Freshwater Ecology (ESPM C115A / INTEGBI C171), Spring 2024

Instructor of record: Albert Ruhi

Graduate Student Instructor (GSI): Maggie Grundler

Hours and location:

- **Lectures**: Tuesdays and Thursdays 2-3 pm (103 Moffitt Library)
- **Labs**: Tuesdays or Thursdays 3-5 pm (306 Wellman)

Sign up for office hours here!

- **Albert Ruhi**: Fridays 3-5pm and by appointment (319 Wellman)
- **Maggie Grundler**: Wednesdays 2-4 pm (146 Hilgard)

Subject/Course Level: Environ Sci, Policy, and Management & Integrative Biology / Undergraduate, upper division.

Grading/Final exam status: Letter grade. Final exam required.

Overview:

Lakes, rivers, wetlands, and estuaries are biologically rich, dynamic, and some of the most vital and vulnerable ecosystems. This course introduces the natural history and evolutionary, population, community, and landscape ecology of the world's freshwater and estuarine ecosystems. We will cover broad principles of organismal biology, ecology, hydrology, and ecosystem science, and we will illustrate these principles with examples drawn from key biota and habitats from California and beyond. The first part of the course (weeks 1-9) will focus on establishing key concepts in freshwater ecosystem structure and functioning. The second part (weeks 10-14) will delve in applied issues around conservation and management of river, wetland, and lake ecosystems. The course has 2 hours of work in a wet laboratory setting every week, and 2 hours of lecture every week. Each lab has an associated reading (one per week, listed below), and builds on the previous week's lecture content. Labs include: discussion on experimental design; hands-on deployment, retrieval, and analysis of high-frequency temperature sensors in Strawberry Creek; hands-on comparison of aquatic invertebrate sampling methods; observation, identification, and measurement of aquatic invertebrates; and analysis of community and hydrology data to test questions around stream ecosystem responses to drought. The lab material will lead to a day-long field trip to Chalone Creek, an instrumented river network in Pinnacles National Park, where we will test wet-dry mapping methods and we will observe aquatic communities persisting in isolated pools. Assignments will emphasize predictive thinking about how freshwater organisms and ecosystems may respond to climate variability, harvesting, land use, and biotic change. Assignments include: (1) short answers to thought questions for each lab, and participation in the labs; (2) a mid-term paper; (3) preparation and participation in a scientific debate; and (4) an open-book final exam.

Syllabus (lecture material, lab, readings, deadlines):

Week 1: January 16 & 18

- **Lecture 1**: Course overview. Introduction to the natural history and ecology of freshwater biota and habitats. Key ecological concepts along axes of time, space, and energy.
- **Lecture 2**: Observation, experiments, and modeling in freshwater ecology. Putting results in the watershed context.
- No lab.

Week 2: January 23 & 25

- **Lecture 1**: The physics of water. Living in freshwater environments.
- **Lecture 2**: Living in freshwater environments (cont.)
- **Lab**: Predictive mapping in stream ecology: drainage area and flow regime as 'master' variables.
- **Reading for lab:** Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. and Cushing, C.E., 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, *37*(1), pp.130-137.
- *Optional reading to expand on lecture material: Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E. and Stromberg, J.C., 1997. The natural flow regime. BioScience, 47(11), pp.769-784.*

Week 3: January 30 & February 1

- **Lecture 1**: Freshwater invertebrates. Natural history, main taxonomic groups, life cycles, traits and functions, ontogenetic bottlenecks. [instructor: Robert J. Fournier]
- **Lecture 2**: Freshwater invertebrates (cont.). Environmental constraints. Using benthic macroinvertebrates as bioindicators.

- **Lab:** Primer to experimental design in freshwater ecology.

- **Reading for lab:** Steel, E.A., Kennedy, M.C., Cunningham, P.G. and Stanovick, J.S., 2013. Applied statistics in ecology: common pitfalls and simple solutions. *Ecosphere*, *4*(9), pp.1-13.
- *Optional reading to expand on lecture material: Vadeboncoeur, Y. and Power, M.E., 2017. Attached algae: the cryptic base of inverted trophic pyramids in freshwaters. Annual Review of Ecology, Evolution, and Systematics, 48, pp.255-279.*

Week 4: February 6 & 8

- **Lecture 1**: Freshwater vertebrates. Natural history. Evolution of the main taxonomic groups. Impacts on aquatic and terrestrial ecosystems [Maggie & Albert].
- **Lecture 2**: Microbes. Natural history of heterotrophic bacteria, cyanobacteria, fungi, attached algae and phytoplankton. Riparian vegetation, aquatic macrophytes.

- **Lab:** Test of invertebrate sampling methods in Strawberry Creek.

- **Reading for lab:** Bonada, N., Prat, N., Resh, V.H. and Statzner, B., 2006. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Annu. Rev. Entomol.*, *51*, pp.495-523.
- *Optional reading to expand on lecture material: He, F., Zarfl, C., Bremerich, V., David, J.N., Hogan, Z., Kalinkat, G., Tockner, K. and Jähnig, S.C., 2019. The global decline of freshwater megafauna. Global Change Biology, 25(11), pp.3883-3892.*

Week 5: February 13 & 15

- **Lecture 1**: Persisting in the face of stress and disturbance. Primary and secondary succession in lentic and lotic ecosystems.
- **Lecture 2**: Resilience and resistance strategies to drought in intermittent streams.

- **Lab:** Identifying aquatic invertebrates under the dissecting scope.

- **Reading for lab:** Harding, J.S., Benfield, E.F., Bolstad, P.V., Helfman, G.S. and Jones Iii, E.B.D., 1998. Stream biodiversity: the ghost of land use past. Proceedings of the national academy of sciences, 95(25), pp.14843-14847.
- *Optional reading to expand on lecture material: Fisher, S.G., Gray, L.J., Grimm, N.B. and Busch, D.E., 1982. Temporal succession in a desert stream ecosystem following flash flooding. Ecological Monographs, 52(1), pp.93-110.*

Week 6: February 20 & 22

- **Lecture 1**: Resilience and resistance strategies to drought in vernal pools. Size-structured populations. Competition and size-dependent predation in fresh waters.
- **Lecture 2**: Body size: interspecific effects, metabolic theory of ecology. Species abundances and performances along environmental gradients. Niche modeling methods and metrics applied to river networks.

- **Lab:** Identifying and measuring aquatic invertebrates under the dissecting scope. (part 2)
- **Reading for lab:** Woodward, G., Ebenman, B., Emmerson, M., Montoya, J.M., Olesen, J.M., Valido, A. and Warren, P.H., 2005. Body size in ecological networks. *Trends in Ecology & Evolution*, *20*(7), pp.402-409.
- *Optional reading to expand on lecture material: Post, D.M., 2003. Individual variation in the timing of ontogenetic niche shifts in largemouth bass. Ecology, 84(5), pp.1298-1310.*

Week 7: February 27 & 29

- **Lecture 1**: Habitat selection and foraging choices: tracking opportunities versus enduring local changes in risk, stress, and opportunities.
- **Lecture 2**: Guest lecture: Prof. Mary Power. Species interactions and impacts in food webs and ecosystems.

- **Lab:** Preparing for the debates and mid-term papers: how to search for scientific evidence and assess its strength.

- **Reading for lab:** Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T., Kidd, K.A., MacCormack, T.J., Olden, J.D., Ormerod, S.J. and Smol, J.P., 2019. Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*(3), pp.849-873.
- **Optional reading for lab:** Landhuis, E., 2016. Scientific literature: Information overload. *Nature*, *535*(7612), pp.457-458.
- *Optional reading on lecture material: Power, M.E., Parker, M.S. and Dietrich, W.E., 2008. Seasonal reassembly of a river food web: floods, droughts, and impacts of fish. Ecological Monographs, 78(2), pp.263-282.*

Week 8: March 5 & 7

- **Lecture 1**: Non-trophic impacts of species on aquatic ecosystems. Ecological engineers.
- **Lecture 2**: Population diversity in river and pond networks. Metapopulation models and assumptions. The Portfolio effect and its drivers.

- **Lab:** Programming and deploying sensors in Strawberry Creek.

- **Reading for lab:** Chapin, T.P., Todd, A.S. and Zeigler, M.P., 2014. Robust, low-cost data loggers for stream temperature, flow intermittency, and relative conductivity monitoring. *Water Resources Research*, *50*(8), pp.6542-6548.
- *Optional reading to expand on lecture material: Wright, J.P., Jones, C.G. and Flecker, A.S., 2002. An ecosystem engineer, the beaver, increases species richness at the landscape scale. Oecologia, 132(1), pp.96-101.*

Week 9: March 12 & 14

- **Lecture 1**: Evidence of the Moran theorem in fresh waters. Metacommunity ecology in fresh waters: theory and methods to assess structure. Applications of the metacommunity concept to conservation and monitoring.
- **Lecture 2**: Guest lecture: Dr. Denise Colombano. Community dynamics in estuaries: tidal effects and nursery function.
- **Lab:** Explore Strawberry Creek's riverine-riparian interactions, using iNaturalist.
- **Reading for lab:** Sabo, J.L., Sponseller, R., Dixon, M., Gade, K., Harms, T., Heffernan, J., Jani, A., Katz, G., Soykan, C., Watts, J. and Welter, J., 2005. Riparian zones increase regional species richness by harboring different, not more, species. Ecology, 86(1), pp.56-62.
- *Optional reading to expand on lecture material: Hilborn, R., Quinn, T.P., Schindler, D.E. and Rogers, D.E., 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences, 100(11), pp.6564-6568.*
- *Optional reading 2 (on Denise's guest lecture): Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., Halpern, B., Hays, C.G., Hoshino, K., Minello, T.J. and Orth, R.J., 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates: a better understanding of the habitats that serve as nurseries for marine species and the factors that create site-specific*

variability in nursery quality will improve conservation and management of these areas. Bioscience, 51(8), pp.633-641.

Friday, March 15th, 5 pm: Mid-term paper is due.

Week 10: March 19 & 21

- **Lecture 1**: Cross-ecosystem linkages of upland watersheds, wetlands, river networks, lakes, estuaries and coastal oceans.
- **Lecture 2**: From freshwater ecosystems to meta-ecosystems. Connectivity, spatial synchrony, and temporal stability.

- **Lab:** Conservation and disruption of cross-ecosystem linkages.
- **Reading for lab:** Baxter, C.V., Fausch, K.D., Murakami, M. and Chapman, P.L., 2007. Invading rainbow trout usurp a terrestrial prey subsidy from native charr and reduce their growth and abundance. Oecologia, 153(2), pp.461-470.
- *Optional reading on lecture material: Nakano, S. and Murakami, M., 2001. Reciprocal subsidies: dynamic interdependence between terrestrial and aquatic food webs. Proceedings of the National Academy of Sciences, 98(1), pp.166-170.*

March 26 & 28: *Spring Recess*

Monday, April 1st, 5 pm: List of literature supporting each debate is due.

Week 11: April 2 & 4

- **Lecture 1**: debate 1.
- **Lecture 2**: debate 2.

- **Labs:** Debates 3 & 4 (Tuesday section), debates 5 & 6 (Thursday section)

- **Readings:** Literature supporting debates.

Week 12: April 9 & 11

- **Lecture 1**: Invasions in fresh waters: causes, consequences, prevention, and management.
- **Lecture 2**: Hydro-ecology in a water-stressed world: drivers of water scarcity, ecological impacts, and management opportunities.
- **Lab:** Reading out, analyzing, and interpreting temperature time series from Strawberry Creek

- **Reading for lab:** Caissie, D., 2006. The thermal regime of rivers: a review. *Freshwater biology*, *51*(8), pp.1389-1406.
- *Optional reading to expand on lecture material: Ruhí, A., Holmes, E.E., Rinne, J.N. and Sabo, J.L., 2015. Anomalous droughts, not invasion, decrease persistence of native fishes in a desert river. Global Change Biology, 21(4), pp.1482-1496.*

Week 13: April 16 & 18

- **Lecture 1**: Guest lecture: Sarah Kupferberg. Effects of dams on freshwater biodiversity in California.
- **Lecture 2**: Guest lecture: Ted Grantham. Water resource management and policy issues in California. The Sacramento-San Joaquin River Delta as the hub of California's water system.
- **Lab:** Visit and discussion of operational Best Management Practices (BMP's) in Berkeley (see: https://creeks.berkeley.edu/best-practices/best-management-practices)

- **Reading for lab:** Wohl, E., Lane, S. N., & Wilcox, A. C. (2015). The science and practice of river restoration. *Water Resources Research*, *51*(8), 5974–5997.
- *Optional reading to expand on lecture material: Palmer, M. and Ruhi, A., 2019. Linkages between flow regime, biota, and ecosystem processes: Implications for river restoration. Science, 365(6459).*

April 20th or 21st (weekend): Trip to Chalone Creek, Pinnacles National Park

This is an optional, all-day trip to Pinnacles National Park, to visit and sample three sites along Chalone Creek. The trip will be offered two days in order to reduce group size and associated impacts to the stream. The instructor, GSI, and Ruhi Lab postdocs and PhD students will guide the excursion. The hike will be around 6 miles, we should expect hot, dry weather. We will review field safety protocols ahead of the field trip.

- **Field trip reading 1:** Clavero, M., Pou-Rovira, Q. and Zamora, L., 2009. Biology and habitat use of three-spined stickleback (*Gasterosteus aculeatus*) in intermittent Mediterranean streams. *Ecology of Freshwater Fish*, *18*(4), pp.550-559.
- **Field trip reading 2:** Fournier, R.J., de Mendoza, G., Sarremejane, R. and Ruhi, A., 2022. Isolation controls reestablishment mechanisms and post-drying community structure in an intermittent stream. Ecology, p.e3911.

Week 14: April 23 & 25

- **Lecture 1**: Ecological restoration of streams and wetlands: from theory to practice.
- **Lecture 2**: Regime shifts in freshwater ecosystems. Managing for resilience. Current and future impacts of climate change on freshwater ecosystems.
- **Lab:** Discussion of urban stream restoration case studies.
- **Reading for lab:** Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M. and Morgan, R.P., 2005. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, *24*(3), pp.706-723.

- *Optional reading to expand on lecture material: Opperman, J.J., Galloway, G.E., Fargione, J., Mount, J.F., Richter, B.D. and Secchi, S., 2009. Sustainable floodplains through large-scale reconnection to rivers. Science, 326(5959), pp.1487-1488.*

Week 15: RRR week.

- **Lectures**: No lectures, but optional office hours to review material for the final exam. See study guides.
- No lab.

Monday, 6, 11:30 am - 2:30 pm (Location TBD): Final Exam

Grading:

- **Lab (total: 40 points):** Each week, students are expected to attend a 2-hour lab. The objectives of the labs are to: (1) unpack concepts from lecture by getting hands-on experience on experimental design, monitoring of water variables with high-frequency sensors and aquatic invertebrate communities, identification of aquatic invertebrates, and analysis of community and hydrology data to test questions around stream ecosystem responses to drought; (2) discuss key concepts based on primary literature, including specific case-studies and experiments; and (3) work on effective scientific writing and presentation. Students are expected to attend and remain thoughtfully engaged throughout the labs and associated discussions (**20 points**); and will complete weekly assignments (mostly answering one short question related to the lab content and/or the associated reading, about ½ page answer submitted to bCourses; **20 points**). We will assess engagement using our own notes and a self-completed log.
- **Mid-term paper (15 points):** We ask students to write a paper (~8 pages double spaced) summarizing their informed opinion on the pros and cons of one issue related to the ecology or management of freshwaters or estuaries. Topics will be discussed in the lab section, and assigned to each student beforehand. Grading will be based on content accuracy, sophistication of the scientific arguments, and writing quality. The paper will be due on Friday, March 15th by 5pm on bCourses.
- **Debate (15 points):** Teams of students will debate current issues related to the ecology or management of freshwaters or estuaries, following the traditional Oxford-style debate format, with one side proposing and the other side opposing a sharply-framed motion (see example here). We will propose (and welcome ideas for) six sharply-framed motions, such as: *Should dams be removed or built in this era of increasing water scarcity?*, or *Should we use gene editing to "resurrect" aquatic species that have gone extinct?* As we choose topics, we will focus on particular regions and specific taxa--to debate the issue adequately, students will need to become experts in the focal system. Arguments will build on this knowledge, with a documented list of peer-reviewed sources supporting the facts being presented. The citations document will be due on bCourses the Friday before debate week, and will be accessible to the entire class. We anticipate that 4 team members will participate in each side of the debate, with 8 debaters per debate, and the instructor moderating, fact-checking statements, and posing prompts. Grading will be based on content, structure, and active listening and participation.

- **Final exam (30 points):** The final exam will be open book, and will seek to demonstrate understanding of the concepts covered in class. It will consist of short answers, interpretation of graphs, and simple computational problems. An example of previous exam questions and a study guide will be circulated before RRR week.

Late assignment policy:

Assignments that are received after the due date and time will incur a penalty: 10% for up to two days late, and 25% for work submitted up to a week late. Assignments received more than a week after the due date will not be accepted unless in the event of a serious emergency. In that case, please let the instructor know with the maximum possible advance notice. We will not typically grant extensions, or accept assignments for regrading.

Academic Integrity:

Any test, paper or report submitted by you and that bears your name is presumed to be your own original work that has not previously been submitted for credit in another course unless you obtain prior written approval to do so from your instructor. In all of your assignments, including your homework or drafts of papers, you may use words or ideas written by other individuals in publications, web sites, or other sources, but only with proper attribution. If you are not clear about the expectations for completing an assignment or taking a test or examination, be sure to seek clarification from your instructor or GSI beforehand. Finally, you should keep in mind that as a member of the campus community, you are expected to demonstrate integrity in all of your academic endeavors and will be evaluated on your own merits. The consequences of cheating and academic dishonesty—including a formal discipline file, possible loss of future internship, scholarship, or employment opportunities, and denial of admission to graduate school—are simply not worth it.

Collaboration and Independence: Reviewing lecture and reading materials and studying for exams can be enjoyable and enriching things to do together with one's fellow students. However, homework assignments should be completed independently and materials turned in as homework should be the result of one's own independent work. Some assignments, namely the preparation for the debate arguments, are meant to be done together in a group.

Cheating: Anyone caught cheating on a quiz or exam will receive a failing grade and will also be reported to the University Office of Student Conduct. In order to guarantee that you are not suspected of cheating, please keep your eyes on your own materials and do not converse with others during the quizzes and exams.

Plagiarism/Self-plagiarism: You must be original in composing the writing assignments in this class. To copy text or ideas from another source (including your own previously, or concurrently, submitted course work) without appropriate reference is plagiarism and will result in a failing grade for your assignment and usually further disciplinary action. For more information, see: http://gsi.berkeley.edu/teachingguide/misconduct/prevent-plag.html.

Academic Accommodations:

The purpose of academic accommodations is to ensure that all students have a fair chance at academic success. If you have Letters of Accommodations from the Disabled Students' Program or another

authorized office, please share them with me as soon as possible, and we will work out the necessary arrangements. While individual circumstances can vary, requests for accommodations often fall into the categories listed on the Academic Calendar and Accommodations website. The campus has well-developed processes in place for students to request accommodations, and you are encouraged to contact the relevant campus offices listed on the Academic Accommodations Hub (https://evcp.berkeley.edu/programs-resources/academic-accommodations-hub). These offices, some of which are confidential, can offer support, answer questions about your eligibility and rights, and request accommodations on your behalf, while maintaining your privacy.