Marine Biological Laboratory | THE UNIVERSITY OF CHICAGO

The Ecosystems Center

Annual Report 2017-2018

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
Anne Giblin
Mananjo Jonahson
Lauren Medeiros

Front cover: Javier Lloret (MBL) and Hamish Asmath (Institute of Marine Affairs) in the mangrove forests of the Caroni Swamp, Trinidad and Tobago (Photo: Daniella Hanacek)

Back cover: Quashnet River estuary in Waquoit Bay, MA (Photo: Kelsey Chenoweth)

This page: Midnight sun over Toolik Lake, Arctic Field Station (Photo: Anne Giblin)

@mblscience @mblscience mblwoodshole

The many meanings of "resilience"

A MESSAGE FROM THE DIRECTOR

Over the last few years the US has endured several major hurricanes, floods, and wildfires that not only caused billions of dollars in property damage but also took a tragically large toll in human life. It is becoming more and more likely that the number and intensity of natural disasters will grow over the next few decades because of climate change. Increasingly we hear that we need to preserve or restore ecosystems to make them more "resilient," and thereby reduce the damage to our cities and towns caused by natural events.

The term "resilience" means different things to different people. The term was first used in an ecological context by C.S. Holling in 1973, and over time the meaning has been altered and redefined. Now, many scientists consider systems resilient if they change in response to a stress and eventually return to some "stable" state.

However, not all scientists agree on this definition. In addition, scientists recognize that there can be alternative ecosystem states. For example, a stress such as gradual warming could push a salt marsh system over a tipping point and into a new state, turning them into either mud flats or mangroves. Precipitation reductions can lead to a forest becoming a grassland. Over a human lifetime these are very dramatic changes, ones that humans often want to avoid, but it is hard to say a mangrove forest is more or less resilient than a salt marsh. Looking back in time, it is important to acknowledge that in the face of a changing climate, ecological change is more common than the maintenance of a static state.

Today, what resource managers and the general public are seeking is something different, known as social-ecological resilience. They are asking if well-functioning natural systems can help maintain their communities in the face of climate change with minimal disruption to both property and quality of life. They are looking at restoring and enhancing coastal wetlands as a way to reduce storm surge, asking if floodplains can be better managed to absorb flood waters, and hoping that some types of vegetation can reduce fire risk.

But unless everyone is clear on the goals of resilience efforts, the results of trying to manipulate ecosystems to increase resilience may be disappointing. Humans have a long history of trying to "improve" ecosystems with mixed results. The good news is that in many places community leaders, scientists, and concerned citizens are now coming together to clarify goals, identify knowledge gaps, and determine the tradeoffs of manipulating ecosystems for increased protection from specific natural hazards.

Anne Giblin (Photo by D. Cojanu)

The articles in this issue highlight stories that directly or indirectly look at ecosystems resilience. Jim Tang and colleagues are studying both agricultural fields and wetlands to see if carbon storage can be enhanced without loss of their other essential functions. Graduate student Ashley Bulseco has worked with scientists at the Ecosystem Center, Northeastern University and the Wood Hole Research Center to examine the tradeoffs between the ecosystem services of nitrogen removal and carbon storage in salt marsh peat. Javier Lloret and Elena Lopez Peredo have combined forces and are working with Ivan Valiela and a number of students to examine the impact that invasive algae are having on coastal ecosystems and to understand if the invasive species increases or decreases the susceptibility of estuaries to eutrophication. Finally, Joe Vallino and colleagues are developing new modeling tools that might help us better understand and predict how systems respond to disturbances.

We must now begin to steward ecosystems as best we know how while continuing to strive for better understanding. This is a pragmatic approach I once might have rejected, but given current rates of global change we don't have the luxury of waiting to act. Decision makers, practitioners, and scientists now need to work together to identify the tradeoffs among ecosystem management regimes and minimize the possibility of bad outcomes. These articles all demonstrate that while there are still many unknowns, through experiments, modeling, and collaborating across disciplines, we are making progress.

Tradeoffs in salt marsh ecosystems services

Salt marshes are important coastal ecosystems that provide a host of benefits to humans. Historically they have functioned as valuable nursery grounds for fish and shellfish and aided in the reduction of storm surge.

Another less recognized benefit they provide to ecosystems is their ability to reduce nitrogen loads from land. Bacteria in salt marsh sediments use nitrate to decompose some of the carbon found abundantly in these sediments. In doing so, they convert the nitrate to nitrogen gas, which then leaves the ecosystem. The loss of this nitrate helps prevent eutrophication of adjacent coastal marine ecosystems, such as sea grass beds, which are highly sensitive to nitrogen inputs.

With atmospheric carbon dioxide levels rising, more emphasis is now being placed upon carbon sequestration. Marshes store more carbon on a "per area" basis than almost any other ecosystem on earth, but if nitrate supports carbon decomposition (loss), what happens to carbon storage in marshes that receive high inputs of nitrogen?

Ashley Bulseco, a graduate student at Northeastern University working with Anne Giblin (MBL) and Jen Bowen (Northeastern), decided to find out. Ashley used a "flow-through reactor" (Figure 1) to expose salt marsh sediments to either seawater with added nitrate or "normal" seawater.

To simulate field conditions, the seawater was first stripped of oxygen, as the oxygen does not penetrate deeply into salt marsh peat. The goal of her experiment was to see if adding nitrate to seawater would increase the rate of carbon degradation compared to "normal" seawater, which contains little nitrate and abundant sulfate, and is also used by microbes in decomposition.

Because microbes can obtain more energy when they use nitrate as opposed to sulfate, Ashley hypothesized that decomposition rates would be higher in the added nitrate treatment, and that some additional, hard-to-degrade peat components would be degraded when nitrate was present. She also theorized that the impact of nitrate would be greater with older peat.

The experiment used peat from different sediment depths to represent recently deposited material (Shallow, 0-5 cm), older material (Mid, 10-15 cm), and peat that is about 100 years old (Deep, 20-25 cm). After the three month duration of the experiment, the results showed that nitrate did indeed stimulate decomposition of salt marsh peat when compared to sulfate. It also showed that the stimulation was greater in the older peat than in recent peat (Figure 2).

Spectroscopic analysis of the sediment suggested that in the presence of nitrate, more complex organic compounds were also being degraded. In other words, the microbes using nitrate

Ashley Bulseco with flow through reactors.

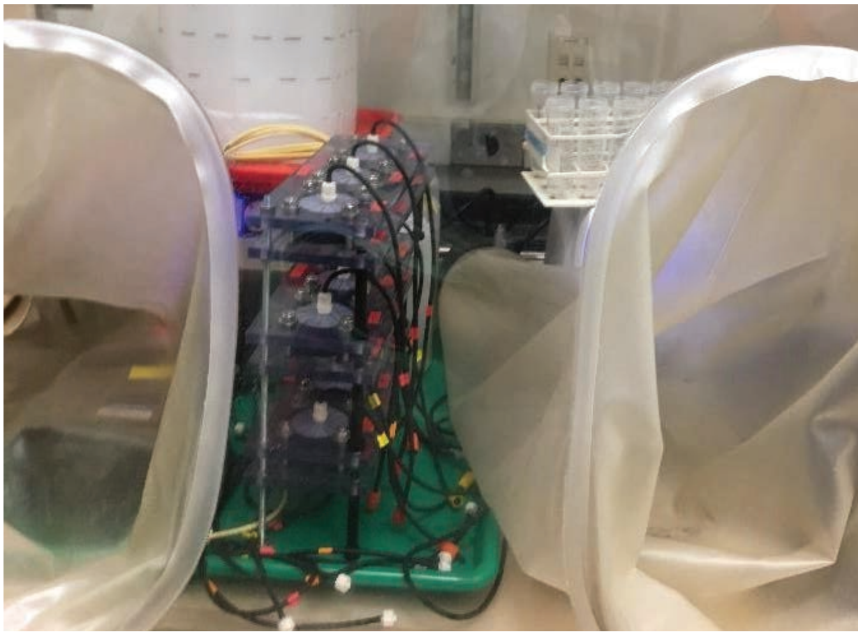
were able to attack some types of carbon that bacteria using sulfate could not decompose. An analysis of the microbial community supported these findings, showing that taxa known to reduce nitrate and oxidize more complex organic matter were more abundant in the nitrate treatment. Together, these results suggest there are pools of organic matter in marsh sediments that can become unstable in the presence of nitrate.

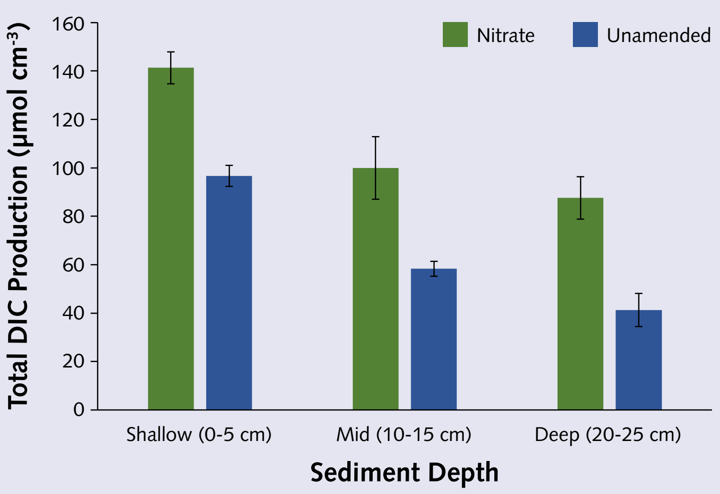
Ashley repeated her initial experiment using peat from a marsh area that has experienced long-term nutrient enrichment from a sewage outfall. She found that the decomposition of peat from this area showed less stimulation after nitrate was added than in the first experiment, which used peat that had not been previously exposed to nitrate.

This result suggests that long-term exposure to nitrate had diminished the pool of organic matter that is susceptible to additional decomposition, and that the size of that pool is limited. However, because both experiments ran for only a few months (not long enough for decomposition rates to fully "bottom out"), we do not yet know the size of this nitrate labile pool of organic matter.

The existence of these organic matter pools, which are stable under low nutrient conditions but capable of decomposition in the presence of nitrate, may mean less carbon is stored in marshes when they are enriched with nutrients. However, data from some other marshes suggest the increase in decomposition in some cases may be offset by the greater organic carbon production by nutrient enriched grasses so that burial rates are not reduced. The amount of nitrogen being added, and the form of nitrogen (nitrate vs. ammonium) may impact both nutrient removal efficiency and carbon storage rates.

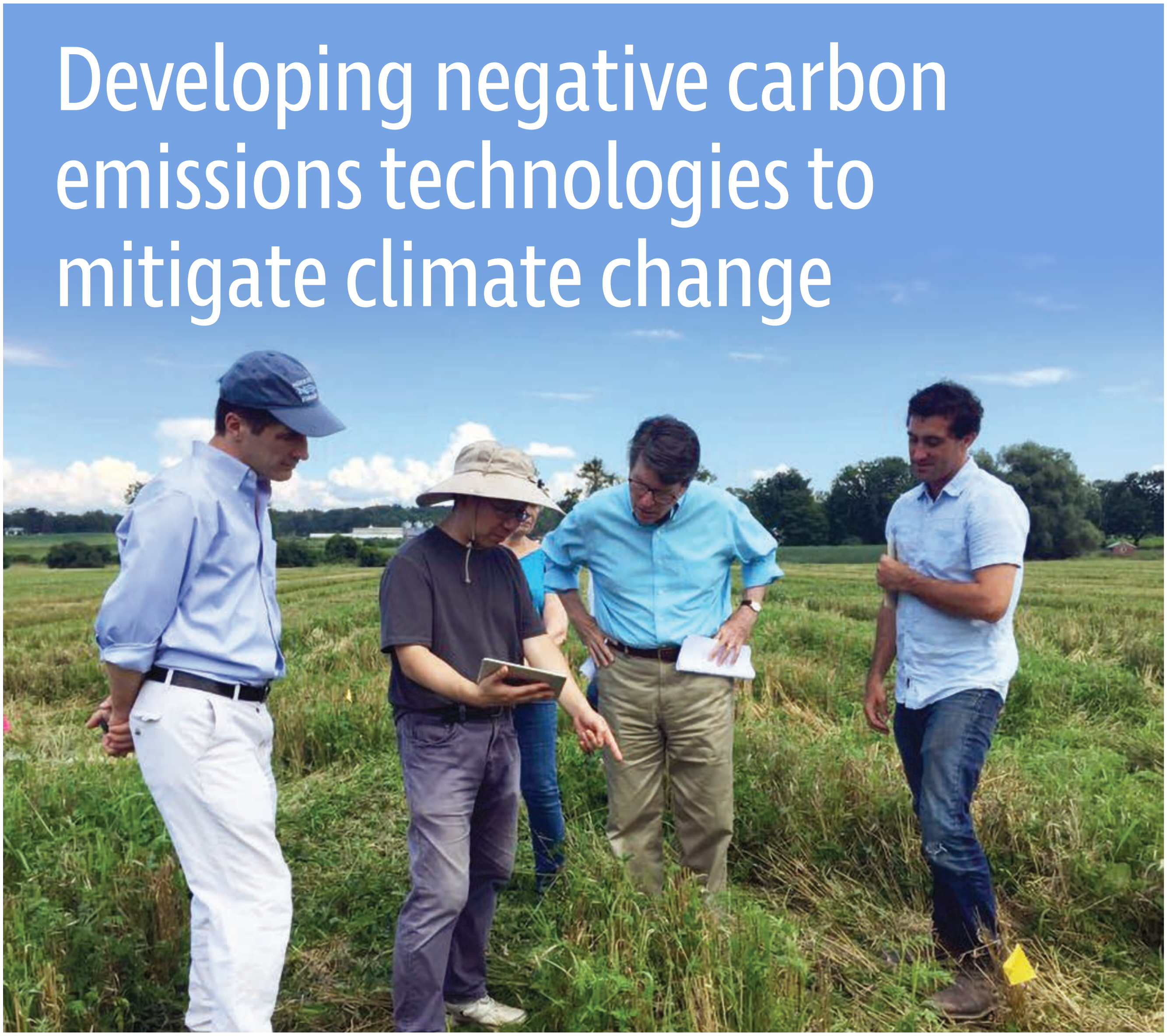
While nitrogen loading to coastal waters has decreased in a few areas, too many others are still experiencing high or increasing nitrogen loads. If we hope to rely on salt marshes to help mitigate these nitrogen loads and serve as long-term carbon sinks, it is imperative that we develop a better understanding of the tradeoffs between these two ecosystem services.





Top: Ashley Bulseco and Jane Tucker set up the flow through reactors in an anaerobic chamber; Middle: Flow through reactors; Bottom: The total amount of dissolved inorganic carbon (DIC) produced from peat in the flow through reactors over the course of the experiment. DIC measured the decomposition of carbon in the sediments. The deeper the peat the older it is. Bars are the mean value of 3 replicates and the standard error.

Developing negative carbon emissions technologies to mitigate climate change



Jim Tang (second from the left) explains the benefit of organic farming for carbon fixation to Congressman John Faso (third from the left) and organic-farming manager Ben Dobson (fourth from the left)

To mitigate the harmful effects of global climate change on the ocean, land, and human society, we need to 1) reduce emissions of greenhouse gases (including carbon dioxide, methane, and nitrous oxide) by increasing energy efficiency and switching to low-carbon or zero-carbon fuels; and 2) actively deploy "negative emissions technologies" that can remove carbon dioxide from the atmosphere and store it in the land or ocean.

The latter, which has received less attention than the former, requires us to fully understand the carbon cycle between the atmosphere and the land/ocean and then transfer the knowledge we have gained to technologies that store carbon and can potentially help reverse the global warming trend.

To advance negative emissions technologies, Ecosystems Center Associate Scientist Jim Tang serves on the Committee for the National Academies of Sciences, Engineering, and Medicine on "Developing a Research Agenda for Carbon Dioxide Removal and Reliable Sequestration" (http://nas-sites.org/dels/studies/cdr/).

The committee recently proposed six negative emissions technologies and sequestration approaches along with a research agenda focusing on: 1) coastal "blue" carbon—the amount of carbon stored in tidal salt marshes, mangroves, and seagrass beds with or near "blue" water; 2) terrestrial carbon removal and sequestration—the carbon stored in forests and agricultural lands; 3) bioenergy with carbon capture and sequestration—the biofuels that can take up carbon dioxide and produce alternative electricity and liquid fuels; 4) direct air capture—directly capturing and absorbing carbon dioxide from the atmosphere; 5) carbon mineralization—using reactive minerals and rocks to fix carbon dioxide; and 6) geological sequestration—capturing carbon dioxide and then storing it deep underground for a long term. The Committee further recommended the nation make substantial investment on these technologies as soon as practicable to fight global warming before it is too late.

Jim Tang and his team are actively engaged in the research and technological advancement for two of the above six approaches: coastal blue carbon and agricultural fixation of carbon. They developed a new comprehensive greenhouse gas measurement system to measure carbon dioxide and methane fluxes in an undisturbed salt marsh in Barnstable, MA and a degraded marsh in Wellfleet, MA, that is tidally restricted by invasive *Phragmites* grasses. Their goal is to quantify the differences in carbon emissions and sequestration rates between the two marshes.

Their results, which suggest that native salt marshes can fix more carbon dioxide and emit less methane than *Phragmites*, will be used to evaluate the salt marsh restoration effect on net carbon emissions. Once the degraded *Phragmites* marsh is restored by breaking the dike in the mouth of Herring River and re-introducing tidal water, the team will evaluate if it can use salt marsh restoration as a negative carbon emissions approach to gain "carbon credit" and thus fight global warming. This carbon credit could be traded at the emergent "carbon market" to further support salt marsh restoration and coastal conservation.

The advanced greenhouse gas measurement system that Dr. Tang's lab assembled includes an automated gas flux system to measure carbon dioxide and methane. It also features a novel fluorescence system that measures high-precision radiation emitted from plant photosynthesis as "solar-induced fluorescence," an addition that was developed by the Tang lab. Other parts include a digital camera to monitor plant growth, a mini-weather station to monitor climate variables, and a power supply system.

This system can capture plant uptake of carbon dioxide through photosynthesis and ecosystem emissions of carbon dioxide and methane through plant respiration and microbial activities. Furthermore, to understand detailed carbon emissions from individual plants, the group used a static chamber method to measure gas fluxes. This chamber can cover the plant and transport the air inside the vessel to a portable gas analyzer through a tube run between them, allowing for instantaneous gas exchange rates to be recorded.

In addition to quantifying blue carbon storage in coastal marshes, Tang's group is also evaluating how organic farming practices help store carbon in soils and act as another negative carbon emissions approach, also known as "carbon farming." To do so, they installed three gas measurement systems in Hudson, New York. One was installed in an organic farm, the second in a conventional corn field, and the third in a cattle-grazing field. They also measured nutrients leaching from the farms as pollution to the Hudson River that flows down to New York City and then to the Atlantic Ocean.

Their results will provide solid data to show if organic farming can not only reduce pollution and waste, but also enhance carbon storage in soils and mitigate the effects of climate change as an additional benefit. Their work has supported the state of New York to pass a bill to establish a carbon farming pilot project to study the potential of carbon sequestration under different farming practices (New York State Bill A11111).

Top: Faming Wang measuring carbon fluxes in *Phragmites*; Bottom: Automated carbon monitoring system installed in New England salt marshes

Synergistic human impacts on coastal areas

THE LINK BETWEEN NUTRIENT POLLUTION AND INVASIVE ALGAE

Elena Lopez Peredo at the MBL Marine Resources Center, where she keeps *Gracilaria* cultures for laboratory experiments (Credit: Tom Kleindinst)

For the last four years, Javier Lloret has studied the estuaries of Waquoit Bay on Cape Cod. His experiences modeling coastal waters are helping us understand and quantify the ecological consequences of nutrient pollution in a constantly changing world. As local developments increase and produce more nitrogen, what are the consequences for the organisms in the Bay?

Building on the long dataset begun by Ivan Valiela, Lloret is mapping changing nitrogen concentrations and examining how plankton, algae, seagrasses, and the communities they support are responding to human pressures. The valuable ecological services these organisms provide depend on the health of the ecosystem as a whole. Understanding the impacts of nitrogen pollution on estuarine flora and fauna is crucial to maintaining healthy ecological balances.

Increased nitrogen loads are not the only changes altering the ecology of the world's estuaries. Other human activities such as boat traffic and shellfish aquaculture contribute to the transport of organisms across the globe, facilitating the arrival of opportunistic species to new areas. Far from their native distribution zones, some thrive in these new ecosystems and become invasive species.

As these "new players" colonize our coasts, they have the potential to change the entirety of the native ecosystem. While some invasive species coexist with native biota, others, through their aggressive growth and their ability to survive in perturbed environments, compete with or even manage to displace other species. This can potentially alter the functioning of the entire ecosystem and its response to nutrient pollution and other drivers of change.

Left: Javier Lloret during macroalgae sampling in Waquoit Bay, Cape Cod, MA. Photo credit: Rut Pedrosa-Pamies

Cape Cod, a densely populated coastal area, is not immune to the arrival of aquatic invasive species. For two years, Elena Lopez Peredo has been examining the geographical distribution and physiology of a new member of the algal community of the Cape-- the invasive red alga *Gracilaria vermiculophylla*. This alga, native to Japan and Korea, is a threat to estuaries across the Northern Hemisphere. Its presence in coastal estuaries has been linked to a reduction in eelgrass beds, decreased productivity, and shifts in invertebrate distributions which can disrupt economically important fisheries.

On the East Coast, the presence of the invasive *G. vermiculophylla* went unnoticed until the late 1990s due to its close resemblance to the native red alga, *G. tikvahiae*. In collaboration with Lloret, Peredo and student Lauren Hamm (SES 2017) used DNA-based methods to identify the different *Gracilaria* species in Waquoit Bay and discovered a well-established population of the invasive alga.

To expand study on the *G. vermiculophylla* invasion at a larger scale, and in collaboration with the Gulf of Maine Institute (GOMI), Peredo has established a citizen science program to monitor the presence of this invasive alga in the New England area.

Gracilaria species are robust, opportunistic algae that thrive in areas that are heavily disturbed by human presence. In areas with high nutrient loads, these algae form massive blooms of floating turfs that regularly wash ashore.

Despite the similar general response to an increase in nutrients in both native and invasive *Gracilaria* species, some adaptive and physiological differences between them have the potential to alter the overall outcome and ecosystem response to nutrient pollution in areas where the invasive species is present. Lloret is interested in understanding how the arrival of this alga to an estuary affects the functioning of the ecosystem.

Peredo is interested in determining what makes this invasive alga such an extraordinary competitor. In part, its flexible physiology offers this species an even greater tolerance to abiotic stressors and pollution than its native counterpart.

2017 SES student Lydia Fox discovered that this alien alga can take up two times more nitrogen from surrounding waters than the native alga. But it is not just its physiology that makes this species such a formidable competitor, as *G. vermiculophylla* also displays outstanding antifouling properties.

This can be a key trait in disturbed ecosystems where water turbidity makes light a limiting factor for growth. Peredo investigates the basis of these advantages by analyzing the specific interactions that *Gracilaria* species develop with their associated microbial communities.

Peredo and Lloret are bringing together their different expertise to build a combined research program that connects processes acting at very different scales, from the selective pressures operating at the organism level to large scale human-driven alterations of ecosystems.

Top Right: 2017 SES students Lauren Hamm and Lydia Fox sampling *Gracilaria* in Waquoit Bay Middle: Invasive *Gracilaria vermiculophylla* growing on a piece of glass collected in Waquoit Bay; Bottom Right: Native and invasive *Gracilaria* collected in the Falmouth area (Credit: Tom Kleindinst)

Global Marine Biogeochemistry Modeling

Nearly half of the oxygen in the air you breathe is produced by microscopic organisms in the surface ocean. These organisms use solar radiation for growth and nutrient uptake and are generically referred to as phytoplankton.

Phytoplankton are the source of food for nearly all organisms in the ocean, from bacteria to whales. Phytoplankton, in turn, depend on the nutrient recycling capabilities of bacteria and other microscopic organisms, collectively referred to as zooplankton.

While not as charismatic as whales and sharks, these phytoplankton constitute the base of all marine food webs that larger organisms depend on. Therefore, understanding how they function and respond to increases in temperature, nutrient inputs, and acidification caused by increased carbon dioxide concentration is critical for managing our ocean resources under global change.

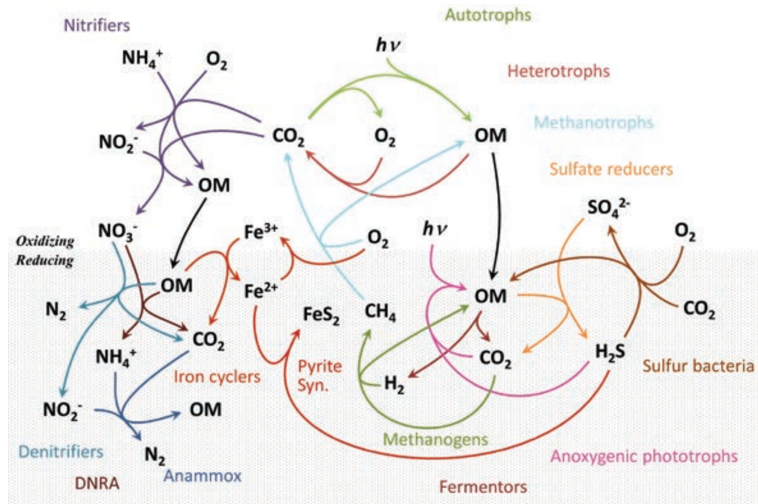


Figure 1: Some of the chemical transformations that occur in marine environments conducted by bacteria, archaea and other members of the planktonic community.

Because of the diversity and complexity of marine planktonic communities, experiments and observations must be used to develop biogeochemistry models to allow us to forecast how communities, and the associated chemistry they conduct, change over time and space, as well as how the marine system may respond to human alterations.

These phytoplankton, by definition, are drifters and are subject to large- and small-scale three dimensional (3D) ocean circulation. This requires that biogeochemistry models must also be embedded within ocean circulation models to obtain a realistic representation of the ocean's microbial ecosystem, in addition to developing models that describe phytoplankton growth dynamics.

Ocean circulation models have developed considerably over the last few decades; however, the embedded biogeochemistry models that describe the base of marine food webs are still quite challenging to get right. The first marine biogeochemistry models were based on simple representations for marine food webs, and consisted of phytoplankton (P), the inorganic nutrients (N) they consume, such as nitrate, and their predators, the zooplankton (Z).

These original "PZN" models capture some of the basic observations in marine science, such as the spring phytoplankton bloom and how thermal stratification limits nutrient availability. To improve on the first simple models, more compartments were added to better represent the species diversity of true marine ecosystems, but these models contain many additional parameters needed to describe growth and interactions of the additional phytoplankton and nutrients compartments.

Consequently, these enhanced-PZN models require extensive observations to "tune" the model parameters, but still often perform poorly since real marine food webs are far more complex than what can reasonably be represented in ocean biogeochemistry models.

Around a decade ago, a new approach to ocean biogeochemistry modeling was introduce by Mick Follows and others at MIT, which is based upon the principles of Darwinian natural selection to determine model parameters. In this approach, phytoplankton are given various traits, such as optimum growth temperature, optimum light level, and optimum nutrient concentration, etc. The model is then run with hundreds of model phytoplankton, where each is assigned random values that correspond to their optimum growth conditions.

These phytoplankton then compete within the simulation, so the model itself selects those characteristics based on which phytoplankton grow best under the prevailing local conditions that vary over space and time as driven by the circulation model. These so-called trait-based models remove much of the uncertainty in assigning parameter values, and the trait values that do best in various locations within the simulation are consistent with oceanographic observations.

Recently, the Simons Foundation funded a large multi-investigator program known as CBIOMES (Computational Biogeochemical Modeling of Marine Ecosystems) to advance trait-based models, led by Mick Follows.

The CBIOMES project consists of four central themes focused on 1) approaches to improving trait-based models, 2) developing a centralized repository of oceanographic data that can be readily queried (the Atlas), 3) development of statistical tools to explore model output as well as observations, and 4) advancement of numerical tools for rigorous model comparison to observations (known as data assimilation).

MBL Scientist, and CBIOME team member, Joe Vallino, along with postdoctoral student Aboozar Tabatabai, are exploring how the trait-based modeling approach can be expanded to encompass thermodynamically-constrained metabolic models of marine biogeochemistry.

In previous work, Vallino and others have developed an approach that represents the activities of marine phytoplankton as a metabolic network that captures the chemical transformations the community conducts, such as carbon dioxide fixation, conversion of nitrate to nitrogen gas, and similar reactions (Fig. 1). The reaction rates in the metabolic network can be determined by solving an optimization problem that maximizes the consumption rate of food (i.e., energy), including light, and belongs to a class of problems in non-equilibrium thermodynamics known as maximum entropy production (MEP).

While the MEP approach has been shown to be an accurate descriptor of marine biogeochemistry, the solution of the optimization problem in 3D ocean models is very challenging computationally. So now, Vallino, in collaboration with Follow's group at MIT, is examining how the trait-based approach can be used to solve the MEP optimization problem indirectly via the actions of many competing organisms.

The team is developing a model for phytoplankton growth that uses a compact set of metabolic reactions to capture phytoplankton metabolism (Fig. 2), which permits energy dissipation, and entropy production, to be accurately tracked. Multiple instances of the compact network are used to populate the ocean circulation model, but instead of solving an optimization problem, trait parameters that govern reaction efficiency, ε_i, and protein allocated to metabolic pathways, Ω_j, are randomly assigned to each phytoplankton instance and then allowed to compete.

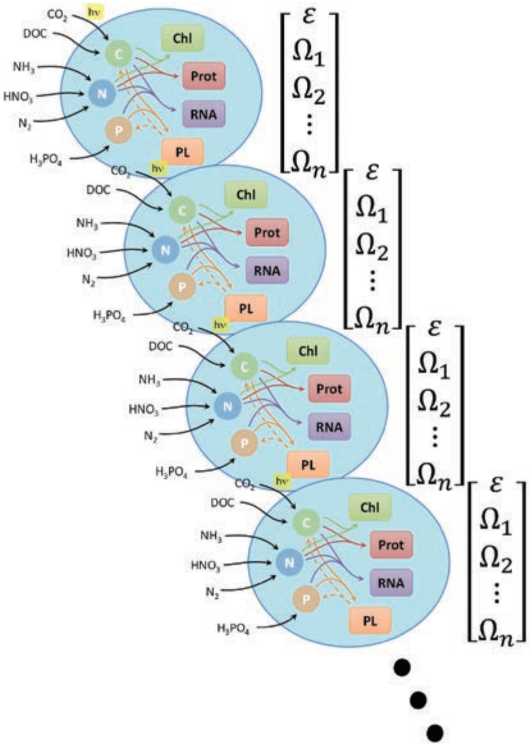


Figure 2: Schematic of the compact set of metabolic reactions used to represent nutrient uptake into intracellular pools of carbon (C), nitrogen (N) and phosphorous (P) that are the precursors to the major macromolecules of the cell that include chlorophyll (Chl), protein (Prot), RNA and phospholipids (PL). Each plankton instance (4 shown here) are randomly assigned reaction efficiency (epsilon) and fractional protein allocation to each reaction in the compact set (omegas).

Initial components of the metabolic network have been incorporated into the existing Darwin modeling framework, which allows the investigators to examine how energy is dissipated in the global ocean (Fig. 3). Changes to configurations in the model change how energy is dissipated both locally and globally in the ocean, so the MEP approach can be used to cull different model designs by selecting those that dissipate more energy. The expectation is that the new approach will allow models to more accurately forecast the future than classic modeling approaches that depend on observations and have no underlying governing principle.

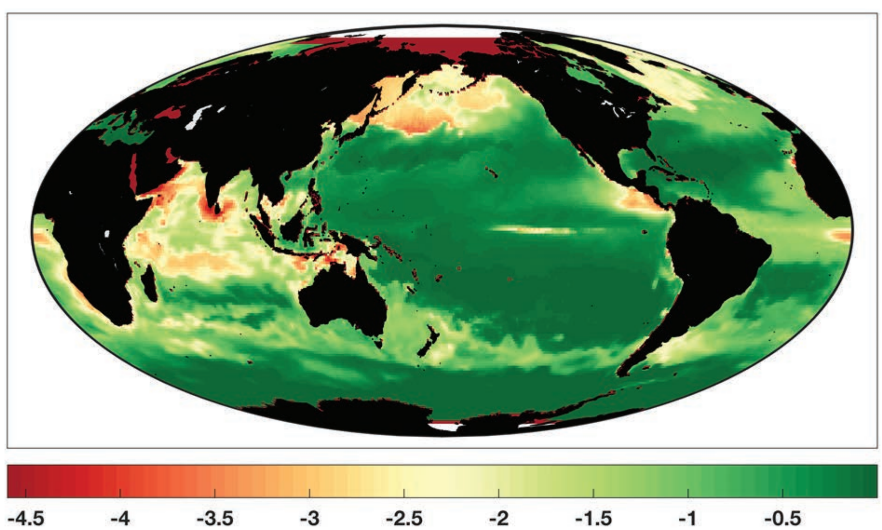


Figure 3: Simulation of surface entropy production associated with carbon dioxide fixation into simple sugars by marine phytoplankton. The negative entropy production depicted here, which is forbidden by the Second Law of Thermodynamics, is offset by a much great production of entropy associated with the dissipation of visible light into heat (not shown).

Semester in Environmental Science

What can the fatty acid composition of sea turtles stranded on Cape Cod beaches tell us about their diet?

How does a 30 year long forest floor warming experiment, designed to simulate a 5°C average increase in temperature, alter the availability of soil organic matter to decay?

Does the distribution of invasive red algae correspond with nitrogen inputs from wastewater?

How will the nutrient balance in a coastal pond change after the construction of a $40 million sewer system?

These are some of the questions that students in the Semester in Environmental Science (SES) addressed during their six week independent research projects in 2017.

Since 1997, 357 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 2017, nineteen students from twelve different colleges and universities participated in the program, including five students from the University of Chicago and our first students from Amherst and Pomona colleges.

All completed ten-week long core courses in Ecosystems Analysis that emphasized issues in global change, while teaching students how to collect and analyze 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.

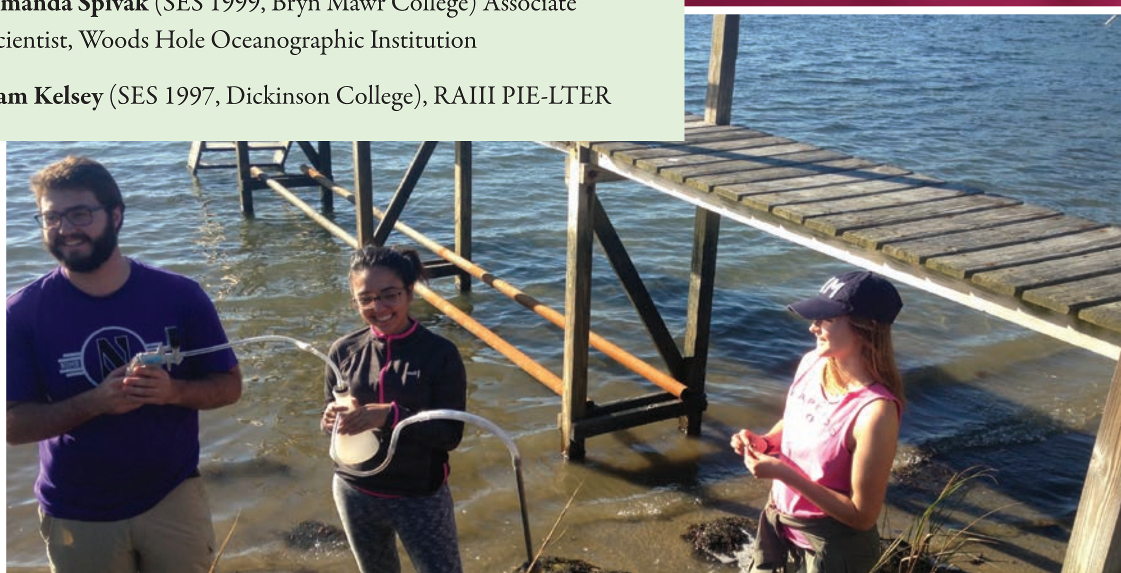
After formal coursework ended, the program's students pursued these independent research projects full-time in the last five weeks of the program, which culminated in a formal symposium that was held open to the public (see: http://videocenter.mbl.edu/videos/channel/41/).

One of the unique and exceptional aspects of the SES Program is the chance for alumni to return after the semester to work as research interns, teaching assistants, or research assistants at the MBL. About one in five SES alumni pursue such opportunities in Woods Hole after graduating from college.

During the 2017 academic year, nineteen SES alumni held a variety of scientific positions in Woods Hole. These ranged from Associate Scientist at the Woods Hole Oceanographic Institution, to research assistant and internship positions at MBL and the Woods Hole Research Center. One student worked an aquaculture technician for the Town of Falmouth Department of Natural Resources. SES prepares students for careers in environmental science, engineering, and management.

SES ALUMNI NOW IN WOODS HOLE

- **Emily DeFelippis** (SES 2017, The New School Eugene Lang College), RA on Oceanic Flux Program time-series
- **Ben Hoekstra** (SES 2017, Grinnell College) Summer Intern, Woods Hole Research Center
- **Erin Gleason** (SES 2016, Rhodes College) REU on ARC-LTER 2017
- **Ruby An** (SES 2015, University of Chicago) terrestrial summer RA for ARC-LTER 2017 & 2018
- **Luke O'Brien** (SES 2015, Boston College), SES Recruiter 2017-18
- **Emily Stone** (SES 2015, RA at Bay-Paul Center for Molecular Evolution)
- **Alana Thurston** (SES 2014, Haverford College), Intern at Toolik Lake LTER, SES TA, RA on the Oceanic Flux Program time-series
- **Kelsey Gosselin** (SES 2013, The New School Eugene Lang College) RAII Woods Hole Oceanographic Institution
- **Jordan Stark** (SES 2013, Skidmore College) SES TA and RA in Cardon Lab
- **Nicholas Uline** (SES 2013, Gettysburg College), Aquaculture Technician Town of Falmouth DNR
- **Melanie Hayn** (SES 2003, Cornell University), RA West Falmouth Harbor LTREB through Cornell
- **Amanda Spivak** (SES 1999, Bryn Mawr College) Associate Scientist, Woods Hole Oceanographic Institution
- **Sam Kelsey** (SES 1997, Dickinson College), RAIII PIE-LTER



Education Highlights

SES student Emily DeFilippis prepares lipid extracts from cold-stunned sea turtles. Her project (mentored by Maureen Conte) provided valuable insight into the ecology and physiology of these turtles. (Photo by JC Weber)

RESEARCH EXPERIENCE FOR UNDERGRADUATES (REU) & UNDERGRADUATE SUMMER FELLOWS

Student	Institution	Project	Mentors
Gabe Duran	University of Maryland, Baltimore County	Water quality analysis of Little Pond	Kenneth Foreman
Erin Gleeson	Rhodes College, SES alumna	Biogeochemical constraints on ecosystems response to disturbance	Ed Rastetter Bonnie Kwiatkowski
Johanna Holo	University of Chicago, Metcalf	Understanding particle cycling in the deep Sargasso Sea through the use of lipid biomarkers	Maureen Conte JC Weber Rut Pedrosa-Pàmies
Leon Perez	University of Chicago SURF Metcalf	Effects of tidal restriction on greenhouse gas emissions in New England coastal wetlands	Jim Tang
Victoria Roberson	Auburn University, Woods Hole Partnership	Determining the warming effect of greenhouse gases in Waquoit Bay	Jim Tang
Sharanya Sarathy	Brown University	Eutrophication of Waquoit Bay estuaries: Effects of land-derived nitrogen loading on the assemblages of macroalgal taxa	Ivan Valiela Javier Lloret Daniella Hanacek
Claire Valva	University of Chicago, Metcalf	Responses of inorganic nitrogen concentrations and producers in Cape Cod estuarine systems subject to differing rates of nitrogen loading	Ivan Valiela Javier Lloret Daniella Hanacek
Franklina Yeboah	University of Maryland Eastern Shore	Use of stable isotopes to determine trophic levels and habitats of sea turtles in Cape Cod waters	Maureen Conte Rut Pedrosa-Pàmies JC Weber Heather Haas (NOAA)

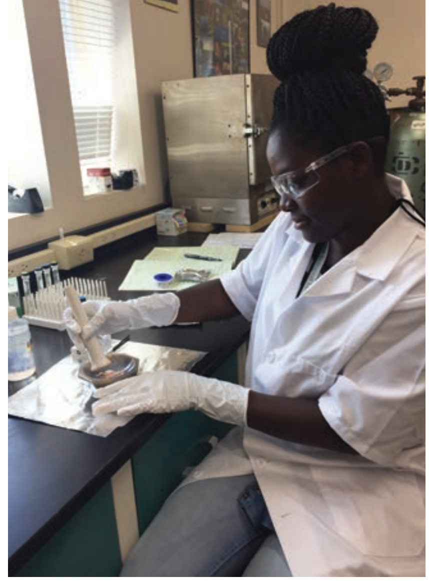
RECENT DOCTORAL RECIPIENTS

Lilian Aoki, Ph.D., University of Virginia 2018: "Seagrass as a coastal filler: investigating the role of seagrass meadows in mediating nitrogen cycling in shallow coastal lagoons" | **Anne Giblin**, committee member

Yinsui Zheng, Ph.D., Brown University 2018: "New approaches to disentangle mixed-alkenone sources and reconstruct salinity and reperature: Black Sea as a case study" | **Maureen Conte**, committee member

CURRENT GRADUATE STUDENTS

Student	Institution	Ecosystems Scientist
Ashley Bulseco	Northeastern University	Anne Giblin, advisor
Kenneth Czapla	Virginia Institute of Marine Science	Anne Giblin, Ph.D. committee
Sarah Foster	Boston University	Anne Giblin, Ph.D. committee
Victoria Gray	SMAST UMass Dartmouth	Maureen Conte, MSc committee
Brooke Osborne	Brown University	Zoe Cardon, Ph.D. committee
Nathalie Steiger	SMAST UMass Dartmouth	Maureen Conte, Ph.D. committee
Joseph Vineis	Northeastern University	Zoe Cardon, Ph.D. committee
Kiran Upreti	LSU	Anne Giblin, Ph.D. committee
Zunqiao Lu	Nanjing University, China	Jim Tang, co-mentor
Ting Ma	Lanzhou University, China	Jim Tang, co-mentor



WOODS HOLE SCIENCE & TECHNOLOGY EDUCATION PARTNERSHIP

Ecosystems Center scientists play an active role in WHSTEP, a network consisting of members from the area science institutions and regional school districts. JC Weber represents MBL on their board and serves as co-chair. Many members of the center's staff participate by mentoring local students for science fair projects and serve as judges in science fair projects.

MBL LOGAN SCIENCE JOURNALISM PROGRAM

In 2018, the Logan Science Journalism Program at MBL entered its 32nd year. The program allows established science and health journalists to “step into the shoes of the scientists they cover” through immersion in hands-on research, with **Anne Giblin** serving as the Environmental Course Director in collaboration with coordinator Diana Kenney from the MBL Office of Communication. On campus, the journalists attended breakfast lectures on MBL's Microbiome research, led by **Zoe Cardon**, and another on coral research led by **Loretta Roberson**. Lectures and talks were also given by **Anne Giblin**, **Javier Lloret**, and **Rich McHorney** throughout the program, with **Elena Lopez Peredo** leading a lab walkthrough that focused on invasive species.

Top: Partnership in Education Program (PEP) student Franklin Yeboah (Summer 2017, mentored by Maureen Conte) prepares sea turtle tissue samples. The samples were analyzed by MBL's Stable Isotope Laboratory and provided insight into the ecology and habitat of three species of sea turtles. (Photo by JC Weber)

COMMUNITY INVOLVEMENT

- **Zoe Cardon** demonstrated aspects of "Imaging in Ecosystems Science" to judges for the Nikon Small World Competition who toured MBL, and to MBL Council Members in Boston, MA (March, 2018).
- **Maureen Conte** is vice-presented of the Sippewissett Association and a volunteer Baywatcher with the Buzzards Bay Coalition.
- **Anne Giblin** participated in a number of public forums on climate change and sea level rise, including one held in Ipswich, MA in October, 2017 and at the Falmouth "Green Fair" in May, 2017. She lectured at the Harvard Lifelong Learning Program on salt marshes on November 1 and for the MIT Knight Science Journalism Fellows program. Anne also served as Chairperson for the Gulf of Maine Institute Board, a non-profit organization working with youth on environmental stewardship.
- **Javier Lloret** is a member of the Advisory Committee for the State of the Waters on Cape Cod, Association to Preserve Cape Cod.
- **Rut Pedrosa-Pàmies** is a volunteer Baywatcher with the Buzzards Bay Coalition.
- **Jane Tucker** is a volunteer editor for the Gulf of Maine Institute online journal.
- **JC Weber** serves as a board member and chair of the Outreach Committee of the Wareham Land Trust and is a volunteer Baywatcher with the Buzzards Bay Coalition.

SCIENCE OUTREACH

Marshall Otter and Hap Garritt mentored Bailey Nance, a senior student from the Upper Cape Cod Regional Technical School, for her science fair project on the dietary preferences of soldier fly larvae. She fed the larvae various food items commonly found in the human garbage system, then used stable isotopes to discern which foods the larvae preferred. Bailey won First Place and the Naval award at the Southeastern Massachusetts Regional Science Fair. She also won a $56,000 scholarship to attend Merrimack College in New Hampshire.

Maureen Conte, JC Weber, Rut Pedrosa-Pàmies, and Alana Thurston continued to host a motivated group of local high school students as lab assistants. In the summer of 2017, Michael Callahan, from Bourne High School, finished his project on "Carbonate fluxes in the deep sea." Michael is currently an undergraduate at the Wentworth Institute of Technology. In the spring and summer of 2018, **the Conte lab** hosted three students from Mashpee High School: Jack Daigneault, Geovanna Pereira, and Deshawn Adler.

Kelsey Chenoweth, Hap Garritt, Bonnie Kwiatkowski, Marshall Otter, Rut Pedrosa-Pàmies, Suzanne Thomas, Alana Thurston, and JC Weber all volunteered as judges at different science fairs across Massachusetts, including those at Bourne High School, Falmouth High School, Falmouth Academy, and the Massachusetts State Science & Engineering Fair.

In October of 2017 **Javier Lloret** (pictured on front cover, left) traveled to Trinidad and Tobago to carry out sampling for a project in the mangrove forests of the Caroni Swamp.

Ed Rastetter hosted Celeste Cruse, a Science teacher at the Falmouth Lawrence Junior High, at the Toolik Field Station, sponsored by donations from the MBL Associates.

Jane Tucker gave a talk about PIE-LTER at the Gulf of Maine Institute professional day for middle and high school science teachers. Tucker also co-authored the PIE-LTER Schoolyard book "Save Our Stream."

Top to Bottom: Preparing a pump deployment near the OFP mooring in the Sargasso Sea; Sampling Toolik Lake, Alaska through the ice in the spring ; Rut Pedrosa-Paimes and Maureen Conte recover a deep ocean sediment trap; Marshall Otter and JC Weber conduct analyses in the Ecosystems Center Mass Spectrometer Facility.

News 2017-2018

APPOINTMENTS TO OFFICES, BOARDS AND COMMITTEES

Zoe Cardon Elected Fellow of the Ecological Society of America; Department of Energy's Biological and Environmental Research (BER) Advisory Subcommittee on the Alignment of User Facilities with BER Grand Challenge goals. (January-June 2018)

Maureen Conte Science oversight committee for the design and construction of Regional Class Research Vessels (RCRV) for the US Oceanographic Fleet.

Anne Giblin NEON Science Technical and Education Advisory Committee; Department of Energy - Biological and Environmental Advisory Committee on user facilities

Jerry Mellilo National Acedemy of Sciences Committees; Gulf Research Program Advisory Board, Chair; US Global Change Research Committee; International Institute for Applied Systems Analysis, National Member Organization Committee; Board membner on International Scientific Organizations; Department of Energy, Biological and Environmental Research Advisory Committee; Stockholm Environment Institute, Council for Evidence-Based Environmental Management, Advisory Board Member; Cary Institute of Ecosystem Studies, Trustee

Ed Rastetter LTER Science Council; NSF Review Panel Division of Environmental Biology; Toolik Field Station Steering Committee; Subject Editor for "Ecosystems"

Jim Tang 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) supported by NSF/RCN

Joe Vallino Served on a Department of Energy panel in June of 2018; In July of 2017, a large collaboration was funded by the Simons Foundation, entitled Computational Biogeochemical Modeling of Marine Investigators (CBIOMES), which is led by Mick Follows at MIT. This involves 8 other principal investigators and 7 institutions, including Vallino and MBL.

UNIVERSITY OF CHICAGO SEMINARS AND MEETINGS

Anne Giblin Presentation to the University of Chicago Board in April 2018

Zoe Cardon Invited participant, UChicago-Argonne-MBL Microbiome Center (MBC) workshop focused on Microbes and Climate, May 2018; Presentation on the Ecosystems Center (with Anne Giblin)to the MBL Board of Trustees Academic Affairs Committee, April 2018; lecture in "Third Annual Quantitative Methods in Biology" Bootcamp at MBL for incoming biological sciences graduat students; lecture in University of Chicago's BIOS 27720 "Microbiomes Across Environments"at MBL

Maureen Conte Invited to talk at the University of Chicago Alumni Club: "Unlocking the Bermuda Triangle: What Sargasso Sea time-series are revealing about our ocean planet," Nov. 2017

Jim Tang Received the University of Chicago - University of Hong Kong Global Partnership Fund to facilitate collaborative research on conservation and restoration of coastal wetlands to preserve carbon storage

Joe Vallino Participated in a workshop with the University of Chicago and MBL faculty on"Microbes and Climate," sponsored by The Microbiome Center. The workshop discussed the development of a Center for Global Ecosystem-Based Bioengineering to Mitigate Atmospheric Carbon Dioxide Buildup

SERVICE TO THE MARINE BIOLOGICAL LABORATORY

Zoe Cardon — Friday Evening Lecture Series Committee; MBL Science Council; Bell faculty Search committee; Research Services Committe; Biosafety Committee; webmaster and co-coordinator (with Jessica Mark Welch) of the MicroEco discussion group, an interdisciplinary and cross-center group focusing on microbes, environmental microbiomes andecosystem function, and host-associated microbiomes; Greenhouse manager; Host for Whitman Scientist and collaborator Dr. Magdalena Bezanilla, Dartmouth College, Summer 2017

Javier Lloret — Participated as MBL's representative in the December 2017 USEPA Southeast New England Program Steering Committee Meeting at the EPA's New England Headquarters, Boston, MA

Joe Vallino — Served as a member of the MBL Hibbitt Fellows search committee from February to July 2018.

Ed Rastetter — MBL Science Council

ECOSYSTEMS CENTER IN THE NEWS & MEDIA PRODUCTIONS

Zoe Cardon
Elena Lopez Peredo

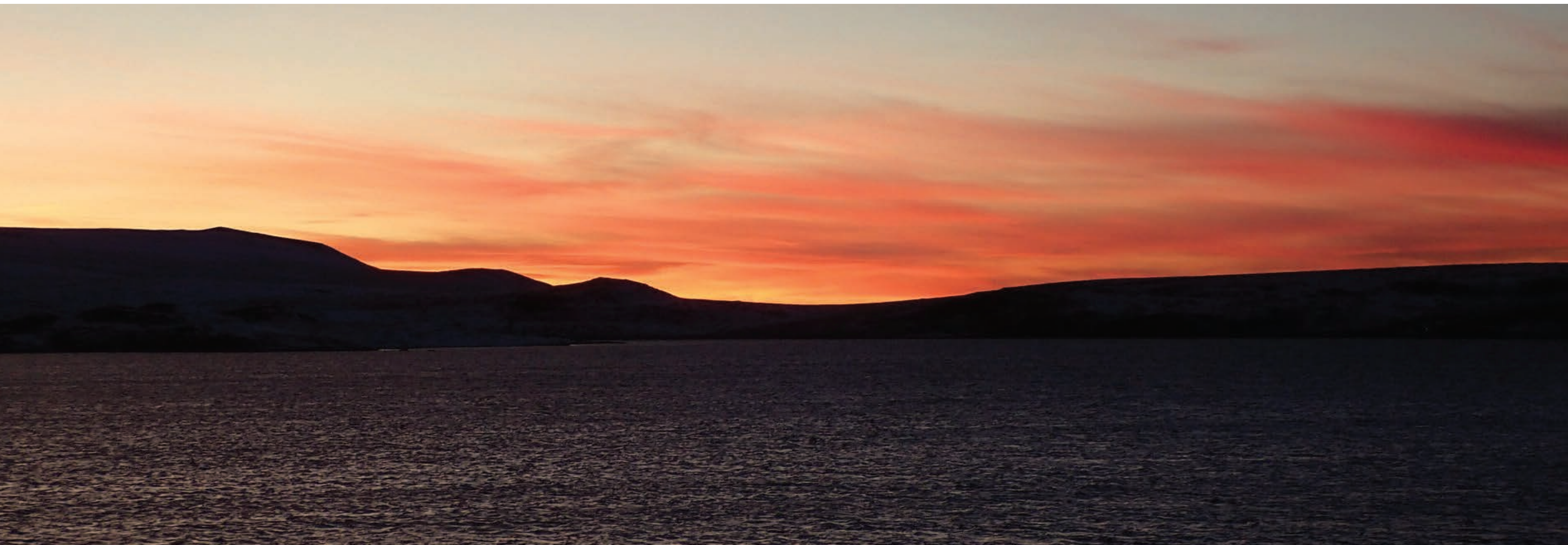
- MBL News story on a paper published by Cardon ZG, Peredo EL, Dohnalkova AC, Gershone HL, Bezanilla M. "A model suite of green algae within the Scenedescmacae for investigating contrasting desiccation tolerance and morphology," which was featured as the cover of the journal issue and was also included in the journal's "Research Highlights."
- MicroscopyU Highlight on use of Nikon microscopes in algal research
- "The Well" (MBL) featuring a project headed by Elena Lopez Peredo comparing native and invasive species of the red marine alga *Gracilaria*, an invasive species that has been found in Waquoit Bay and other New England locations

Maureen Conte — The Oceanic Flux Program (OFP) time-series of particle flux in the deep Sargasso Sea celebrated its 40th year of continuous operation in April 2018. TheOFP is the longest time-series of its kind and focuses on the ocean's "biological pump," which refers to material and energy transfer from the surface to the deep ocean sea floor mediated by marine ecosystems

Javier Lloret — "The Well" (MBL) featured a story on a new project aimed at quantifying the potential of forested land cover management in order to reduce nitrogen loads in several Cape Cod watersheds.

Chris Neill — Chris Neill is a science contributor for the Falmouth Enterprise. His recent articles include:

- Dedicated Pond watchers gather valuable data on estuaries. July 28, 2017.
- New plant will deliver high-quality water even under high demand. August, 25, 2017.
- Birds are harbingers of a changing climate. September 22, 2017.
- Sewering was a big step, next is to measure the impact. October 27, 2017.
- Bird counts tell a story and it's not always good. November 24, 2017.
- Restraint the key to keeping wilderness wild. December 22, 2017.
- Bad idea all around. February 23, 2018.



Postdoctoral Scientists

POSTDOCTORAL SCIENTISTS

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.

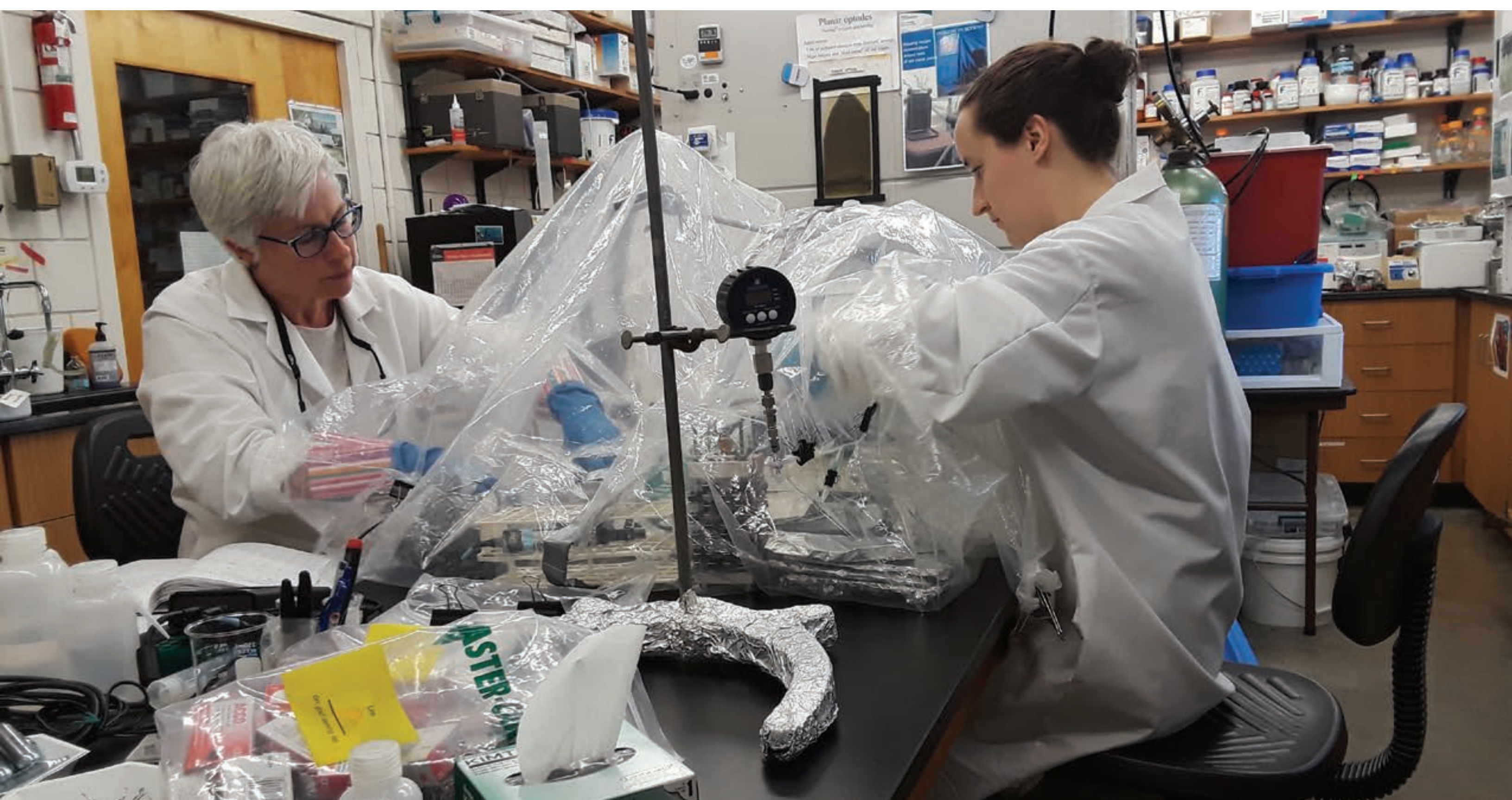
Mary Heskel Mary's research from Harvard Forest on daytime carbon cycling was presented at the annual fall meeting of the American Geophysical Union in December 2017 and was published in Tree Physiology. She started a position at Macalester College as an assistant professor in the Biology Department in Fall 2018.

Rut Pedrosa-Pàmies Rut's research interest is the cycling of elements in marine environments, especially the biogeochemistry of carbon. A major focus of her research is on the factors that regulate the downward flux of material from the surface to the deep ocean. She is currently focused on the impact of episodic extreme weather events, such as hurricanes, in the oceanic carbon cycle and in the deep-sea ecosystems.

Aboozar Tabatabai Postdoctoral scholar Aboozar, working with Joe Vallino at MBl and Mick Follows at MIT, 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 phosphorous through metabolic pathways catalyzed by bacteria, algae, and zooplankton.

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

Research assistants Suzanne Thomas and Jordan Stark work in a "glove bag" filled with nitrogen gas to sample methane-producing microbes, which only thrive in an environment without oxygen.



Publications 1 July 2017 to 30 June 2018

Asmus, A., Koltz, A., McLaren, J., Shaver, G. R., & Gough, L. (2018). Long-term nutrient addition alters arthropod community composition but does not increase total biomass or abundance. OIKOS, 127(3), 460-471. doi: 10.1111/oik.04398

Baatz, R., Sullivan, P. L., Li, L., Weintraub, S. R., Loescher, H. W., Mirtl, M., Groffman, P. M., Wall, D. H., Young, M., White, T., Wen, H., Zacharias, S., Kuehn, I., Tang, J., Gaillardet, J., Braud, I., Flores, A. N., Kumar, P., Lin, H., Ghezzehei, T., Jones, J., Gholz, H. L., Vereecken, H., & Van Looy, K. (2018). Steering operational synergies in terrestrial observation networks: opportunity for advancing Earth system dynamics modelling. EARTH SYSTEM DYNAMICS, 9(2), 593-609. doi: 10.5194/esd-9-593-2018

Cardon, Z. G., Peredo, E. L., Dohnalkova, A. C., Gershone, H. L., & Bezanilla, M. (2018). A model suite of green algae within the Scenedesmaceae for investigating contrasting desiccation tolerance and morphology. JOURNAL OF CELL SCIENCE, 131(7). doi: 10.1242/jcs.212233

Carey, J. C., Parker, T. C., Fetcher, N., & Tang, J. (2017). Biogenic silica accumulation varies across tussock tundra plant functional type. FUNCTIONAL ECOLOGY, 31(11), 2177-2187. doi: 10.1111/1365-2435.12912

Chen, X., Zeng, G., Xie, Q., Chen, Y., Huang, Y., Qiu, J., Cai, J., Chen, C., & Tang, J. (2017). A novel combined recirculating treatment system for intensive marine aquaculture. AQUACULTURE RESEARCH, 48(9), 5062-5071. doi: 10.1111/are.13323

Daniels, W. C., Russell, J. M., Giblin, A. E., Welker, J. M., Klein, E. S., & Huang, Y. (2017). Hydrogen isotope fractionation in leaf waxes in the Alaskan Arctic tundra. GEOCHIMICA ET COSMOCHIMICA ACTA, 213, 216-236. doi: 10.1016/j.gca.2017.06.028

Euskirchen, E. S., Bret-Harte, M. S., Shaver, G. R., Edgar, C. W., & Romanovsky, V. E. (2017). Long-term release of carbon dioxide from Arctic tundra ecosystems in Alaska. ECOSYSTEMS, 20(5), 960-974. doi: 10.1007/s10021-016-0085-9

Fan, J. L., Luo, R. Y., Liu, D. Y., Chen, Z. M., Luo, J. F., Boland, N., Tang, J. W., Hao, M. D., McConkey, B., & Ding, W. X. (2018). Stover retention rather than no-till decreases the global warming potential of rainfed continuous maize cropland. FIELD CROPS RESEARCH, 219, 14-23. doi: 10.1016/j.fcr.2018.01.023

Forbrich, I., Giblin, A. E., & Hopkinson, C. S. (2018). Constraining marsh carbon budgets using long-term C burial and contemporary atmospheric CO_2 Fluxes. JOURNAL OF GEOPHYSICAL RESEARCH-BIOGEOSCIENCES, 123(3), 867-878. doi: 10.1002/2017JG004336

Fu C, Wang G, Goulden ML, Saleska SR, Scott RL, Cardon ZG. (2018) Hydrauic redistribution affects modeled carbon cycling via soil microbial activity and suppressed fire. GLOBAL CHANGE BIOLOGY, 24(8), 3472-3485. doi:10.1111/gcb.14164

Groisman, P., Shugart, H., Kicklighter, D., Henebry, G., Tchebakova, N., Maksyutov, S., Monier, E., Gutman, G., Gulev, S., Qi, J., Prishchepov, A., Kukavskaya, E., Porfiriev, B., Shiklomanov, A., Loboda, T., Shiklomanov, N., Nghiem, S., Bergen, K., Albrechtova, J., Chen, J., Shahgedanova, M., Shvidenko, A., Speranskaya, N., Soja, A., de Beurs, K., Bulygina, O., McCarty, J., Zhuang, Q., & Zolina, O. (2017). Northern Eurasia Future Initiative (NEFI): facing the challenges and pathways of global change in the twenty-first century. PROGRESS IN EARTH AND PLANETARY SCIENCE, 4(ARTN 41). doi: 10.1186/s40645-017-0154-5

He, H., Cheng, X., Li, X., Zhu, R., Hui, F., Wu, W., Zhao, T., Kang, J., & Tang, J. (2017). Aerial photography based census of Adelie Penguin and its application in CH_4 and N2O budget estimation in Victoria Land, Antarctic. SCIENTIFIC REPORTS, 7(ARTN 12942). doi: 10.1038/s41598-017-13380-6

Heskel, M. A. (2018). Small flux, global impact: Integrating the nuances of leaf mitochondrial respiration in estimates of ecosystem carbon exchange. AMERICAN JOURNAL OF BOTANY, 105(5), 815-818. doi: 10.1002/ajb2.1079

Shell of the heteropod *Carinaria* spp. collected at 3200m by a sediment trap on the Oceanic Flux Program (OFP) mooring in the deep Sargasso Sea. (Photo by JC Weber/OFP)

Hobbie, E. A., Shamhart, J., Sheriff, M., Ouimette, A. P., Trappe, M., Schuur, E. A. G., Hobbie, J. E., Boonstra, R., & Barnes, B. M. (2017). Stable isotopes and radiocarbon assess variable importance of plants and fungi in diets of Arctic ground squirrels. ARCTIC ANTARCTIC AND ALPINE RESEARCH, 49(3), 487-500. doi: 10.1657/AAAR0016-062

Huntingford, C., Atkin, O. K., Martinez-de la Torre, A., Mercado, L. M., Heskel, M. A., Harper, A. B., Bloomfield, K. J., O'Sullivan, O. S., Reich, P. B., Wythers, K. R., Butler, E. E., Chen, M., Griffin, K. L., Meir, P., Tjoelker, M. G., Turnbull, M. H., Sitch, S., Wiltshire, A., & Malhi, Y. (2017). Implications of improved representations of plant respiration in a changing climate. NATURE COMMUNICATIONS, 8(ARTN 1602). doi: 10.1038/s41467-017-01774-z

Kinney, E. L., & Valiela, I. (2018). *Spartina alterniflora* δ15N as an indicator of estuarine nitrogen load and sources in Cape Cod estuaries. MARINE POLLUTION BULLETIN, 131, 205-211. doi: 10.1016/j.marpolbul.2018.04.006

Kroeger, K. D., Crooks, S., Moseman-Valtierra, S., & Tang, J. (2017). Restoring tides to reduce methane emissions in impounded wetlands: A new and potent Blue Carbon climate change intervention. SCIENTIFIC REPORTS, 7(ARTN 11914). doi: 10.1038/s41598-017-12138-4

Liang, L. L., Arcus, V. L., Heskel, M. A., O'Sullivan, O. S., Weerasinghe, L. K., Creek, D., Egerton, J. J. G., Tjoelker, M. G., Atkin, O. K., & Schipper, L. A. (2018). Macromolecular rate theory (MMRT) provides a thermodynamics rationale to underpin the convergent temperature response in plant leaf respiration. GLOBAL CHANGE BIOLOGY, 24(4), 1538-1547. doi: 10.1111/gcb.13936

Liu, X. Y., Koba, K., Koyama, L. A., Hobbie, S. E., Weiss, M. S., Inagaki, Y., Shaver, G. R., Giblin, A. E., Hobara, S., Nadelhoffer, K. J., Sommerkorn, M., Rastetter, E. B., Kling, G. W., Laundre, J. A., Yano, Y., Makabe, A., Yano, M., & Liu, C. Q. (2018). Nitrate is an important nitrogen source for Arctic tundra plants. PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA, 115(13), 3398-3403. doi: 10.1073/pnas.1715382115

Longo, W. M., Huang, Y., Yao, Y., Zhao, J., Giblin, A. E., Wang, X., Zech, R., Haberzettl, T., Jardillier, L., Toney, J., Liu, Z., Krivonogov, S., Kolpakova, M., Chu, G., D'Andrea, W. J., Harada, N., Nagashima, K., Sato, M., Yonenobu, H., Yamada, K., Gotanda, K., & Shinozuka, Y. (2018). Widespread occurrence of distinct alkenones from Group I haptophytes in freshwater lakes: Implications for paleotemperature and paleoenvironmental reconstructions. EARTH AND PLANETARY SCIENCE LETTERS, 492, 239-250. doi: 10.1016/j.eps1.2018.04.002

Lu, X., Cheng, X., Li, X., & Tang, J. (2018). Opportunities and challenges of applications of satellite-derived sun-induced fluorescence at relatively high spatial resolution. SCIENCE OF THE TOTAL ENVIRONMENT, 619, 649-653. doi: 10.1016/j.scitotenv.2017.11.158

Lu, X., Liu, Z., Zhou, Y., Liu, Y., & Tang, J. (2018). Performance of solar-induced chlorophyll fluorescence in estimating water-use efficiency in a temperate forest. REMOTE SENSING, 10(5). doi: 10.3390/rs10050796

Lu, X. L., Liu, Z. Q., An, S. Q., Miralles, D. G., Maes, W. H., Liu, Y. L., & Tang, J. W. (2018). Potential of solar-induced chlorophyll fluorescence to estimate transpiration in a temperate forest. AGRICULTURAL AND FOREST METEOROLOGY, 252, 75-87. doi: 10.1016/j.agrforrnet.2018.01.017

Mayes, M., Mustard, J., Melillo, J., Neill, C., & Nyadzi, G. (2017). Going beyond the green: senesced vegetation material predicts basal area and biomass in remote sensing of tree cover conditions in an African tropical dry forest (miombo woodland) landscape. ENVIRONMENTAL RESEARCH LETTERS, 12(8). doi: 10.1088/1748-9326/aa7242

Martin, R. M., Wigand, C., Elmstrom, E., Lloret, J., & Valiela, I. (2018). Long-term nutrient addition increases respiration and nitrous oxide emissions in a New England salt marsh. ECOLOGY AND EVOLUTION, 8(10), 4958-4966. doi: 10.1002/ece3.3955

May, J. L., Parker, T., Unger, S., & Oberbauer, S. F. (2018). Short term changes in moisture content drive strong changes in Normalized Difference Vegetation Index and gross primary productivity in four

Arctic moss communities. Remote Sensing of Environment, 212(C), 114-120. doi: 10.1016/j.rse.2018.04.041

Melillo, J. M., Frey, S. D., DeAngelis, K. M., Werner, W. J., Bernard, M. J., Bowles, F. P., Pold, G., Knorr, M. A., & Grandy, A. S. (2017). Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world. SCIENCE, 358(6359), 101-104. doi: 10.1126/science.aan2874

Monier, E., Kicklighter, D. W., Sokolov, A. P., Zhuang, Q., Sokolik, I. N., Lawford, R., Kappas, M., Paltsev, S. V., & Groisman, P. Y. (2017). A review of and perspectives on global change modeling for Northern Eurasia. ENVIRONMENTAL RESEARCH LETTERS, 12(8). doi: 10.1088/1748-9326/aa7aae

Monier, E., Paltsev, S., Sokolov, A., Chen, Y. H. H., Gao, X., Ejaz, Q., Couzo, E., Schlosser, C. A., Dutkiewicz, S., Fant, C., Scott, J., Kicklighter, D., Morris, J., Jacoby, H., Prinn, R., & Haigh, M. (2018). Toward a consistent modeling framework to assess multi-sectoral climate impacts. NATURE COMMUNICATIONS, 9(ARTN 660). doi: 10.1038/s41467-018-02984-9

Nagy, R. C., Porder, S., Brando, P., Davidson, E. A., Figueira, A. M. E. S., Neill, C., Riskin, S., & Trumbore, S. (2018). Soil carbon dynamics in soybean cropland and forests in Mato Grosso, Brazil. JOURNAL OF GEOPHYSICAL RESEARCH-BIOGEOSCIENCES, 123(1), 18-31. doi: 10.1002/2017JG004269

Neill, C., Jankowski, K., Brando, P. M., Coe, M. T., Deegan, L. A., Macedo, M. N., Riskin, S. H., Porder, S., Elsenbeer, H., & Krusche, A. V. (2017). Surprisingly modest water quality impacts from expansion and intensification of large-scale commercial agriculture in the Brazilian Amazon-Cerrado Region. TROPICAL CONSERVATION SCIENCE, 10. doi: 10.1177/1940082917720669

Parker, T. C., Tang, J., Clark, M. B., Moody, M. M., & Fetcher, N. (2017). Ecotypic differences in the phenology of the tundra species *Eriophorum vaginatum* reflect sites of origin. ECOLOGY AND EVOLUTION, 7(22), 9775-9786. doi: 10.1002/ece3.3445

Pearse, W. D., Cavender-Bares, J., Hobbie, S. E., Avolio, M. L., Bettez, N., Chowdhury, R. R., Darling, L. E., Groffman, P. M., Grove, J. M., Hall, S. J., Heffernan, J. B., Learned, J., Neill, C., Nelson, K. C., Pataki, D. E., Ruddell, B. L., Steele, M. K., & Trammell, T. L. E. (2018). Homogenization of plant diversity, composition, and structure in North American urban yards. ECOSPHERE, 9(2). doi: 10.1002/ecs2.2105

Peredo, E. L., & Simmons, S. L. (2018). Leaf-FISH: Microscale imaging of bacterial taxa on phyllosphere. FRONTIERS IN MICROBIOLOGY, 8(ARTN 2669). doi: 10.3389/fmicb.2017.02669

Pold, G., Grandy, A. S., Melillo, J. M., & DeAngelis, K. M. (2017). Changes in substrate availability drive carbon cycle response to chronic warming. SOIL BIOLOGY & BIOCHEMISTRY, 110, 68-78. doi: 10.1016/j.soilbio.2017.03.002

Qiu, C., Zhu, D., Ciais, P., Guenet, B., Krinner, G., Peng, S., Aurela, M., Bernhofer, C., Bruemmer, C., Bret-Harte, S., Chu, H., Chen, J., Desai, A. R., Dusek, J., Euskirchen, E. S., Fortuniak, K., Flanagan, L. B., Friborg, T., Grygoruk, M., Gogo, S., Gruenwald, T., Hansen, B. U., Holl, D., Humphreys, E., Hurkuck, M., Kiely, G., Klatt, J., Kutzbach, L., Largeron, C., Laggoun-Defarge, F., Lund, M., Lafleur, P. M., Li, X., Mammarella, I., Merbold, L., Nilsson, M. B., Olejnik, J., Ottosson-Lofvenius, M., Oechel, W., Parmentier, F. J. W., Peichl, M., Pirk, N., Peltola, O., Pawlak, W., Rasse, D., Rinne, J., Shaver, G., Schmid, H. P., Sottocornola, M., Steinbrecher, R., Sachs, T., Urbaniak, M., Zona, D., & Ziemblinska, K. (2018). ORCHIDEE-PEAT (revision 4596), a model for northern peatland CO_2, water, and energy fluxes on daily to annual scales. GEOSCIENTIFIC MODEL DEVELOPMENT, 11(2), 497-519. doi: 10.5194/gmd-11-497-2018

Roberti, J. A., Ayres, E., Loescher, H. W., Tang, J., Starr, G., Durden, D. J., Smith, D. E., de la Reguera, E., Morkeski, K., McKlveen, M., Benstead, H., SanClements, M. D., Lee, R. H., Gebremedhin, M., & Zulueta, R. C. (2018). A robust calibration method for continental-scale soil water content measurements. VADOSE ZONE JOURNAL, 17(1). doi: 10.2136/vzj2017.10.0177

Schedlbauer, J. L., Fetcher, N., Hood, K., Moody, M. L., & Tang, J. (2018). Effect of growth temperature on photosynthetic capacity and respiration in three ecotypes of *Eriophorum vaginatum*. ECOLOGY AND EVOLUTION, 8(7), 3711-3725. doi: 10.1002/ece3.3939

Svensson, B. M., Carlsson, B. A., & Melillo, J. M. (2018). Changes in species abundance after seven years of elevated atmospheric CO_2 and warming in a Subarctic birch forest understorey, as modified by rodent and moth outbreaks. PEERJ, 6(ARTN e4843). doi: 10.7717/peerj.4843

Tang, J., Ye, S., Chen, X., Yang, H., Sun, X., Wang, F., Wen, Q., & Chen, S. (2018). Coastal blue carbon: Concept, study method, and the application to ecological restoration. SCIENCE CHINA-EARTH SCIENCES, 61(6), 637-646. doi: 10.1007/s11430-017-9181-x

Tcherkez, G., Gauthier, P., Buckley, T. N., Busch, F. A., Barbour, M. M., Bruhn, D., Heskel, M. A., Gong, X. Y., Crous, K. Y., Griffin, K., Way, D., Turnbull, M., Adams, M. A., Atkin, O. K., Farquhar, G. D., & Cornic, G. (2017). Leaf day respiration: low CO_2 flux but high significance for metabolism and carbon balance. NEW PHYTOLOGIST, 216(4), 986-1001. doi: 10.1111/nph.14816

Valiela, I., Pascual, J., Giblin, A., Barth-Jensen, C., Martinetto, P., Otter, M., Stone, T., Tucker, J., Bartholomew, M., & Viana, I. G. (2018). External and local controls on land-sea coupling assessed by stable isotopic signatures of mangrove producers in estuaries of Pacific Panama. MARINE ENVIRONMENTAL RESEARCH, 137, 133-144. doi: 10.1016/j.marenvres.2018.03.003

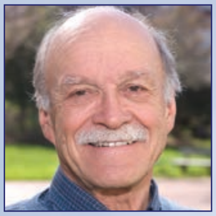
Wang, F., Ding, Y., Sayer, E. J., Li, Q., Zou, B., Mo, Q., Li, Y., Lu, X., Tang, J., Zhu, W., & Li, Z. (2017). Tropical forest restoration: Fast resilience of plant biomass contrasts with slow recovery of stable soil C stocks. FUNCTIONAL ECOLOGY, 31(12), 2344-2355. doi: 10.1111/1365-2435.12925

Wheeler, M. M. T., Neill, C., Groffman, P. M., Avolio, M., Bettez, N., Cavender-Bares, J., Chowdhury, R. R., Darling, L., Grove, J. M., Hall, S. J., Heffernan, J. B., Hobbie, S. E., Larson, K. L., Morse, J. L., Nelson, K. C., Ogden, L. A., O'Neil-Dunne, J., Pataki, D. E., Polsky, C., Steele, M., & Trammell, T. L. E. (2017). Continental-scale homogenization of residential lawn plant communities. LANDSCAPE AND URBAN PLANNING, 165, 54-63. doi: 10.1016/j.landurbplan.2017.05.004

Director

Anne Giblin
Ph.D. Boston University

Distinguished Scientists



John Hobbie
Ph.D. Indiana University

Jerry M. Melillo
Ph.D. Yale University

Ivan Valiela
Ph.D. Cornell University

Senior Scientist Emeritus

Bruce J. Peterson
Ph.D. Cornell University

Gaius R. Shaver
Ph.D. Duke University

Senior Scientists

Zoe G. Cardon
Ph.D. Stanford University

Edward B. Rastetter
Ph.D. University of Virginia

Joseph J. Vallino
Ph.D. Massachusetts Institute of Technology

Associate Scientist

Jianwu Tang
Ph.D. University of California, Berkeley

Director, SES

Kenneth H. Foreman
Director, SES
Ph.D. Boston University

Senior Research Scholar

Paul Steudler
M.S. University of Oklahoma

MBL Fellows

Maureen Conte
Bermuda Institute of Ocean Sciences
Ph.D. Columbia University

Linda A. Deegan
Woods Hole Research Center
Ph.D. Louisiana State University

Robert Howarth
Cornell University
Ph.D. MIT/WHOI

Christopher Neill
Woods Hole Research Center
Ph.D. UMass Amherst

Research Scientists and Associates

Inke Forbrich
Ph.D. University of Greiswald

Elena Lopez Peredo
Ph.D. University of Oviedo

Javier Lloret
Ph.D. University of Murcia

David W. Kicklighter
M.S. University of Montana

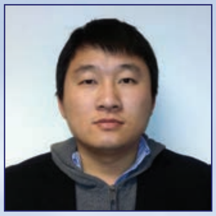
Postdoctoral Scientists

Heidi Golden
Ph.D. University of Connecticut

Mary Heskel
Ph.D. Columbia University

Rut Pedrosa-Pàmies
Ph.D. University of Barcelona

Aboozar Tabatabai
Ph.D. Rutgers University



Faming Wang
Ph.D. University of Chinese Academy of Sciences

Senior Research Assistants

Robert Hap Garritt, III
M.S. Cornell University

James A. Laundre
M.S. University of Connecticut

Richard McHorney
M.S. University of Pennsylvania

Suzanne M. Thomas
M.S. University of Pennsylvania

Jane Tucker
M.S. University of North Carolina

J.C. Weber
M.S. University of Delaware

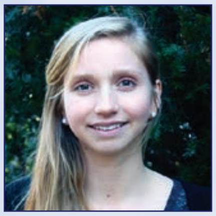
Daniel White
M.S. SUNY College at Brockport

Stable Isotope Lab Manager

Marshall L. Otter
Ph.D. University of Cape Town, South Africa

Research Assistants

Kelsey Chenoweth
B.S. Bates College



Elizabeth Elmstrom
B.S. University of Vermont

Kyle Fisk
B.S. Bridgewater State University

Daniella Hanacek
B.S. St. Mary's College of Maryland

Melanie Hayn
M.S. Cornell University

Samuel Kelsey
B.S. Dickinson College

Bonnie L. Kwiatkowski
M.S. University of New Hampshire

Zhunqiao Liu
Nanjing University

Tyler Messerschmidt
B.S. Rippon College

Elizabeth de la Reguera
B.S. Dickinson College

Sophia Rudin
B.S. Brown University

Jordan Stark
B.S. Skidmore College

Alana Thurston
B.S. Haverford College

Erin VanderJeugdt
B.S. Univ. of North Carolina, Chapel

HillWilliam Werner
B.S. Belloit College

Visiting Scientists


Magdalena Bezanilla
Darmouth College


Prof. James Galloway
University of Virginia
Ph.D. University of California, San Diego


Ketil Koop-Jakobsen
University of Bermen


Roxanne Marino
Cornell University


Mirta Teichberg
University of Bremen

Administrative Staff


Kelly Holzworth
Center Administrator
University of San Diego


Aileen Jensen
Center Coordinator
B.A. UMass Amherst

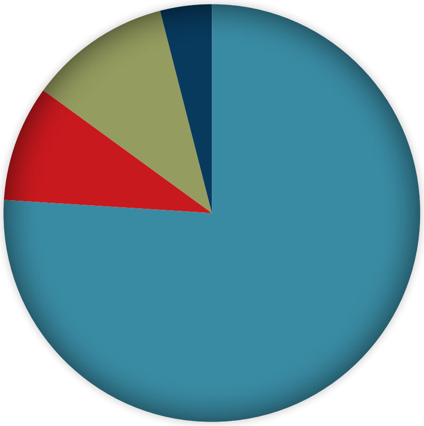

Alison Maksym
SES Coordinator
M.S. University of Alaska, Fairbanks

Temporary Staff & Students

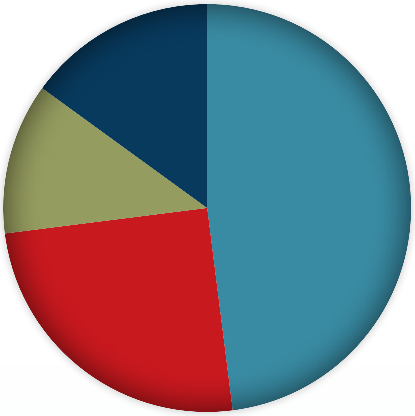
Deshawn Adler
Mashpee High School, REU student
Dominic Arcona
Dartmouth College, Undergrad Student
Laura Agusto
Hong Kong University, Graduate Student
Jacob Athamni
Temporary Staff
Cameron Bechtold
REU Student
Ashley Bulseco
Northeastern University, Ph.D. Student
Kristen Burk
Temporary Staff
Michael Callahan
Bourne High School, REU Student
John Daigneault
Temporary Staff
Emily DeFilippis
Temporary Staff
Caroline Dodd
Cornell University, Undergraduate Student
Brecia Douglas
Temporary Staff
Gabriel Duran
PEP Student
Samuel Finnerty
Temporary Staff
Kyle Fisk
Temporary Staff
Vera Gaddi
Cornell University, Undergraduate Student
Erin Gleeson
REU Student
Jonathan Gewirtzman
Temporary Staff
Victoria Gray
UMass Dartmouth, Graduate Student
Nathalie Griffiths
Cornell University, Undergraduate Student
Thomas Hafen
REU Student
Katherine Haviland
Cornell University, Graduate Student
Johanna Holo
University of Chicago, Metcalf Student
Yujie Hua
Florida International University, Graduate Student
Rachel Kaplan
Temporary Staff
Zhenyue Lin
Xiamen University, Graduate Student
Allie Pankoff
REU Student
Nicole Peckham
REU Student
Geovanna Pereirra
Temporary Staff
Leron Perez
University of Chicago, Metcalf Student
Victoria Roberson
PEP Student
Sharanya Sarathy
Brown-MBL Summer Intern
Nathalie Steiger
UMass Dartmouth, Graduate Student
Kristy Sullivan
Temporary Staff
Justin Susarchick
Temporary Staff
Bonnie Turek
REU Student
Steven Unger
Temporary Staff
Claire Valva
University of Chicago, Metcalf Student
Michael Whittemore
Temporary Staff
Alexandria Walus
REU Student
Liuying Wang
Xiamen University, Graduate Student
Ryan West
REU Student
Shu-Zon Wu
Dartmouth College, Postdoc Scientist
Franklina Yeboah
PEP Student
Gyujong Yoo
REU Student

Sources of Support for Research

The operating budget of The Ecosystems Center for the period of July 2017 – June 2018 was $5,743,000. Approximately 76% of the income of the center came from grants for basic research, including support from the National Science Foundation, the Department of Energy and the National Oceanic and Atmospheric Administration. The other 24% 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.



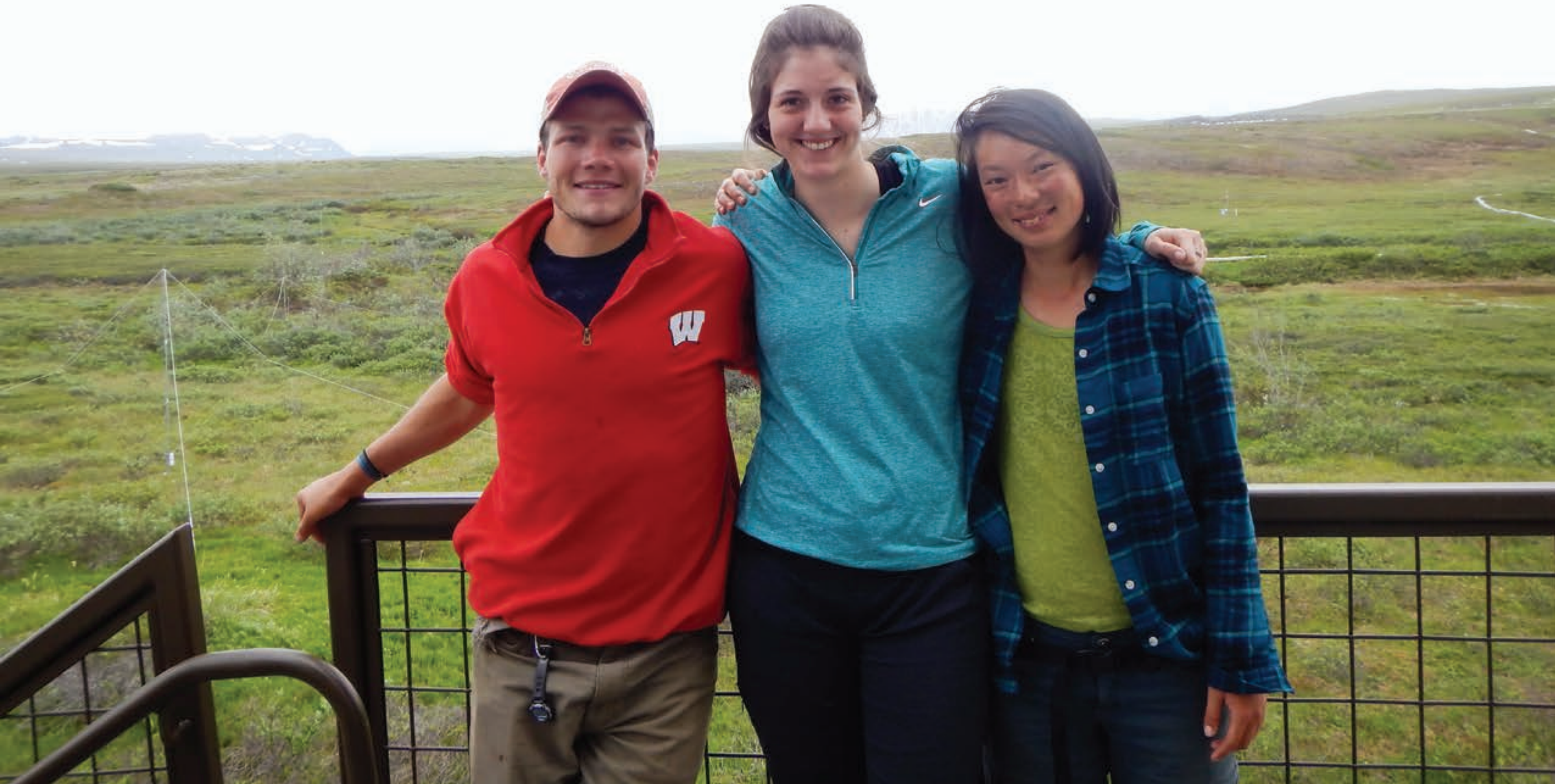
SOURCES OF SUPPORT
- Federal Grants 76%
- Non-Federal Grants 9%
- Gifts & Endowments 11%
- Internal & Other 4%



EXPENSES
- Personnel 48%
- Overhead 25%
- Operating 12%
- Subcontracts 15%

The following donations were made to the Ecosystems Center and the SES Program between July 1, 2017 and June 30, 2018. More information can be found in the MBL Annual Report.

Anonymous (4)
The Bailey Wildlife Foundation
Margaret C. and Francis P. Bowles
David Clarke - in Honor of John Hobbie
Bradley and Katie Cohen
Steven and Lois Eisen
Christopher Foreman
Peter and Ginny Foreman
Mark Gasarch
The Foundation for Agricultural Integrity
Harken Foundation
Barbara Woll Jones - in Honor of Anne Giblin and Ken Foreman
Frank S. and Nancy Karger
Thomas E. Lovejoy
Robert and Christina McKane
Morgenstern-Davis Family Foundation
Noribachi
The Oppenheimer Family Foundation
Michael G. Ryan and Linda A. Joyce
Sara Lee Schupf
John and Cheryl Seder - in Honor of Ken Foreman
Simons Foundation
Lisa Warshauer
St. Andrews Foundation
Ann S. Wolff



Join the MBL Community @mblscience @mblscience mblwoodshole