restoration. We will then work on projects with a special emphasis on integrating fungal interactions in them.

In the second hour, we will have our second **guest lecture** from a restoration practitioner, *Willemijn Stoffels*, COO at Land Life, to discuss the problems and solutions they commonly found in restoration projects. LandLife is a rapidly growing firm based in the Netherland that is capitalizing in C markets to promote large-scale ecosystem restoration all over the world.

Readings:

1. Morriën *et al*. 2017. Soil networks become more connected and take up more carbon as nature restoration progresses. *Nature Communications* 8:14349.
2. Koziol *et al*. 2018. The plant microbiome and native plant restoration: The example of native mycorrhizal fungi. *BioScience* 68:996–1006.
3. Wubs *et al*. 2016. Soil inoculation steers restoration of terrestrial ecosystems. *Nature Plants* 2:16107.
4. Koziol, L., Bauer, J. T., Duell, E. B., Hickman, K., House, G. L., Schultz, P. A., Tipton, A. G., Wilson, G. W. T., & Bever, J. D. (2022). Manipulating plant microbiomes in the field: Native mycorrhizae advance plant succession and improve native plant restoration. *Journal of Applied Ecology*, *59*(8), 1976–1985.

Optional: Policelli *et al*. 2020. Back to Roots: The Role of Ectomycorrhizal Fungi in Boreal and Temperate Forest Restoration. *Frontiers in Forests and Global Change* 3.

Mar. 31. *Field trip*. Great Marsh Adaption Project, Newburyport, MA. From 8am to 4pm.

We will visit a series of restoration actions around the area of the Great Marsh, mostly within the Parker River Wildlife Refuge, near Newburyport. We will joined by people from the Division of Ecological Restoration from the Massachusetts Government and from the Trustees of Reservations to explain us the many actions they are developing in the area.

Readings: TBD.

Apr. 7. *Restoring complexity*

Today we will dig deeper into the complexity of ecosystems within and beyond soils. This is key to restoring an ecosystem composed of thousands of interacting elements.

On the second part of the class, we will **work on projects**.

Readings:

1. Moreno-Mateos *et al.* 2020. The long-term restoration of ecosystem complexity. *Nature Ecology and Evolution* 4:676–685.
2. Raimundo *et al.* 2018. Adaptive Networks for Restoration Ecology. *Trends in Ecology and Evolution* 33:664–675.
3. Pocock *et al*. 2012. The Robustness and Restoration of a Network of Ecological Networks. *Science* 335, 973–977.
4. Video: Yellowstone NP wolf reintroduction effects.

Apr. 14. *Field trip*. TBD but likely to Great Marsh Salt Marsh Adaptation Projects. 8pm to 4pm.

This time we will go visit the successful restoration of an urban stream in Plymouth, MA. This project consisted in the removal of six small dams and has led to the recovery of the migration of part of the herring population that used to swim up the stream every year. Along with it, the whole stream community and the riparian ecosystem are also recovering. Weill be joined by people form the Town of Plymouth, NOAA and the Division of Ecological Restoration form the Massachusetts Government.

Readings: TBD.

Apr. 21. *Earth's restoration*

On our last day in the classroom, we go back to the global picture. We will study recent analyses of the global effects and need of restoration. We will open a discussion on the feasibility of these approaches linking them with the readings of the first day.

In the last class, we will **work on projects** before our final deadline on May 3.

Readings:

1. Moreno-Mateos *et al*. 2017. Anthropogenic ecosystem disturbance and the recovery debt. *Nature Communications* 8:14163.
2. Strassburg *et al*. 2020. Global priority areas for ecosystem restoration. *Nature* 586:724–729.
3. Bastin *et al.* 2019. The global tree restoration potential. *Science* 364:76–79.
4. Cook-Patton *et al*. 2020. Mapping carbon accumulation potential from global natural forest regrowth. *Nature* 585:545–550.

Optional: Skidmore *et al.* 2019. Comment on "The global tree restoration potential." *Science* 366:1–5.

May 3-5. *Final reviews*