Marine Biological Laboratory | THE UNIVERSITY OF CHICAGO

The Ecosystems Center

Annual Report 2018–2019

About the MBL

The Marine Biological Laboratory (MBL) is dedicated to scientific discovery – exploring fundamental biology, understanding biodiversity and the environment, and informing the human condition through research and education. Founded in Woods Hole, Massachusetts, in 1888, the MBL is a private, nonprofit institution. In July 2013, the MBL and the University of Chicago formed an affiliation that enhances both institutions' missions of leadership and innovation in scientific research and education.

About The Ecosystems Center

Established in 1975, the Ecosystems Center operates as a collegial association of scientists. Its mission is to investigate the structure and functioning of ecological systems and to predict their response to changing environmental conditions; to apply the resulting knowledge to the preservation and management of natural resources; and to educate both future scientists and concerned citizens.

Editors

Rut Pedrosa Pamies
Javier Lloret
Kelsey Chenoweth

Front cover

The Great Sippewissett Marsh in Cape Cod, MA. Ecosystems Center scientists have been studying the site for over 50 years (Photo credit: Erin VanderJeugdt).

Back cover

Maureen Conte, Rut Pedrosa Pamies and R/V Atlantic Explorer crew deploying flotation on the Oceanic Flux Program mooring. Since 1978, the mooring has continuously measured particle fluxes in the deep Sargasso Sea (Photo credit: JC Weber).

This page

MBL scientists have studied arctic ecosystems through the Arctic Long Term Ecological Research site since 1975. The site operates out of Toolik Field Station on Alaska's North Slope (Photo credit: Anya Bashkirova).

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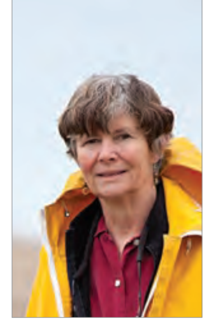
A message from the director



By Anne Giblin

At a recent scientific meeting, a group of "old timers" were reminiscing on our scientific careers when one of our group referred to us as "the eutrophication generation". Eutrophication is the input of excess nutrients into water bodies, which causes algal blooms and low oxygen levels (hypoxia). Certainly, when I reflect on my career, a great deal of it has been spent examining the impacts of coastal eutrophication.

Coastal eutrophication is a major issue worldwide, and one that is increasing. A global research organization, the World Resources Institute, maintains a growing data base of more than 500 coastal bays and estuaries which experience eutrophic conditions. A map of these sites covers the globe from Antarctica to Alaska. Locally, on Cape Cod and around Massachusetts, we see impairment of water quality from nutrient over-enrichment in nearly half of our estuarine embayments.

I have been fortunate to see some success stories. In the 1980s Boston Harbor was once considered to be one of the dirtiest Harbors in the country. Large inputs of wastewater, sewage sludge and industrial pollutants had led to major declines in water and sediment quality and compromised the health of fish and shellfish. However, in the 1990s Boston began a series of major improvements in sewage disposal that reduced nutrient and organic inputs by 80-90%. Scientists at the Ecosystems Center, along with many, many others, measured the changes in the harbor as inputs were reduced. The results were dramatic and improved water quality helped revitalize the waterfront area.

Unfortunately, added to the impacts of nutrients and other pollutants on coastal systems is climate change. The Intergovernmental Committee on Climate Change (IPCC) recently released a special report on Oceans and the Cyrosphere in a Changing Climate. The findings are sobering, although not surprising to those of us working on these issues. The report documents how the environmental changes predicted in previous IPCC reports, such as warming ocean temperatures, loss of ice, and accelerated rates of sea-level rise, are now being observed with high confidence. Even assuming future carbon emissions to the atmosphere peak close to current values, the report predicts we will see a rise in sea level globally by 1-2 feet by the turn of the century. If we pursue a high carbon dioxide economy, however, we see much greater losses of ice, sea water temperatures increasing by up to 5°F, and sea levels rising globally as much as 3-6 feet in 2100.

These changes in temperature and sea levels will have impacts in their own right, but they will also negatively interact with eutrophication in coastal areas. Warming water exacerbates hypoxia because warm water holds less oxygen than cold water. The consumption of oxygen by organisms will increase with increasing temperature. Increased respiration increases the amount of carbon dioxide in the water, which in turn lowers the pH, adding to local acidification. Rising sea levels threaten our coastal marshes and mangroves which currently absorb nutrients helping to protect coastal waters. Fortunately, the growing realization of the threat that rising sea level poses to our coastal cities and towns, and the loss of the important ecological and economic services they provide, has focused more attention on preserving coastal marshes and estuaries. As a result, the Ecosystems Center is launching a new initiative in coastal ecosystems ecology. The hiring of several new faculty will allow us to carry out collaborative, interdisciplinary studies on coastal estuaries, bays, marshes, and coastal watersheds across the globe. Look to next years' annual report for more information on this exciting program.

In this report we bring you stories on some of the other exciting research going on at the Center. Javier Lloret and Rut Pedrosa Pamies are examining the distribution of microplastics, a threat to the coastal zone which is just beginning to be fully recognized. Emil Ruff describes how microbial communities on the seafloor assemble to consume methane, work that provides a framework for understanding how these complex but important communities function. Zoe Cardon is exploring how we can learn how plants may respond to extreme climates by studying desert algae. Finally, David Kicklighter and Jerry Melillo are examining how carbon storage in a vast area of the earth may be impacted by nitrogen inputs from changing human activities and the degradation of permafrost. Their work is helping us understand the complex interactions between humans and the environment in a constantly and rapidly changing world.

Microplastic pollution in estuarine ecosystems

Microplastic particles found in sediment core samples collected in the salt marshes of Waquoit Bay, Cape Cod, MA (Photo Credit: Miriam Ritchie).

SINCE THE 1950S, GLOBAL PLASTIC PRODUCTION AND USE HAVE GROWN EXPONENTIALLY. Currently, we produce over 350 million tons of plastic worldwide in a year, 50% of which is for single-use purposes. A large fraction of these plastics enters the environment. It is estimated that, for each person in the world, 4 lbs of plastics are dumped annually into the oceans. There, they add to the estimated 165 million tons that already contaminate our marine ecosystems. Once in the ocean, plastics take a long time to degrade, and accumulate across the environment.

Microplastics, a subset of plastic debris smaller than 5 mm, some of them resulting from the fragmentation of larger plastic items, are ubiquitous in the marine environment. An increasing number of studies confirm the presence of microplastics in almost every single ecosystem of the Earth, from the ice caps in the Artic to the tropical shores of Caribbean islands; from the top of some of the highest mountains on Earth to the bottom of the world's oceans.

Due to their location between land and sea, estuaries and shallow bays are subject to the pressures and impacts originated by rapidly growing human populations that live near the coast. Microplastic contamination is just another one in the large list of man-made impacts on estuaries. However, very little is known about the extent of microplastic contamination in these coastal ecosystems, its sources, transport mechanisms, and its effects on estuarine biota. Do microplastics accumulate in the proximity of densely populated areas? What can we learn about sources and transport of microplastics by looking at their different types, shapes, sizes, and chemical compositions? As the land surrounding estuaries and coasts became increasingly urbanized over the course of recent decades, how did microplastics accumulate?

Ecosystems Center scientists Rut Pedrosa Pamies and Javier Lloret are trying to answer these and other important questions. They are bringing together their different expertise to build a new program to study microplastic pollution in the estuaries and marshes of Cape Cod and elsewhere. Students are a central part and have been involved in the various activities of the program since its inception. Pedrosa Pamies and Lloret have mentored several SES and summer undergraduate student projects on different aspects of microplastic contamination.

Their results show that, indeed, microplastics are everywhere. A large number of fragments, synthetic fibers, and other microplastic items tend to accumulate in estuarine sediments in the proximity of densely populated areas, but they are also present in areas far from the direct influence of humans, highlighting the effective transport of these materials in the environment. Furthermore, their results show that microplastics have been accumulating in salt marsh sediments over the course of several decades, since mass production and use of plastics started, and following the parallel increase in development and urbanization of Cape Cod shores.

All countries in the world have to acknowledge microplastic pollution, because it is a worldwide problem. As to the policy makers, stakeholders, managers, and society in general, actions must be taken according to an improved understanding of the distribution and effects of microplastics in the environment. This program and its activities aim to address this need and shed some light on this increasingly important pollution issue.

Top: Semester in Environmental Science (SES) student Claire McGuire collecting sediment cores to quantify microplastic abundances in the salt marshes of Waquoit Bay for the first time (Photo Credit: Rut Pedrosa Pamies).

Bottom: Abundant plastic debris can be found on the surface of sediments of salt marshes in highly populated areas like New Bedford, MA in the photo (Photo Credit: Miriam Ritchie).

Methane munchers of the deep sea

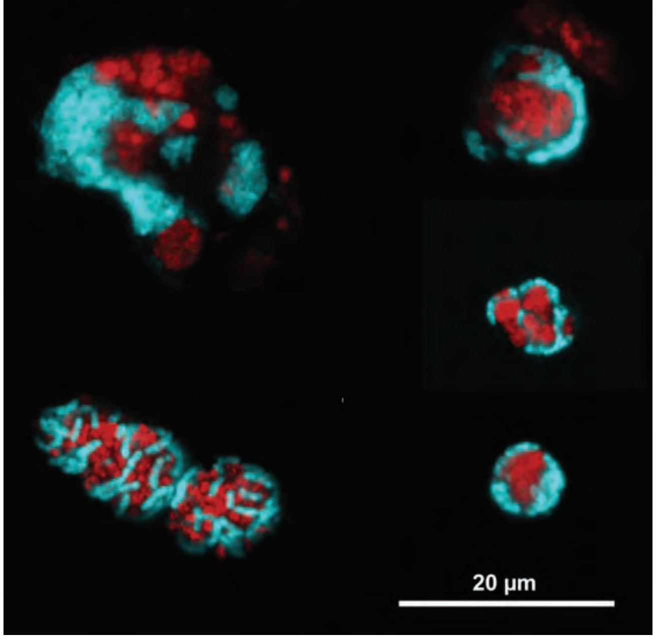
VERY LARGE QUANTITIES OF THE GREENHOUSE GAS METHANE ARE STORED IN THE SEAFLOOR WITH THE LATEST ESTIMATES AGREEING ON MORE THAN ONE TRILLION TONS OF METHANE. Fortunately, only a small fraction of the stored methane escapes the seabed, and an even smaller fraction reaches the atmosphere, where it acts as a climate-relevant gas. Most of the methane is degraded within the sediment. This degradation is carried out by a specialized community of microbes, which removes up to 90% of the escaping methane. Thus, these microbes are often referred to as the "microbial methane filter". If the greenhouse gas were to rise through the water and into the atmosphere, it could have a significant impact on our climate.

It is estimated that around 60 million tons of methane are removed annually by methane-munching microbes of the seafloor around the globe. Over the last 20 years, research has provided many insights into the functioning of these ecosystems, their impact on the global carbon cycle, and their role as oases of diversity in the deep sea. An unresolved question was concerning the time scale these ecosystems needed to develop in the permanently cold and dark deep sea. Emil Ruff, Assistant Scientist at the Ecosystems Center and his colleagues from the Max Planck Institute for Marine Microbiology and the University of Bremen in Germany aimed to answer this question using a long-term observatory deployed at such a methane-fueled ecosystem in the Arctic Ocean.

Between Norway and Svalbard at 1250 meters water depth lies the Håkon Mosby mud volcano (HMMV). Marine mud volcanoes are mainly driven by mud rising from deep sediment layers due to differences in buoyancy, not due to magmatic activity like their lava-spitting namesakes. In mud volcanoes the fluidized mud rises slowly to the seafloor due to slight differences in density and temperature compared to the surrounding sediment. In the case of HMMV the mud originates at approximately three kilometers depth below the seafloor; the structure has been erupting for at least 30,000 years. The subsurface-derived muds are enriched in reduced chemical compounds such as methane. These can be used by microorganisms as an energy source. The microorganisms in turn produce other compounds that can be used by yet other organisms, forming a complex food web. These so-called chemosynthetic

Ruff on his way to the seafloor to take samples for his work on deep-sea ecosystems. The submersible *Alvin* is operated by the Woods Hole Oceanographic Institution and has taken hundreds of marine researchers to unchartered landscapes and enigmatic ecosystems for more than four decades (Photo credit: Alexander Epp).

Methane-munching symbiotic consortia of anaerobic methane-oxidizing archaea (red) and sulfate-reducing bacteria (cyan). Each individual microbe is only about 1 micrometer in size. Together they achieve the almost impossible – the anaerobic oxidation of methane – an energy metabolism that is close to the thermodynamic limit of life. Because the energy yield is so low, they consume a lot of methane in deep-sea sediments; tiny creatures that because of their abundance and activity have a globally relevant influence on Earth's carboncycle (Photo credit: Hanna Kuhfuss/Emil Ruff).



ecosystems evolved independent of sunlight, which is the ultimate energy source for most ecosystems on Earth's surface.

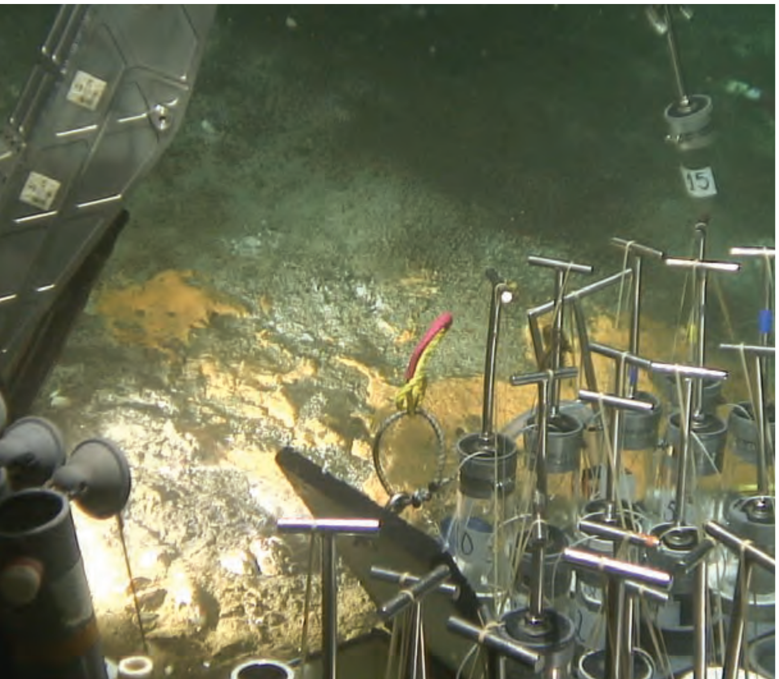
In a long-term experiment, Ruff and his colleagues were able to film eruptions of the mud volcano, take samples, and examine them in detail. Freshly erupted muds contained very few microorganisms. The longer the mud was exposed to the conditions at the seafloor, the more life it contained. Within a few years after the eruption, the number of microorganisms as well as their diversity increased tenfold. Also, the metabolic activity of the microbial community increased significantly over time. While there were methane consumers even in the fresh mud, efficient filtering of the greenhouse gas seems to require more complex communities that took many years to develop.

The large time scale necessary for the development of these ecosystems implies that these habitats need to be protected. If the methane-munchers are to continue to help remove methane, then we must not destroy their habitats with bottom trawling and deep-sea mining. These habitats are almost like a rainforest—they take decades to grow back after a disturbance.

Currently, Ruff and his team are trying to understand which microorganisms are eating the methane munchers. Methane-consuming microbes are turning methane into energy and biomass, producing new microbial cells. Just like any other organism, microbial cells eventually die, bursting the cells' interiors into the environment. The released cellular building blocks—proteins, sugars, lipids and fatty acids—become available to an illustrious community of microorganisms, some of which are specialized on the degradation of specific cellular building blocks. These microorganisms represent an understudied link in the complex food web at methane seeps and hence merit further research.

Left: Sampling of a bacterial mat (orange) growing at a methane seep as seen from the inside of *Alvin*. The bottles on the left are for water sampling, the acrylic tubes on the right are for sediment samples. T-handles are needed so that *Alvin*'s robotic arm is able to grab the tubes and take samples (Photo credit: Emil Ruff/WHOI).

Right: *Lamellibrachia* tubeworms within the family *Siboglinidae* grow in dense patches and can live for centuries. They lack a mouth and gut and are dependent on nutrition provided by sulfur-oxidizing endosymbionts (Photo credit: Andreas Teske/WHOI).

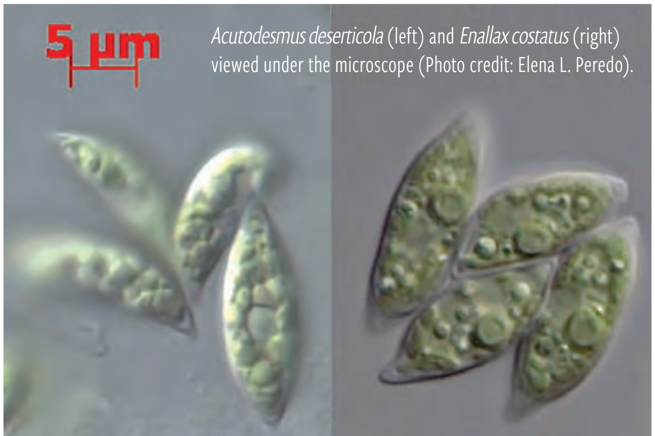


Dried out but not dead!

IMAGINE GREEN ALGAE. PROBABLY A POND WITH GREEN WATER COMES TO MIND, OR PERHAPS A LAB FLASK FILLED WITH BUBBLING GREEN LIQUID. What probably does not come to mind is dry desert soil and sand dunes. But green algae of many types live in very dry environments, and there is a lot to learn from them. Some of these algae are as small as five microns (two ten-thousandths of an inch!) in size, and their entire body is just one cell. They are common community members in the living "microbiotic" crusts found on soils in arid areas world-wide. These soil crusts provide critical ecosystem services, binding soil grains and organisms together in layers strong enough to protect the soil from wind and rain erosion. And in some places, algae in the crusts even eke out a living where larger plants can't, providing a base of "plant" productivity where otherwise there would be none.

Cardon has been studying these tiny, green, photosynthetic powerhouses for nearly two decades, trying to understand how they survive the extreme drought of deserts in the southwestern US. Most familiar larger plants die if they dry out completely, but algae in microbiotic crusts can dry to the point of appearing like dust yet they are not dead! Cardon and colleagues Elena L. Peredo, Magdalena Bezanilla (Dartmouth), Alice Dohnalkova (PNNL), and SES student Hannah Gershone recently showed in the *Journal of Cell Science* that when hit by a raindrop, dried algae bounce back into operation and can be photosynthesizing in seconds, taking advantage of precious water when it is available. This resilience is particularly remarkable given that the physiology of these single-celled green algae is very similar to the physiology in the individual cells inside leaves of larger plants; in fact larger plants are all thought to have evolved from green algae. But when leaves dry out, they die. When these algae dry out, they are just waiting for rain. How are these simple, single-celled, desert-dwelling algae so resilient in the face of drought?

L. Peredo thinks one surprising part of the answer may be what the desert-dwelling algae don't do. By studying desiccation tolerant as well as desiccation intolerant algae



Acutodesmus deserticola (left) and *Enallax costatus* (right) viewed under the microscope (Photo credit: Elena L. Peredo).

On the Provincetown dunes at Cape Cod National Seashore (CCNS), green algae form a microbiotic crust on sand between grasses (Photo credit: Claire K Lunch).

that are closely related, she and Cardon recently showed in the *Proceedings of the National Academy of Sciences* (https://doi.org/10.1073/pnas.1906904117) that two desert green algae (*Acutodesmus deserticola* and *Fletchnaria rotunda*) increase the expression of genes that code for special proteins and other protective compounds as they dry out. But, surprisingly, their aquatic relative *Enallax costatus* does too, even though it is not desiccation tolerant and dies once dry. The key difference may be that desert algae do something more: as they dry out, they also ramp down the expression of genes coding for many other basic processes in their cells, seemingly putting the brakes on their metabolism. Their aquatic relative does not. Given that climate change is expected to shift patterns of soil drought and precipitation in much of the US, there is great interest in learning from the desiccation tolerance strategies that have evolved naturally in desert-dwelling organisms, and perhaps even in deploying some of those strategies in crops for the future. Certainly identifying protective compounds is vital. But L. Peredo and Cardon's results suggest that it may be just as important to figure out how desert-dwelling green algae coordinate and calmly ramp down a large swath of their gene expression, leaving them dried out, but very much alive.

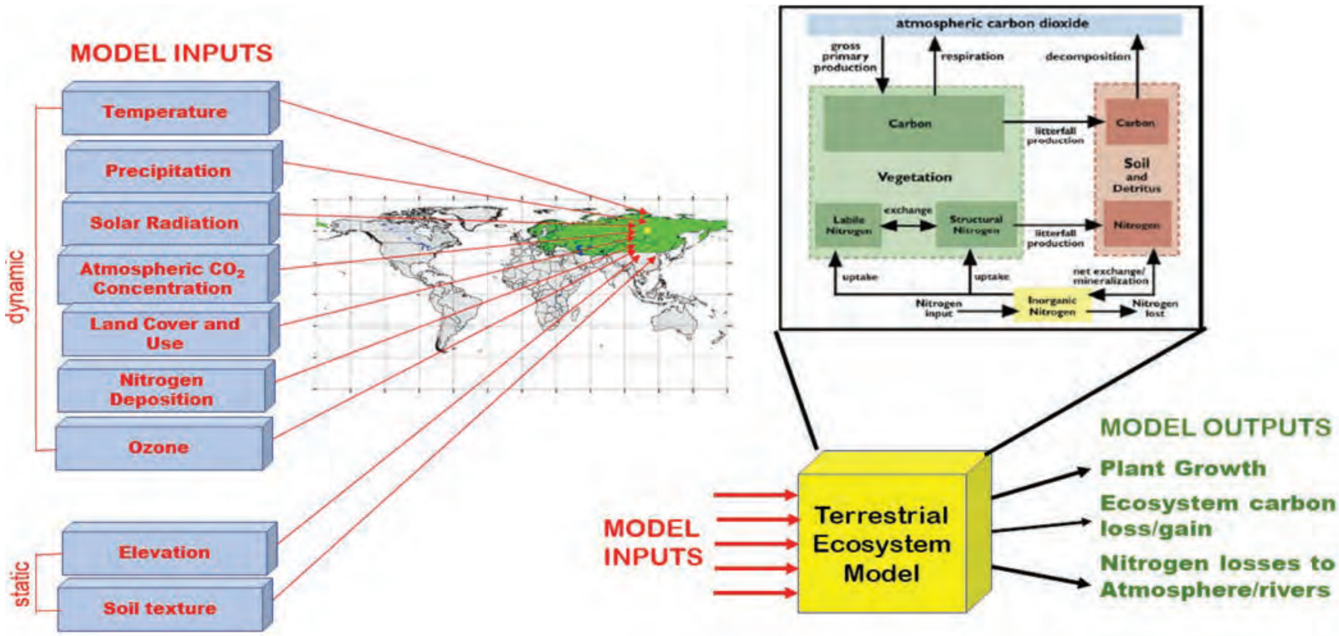
Sandy landscape at CCNS near Marconi Station (Photo credit: Zoe G Cardon). Inset: Elena L. Peredo readying tiny drops of cultured green algae for desiccation experiments (Photo credit: Suzanne Thomas).

Nitrogen controls on future carbon sequestration in Northern Eurasia

Ecosystems Center Scientists David Kicklighter and Jerry Melillo have collaborated in a large number of projects for the last 32 years. Their interests focus on the impacts of climate change and human activities on regional carbon-nitrogen interactions and associated effects on land carbon sequestration in regions across the globe.

NORTHERN EURASIA PLAYS A SIGNIFICANT ROLE IN THE PLANET'S CARBON CYCLE. This region includes roughly 70% of the Earth's boreal forests and more than two-thirds of the earth's permafrost, the perennially frozen ground found in cold climates that holds substantial amounts of carbon. The availability of soil inorganic nitrogen is a critical controller of plant productivity and carbon sequestration in the forests of Northern Eurasia. However, nitrogen availability in forests has been altered by human activities such as: 1) the enhanced atmospheric nitrogen deposition from fossil fuel combustion and ammonia emissions from the application of nitrogen fertilizers to croplands; 2) the release of nitrogen from the decomposition of organic matter on abandoned agricultural land (both fertilized and unfertilized); and 3) the release of nitrogen from the decomposition of organic matter exposed by climate change-induced permafrost degradation. Understanding the future availability of nitrogen and its effect on carbon sequestration in Northern Eurasia is key to developing more effective regional and sub-regional strategies for addressing global change (climate and land-use change) impacts and promoting carbon sequestration in land ecosystems.

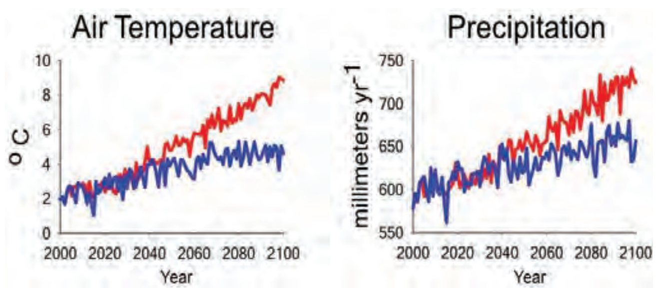
In a new study published in *Nature Communications*, Kicklighter and Melillo collaborated with scientists at the University of California-Davis, MIT, and Purdue University to explore how changes in nitrogen availability associated with atmospheric nitrogen deposition, the abandonment of agricultural land to forest regrowth, and permafrost degradation influence carbon storage in the region's forest vegetation over the 21st century. They used a numerical model that explicitly considers basic ecosystem functions, such as photosynthesis and soil organic matter decay, to simulate land carbon-nitrogen-water interactions under two different scenarios of global change. The Terrestrial Ecosystem Model (TEM) is driven by spatially referenced information on climate, atmospheric chemistry, elevation, soils, and land cover to estimate the influence of multiple factors such as carbon dioxide fertilization, climate change and variability, permafrost degradation, land-use change, ozone pollution, and atmospheric nitrogen deposition on land carbon, nitrogen, and water dynamics. The global change scenarios are based on two emission scenarios developed for the Intergovernmental Panel on Climate Change (IPCC): a rising greenhouse gas emissions scenario (Representative Concentration Pathway or RCP8.5) that leads to substantial warming and a climate stabilization scenario (RCP4.5) that leads to modest warming. Projected future climate changes associated with each scenario were estimated by the MIT Earth System Model.



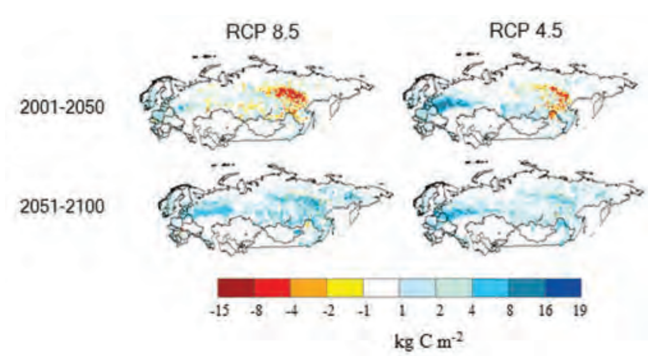
Application of the Terrestrial Ecosystem Model to gridded data within a region, like Northern Eurasia (green area), allows scientists to relate temporal changes in the spatial patterns of environmental controls (e.g. climate, atmospheric chemistry, land use) to those of plant growth, land carbon sequestration or loss, and nitrogen losses to rivers and the atmosphere.

The study shows that enhanced nitrogen availability resulting from human activities and permafrost degradation increases carbon sequestration in forest vegetation and accounts for 30-50% of the future net carbon sinks estimated for Northern Eurasia. Under the high emissions scenario, which includes substantial forest harvesting, enhanced nitrogen availability increases carbon storage in trees by 13.4 Pg C, mainly caused by permafrost degradation. In contrast, under the low emissions scenario, which includes climate mitigation and forest restoration efforts, enhanced nitrogen availability increases tree carbon storage by 27.8 Pg C or double that under the high emissions scenario. In this second scenario, the main driver is the abandonment of agricultural land to forest regrowth. The study reveals complex patterns in how the distribution of land carbon sources and sinks across the region evolve over time, highlighting the interactions among climate change, land-use change, and the carbon cycle.

This study provides new insight into the role of human activity on future nitrogen availability and its influence on carbon sequestration in Northern Eurasia forests. It further highlights the importance of accounting for carbon-nitrogen interactions when assessing the regional and sub-regional impacts of climate and land-use change policies.



Projected changes in mean annual air temperature and annual precipitation under the RCP8.5 (red line) and RCP4.5 (blue line) scenarios during the 21st century for Northern Eurasia. (From Figure 2 in Kicklighter et al. 2019)



Changes in the distribution of carbon sequestration and loss in forests across Northern Eurasia under the IPCC RCP8.5 and RCP4.5 global change scenarios during the first half (2001-2050) and second half (2051-2100) of the 21st century. (From Figure 8 in Kicklighter et al. 2019).

Semester in Environmental Science

What is the microplastic content in Cape Cod beaches and how is it distributed across tidal zones?

What can carbon and nitrogen stable isotopes tell us about the diet and physiology of the endangered Kemp's Ridley sea turtles?

How does urbanization affect nitrogen supply and the symbiotic relationship between oak trees and ectomycorrhizal fungi?

Is phosphorus or nitrogen limiting to phytoplankton growth in estuaries receiving high inputs of wastewater derived nutrients?

THESE ARE SOME OF THE QUESTIONS THAT STUDENTS IN THE SEMESTER IN ENVIRONMENTAL SCIENCE (SES) ADDRESSED DURING THEIR SIX-WEEK INDEPENDENT RESEARCH PROJECTS IN 2018.

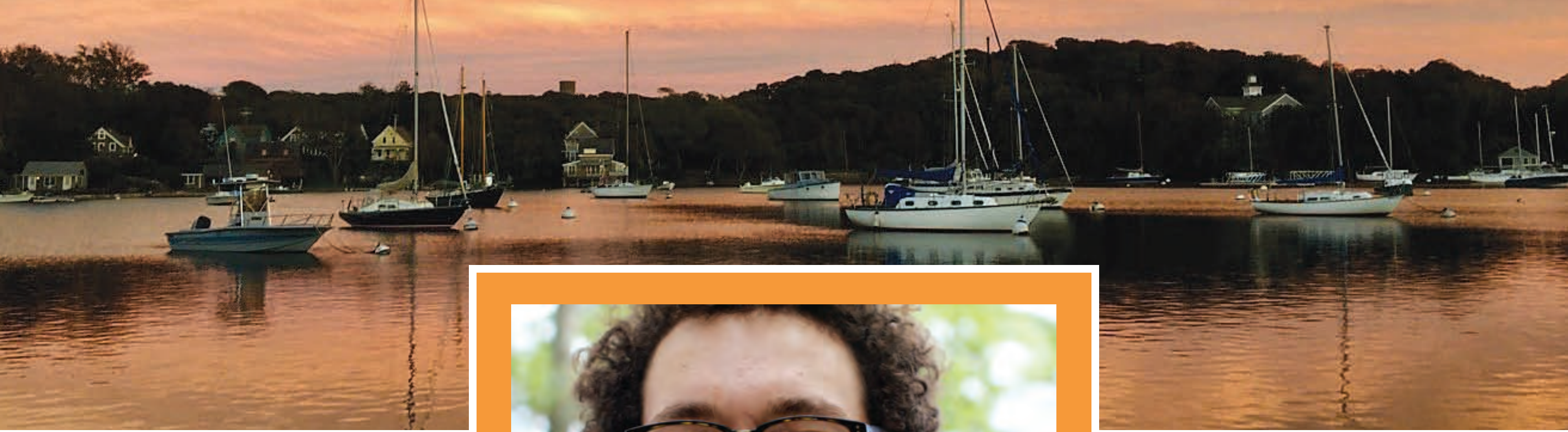
Since 1997, 384 students from more than 65 colleges and universities around the nation have completed the SES program. Nearly three-quarters of these students go on to earn advanced degrees in fields related to ecosystems science, environmental engineering, policy, public health, and environmental management.

During the Fall of 2018, twenty-four students from seventeen different colleges and universities participated in the program, including our first student from Lynchburg College.

All completed ten-week long core courses in Terrestrial and Aquatic Ecosystems Analysis that emphasized issues in global change, while teaching students how to collect and interpret data in coastal ponds, estuaries, marshes, forests, and unique sandplain grassland ecosystems on Cape Cod. Students also deepened their understanding of either Mathematical Modeling of Ecosystems or Microbial Methods in Ecology in their chosen elective course.

About midway through the semester, students developed a research proposal and worked with one of the dozen lead faculty instructors teaching the program. After formal coursework ended, students pursued these independent research projects full-time in the last five weeks of the program, and reported on their results during a formal symposium held at the end of the semester (see: https://www.mbl.edu/ses/videos/).

One of the unique and exceptional aspects of the SES Program is the chance for alumni to return after the semester to work with SES faculty as research interns, teaching assistants, or research assistants. About one in five SES alumni pursue such opportunities in Woods Hole after graduating from college. During 2018: Ruby An (SES 2015, University of Chicago) returned to the Toolik Lake Arctic LTER site on the North Slope of Alaska for the third summer to work as the Terrestrial Research Assistant for Dr. Laura Gough, who was also a post doc at the Ecosystems Center before becoming a PI and Professor. Abby Rec (SES 2018, Gettysburg College) was awarded an NSF REU internship working for the Streams Group under the guidance of Dr. Breck Bowden, Co-PI on the Toolik LTER and a professor at University of Vermont (UVM). Abby will be expanding on the work she started as a doctoral student at UVM in 2019. Sarah Messenger (SES 2016 and SES Teaching Assistant 2018, Trinity College) joined the Ecosystems Center staff full-time as the research assistant on the Lake Warming Experiment at Toolik and spent her first summer in the Arctic. In the photo, from left to right: Ruby An, Abigail Rec and Sarah Messenger.



"SES got me a job opportunity in my desired field directly out of college. The agricultural research I conducted as part of the program taught me techniques for sampling, sharing data, and integrating my work with an independent agricultural research organization—The Hudson Carbon Project. This relationship evolved into a unique and fulfilling full-time job. I look back to past SES labs and data analysis for direct insight into the experimental design I work with today. SES enabled me to develop relevant scientific skills, form incredible friendships, and explore an oceanic landscape. There are incredible opportunities awaiting students who challenge themselves in the SES program."—MIKE HOWARD (SES CLASS OF 2018, CLARKSON UNIVERSITY 2019)

Education Highlights

RESEARCH EXPERIENCE FOR UNDERGRADUATES (REU) AND UNDERGRADUATE SUMMER FELLOWS

Student	Institution	Project	Mentors
Claire Valva	University of Chicago, Metcalf	Nitrogen load regime change: Changes in atmospheric deposition drive trajectory of nitrogen loads in Buzzards Bay estuaries.	Ivan Valiela Javier Lloret Daniella Hanacek Kelsey Chenoweth
Paige Torres	Brown University, LINK Program	Stable isotope signatures of macrophytes as indicators of N loads & sources, and photosynthetic pathways in estuaries of Waquoit Bay, MA.	Ivan Valiela Javier Lloret Daniella Hanacek Kelsey Chenoweth
Abigail Rec	University of Vermont, REU	Arctic stream nutrient limitation and nutrient spatial variation: insight from nutrient diffusing substrata bioassay in nine Arctic stream systems	Ed Rastetter Breck Bowden
Daison Weedop	Utah State University, REU	Beyond the lake: Fish movement in open aquatic ecosystems	Ed Rastetter Phaedra Budy
Emily DeFilippis	The New School, REU	Seasonality in lipid biomarker composition of suspended and sinking particles in the Sargasso Sea	Maureen Conte JC Weber Rut Pedrosa Pamies
Marianna Karagiannis	University of Chicago, Metcalf	Stable carbon isotopic composition of deep ocean suspended particles for assessment of lipid biosynthesis by piezophilic microbes	Maureen Conte JC Weber Rut Pedrosa Pamies
Allison Palmer	Hobart and William Smith Colleges	Methods in microbial ecology	Sherlynette Pérez Castro Kathleen Regan Emil Ruff
Rohan Kremer Guha	University of Chicago	Anaerobic salt marsh microbial consortia remain stable over time when exposed to high nitrate concentrations	Ashley Bulseco Joe Vineis Jen Bowen Joe Vallino

RECENT DOCTORAL RECIPIENTS

Ashley Bulseco, PhD. Northeastern University. "The role of nitrate in salt marsh sediment organic matter decomposition" | **Anne Giblin** co-advised with Jennifer Bowen

Tori Gray, MSci, University of Massachusetts, School for Marine Science and Technology. "Environmental controls on *Heliconoides inflatus* and *Styliola subula* pteropod shell flux and isotopic composition in the Sargasso Sea" | **Maureen Conte**

Nathalie Steiger, MSci, University of Massachusetts School for Marine Science and Technology. "Seasonal and intra-annual variability in shell chemistry of planktonic foraminifera *Globigerinoides ruber* (white) morphotypes in the Sargasso Sea" | **Maureen Conte**

Brooke Osborne, PhD. Brown University. "Abiotic and biotic controls of nitrogen cycling in a lowland tropical rainforest" (PhD advisor Dr. Stephen Porder) | **Zoe Cardon**, Committee member

Left: Claire Valva (Left) and Paige Torres (right) during fieldwork in Sage Lot Pond (Photo credit: Kelsey Chenoweth). Right: Ashley Bulseco (center) with co-advisors Jennifer Bowen (left) and Anne Giblin (right) (Photo credit: Jane Tucker).

Top, left to right: Javier Lloret and several journalists from the Logan Science Journalism Program doing sampling in Waquoit Bay (Photo credit: Rich McHorney). Logan Science Journalism fellows analyzing water samples in the lab (Photo Credit: Olga Dobrovidova). Anne Giblin assisting Logan Science Journalism fellows with the collection of groundwater samples (Photo Credit: Olga Dobrovidova). Bottom, left to right: 2019 Logan Science Journalism Program fellows and faculty (Photo Credit: Tom Kleindinst). Metcalf student Marianna Karagiannis prepares lipid extracts from suspended particles from the Sargasso Sea (Photo credit: JC Weber). Summer intern Allison Palmer processing samples for microbial community analyses (Photo credit: Sherlynette Pérez Castro).

CURRENT GRADUATE STUDENTS

Student	Institution	Ecosystems Scientist
Rachel Presley	University of Maine	Anne Giblin. Committee Member
Kiran Upreti	Louisiana State University	Anne Giblin. Committee Member
Sarah Foster	Boston University	Anne Giblin. Committee Member
Kenneth Czapla	Virginia Institute of Marine Science	Anne Giblin. Committee Member
Joseph Vineis	Northeastern University	Zoe Cardon. Committee Member

WOODS HOLE SCIENCE & TECHNOLOGY EDUCATION PARTNERSHIP

Ecosystem Center scientists continue to play an active role in WHSTEP, a network consisting of members from nearby science institutions and regional school districts. **Ed Rastetter** presented a lecture, while **Anne Giblin**, **Elena L. Peredo**, **Maureen Conte**, **JC Weber** and **Rut Pedrosa Pamies** took part in the Annual WHSTEP Liaison Dinner on November 7th, 2018 in Woods Hole, Massachusetts where the theme was "Women in Science". **Maureen Conte** and **Rut Pedrosa Pamies** participated in WHSTEP Family Science Night, and **JC Weber** participated in the WHSTEP Science Fair mentoring program (Falmouth's Lawrence School) helping students refine science fair project ideas.

MBL LOGAN SCIENCE JOURNALISM PROGRAM

Anne Giblin, **Javier Lloret**, and **Rich McHorney** co-taught the 2019 Logan Science Journalism Program, Marine Biological Laboratory, Woods Hole, MA. Other Ecosystems Center scientists were involved by leading the guided lab tour that focused on invasive species (**Elena L. Peredo**) and giving presentations (**Emil Ruff** "Microbial life in the deep biosphere", **Zoe Cardon** and **Elena L. Peredo** "Microbiome Deep Dive").

HIGH SCHOOL STUDENTS

Maureen Conte, **JC Weber**, and **Rut Pedrosa Pamies** hosted three high school students as lab assistants during the summer of 2018 from Mashpee High School: Jack Daigneault, Geovanna Pereira and Deshawn Adler. In the spring of 2019, they had a student from Falmouth Academy, Maya Peterson, work as a high school lab assistant. **Sherlynette Pérez Castro** worked with two Falmouth High School students (Melissa Ham and Alley Rivera) on their Science Fair project.

COMMUNITY INVOLVEMENT

- **Anne Giblin** is chair of the Gulf of Maine Institute board, a non-profit working with youth on environmental stewardship.
- **Ed Rastetter** brought three K-12 teachers to present at the Arctic LTER site review: Amanda Morroson, Fort Collins CO; Mary Richmond, Fort Collins, CO; and Catherine Kershner, Fairbanks, AK.
- **Maureen Conte** is Vice-President of the Sippewissett Association and a volunteer Baywatcher with the Buzzards Bay Coalition.
- **Jane Tucker** is a volunteer editor for the Gulf of Maine Institute online journal.
- **JC Weber** is a board member and Chair of the outreach committee of the Wareham Land Trust. JC is also a volunteer Baywatcher for the Buzzards Bay Coalition.
- **Rut Pedrosa Pamies** and **Marshall Otter** are volunteer Baywatchers with the Buzzards Bay Coalition.
- **Hap Garritt** is a part of the Northeast Coastal Acidification Network (NECAN), Shell Day
- **Kathleen Regan** is a member of the Bourne Recycling Committee and Friends of the Bourne Rail Trail

SCIENCE OUTREACH

Marshall Otter, Bonnie Kwaitkowski, Sherlynette Pérez Castro and **Hap Garritt** volunteered as judges and/or mentors to students during the Falmouth High School Science and Engineering Fair, the Lawrence School Science Fair, the Falmouth Academy Science Fair and the Massachusetts State School Science and Engineering Fair.

Anne Giblin, Rich McHorney, Maureen Conte, Jane Tucker, Rut Pedrosa Pamies and **Emily DeFelippis** participated in the Woods Hole Science Stroll, representing the Ecosystems Center.

Maureen Conte presented an invited public lecture "A Changing Climate, A Changing Ocean" at the Maria Mitchell Association's Science Speaker Series on Nantucket.

Elena L. Peredo was an invited poster reviewer for the 9th Annual MBL Undergraduate Research Symposium Program Biological Discovery in Woods Hole REU. She was also invited to present "Invite a scientist to lunch" as part of the activities of the MBL Undergraduate Research Program Biological Discovery in Woods Hole REU.

Emil Ruff lectured at the Microbial Diversity Summer Course.

Maureen Conte, Rut Pedrosa Pamies and **JC Weber** contributed to the middle school science textbook from Christy Peterson "Into the Deep: Science, Technology, and the Quest to Protect the Ocean" (Lerner Publications).

Jim Tang gave a seminar to the general public: "What can tea bags in salt marshes tell us about climate change?" The Waquoit Bay Reserve, MA.

Top to bottom: SES students collecting algae in local estuaries (Photo credit: Elena L. Peredo). Rich McHorney at the Woods Hole Science Stroll (Photo credit: Rut Pedrosa Pamies). Anne Giblin speaking at the PIE LTER open house (Photo credit: Jane Tucker). Waquoit Bay (Photo credit: Javier Lloret).

News 2018-2019

Daniella Hanacek sampling in Childs River to analyze water quality in the larger Waquoit Bay estuarine system. (Photo credit: Kelsey Chenoweth)

CURRENT OFFICES, BOARDS AND COMMITTEES

Anne Giblin: Is part of STEAC, an advisory committee for NSF-NEON; serves on the Scientific Advisory Panel of the Buzzards Bay Coalition; and is chair of the board of the Gulf of Maine Institute.

Jerry Melillo: Serves on several National Academy of Sciences Committees: Gulf Research Program (chair); US Global Change Research Program; US National Member Organization for IIASA; Board on International Scientific Organizations. US Department of Energy Committee: Biological and Environmental Research Advisory Committee

Ivan Valiela: Serves on the Steering Committee, EPA South East New England Program; Matrix Review Committee, Cape Cod Commission; Scientific Review Committee, Waquoit Bay National Estuarine Research Reserve (NOAA); Advisory Committee for the State of the Waters. Cape Cod Project, Association to Preserve Cape Cod.

Zoe Cardon: Is part of the U.S. Department of Energy triennial review panel, Oak Ridge National Laboratory TES SFA.

Jim Tang: Serves on the National Academies of Sciences, Engineering, and Medicine's Committee on Developing a Research Agenda for Carbon Dioxide Removal and Reliable Sequestration; Steering Committee, The Coastal Carbon Research Coordination Network (CCRCN); National Ecological Observatory Network (NEON) Technical Working Group for Biogeochemistry; Working group member, the UNEP International Nitrogen Management System (INMS) Activity 1.3: Development of Methodology for N Fluxes and Distribution.

Maureen Conte: Is chairperson of the National Science Foundation's Science Oversight Committee for the Regional Class Research Vessel construction project.

Javier Lloret: Is a member of the Advisory Committee for the State of the Waters: Cape Cod Project, Association to Preserve Cape Cod.

Jane Tucker: Serves as the Plum Island Ecosystems-LTER representative on the Great Marsh Coalition.

David Kicklighter: Serves on the Department of Energy Review Panel.

Hap Garritt: Represented the Plum Island Ecosystems LTER at the LTER Information Management Committee.

SEMINARS, CONFERENCES, COURSES & WORKSHOPS

Anne Giblin: Presented a workshop for teacher training at the Gulf of Maine Institute.

Ed Rastetter: Gave a Seminar at Harvard Forest; Workshop on Cross biome comparison of biogeochemical cycles, Santa Barbara, CA; LTER All-Scientists Meeting, Pacific Grove, CA; Gave talk at the Toolik All-Scientists Meeting; remote link Arctic LTER annual meeting, Woods Hole, MA.

Zoe Cardon: Gave a seminar at Northern Arizona University, Department of Biological Sciences Seminar Series, "Ebb and flow in soil down below - Hydraulic redistribution and rhizosphere resource exchange." Invited keynote speaker, Goldschmidt Conference, session 12d "Interactions between Soil and Biota as Controls on Ecosystem Function from Canopy to Rhizosphere", Geochemical Society and the European Association of Geochemistry, Boston, MA. Invited speaker, Goldschmidt Conference, session 12f "Identifying and Modeling Mechanistic Drivers of Elemental Cycles Across the Critical Zone", Geochemical Society and the European Association of Geochemistry, Boston, MA.

Elena L. Peredo: Gave a talk at the SICB 2019 Integrative Plant Biology Symposium - Division of Integrative Plant Biology, Tampa, FL.

Emil Ruff: Gave an invited talk at the Deep Life Community Meeting, Shangai, China.

UNIVERSITY OF CHICAGO SEMINARS AND MEETINGS

Anne Giblin: Participated in a workshop with the Microbiome Center

Zoe Cardon: Presented at the Microbiome Center retreat "Microbial Communities to Mitigate Climate Change" University of Chicago. "Microbiomes Across Environments" course, guest lecture "Dried out but not dead! Hints from desert green algae about the evolution of desiccation tolerance among green plants."

Joseph Vallino: Was nominated to the University of Chicago Consortium for Advanced Science and Engineering (CASE) as a University of Chicago Senior Scientist At-Large.

Jim Tang: Serves on the University of Chicago Faculty Committee on Environmental and Energy Science and Technology.

Sherlynette Pérez Castro: Presented at the Microbiome Research Symposium - The Microbiome Center, University of Chicago.

SERVICE TO THE MARINE BIOLOGICAL LABORATORY

Joseph Vallino: Honored for 25 years of employment at MBL.

Ed Rastetter: Is part of the MBL Science Council.

Zoe Cardon: Serves on several MBL-Wide Committees: MBL Science Council; Imaging Initiative Committee; Search Committee, Bay Paul Center faculty search; Biosafety Committee; Friday Evening Seminar Series planning committee; Co-Organizer and webmaster of the weekly MBL "MicroEco" discussion group. Ecosystems Center Committees: Stable Isotope Committee; Head, Facilities Committee; Manager, MBL Research Greenhouse.

Elena L. Peredo: Was an invited speaker at the Bay Paul Center Seminar (MBL), "Genetic adaptations during habitat transitions in photosynthetic organisms."

ECOSYSTEMS CENTER IN THE NEWS & MEDIA PRODUCTIONS

Anne Giblin: Became a Sustaining Fellow of the Association for the Sciences of Limnology and Oceanography.

Jerry Melillo: Attended a gathering at Harvard Forest in central Massachusetts to mark the 30th anniversary of the forest's designation as a Long Term Ecological Research site (LTER) by the National Science Foundation. Featured in the Harvard Gazzette and in Experience Magazine.

Jerry Melillo, Anne Giblin, and Javier Lloret: Presented at the panel discussion "Adapting to a Climate-Changed World" for the visit of H.S.H. Prince Albert II of Monaco to the Marine Biological Laboratory. Woods Hole, MA.

Zoe Cardon: Featured in the *Boston Globe* for her experiments on warming effects on interactions between plant roots and the surrounding soil.

Top to bottom: Drone image of Great Sippewissett Marsh capturing Erin VanderJeugdt (left) and Kelsey Chenoweth (right) standing at the edge of one of the experimental plots which have been studied for over 50 years (Photo credit: Erin VanderJeugdt). Inke Forbrich collecting greenhouse gas data from an eddy covariance tower in the marshes of the Plum Island Ecosystems LTER (Photo credit: Jane Tucker). Storm over Eel Pond (Photo credit: Kelsey Chenoweth).

Postdoctoral Scientists

Ashley Bulseco

Ashley is a postdoctoral scholar working with Joe Vallino at MBL and Julie Huber at WHOI and is using integrated RNA-SIP methodologies to understand connectivity within complex microbial communities. She more broadly is interested in how microbial properties drive carbon and nitrogen cycling in coastal ecosystems.

Ioannis Tsakalakis

Ioannis is a postdoc in the group of Joe Vallino, focusing on phytoplankton ecology and ocean ecosystem modelling. He is particularly interested in the importance of temporal strategies of phytoplankton for predicting phytoplankton biogeography and diversity in the global ocean.

Sherlynette Perez Castro

Sherly is a postdoctoral researcher in the Ruff Lab with a background in soil science and microbial ecology. Her research focuses on understanding how microbes interact in their communities and their role in maintaining ecosystem balances. She is currently assembling and analyzing metagenome-assembled genomes from hydrothermal sediments in deep sea habitats.

Heidi Golden

Heidi is a postdoctoral fellow with the Northeast Climate Adaptation Science Center. She is researching the Coonamessett River herring migration and river restoration to evaluate the causes of river herring decline and recovery in New England.

Aboozar Tabatabai

Aboozar is working with Joe Vallino at MBL and Mick Follows at MIT. He is developing a metabolic network model for marine planktonic ecosystems that is based on the MIT Darwin trait-based model. Like the Darwin model, the metabolic network operates within a global 3D ocean circulation model and allows predictions of the flow of organic carbon, nitrogen, and phosphorus through metabolic pathways catalyzed by bacteria, algae, and zooplankton.

Faming Wang

Faming is working on the gas flux for tidal wetlands and agricultural soils. His recent work focuses on the blue carbon sequestration in tidal marshes of the United States.

Sampling in the mangroves of the Pacific coast of Panama (Photo credit: Ivan Valiela).

Publications July 2018–June 2019

Abdul-Aziz, O., K. S. Ishtiaq, J. Tang, S. Moseman-Valtierra, K. D. Kroeger, M. E. Gonneea, J. Mora, and K. Morkeski. 2018. Environmental Controls, Emergent Scaling, and Predictions of Greenhouse Gas (GHG) Fluxes in Coastal Salt Marshes. JOURNAL OF GEOPHYSICAL RESEARCH-BIOGEOSCIENCES **123**:2234-2256.

Bhatnagar, S., E. S. Cowley, S. H. Kopf, S. P. Castro, S. Kearney, S. C. Dawson, K. Hanselmann, and S. E. Ruff. 2019. Microbial community dynamics and coexistence in a sulfide-driven phototrophic bloom. bioRxiv.

Carey, J. C., K. D. Kroeger, B. Zafari, and J. Tang. 2018. Passive experimental warming decouples air and sediment temperatures in a salt marsh. LIMNOLOGY AND OCEANOGRAPHY-METHODS **16**:640-648.

Cisneros, M., I. Cacho, J. Frigola, A. Sanchez-Vidal, A. Calafat, R. Pedrosa Pamies, A. Rumin-Caparros, and M. Canals. 2019. Deep-water formation variability in the north-western Mediterranean Sea during the last 2500 yr: A proxy validation with present-day data. GLOBAL AND PLANETARY CHANGE **177**:56-68.

Conte, M. H., A. M. Carter, D. A. Koweek, S. Huang, and J. C. Weber. 2019. The elemental composition of the deep particle flux in the Sargasso Sea. CHEMICAL GEOLOGY **511**:279-313.

Conte, M. H. 2019. Oceanic Particle Flux. In Cochran, J. Kirk; Bokuniewicz, J. Henry; Yager, L. Patricia (eds.) Encyclopedia of Ocean Sciences, 3rd Edition. Oxford: ELSEVIER **4**:192-200."

Cramm, M. A., A. Chakraborty, C. Li, S. E. Ruff, B. B. Jorgensen, and C. R. J. Hubert. 2019. Freezing Tolerance of Thermophilic Bacterial Endospores in Marine Sediments. FRONTIERS IN MICROBIOLOGY **10:**945.

Curasi, S. R., T. C. Parker, A. V. Rocha, M. L. Moody, J. Tang, and N. Fetcher. 2019. Differential responses of ecotypes to climate in a ubiquitous Arctic sedge: implications for future ecosystem C cycling. NEW PHYTOLOGIST **223**:180-192.

Daniels, W. C., Y. Huang, J. M. Russell, and A. E. Giblin. 2018. Effect of continuous light on leaf wax isotope ratios in Betula nana and Eriophorum vaginatum: implications for Arctic paleoclimate reconstructions. ORGANIC GEOCHEMISTRY **125**:70-81.

Daniels, W. C., Y. S. Huang, J. M. Russell, and A. E. Giblin. 2018. Effect of continuous light on leaf wax isotope ratios in Betula nana and Eriophorum vaginatum: implications for Arctic paleoclimate reconstructions. ORGANIC GEOCHEMISTRY **125**:70-81.

Djukic, L. and 311 others (including J. Tang of the Ecosystems Center). Early stage litter decomposition across biomes. SCIENCE OF THE TOTAL ENVIRONMENT **628-629**:1369-1394

Dohnalkova, A., and Z. Cardon. 2018. Addressing Challenges in Ultrastructural TEM Imaging of

Tiny "bird's nest" fungi, with cups ~1 cm diameter, growing on wood chips (Photo credit: Zoe G. Cardon).

Chlorophyceae (Green Algae). MICROSCOPY AND MICROANALYSIS, **24**(S1):1346-1347.

Dornelas, M. and 271 others (including G. R. Shaver of the Ecosystems Center). 2018. BioTIME: A database of biodiversity time series for the Anthropocene. GLOBAL ECOLOGY AND BIOGEOGRAPHY **27**:760-786..

Elmstrom, E., I. Valiela, and S. E. Fox. 2018. Watershed-Estuary Coupling in Pacific Panama: Isotopic Evidence of Forest and Pasture Land Covers on Watersheds and Marine Contributions to Suspended Particulate Matter in Mangrove Estuaries. ESTUARIES AND COASTS **41**:1968-1976.

Fiore-Donno, A. M., T. Richter-Heitmann, F. Degrune, K. Dumack, K. M. Regan, S. Marhan, R. S. Boeddinghaus, M. C. Rillig, M. W. Friedrich, E. Kandeler, and M. Bonkowski. 2019. Functional Traits and Spatio-Temporal Structure of a Major Group of Soil Protists (Rhizaria: Cercozoa) in a Temperate Grassland. FRONTIERS IN MICROBIOLOGY **10**.

Fu, C. S., G. L. Wang, K. Bible, M. L. Goulden, S. R. Saleska, R. L. Scott, and Z. G. Cardon. 2018. Hydraulic redistribution affects modeled carbon cycling via soil microbial activity and suppressed fire. GLOBAL CHANGE BIOLOGY **24**:3472-3485.

Heskel, M. A., and J. Tang. 2018. Environmental controls on light inhibition of respiration and leaf and canopy daytime carbon exchange in a temperate deciduous forest. TREE PHYSIOLOGY **38**:1886-1902.

Hiller-Bittrolff, K., K. Foreman, A. N. Bulseco-McKim, J. Benoit, and J. L. Bowen. 2018. Effects of mercury addition on microbial community composition and nitrate removal inside permeable reactive barriers. ENVIRONMENTAL POLLUTION **242**:797-806.

Howard, E. M., I. Forbrich, A. E. Giblin, D. E. Lott, K. L. Cahill, and R. H. R. Stanley. 2018. Using Noble Gases to Compare Parameterizations of Air-Water Gas Exchange and to Constrain Oxygen Losses by Ebullition in a Shallow Aquatic Environment. JOURNAL OF GEOPHYSICAL RESEARCH-BIOGEOSCIENCES **123**:2711-2726.

Jankowski, K., C. Neill, E. A. Davidson, M. N. Macedo, C. Costa, G. L. Galford, L. M. Santos, P. Lefebvre, D. Nunes, C. E. P. Cerri, R. McHorney, C. O'Connell, and M. T. Coe. 2018. Deep soils modify environmental consequences of increased nitrogen fertilizer use in intensifying Amazon agriculture. SCIENTIFIC REPORTS **8**.

Kendrick, M. R., A. D. Huryn, W. B. Bowden, L. A. Deegan, R. H. Findlay, A. E. Hershey, B. J. Peterson, J. P. Benes, and E. B. Schuett. 2018. Linking permafrost thaw to shifting biogeochemistry and food web resources in an arctic river. GLOBAL CHANGE BIOLOGY **24**:5738-5750.

Lamborg, C., T. Mincer, W. Buchanan, C. Collins, G. Swarr, P. Ganguli, K. Whalen, M. Bothner, and I. Valiela. 2019. Mercury speciation and retention in a salt marsh undergoing long-term fertilization. ESTUARINE COASTAL AND SHELF SCIENCE **218**:188-196.

Li, J., G. Wang, M. A. Mayes, S. D. Allison, S. D. Frey, Z. Shi, X. M. Hu, Y. Luo, and J. M. Melillo. 2019. Reduced carbon use efficiency and increased microbial turnover with soil warming. GLOBAL CHANGE BIOLOGY **25**:900-910.

Liang, A., Y. Zhang, X. Zhang, X. Yang, N. McLaughlin, X. Chen, Y. Guo, S. Jia, S. Zhang, L. Wang, and J. Tang. 2019. Investigations of relationships among aggregate pore structure, microbial biomass, and soil organic carbon in a Mollisol using combined non-destructive measurements and phospholipid fatty acid analysis. SOIL & TILLAGE RESEARCH **185**:94-101.

Liu, Z., S. An, X. Lu, H. Hu, and J. Tang. 2018. Using canopy greenness index to identify leaf ecophysiological traits during the foliar senescence in an oak forest. ECOSPHERE **9**.

Locke, D. H., M. Avolio, T. L. E. Trammell, R. R. Chowdhury, J. M. Grove, J. Rogan, D. G. Martin, N. Bettez, J. Cavender-Bares, P. M. Groffman, S. J. Hall, J. B. Heffernan, S. E. Hobbie, K. L. Larson, J. L. Morse, C. Neill, L. A. Ogden, J. P. M. O'Neil-Dunne, D. Pataki, W. D. Pearse, C. Polsky, and M. M. Wheeler. 2018. A multi-city comparison of front and backyard differences in plant species diversity and nitrogen cycling in residential landscapes. LANDSCAPE AND URBAN PLANNING **178**:102-111.

Lu, X., X. Cheng, X. Li, J. Chen, M. Sun, M. Ji, H. He, S. Wang, S. Li, and J. Tang. 2018. Seasonal patterns of canopy photosynthesis captured by remotely sensed sun-induced fluorescence and vegetation indexes in mid-to-high latitude forests: A cross-platform comparison. SCIENCE OF THE TOTAL ENVIRONMENT **644**:439-451.

Lu, Y. L., R. S. Wang, Y. J. Shi, C. Su, J. J. Yuan, A. C. Johnson, A. Jenkins, R. C. Ferrier, D. L. Chen, H. Q. Tian, J. Melillo, S. Song, and A. M. Ellison. 2018. Interaction between pollution and climate change augments ecological risk to a coastal ecosystem. ECOSYSTEM HEALTH AND SUSTAINABILITY **4**:161-168.

Daniella Hanacek sampling water in Buttermilk Bay (Photo credit: Kelsey Chenoweth).

Mayes, M., J. Melillo, C. Neill, C. Palm, J. Mustard, and G. Nyadzi. 2019. Nitrogen Cycle Patterns During Forest Regrowth in an African Miombo woodland Landscape. JOURNAL OF GEOPHYSICAL RESEARCH-BIOGEOSCIENCES **124**:1591-1603.

Mo, Q., Z. Li, E. J. Sayer, H. Lambers, Y. Li, B. Zou, J. Tang, M. Heskel, Y. Ding, and F. Wang. 2019. Foliar phosphorus fractions reveal how tropical plants maintain photosynthetic rates despite low soil phosphorus availability. FUNCTIONAL ECOLOGY **33**:503-513.

Morrison, E. W., A. Pringle, L. T. A. van Diepen, A. S. Grandy, J. M. Melillo, and S. D. Frey. 2019. Warming alters fungal communities and litter chemistry with implications for soil carbon stocks. SOIL BIOLOGY & BIOCHEMISTRY **132**:120-130.

Moss, R. H., S. Avery, K. Baja, M. Burkett, A. M. Chischilly, J. Dell, P. A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M. C. Lemos, J. Melillo, R. Pandya, T. C. Richmond, L. Scarlett, J. Snyder, M. Stults, A. Waple, J. Whitehead, D. Zarrilli, J. Fox, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman. 2019. A Framework for Sustained Climate Assessment in the United States. BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY **100**:897-908.

Nelson, J. A., D. S. Johnson, L. A. Deegan, A. C. Spivak, and N. R. Sommer. 2019. Feedbacks Between Nutrient Enrichment and Geomorphology Alter Bottom-Up Control on Food Webs. ECOSYSTEMS **22**:229-242.

Patterson, A. E., R. Arkebauer, C. Quallo, M. A. Heskel, X. M. Li, N. Boelman, and K. L. Griffin. 2018. Temperature response of respiration and respiratory quotients of 16 co-occurring temperate tree species. TREE PHYSIOLOGY **38**:1319-1332.

Pedrosa Pamies, R., M. H. Conte, J. C. Weber, and R. Johnson. 2018. Carbon cycling in the Sargasso Sea water column: Insights from lipid biomarkers in suspended particles. PROGRESS IN OCEANOGRAPHY **168**:248-278.

Puritty, C. E., E. H. Esch, S. Pérez Castro, E. M. Ryan, D. A. Lipson and E. E. Cleland. 2019. Drought in Southern California coastal sage scrub reduces herbaceous biomass of exotic species more than native species, but exotic growth recovers quickly when drought ends. PLANT ECOLOGY **220**:151-169.

Ruff, S. E., J. Felden, H. R. Gruber-Vodicka, Y. Marcon, K. Knittel, A. Ramette, and A. Boetius. 2019. In situ development of a methanotrophic microbiome in deep-sea sediments. THE ISME JOURNAL **13**:197-213.

Sokolov, A., D. Kicklighter, A. Schlosser, C. Wang, E. Monier, B. Brown-Steiner, R. Prinn, C. Forest, X. Gao, A. Libardoni, and S. Eastham. 2018. Description and Evaluation of the MIT Earth System Model (MESM). JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS **10**:1759-1789.

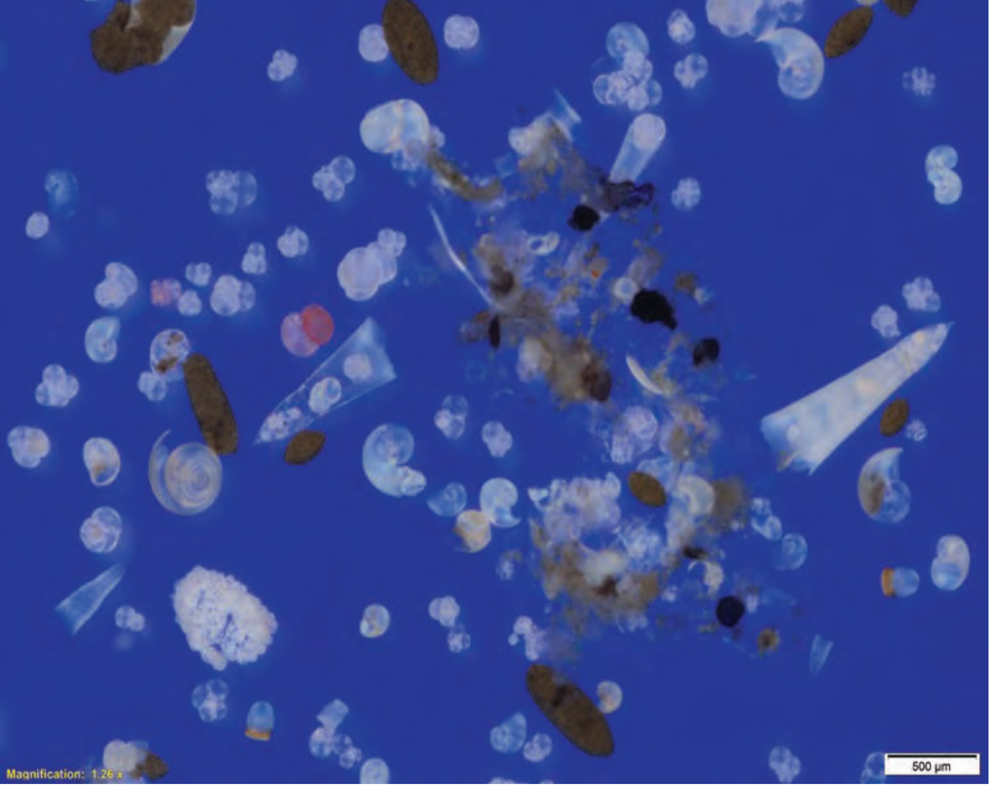
Stewart, L. C., C. K. Algar, C. S. Fortunato, B. Larson, J. J. Vallino, J. A. Huber, D. A. Butterfield, and J. F. Holden. 2019. Fluid geochemistry, local hydrology, and metabolic activity define methanogen community size and composition in deep-sea hydrothermal vents. ISME JOURNAL **13**:1711-1721.

Tan, S., B. Chen, H. Zheng, F. Xu, H. Xu, J. Wei, H. Huang, and J. Tang. 2019. Effects of cultivation techniques on CH4 emissions, net ecosystem production, and rice yield in a paddy ecosystem. ATMOSPHERIC POLLUTION RESEARCH **10**:274-282.

Taylor, D. I., C. A. Oviatt, A. E. Giblin, J. Tucker, R. J. Diaz, and K. Keay. 2019. Wastewater input reductions reverse historic hypereutrophication of Boston Harbor, USA. AMBIO **49**:187-196.

Tian, H., C. Lu, S. Pan, J. Yang, R. Miao, W. Ren, Q. Yu, B. Fu, F. F. Jin, Y. Lu, J. Melillo, Z. Ouyang, C. Palm, and J. Reilly. 2018. Optimizing resource use efficiencies in the food-energy-water nexus for sustainable agriculture: from conceptual model to decision support system. CURRENT OPINION IN ENVIRONMENTAL SUSTAINABILITY **33**:104-113.

Lichen diversity on a local Cape Cod rock. Dime for scale (Photo credit: Zoe Cardon).



Foraminifera, pteropod shells, fecal pellets and a fibrous aggregates collected at 3200 m depth in the Sargasso Sea by the Oceanic Flux Program sediment trap (Photo credit: JC Weber).

Trammell, T. L. E., D. E. Pataki, C. J. Still, J. R. Ehleringer, M. L. Avolio, N. Bettez, J. Cavender-Bares, P. M. Groffman, M. Grove, S. J. Hall, J. Heffernan, S. E. Hobbie, K. L. Larson, J. L. Morse, C. Neill, K. C. Nelson, J. O'Neil-Dunne, W. D. Pearse, R. R. Chowdhury, M. Steele, and M. M. Wheeler. 2019. Climate and lawn management interact to control C-4 plant distribution in residential lawns across seven US cities. ECOLOGICAL APPLICATIONS **29**.

Vachula, R. S., Y. S. Huang, W. M. Longo, S. G. Dee, W. C. Daniels, and J. M. Russell. 2019. Evidence of Ice Age humans in eastern Beringia suggests early migration to North America. QUATERNARY SCIENCE REVIEWS **205**:35-44.

Vachula, R. S., J. M. Russell, Y. S. Huang, and N. Richter. 2018. Assessing the spatial fidelity of sedimentary charcoal size fractions as fire history proxies with a high-resolution sediment record and historical data. PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY **508**:166-175.

Valiela, I., E. Elmstrom, J. Lloret, T. Stone, and L. Camilli. 2018. Tropical land-sea couplings: Role of watershed deforestation, mangrove estuary processing, and marine inputs on N fluxes in coastal Pacific Panama. SCIENCE OF THE TOTAL ENVIRONMENT **630**:126-140.

Valiela, I., D. Liu, J. Lloret, K. Chenoweth, and D. Hanacek. 2018. Stable isotopic evidence of nitrogen sources and C4 metabolism driving the world's largest macroalgal green tides in the Yellow Sea. SCIENTIFIC REPORTS **8**.

Kelsey Chenoweth collecting water samples in Childs River (Photo Credit: Daniella Hanacek).

Valiela, I., J. Lloret, T. Bowyer, S. Miner, D. Remsen, E. Elmstrom, C. Cogswell, and E. R. Thieler. 2018. Transient coastal landscapes: Rising sea level threatens salt marshes. SCIENCE OF THE TOTAL ENVIRONMENT **640**:1148-1156.

Vallino, J. J., and J. A. Huber. 2018. Using Maximum Entropy Production to Describe Microbial Biogeochemistry Over Time and Space in a Meromictic Pond. FRONTIERS IN ENVIRONMENTAL SCIENCE **6**.

Wang, F., K. D. Kroeger, M. E. Gonneea, J. W. Pohlman, and J. Tang. 2019. Water salinity and inundation control soil carbon decomposition during salt marsh restoration: An incubation experiment. ECOLOGY AND EVOLUTION **9**:1911-1921.

Zheng, H., X. Wang, Y. Li, G. Huang, Q. Tang, and J. Tang. 2018. Contributions of photosynthetic organs to the seed yield of hybrid rice: the effects of gibberellin application examined by carbon isotope technology. SEED SCIENCE AND TECHNOLOGY **46**:533-546.

Zheng, Y., P. Heng, M. H. Conte, R. S. Vachula, and Y. Huang. 2019. Systematic chemotaxonomic profiling and novel paleotemperature indices based on alkenones and alkenoates: Potential for disentangling mixed species input. ORGANIC GEOCHEMISTRY **128**:26-41.

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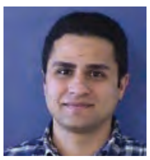

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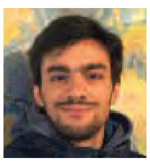

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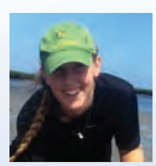

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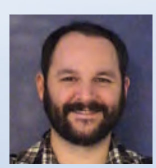

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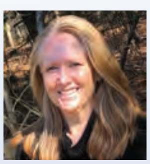

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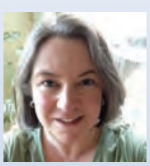

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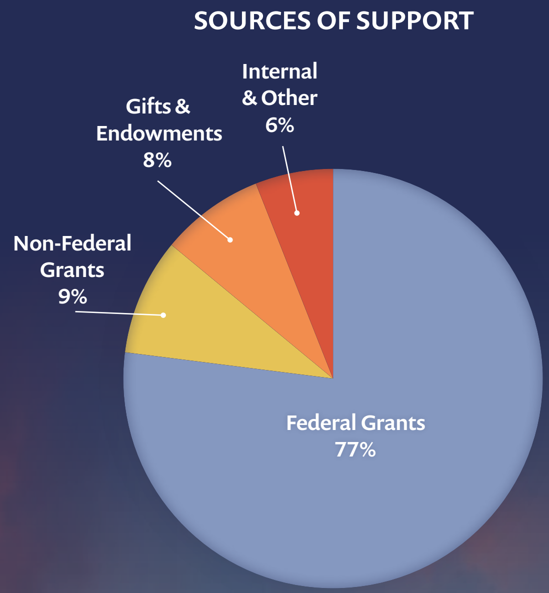
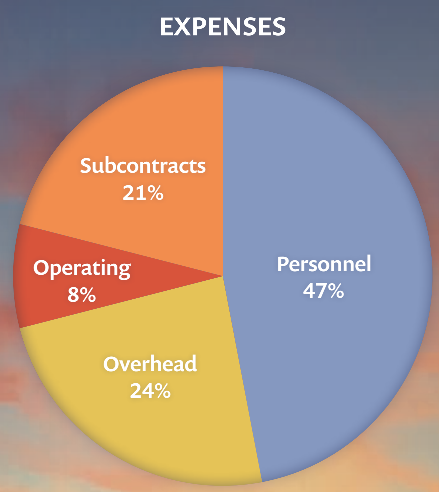
Twiggy Cui collecting water samples and water quality measurements in Quashnet River, a sub-watershed of Waquoit Bay (Photo credit: Rut Pedrosa Pamies).

Sources of Support for Research

The operating budget of The Ecosystems Center for the period of July 2018 – June 2019 was $5,354,000. Approximately 77% of the income of the center came from federal grants for basic research, including support from the National Science Foundation, the Department of Energy, and the National Oceanic and Atmospheric Administration. The other 23% comes from non-federal grants, private gifts, income from the center's reserve and endowment funds, and institutional support for administration.

These non-governmental funds provide flexibility for the development of new research projects, public policy activities and educational programs.





The following donations were made to the Ecosystems Center and the SES program between July 1, 2018 and June 30, 2019. More information can be found in the MBL Annual Report.

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Derek Dixon
Stephen and Lois Eisen
Christopher Foreman
The Foundation for Agricultural Integrity
Mark Gasarch
The Glore Fund
Barry S. Golden
The Harken Foundation
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