INDEPENDENT PROJECT TIMETABLE AND GENERAL INFORMATION – 2023

If previous years are any guide, the project will be the most rewarding and enjoyable part of your SES experience. It can be advantageous to work in a **team** dividing up a coherent set of tasks on a related aspect of the research problem. Each team is mentored by at least one SES faculty member. Every student on a team should be pursuing work that stands alone; this should be a true collaboration, in which one person's work compliments, but does not duplicate the work done by others.

You will be expected to develop a formal research proposal for the project and report on your work in two ways, orally, at a **symposium** held **Friday December 15, 2023** and in a **scientific paper** following the format of the journal *Ecology* due on **Monday December 18, 2023.** The projects are graded as follows:

Oral proposal presentation (10%)
Final Written Proposal (20%)
Paper (45%)
Oral Presentation (25%)

Though we have allocated 5 weeks for project work, this time goes *very* fast. We try to get you started before thinking about project ideas early on as well as learning how to do a literature search and principles of research design, proposal writing, oral presentations, data analysis, and writing your research papers. It will take you close to a week to really get going on your project (assemble the equipment and supplies you need, etc.), leaving about 2-2.5 weeks for data collection, and 1-1.5 weeks for analysis and writing. Thanksgiving break comes in the middle of the project period, and your project must be well underway by the time you leave for your well-deserved turkey, rest and relaxation. The weekly activities and most important deadlines and dates during the project period are given below:

Week 1 - Discussion on Research Topics (with faculty flash talks)
Week 3 – Literature Search
Week 4 - Project Concept
Week 6 – Free time to meet with Faculty
Week 7 – Project Concepts due, Project Lab Procedures
Week 8 - Session 1: Writing Proposals, Session 2: Free Project Time, Project Proposal Draft Due
Week 9 - Session 1: Proposal/Project Time, Session 2: Project Proposal Presentations
Week 10 - Free Project Time and Data Visualization and Statistics, Final Written Proposal Due
Week 11 – Free Project Time and How to Write a Scientific Paper
Week 12 - Free Project Time
Week 13 - Free Project Time
Week 14 - Free Project Time
Week 15 - Session 1: Draft Project Report Due, Session 2: Presentation Rehearsals, Session 3: Student Research Symposium and Oral Presentations
Week 16: Final Project Report Due

Important dates:
29 September – Project concepts
16 October – Project concepts due
27 October –Draft (3-5 page) project proposal
3 November – Project proposal presentations
10 November – Final written proposal due, including budget and supplies.

11/23-11/26 Nov– Thanksgiving break (*tempting as it is to take a longer break, we encourage you to confine your break to these dates - you will need time the week of 11/27 to complete your project work*)
11 December – Draft project report due (Introduction, methods, results/discussion)
13 December – Target for return of draft project paper with comments
14 December– Presentation rehearsals
15 December – SES Student Symposium
18 December – Final written project paper & data due (**electronic files, Word & Excel, etc**).

You don't need to confine your work to the ecosystems we have visited, but hopefully the core labs and electives have given you a feeling for the types of ecosystems science we can do and perhaps helped to generate some questions or ideas for further work. We would like your projects to be focused on **ecosystem level questions** and to involve collection of **new data**, not simply literature review or modeling, though modeling can be part of a project.

SOME STUDENT PROJECT TOPICS & POSSIBLE MENTORS

A number of different possible mentors have expressed an interest in working with you on a variety of projects. The list and descriptions below are intended as a **starting point** to help guide you toward possible projects that will be most interesting to you. If one of these projects strikes your fancy, contact Program Director, Mirta Teichberg and she will assist you in setting up a meeting with potential mentors to discuss your ideas.

During your discussions you may discover that the topic is not what you were interested in after all. You may find that you can develop a new and different idea that is feasible given the expertise, methods and equipment available that you would rather pursue. Or you may decide to take the ball and run with it, refining the concept and design and building a full-fledged project proposal from these ideas.

Bear in mind, *we encourage you to work in groups of at least two students*, with each student conducting a stand-alone piece of the project and sharing a mentor. This might mean, for example, that one student works on the chemistry soils or sediments from a particular site or experiment, and another student works on the microbial or animal community at the same sites.

ZOE CARDON - Plant Physiological Ecology / Plant-Soil-Microbe Interactions

Cattail (Typha angustifolia) root physiology and its implications for coastal marsh methane production.

We have a coastal brackish marsh mystery on our hands! Half-way through summer in 2022, during drought, a saline tide flooded brackish marsh at Plum Island LTER. Before the tide, the marsh was emitting a lot of methane to the atmosphere. After the tide, the methane efflux to atmosphere stopped, though there was still methane in the marsh porewater. We have several hypotheses for why these patterns emerged, several of which focus on root physiology of the cattails that blanket the marsh. Students could work to test whether (1) salinity stress causes production of glycine betaine (GB) by Typha angustifolia --GB supports methylotrophic methanogenesis; (2) whether salinity stress triggers production of peroxide and catalase in T. angustifolia roots; and/or (3) whether salinity stress triggers increased oxygen loss from the roots into their surroundings (detected using oxygen electrodes and perhaps optode-based 2D imaging, if students are interested in learning image analysis).

KEN FOREMAN – Nutrients in the Coastal Zone. Contamination of coastal systems with wastewater and fertilizer derived nitrogen is a world-wide environmental problem. Ken is interested in learning about how ecosystems *respond* to and *recover* from excess inputs of N and P.

Assessment of Wastewater Remediation on ecology of Little Pond - The Town of Falmouth has spent $40 million to build a sewer system that diverts wastewater from the watershed of Little Pond, a highly eutrophic coastal salt pond along the shores of Vineyard Sound, to the Falmouth Wastewater Treatment Plant. This large-scale ecosystem manipulation provides a great opportunity for studying how ecosystems recover from eutrophication. A group working on this site could:

- Compare inputs of nutrients to outputs of nutrients through the channel for the whole pond.
- Collect and sample groundwater for nutrients including organic N, trace gases (e.g. N_2O), and contaminants of emerging concern (triclosan, estradiol, etc.).
- Measure sediment infauna composition and respiration in the benthos of Little Pond.
- Measure total system metabolism, nutrient levels, etc. in surface water of Little Pond.

Biogeochemistry and effectiveness of wood-chip based permeable reactive barrier in remediating nitrate pollution in wastewater or ground water – In many coastal settings nitrogen is delivered to the shore as nitrate carried in groundwater. Currently, the most common solution to nitrate pollution is construction of centralized wastewater treatment facilities, which could cost more than $4 billion Cape wide. We have developed and tested a novel approach using wood chip bioreactors to increase denitrification in groundwater. Possible projects related to this work could be:

- Feasibility of a woodchip based reactor to treat contaminated waters.
- Studies of the stoichiometry and biogeochemistry of groundwater within the barrier and vs. control sites (e.g. measuring patterns of Fe, Mn, SO_4, S^{2-}, ammonium, nitrate, N_2O and N_2).
- Evaluation of the rates of wood decay and lifetime of the barrier measured in wood collected from the barrier system and incubated in microcosms.
- Ability treated wastewater to support algal or plankton growth.

ANNE GIBLIN - Biogeochemistry and organic matter diagenesis in sediments.

Anne works on sediment processes (e.g. respiration, N and P cycling in sediment cores), and on measuring and interpreting the historical record preserved in sediments. Changes in sediment concentrations of organic C, N, P, S, Fe, and trace metals can provide information about how sources of nutrients or organic matter have changed and whether the local environment was more or less productive in the past. Currently Anne is also working on the impact of the oil spills on marshes and does have access to oil from the region that could be used in an experiment on sediment processes.

Some possible and former projects include:

- Impacts of oil on N cycling in salt marsh sediments
- Impact of small differences in elevation on salt marsh N cycling
- Controls on N pathways in sediments and N microbial communities
- Burial and storage of sulfur and carbon in estuarine and lake sediment
- Impacts of eutrophication on sediment respiration and nitrogen cycling
- The effects of iron addition on phosphorous cycling in salt and freshwater ecosystems

KRISTIN GRIBBLE – Phytoplankton and zooplankton ecology, stress resistance, and life history

Many planktonic organisms have complex life cycles, including transitions between sexual and asexual reproduction, vegetative and dormant stages, and pelagic and benthic forms. Changing environmental conditions--including nutrient or chemical contamination, the presence of predators, or changing temperatures--can shift these life stage transitions and thereby alter population and community dynamics in coastal waters. Kristin has studied the ecology and evolution of harmful algal bloom species, and her lab currently uses rotifers as a model to understand how the genome and environment interact to determine fitness. Potential student projects include studies of:

· Harmful algal bloom ecology and life history strategy responses to anthropogenic nutrient contamination

· Impacts of combined environmental stressors--including temperature, eutrophication, pH, and chemical contaminants--on lifespan, health, reproduction, and gene expression in zooplankton.

KETIL KOOP-JAKOBSEN

Ketil Koop-Jakobsen's research centers around investigating the spatial and temporal dynamics of chemical gradients in soils and sediments and their significant role in ecosystem functions and services. His work spans various aquatic environments, including estuaries, marshes, ponds, and rice paddies. Several potential research projects aligned with his research interests are outlined below:

<u>Project 1: Unraveling Root-Sediment Interactions</u>. This project delves into the influence of aquatic plants on the surrounding chemical composition near their roots. The research uses state-of-the-art laboratory-based planar optode technology to visualize minute-scale alterations in O2, pH, and CO2 concentrations surrounding plant roots. The research project can be carried out on plants sourced from the Cape Cod Kettle ponds, which absorb CO2 for photosynthesis via their root systems, or salt marsh plants that release oxygen into the sediment.

<u>Project 2: Infauna-Sediment Interplay</u>. The interaction between infauna (organisms living within sediments) and sediment chemistry is explored in this project. The study uses advanced planar optode and microelectrode technology to image subtle variations in O2, pH, and CO2 levels in the vicinity of infauna burrows. The research project can be carried out on chironomids in beaver pond sediment, whose activity potentially affects methane fluxes, or on fiddler crabs in salt marshes, which may alter nutrient turnover.

<u>Project 3: Dynamics of Oxygen and H2S in Marsh Ponds</u>: Focusing on the expanding tidal ponds within salt marshes, this project addresses the intriguing dynamics of Oxygen and Sulfide concentrations. Despite the extreme levels of these compounds in pond water, the underlying biogeochemical changes remain relatively unexplored. The project employs microelectrode profiling of O2, pH, and H2S, allowing in-depth exploration of daily variations in these essential parameters.

Ketil Koop-Jakobsen's research underscores the intricate interplay of plants and animals and sediment chemistry in aquatic ecosystems and their profound implications for ecosystem functions. Through a series of meticulously designed projects, his work sheds light on the complex relationships that drive nutrient cycling, carbon sequestration, and other essential services within diverse aquatic habitats.

JAVIER LLORET – Nutrient inputs, pollution and climate change in estuaries / Ecology of estuarine plants and algae / Microplastics in the environment. Javier is interested in the biotic feedbacks that determine the response of marine organisms to excess nutrients and pollutants in estuarine ecosystems. He is also interested in how large-scale external drivers, including climate change, modulate that response. Possible projects related to this work could be:

· Forest land cover as a tool in estuarine water quality management –The goal of this project is to quantify the potential of forested land cover management to reduce nitrogen loads to sensitive coastal waters. We would examine historical and current nitrogen inputs to Cape Cod watersheds with different degrees of forest cover (high, intermediate, and low) and associated nitrogen retention.

· Algal carbon stable isotopes as indicators of coastal eutrophication – Coastal ecologists frequently use nitrogen stable isotopes to trace and monitor sources of anthropogenic nitrogen. When growing under nutrient-rich conditions, bloom-forming macroalgal species of the genus Ulva seem to display a very marked shift in carbon isotopic signatures, from relatively depleted values typical of marine macroalgae to heavier signatures that resemble those of C4 plants. To test this hypothesis we would survey Ulva specimens in different estuaries of Cape Cod subject to different nutrient loads, and characterize their isotopic signatures.

· Accumulation and effects of microplastics in estuarine organisms – The goal of this project is to quantify the effect of urbanization on microplastic accumulation in estuarine organisms, particularly mollusks. We could also examine whether differences in organisms' habitat preferences and feeding types plays a role in these accumulations. To test these hypotheses, we will collect specimens of different bivalves and gastropods in local estuaries subject to different levels of urbanization of the land, and extract and quantify microplastics found in their bodies. To test the effects of microplastic ingestion on the organisms' health we could conduct laboratory experiments in which we expose filter feeding bivalves to microplastics and determine particle ingestion/egestion rates, and potential effects on metabolic functions like respiration.

RUT PEDROSA PAMIES - Ecosystems health and emerging environmental pollutants in Cape Cod.

Chemical tracers:

- Trace ecosystem energy and carbon cycling, as well as the impact of anthropogenic factors, by analyzing lipid molecular (lipid biomarkers) and isotopic (d13C and d 15N) composition in coastal marsh suspended particles and surface sediments.
- Use of lipid biomarkers to evaluate marine ecosystem health, dynamics, and stress factors of fauna and flora.

Plastic pollution:

- Quantification and characterization of microplastic pollution in Cape Cod beaches and marshes. The presence of microplastics in marine environments is rapidly becoming of global concern, affecting both humans and other organisms.
- Characterization of biofilm formation on different plastic types.

Pharmaceuticals and personal care products (PPCPs) pollution:

- Investigation of the impact of PPCPs like triclosan, ibuprofen, estradiol, clofibric acid, etc. in different Cape Cod fauna and flora.
  Evaluation of PPCPs sorption in plastics.
- Studies the PPCPs affect bioaccumulation in the estuarine blue mussel

ED RASTETTER - Responses of Spartina and Typha marshes to elevated CO_2 and climate change.

Ed's research involves modeling the biogeochemistry of terrestrial ecosystems ranging from arctic tundra to tropical rain forest, from grasslands of the Great Plains to hardwood forest of New England. The proposed project would involve mining the Plum Island LTER data base for the data needed to calibrate an existing model, conducting field work to fill gaps in those data, making changes to the model to fit the characteristics of tidal marshes, and using the model to assess responses to elevated CO_2, climate warming, and changes in nutrient loading.

LORETTA ROBERSON - Ecophysiology and coral biology.

Loretta is interested in how organisms respond to changes in temperature, light, oxygen concentration, contaminants. Sensitive species like corals can become stressed if water temperatures change by only a few degrees, leading to bleaching or death, and can leave a record of the stress event in their calcium carbonate skeletons. However, despite being well studied, the underlying mechanisms of many aspects of coral biology and physiology are unknown (e.g., calcification, bleaching, larval settlement). Some possible projects related to corals include:

- The effects of temperature and/or hypoxia on coral growth
- Impact of symbionts and bioeroders on calcification
- Impact of seaweeds on coral growth and survivoship
- Cultivation of seaweeds for water quality improvement

EMIL RUFF – Microbial ecology and physiology

Emil works on the ecology and ecophysiology of microorganisms, their metabolisms and metabolites, and interactions with the environment. His research combines field experiments, lab cultivations, biogeochemical measurements, microscopy, multi-omics analyses and bioinformatics. He has three topics/projects that SES students can be involved in:

1. Effect of bioirrigation on methane removal from a wetland. Methane is a strong greenhouse gas, and its emission from wetlands is relevant for global change. In this project we study the effect of bioirrigation by Chironomid fly larvae on the methane cycle. First results show that the larvae change the wetland biogeochemistry by oxygenating the sediment through burrowing and bioirrigation. We show that the larvae's diet is likely based on methane, which suggests that the insect consume microbes involved in methane cycling. SES students could be involved in experiments and analyses aimed at understanding the methane fluxes, microbial metabolisms, and structure of the food web. Methods can include DNA extraction, -omics, bioinformatics, carbon stable isotope analyses, methane analyses, cell staining and microscopy. Field site: Beaver ponds at PIE-LTER, MA.

2. Blooms of anoxygenic sulfur-oxidizing phototrophs in a coastal lagoon. Emils's team has studied blooms of these phototrophs for many years and is using this lagoon as a model ecosystem to

understand the ecology, biogeochemistry and biomarkers of new lineages of anoxygenic phototrophs. Emil and colleagues showed that these phototrophs, which were considered strictly anaerobic, can thrive and bloom in the presence of oxygen. https://rdcu.be/diumD. SES students could be involved in follow-up projects investigating viruses in the phototrophic blooms, biogeochemical gradients, ecosystem engineering of the phototrophs and diel cycling within the bloom. Methods can include DNA extraction, -omics, bioinformatics, microsensor measurements, oxygen isotope analyses, biogeochemical rate measurements, cell staining, microscopy. Field site: Trunk River lagoon, MA.

3. Microbial production of oxygen in the absence of light. In a recent publication, Emil and colleagues showed that groundwater microbiomes harbor microbes that can produce oxygen independent of photosynthesis through a process called dismutation https://www.nature.com/articles/s41467-023-38523-4 The team now wants to understand how widespread this process is locally and globally and has received funding to study groundwater aquifers. SES students could be involved by sampling aquifers on Cape Cod and analyzing molecular oxygen and nitrogen compounds as well as searching for the key gene in the microbiome. Methods can involve analyses of oxygen and nitrogen concentrations, O + N stable isotope analyses, DNA extraction, -omics, PCR, target gene analyses, bioinformatics. Field site: Cape Cod, MA.

MIRTA TEICHBERG – Coastal ecology and physiology of marine macrophytes

- Understanding top-down and bottom-up pressures controlling seagrass communities under different environmental conditions
- Testing methods of seagrass restoration (e.g. field and lab experiments growing seagrass plants and seedlings under varying environmental conditions)
- Developing in vitro cultures of seagrasses from seeds under varying hormone treatments
- Environmental drivers of macroalgal growth and physiology
- Effects of plant traits on primary production and nutrient cycling

JOE VALLINO – Microbial biogeochemistry and structure of microbial communities

Joe's research involves understanding how microbial communities organize and function, as well as identifying fundamental rules that may govern them. His focus is on biogeochemistry but use of molecular approaches is sometimes possible with the help of collaborates at MBL or WHOI. He also makes extensive use of microcosms (chemostats, bioreactors, etc.) to study microbial processes in the lab under controlled conditions and uses Siders Pond as a local field site. Many of the possible projects below focus on Siders Pond, and WHOI installed a vertical profiler in the pond starting in 2023, data from which can be found here: https://www.siderspond.com/

· Methanotrophy versus sulfate reduction in the anaerobic zone of Siders Pond
· Importance of grazers (or viruses) in aerobic versus anaerobic zones (Siders Pond)
· Siders Pond chemical budgets: How much does the ocean contribute to Siders Pond biogeochemistry?
· How much hydrogen sulfide do anaerobic phototrophs remove from Siders Pond water column?
· Transcriptomics in Siders Pond shows high expression of arsenic detoxification genes. Is arsenic a problem in Siders Pond or is arsenic used for metabolism?
· Are microbial communities inherently unstable?
· Response of microbial communities to disturbance (e.g. grazing, disruption of nutrient or energy supply).

· How important is bacterial predation (protists or viruses) in microbial biogeochemistry?
· Tests of the Maximum Entropy Production (MEP) theory in microbial communities in microcosms or mesocosms, or in the field. MEP theory proposes system organize to dissipate energy and drives evolution.
· How adaptive are phytoplankton circadian clocks? How far can they be pushed from 24 hr cycles and still function correctly?