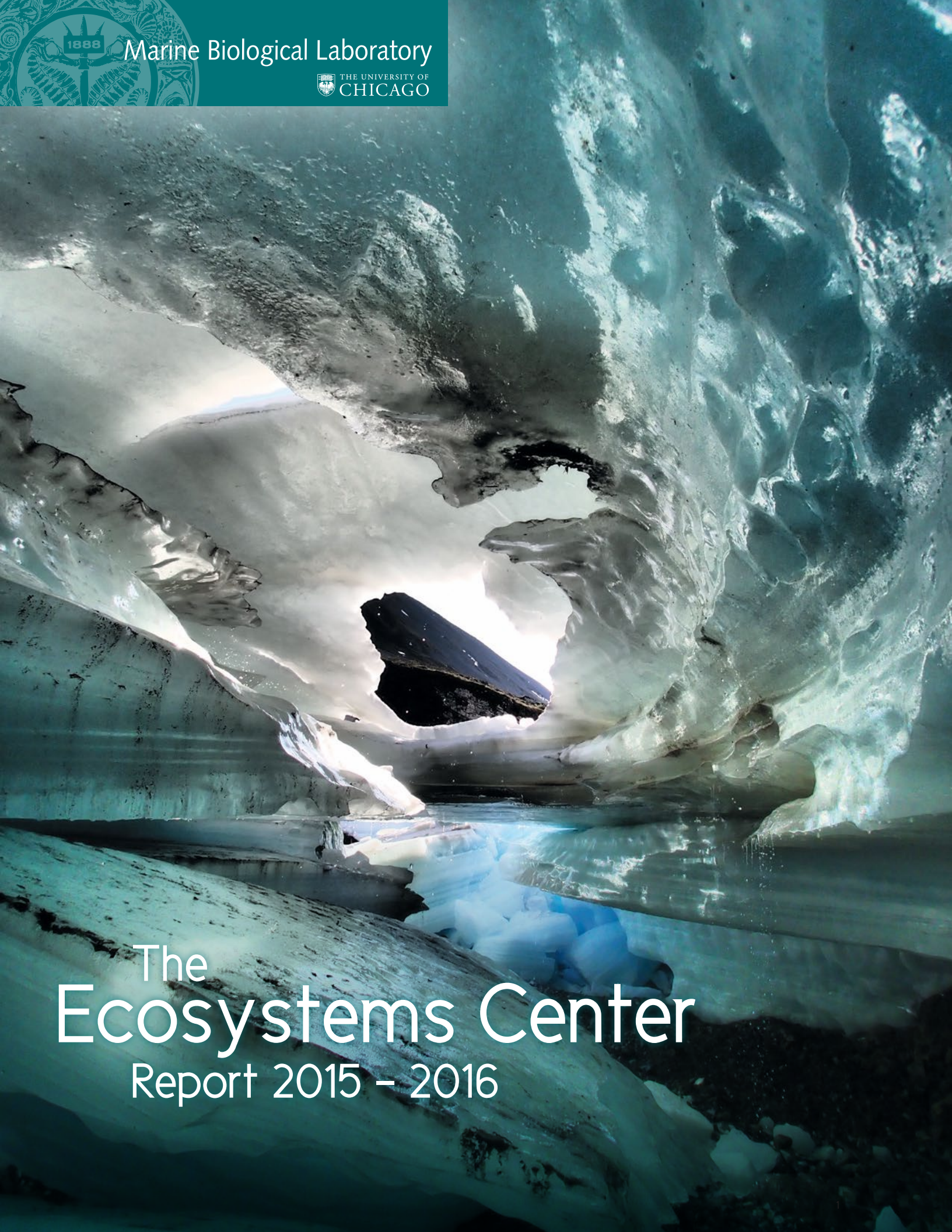
Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO



The Ecosystems Center

Report 2015 – 2016

About the MBL – University of Chicago
The Marine Biological Laboratory and the University of Chicago share a common history and collaborative values. The MBL has been a driving force in biological discovery and research training since its founding in 1888. MBL – Uchicago are working to strengthen their leadership and innovation in scientific research, scientific excellence and education.

Cover Photo
Aufeis in the Arctic Circle, Alaska
(Photo: Daniel White)

This Page
Ecosystems staff
(Drone photo: Brian Switzer)

Opposite Page
Great Sippewissett Marsh
(Drone photo: Rhys Probyn, MRC/Valiela Lab)

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Ecosystem Science

DIRECTOR'S NOTE

By Anne Giblin

The Ecosystems Center was founded four decades ago to investigate the structure and functioning of ecological systems and to predict their response to changing environmental conditions. At that time the changing global carbon cycle was just becoming recognized as an urgent environmental issue and became one of the focal points for research at the Center.

How high will carbon dioxide (CO_2) levels rise and how much do human emissions need to be decreased to stabilize or reduce atmospheric CO_2 concentrations? The answer to this depends a great deal on how natural systems respond. Will we see more or less carbon being stored in forest soils? How much carbon can be sequestered in the coastal and deep ocean? Will the large depot of carbon stored in permafrost in the Arctic be released or will the Arctic become a large source of CO_2 to the atmosphere? These are complex questions which require that we understand how factors such as temperature, disturbance and nutrient inputs alter the carbon balance of different ecosystems.

Understanding these questions has only become more urgent over the last 40 years. This March marked the first month that global atmospheric carbon dioxide levels rose above 400 ppm. The world has not seen this level of CO_2 in the atmosphere for the entire time span that humans have been on the planet. Carbon dioxide concentrations were still above 400 ppm this September, usually the month when CO_2 concentration are at their lowest, and may not fall below 400 ppm again in our lifetime. This level of CO_2 is believed to commit the world to a warming of 1.5°C and levels are still increasing.

In this issue we highlight some of the ways that The Ecosystems Center scientists and their colleagues are advancing our understanding of the global carbon cycle. Long-term observations such as the Ocean Flux Program time series off of Bermuda help unravel the controls on carbon burial in the deep ocean. Our understanding of processes is also informed by long-term experiments, such as the long-term soil warming experiments at the Harvard Forest, and sustained observations of the results of natural events, such as wild fires in Arctic tundra. The development of new methods to observe plant phenology and gross photosynthesis at regional to global scales allow us not only to monitor change, but also provide information to improve global models. Finally, a more sophisticated understanding of how microbes interact as communities allows us to better understand global element cycles.

The other part of the mission of the Ecosystems Center is to apply the knowledge we gain from our science to the preservation and management of natural resources, and to educate both future scientists and concerned citizens. Over the last 40 years, our education and outreach activities have continued to grow and we expect that our new affiliation with the University of Chicago will allow for further expansion. As we look back on the last 40 years of the Ecosystems Center with pride, we also know that there is still much work to be done.

This special issue on our 40th anniversary covers an 18 month period from January 1, 2015 until June 30th 2016. Future issues will cover a one-year period from July 1 until June 30 as we align with MBL's new academic and financial calendar.

The Impacts of climate change on ecosystems

When the Ecosystems Center was first founded just over 40 years ago, scientists were largely focused on fossil fuel burning as a source of CO_2 to the atmosphere. Scientists at the Ecosystems Center were among the first to point out that deforestation was an important contributor to the build-up of carbon dioxide to the atmosphere. We now know more about how the concentration of carbon dioxide and other greenhouse gases in the atmosphere is controlled by a complex balance between anthropogenic fossil fuel emissions, uptake and release by the biosphere, and carbon losses to the deep ocean. But many questions about the long-term response of the biosphere and the oceans to changing climate remain unanswered. Will soils become another major source of carbon dioxide to the atmosphere and what role will events like fire and permafrost thawing play in the responses? Will the oceans take up more or less carbon as the climate changes? These are critical gaps in our understanding that Ecosystems Scientist continue to address with long-term data, long-term experiments, and models.

Maureen Conte redeploying Oceanic Flux Program mooring in the Sargasso Sea (Photo: JC Weber)

Scientists from The Ecosystems Center began conducting research on arctic ecosystems on the North Slope of Alaska near Toolik Lake in 1975. Things have changed dramatically in that time. One unexpected change is in the frequency of thunderstorms. Forty years ago thunderstorms were extremely rare in the Toolik Lake region; now they are a common occurrence every summer.

The change in thunderstorms has consequences for tundra ecosystems. In 2007 a lightning strike ignited a wildfire that burned 1000 square kilometers of tundra, making it the largest tundra fire ever recorded. It was also the only fire in the area for over 5000 years. This fire released an estimated 2.3 million tons of carbon to the atmosphere as CO_2, which contributes to global climate warming. But as the tundra recovers from the fire, will it reabsorb that carbon? If so, how long will it take? These are long-term questions requiring a long-term strategy to address them. Thus far, we know that the plant canopy recovers in about five years and the tundra is even more productive and absorbing carbon faster than it did before the fire. Examination of some of the few older fires elsewhere on the North Slope indicate that that elevated productivity might last a few decades. However, the soils, where most of the tundra carbon is stored, are likely to take far longer to recover, perhaps thousands of years.

One way to address these really long-term questions is through models, but we need data to make sure the models are right. Monitoring the long-term monitoring of the recovery from fire is vital to improving those model predictions as well as long-term monitoring of responses to elevated CO_2 and climate change and to the thawing of permafrost in areas unaffected by fire.

Closer to home, at Prospect Hill in the Harvard Forest, a soil warming experiment is trying to tease out the way that

forest soils will respond to increased temperatures. During the 24-year period that the soils have been warmed, Jerry Melillo and colleagues have observed a pattern of soil carbon fluxes that can be broken into three distinct phases. First, there is an increase in the rate of soil CO_2 release relative to control plots that lasts about ten years (Phase I). This was followed by a seven-year period (Phase II) during which there was no difference if the response of the heated soils compared to the control soils. Then there was a resumed increase in soil CO_2 loss in the heated plots that has continued on for the last 7 years and is currently ongoing (Phase III). The loss of soil carbon by 2013 was 1350 ± 140 g C m^{-2}, or 16% of the total soil carbon found in the top 60 cm of soil at the start of the experiment. The release of soil carbon as CO_2 to the atmosphere in response to warming sets up a self-reinforcing feedback loop between the land and the atmosphere that leads to further climate warming.

The flux of particulate carbon to the deep ocean is one way in which carbon dioxide is removed from the atmosphere. MBL Fellow Maureen Conte heads the Oceanic Flux Program (OFP) time-series off Bermuda, the longest running time-series of its kind. For nearly four decades the OFP has continuously measured how particle sedimentation (or flux) in the deep Sargasso Sea varies in relation to natural variation in climate forcing and upper ocean physical and biological processes. Understanding what generates the particle flux and its recycling within the ocean's interior is of fundamental importance as the particle flux regulates many aspects of ocean biogeochemistry and global element cycles.

By studying natural climate cycles the OFP is providing tantalizing evidence on how the flux of carbon to the deep ocean might be altered with climate change. When the North Atlantic Oscillation (NAO; - the pressure differential between the Iceland Low and the Azores High and the major North Atlantic climate driver) - is in its "low" phase, storm systems track more southerly which results in colder winter air temperatures and increased winter storminess in the northern Sargasso Sea. This strengthens the upward nutrient flux into surface waters, which supports greater phytoplankton productivity. Importantly, the deep ocean flux of particulate carbon nitrogen also increases. Even so, the observed relationship between NAO status and the deep particle flux is weak. This underscores the importance of multi-decadal time-series such as the OFP to fully understand how climate has the capacity to alter particle flux patterns, with global repercussions for the global carbon budget.

Below: Heated Plot from the Soil Warming Experiment at Prospect Hill, Harvard Forest. Bottom, from left to right: Dr. Jeff Blanchard (UMass Amherst), Rebecca Bonilla (2016 Harvard Forest REU Program; UMass Boston), William Werner (MBL Ecosystems Center), and Catherine Polik (2016 Harvard Forest REU Program; Harvard University) process soil cores from the Soil Warming Experiment or nitrogen mineralization analysis NMIN

Microbiomes: Sustaining the Earth System

Microbes have shaped our planet's environment for over 3.5 billion years, and they continue influencing the evolution, development, and health of all life on Earth. Microbes counteract and cause disease, transform pollutants, and provide new sources of fuel. Photosynthetic microbes support the food webs that fuel our fisheries. Microbes salvage and recycle the building blocks of life that are essential for the growth of all plants and animals, on land and in the sea.

Recognizing the critical roles microbes play in meeting the needs of a growing human population, and in addressing associated challenges of global environmental change, the White House Office of Science and Technology Policy (OSTP) announced the creation of The National Microbiome Initiative (NMI) in May 2016. The NMI fosters the integrated study of microbial communities (microbiomes) across extremely diverse ecosystems, from arctic permafrost to deep ocean ridges, human guts to plant roots. Zoe Cardon, Senior Scientist at the Ecosystem Center, and Jack Gilbert, from the University of Chicago and MBL Fellow at the Bay Paul Center, worked with microbiome scientists from around the nation in developing the NMI. Cardon also joined ten others to author an overview paper released in the American Society for Microbiology's journal mBio as part of the NMI launch. That paper emphasized that attempting to harness microbial power to solve environmental or local health problems is an attractive idea, but also human manipulation of microbiomes at small or large scales entails real risk of unintended consequences. Microbes interact with each other and with their local environments in complex, imperfectly-understood, ecological systems on which all humanity depends. Given the coupled promise and risk of microbiome manipulation by humans, and the interdisciplinarity required to recognize both, the MBL's Ecosystems and Bay Paul Centers, working together, are very well positioned to make substantial contributions to the NMI.

For example, at the coastal and polar frontlines of climate change, major players (and major uncertainties) are microbial. Microbes may turn carbon liberated from thawing arctic permafrost into the very strong greenhouse gas methane, but triggers for that methane production remain unknown. In coastal salt marsh, if conditions are right, microbes can process pollutant nitrate into harmless nitrogen gas, but if conditions are wrong, they may retain the nitrogen in sediments. In the past, microbes in natural environments have often been viewed simply as interchangeable micro-machines carrying out such functions of interest to humans. But with the advent of very precise DNA sequencing and identification of individual microbes, it is clear that particular microbes can have specific environmental sensitivities and capabilities. Oxygen availability, pH, precipitation, and temperature are changing worldwide, and changing conditions may either support, or preclude, the translation of microbial DNA blueprints into action.

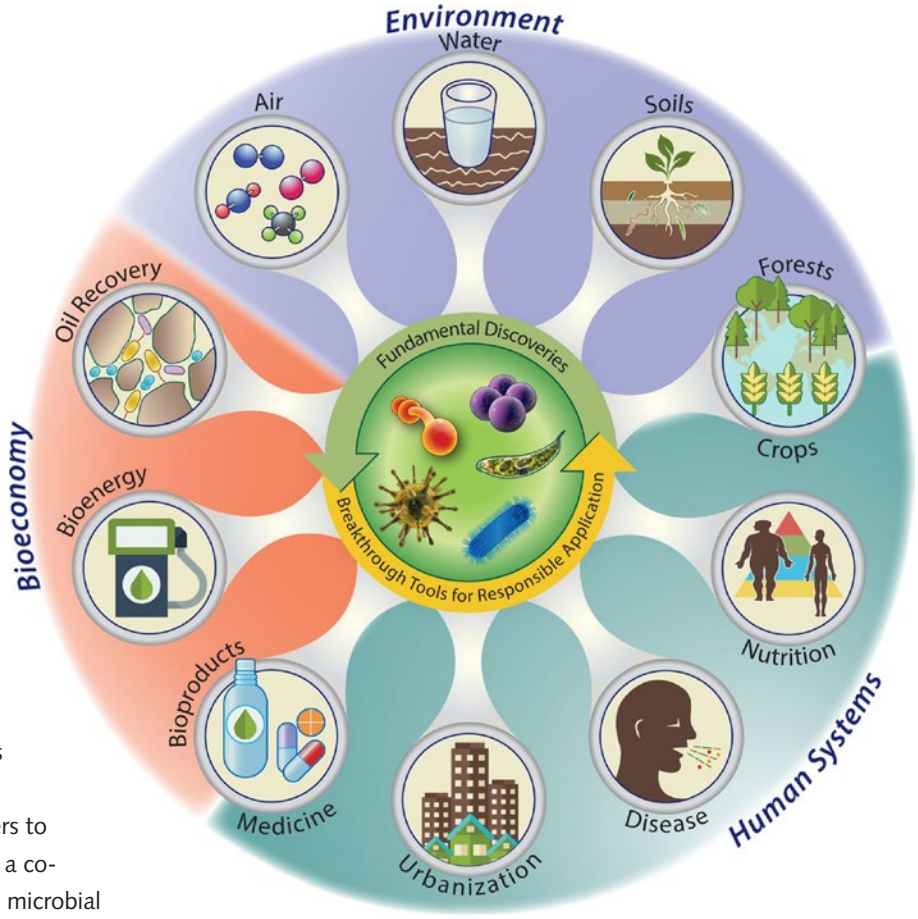
How rapidly can one type of microbe, unable to thrive in the changing environment, be replaced by another microbe

At the launch of the National Microbiome Initiative on May 13, 2016 at the White House. Left to right: David Mark Welch, Director of the Bay Paul Center and Associate Director of the Microbiome Center; Eugene Chang, Professor of Medicine at the UChicago, and collaborator of Mitch Sogin of MBL; Jack Gilbert, Professor of Surgery at the UChicago, Faculty Director of the Microbiome Center and MBL Fellow in the Bay Paul Center; Zoe Cardon, Senior Scientist at the Ecosystems Center; and Erin Lane, Executive Director of The Microbiome Center.

Opposite page top: Methanogene Project - Suzanne Thomas in glove bag to create anoxic environment.

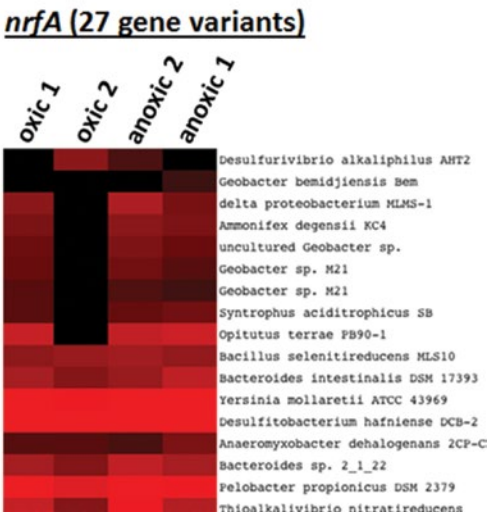
with that same functional capability and different environmental tolerances? Are functions carried out by very few types of microbes more likely to fade or fail under future climate or land-use scenarios? What would be the larger consequences of such functional failures for human societies?

Though genomic techniques are revealing answers to such questions for particular types of microbiomes, a conundrum remains. In most ecosystems world-wide, microbial genomes will remain unsampled for the foreseeable future. Because we will not know what microbes are present, or what functions their DNA blueprints encode, Ecosystems Center scientists are also pursuing complementary approaches for predicting microbiome-controlled biogeochemistry, based on thermodynamic principles. As the human population approaches 7.5 billion, the synergy of multiple approaches to understanding and predicting function of the world's microbiomes will be critical to our future on Earth.



The potential impact of a unified microbiome initiative on understanding and responsibly harnessing the activities of microbial communities. From: Blaser, M.J., Cardon, Z.G. et al., 2016

Bottom left: Microbial genes sampled around *Spartina* (cordgrass) roots from Plum Island LTER. Bottom right: SONiCC greenhouse experiment with *Spartina* cores



Imaging plants: beyond visualization

Earth is entering a new period so called "Anthropocene." The term is a result of the influences and dramatic changes that human activities have had on the Earth, the climate and on the environment in the past century. Plants, which provide essential sources of food, fiber, and other services for humans, are sensitive to these alterations. Therefore monitoring how plants respond to the changing environment is critically important to inform decision makers of sound strategies and policies to mitigate and adapt to global change.

Plants function in different ways depending on the day and the seasons. For example, photosynthesis increases during the day and peaks around noon. It then slows down later in the afternoon, while the plant absorbs solar energy, fix carbon dioxide, and produce carbohydrate. At night, in the dark, plants continuously use some of the bioenergy fixed during the day to grow and regenerate. These ecosystem functions are subject to deviations in sunlight, temperature, precipitation, and other climatic variables and disturbances. In temperate zones, many green plants experience leaf out, peak leaf coverage, and leaf fall – a phenology pattern that we can observe, even appreciate, in autumn.

Recent development in digital cameras enables us to continuously record the color of the plants, its phenology and the actual length of the growing season. These cameras can record images of the plants and their variations across species and seasons. The cameras also record the color bands of red, green, and blue. We can then digitally plot the percentage of green color and analyze the seasonal pattern of greenness.

However, regular digital cameras only record the visible bands. They may not capture some special plant functions. For example, green plants strongly reflect near-infrared because bands of light are not intensive enough to be used by plant photosynthesis. To address this issue, Ecosystems Center Associate Scientist Jim Tang and his group are incorporating near-infrared bands using an index called "normalized differ-

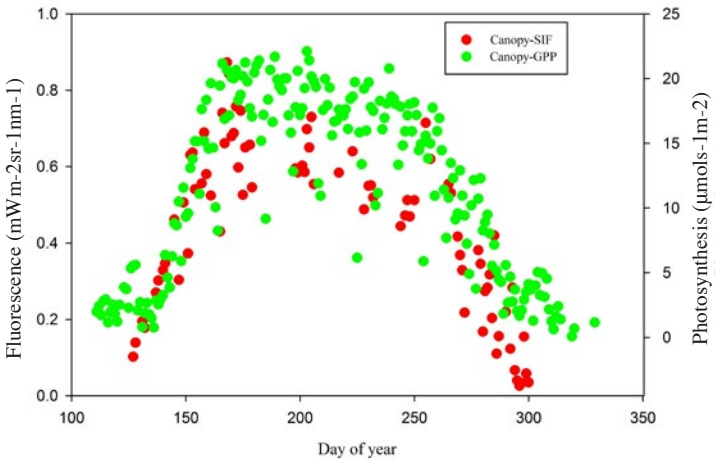
The Tang group used an infrared camera to record infrared and visible reflectance from trees at Harvard Forest. On the left is a real, untouched image. On the right is the infrared image. However, infrared being invisible to the human eyes, the colors are modified such that the color red = infrared, red=green, green=blue.

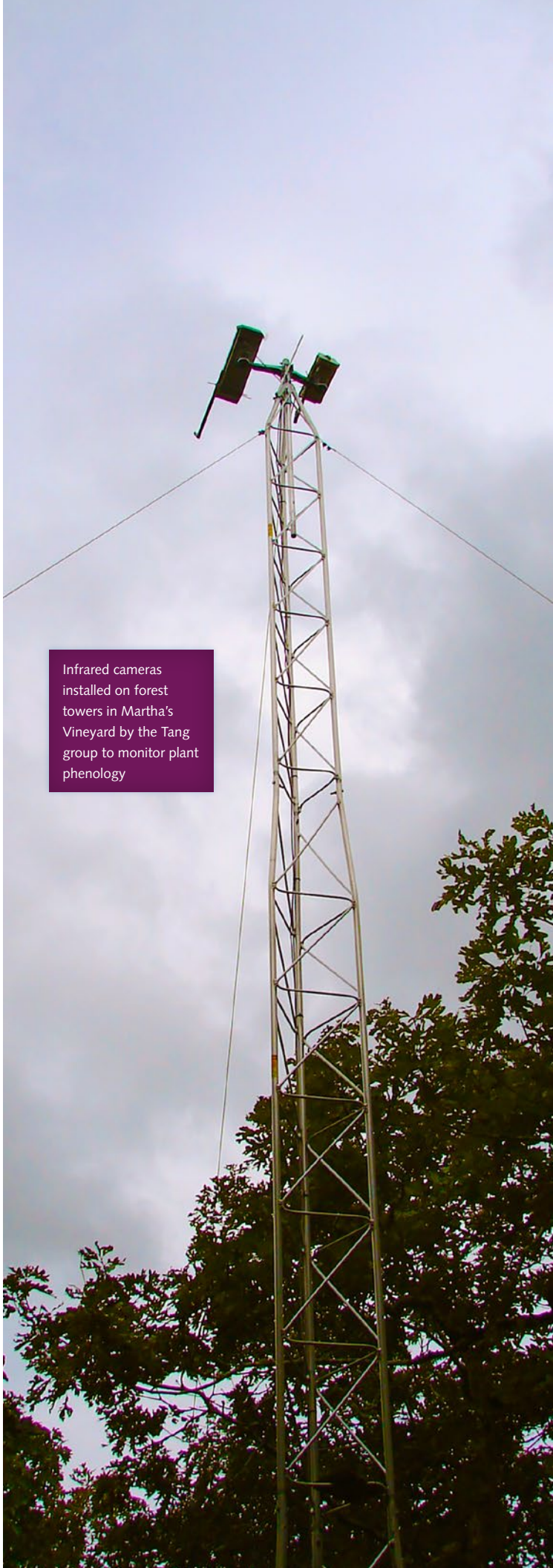
ence vegetation index", or NDVI, into plant monitoring. The team installed infrared cameras on forest towers and they hope to better detect the functioning of plants and the layer of plant leaves across heights.

Recently, a new technique has been developed to accurately monitor plant photosynthesis by measuring plant chlorophyll fluorescence. When carbon dioxide is assimilated under the sunlight, a small portion of visible light captured by chlorophyll is emitted as fluorescence at a longer wavelength. Thus, sun-induced fluorescence acts as a proxy to measure photosynthesis. However, recording the fluorescence signal is extremely difficult because the weak radiation is obscured by the much higher intensity of solar radiation and its reflection from plants. By developing a new sensor system, Jim Tang and his group are pioneering in the continuous measurements of sun-induced fluorescence.

Using these hyperspectral reflectance signals with the wavelengths beyond visible light, the team is paving a new way to estimate plant biochemical and biophysical properties including chlorophyll content, canopy moisture, and foliage chemistry. Jim Tang is also collaborating with scientists from Argonne National Laboratory to explore this new area of imaging plants beyond the visible information. This work is expected to shed light for the next generation of remote sensing using satellites, miniaturized satellites, and unmanned aircrafts to detect plants and their responses to the changing environment.

Fluorescence serves as a proxy for photosynthesis measured independently across the season of a year (red dots: fluorescence, green dots: photosynthesis)





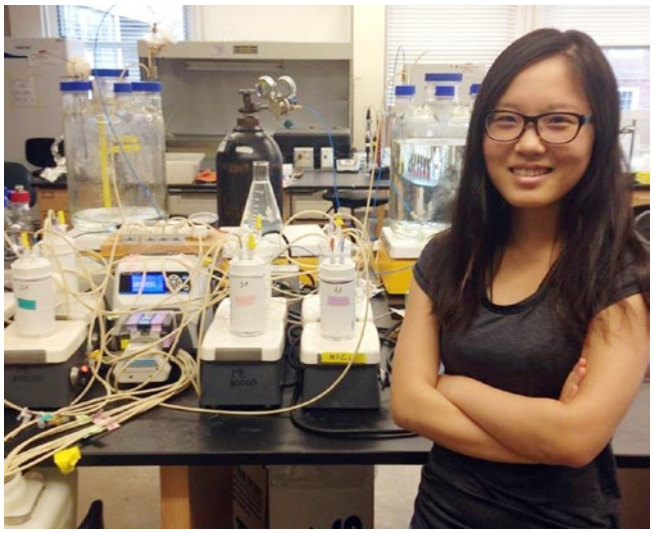
Infrared cameras installed on forest towers in Martha's Vineyard by the Tang group to monitor plant phenology

Semester in Environmental Science

Nia Bartolucci from Mt. Holyoke College conducting lab experiments for her independent research project on greenhouse gas flux from coastal marshes on Cape Cod.

The Semester in Environmental Science at the MBL is to offer undergraduates the opportunity to learn first-hand how scientists conduct research on ecosystems while gaining an understanding of the fundamentals of global change ecology and biogeochemistry. The faculty is committed to demonstrating how a fact-based understanding of ecosystem processes and their controls is essential to formulating wise environmental policy and management strategies.

Students in the program complete courses in Aquatic and Terrestrial Ecosystems Analysis during which they investigate the structure and functioning of coastal forests, wetlands, fresh and salt ponds on Cape Cod. They evaluate how human activities change land use, inputs of wastewater and sea level rise in estuaries. Students also take an elective in either Mathematical Modeling of Ecosystems or Microbial Methods in Ecology. After ten weeks of formal coursework, students embark on an independent project to investigate a topic of their choice. They are mentored by faculty drawn from MBL and other research institutions in Woods Hole. For many of the students, it marks their first foray into research.



Jessie Yang from Grinnell College works on her independent research project on fuel cells in the microbial lab

In 2015, 23 students from 20 colleges across the nation participated in the program, including the first students from the University of Chicago. For a complete list of student projects in 2015, visit http://www.mbl.edu/ses/courses/projects/

The SES program has trained over 300 students; about 70% of these alums have pursued advanced degrees in fields related to environmental science. They are making impact in careers dedicated to public health, science journalism, K-12 environmental education, advocacy at non-governmental organizations, government research, environmental law and policy, and consulting, as well as academic research and teaching. More than a dozen of our former students are now in tenure track faculty members at colleges and universities around the nation.

One of those is Amanda Mifflin (SES 1999, Wellesley College 2001, Northwestern University Ph.D. 2006), now Associate Professor of Chemistry University of Puget Sound (UPS). Amanda returned to the MBL for sabbatical leave in Fall 2015. Her research explores how soil particles interact with organic and inorganic contaminants such phthalates that can act as endocrine disruptors and heavy metals. While at the Ecosystems Center, Amanda reconnected with her colleagues in Woods Hole including Amanda Spivak, another member of the SES class of 1999. Spivak is currently a tenure track Associate Scientist at the Woods Hole Oceanographic Institution (WHOI).

SES ALUMNI STORIES AND HIGHLIGHTS 2015-2016

Toby Ahrens (SES 1997): In September 2016, Toby became the National Leader for Agricultural Bioproducts for USDA. Prior to that, he was Chief Technology Officer at BioProcess Algae LLC, developing biofuels and other products based on renewable sources. Toby completed his Masters degree in Environmental Engineering and his Ph.D. in biogeochemistry at Stanford University. He worked at the Ecosystems Center as a summer field assistant and as a research assistant for two

years after completing his undergraduate degree.

Lisa Brunie-McDermott (SES 2004): has devoted her career to establishing environmental management and compliance programs to protect air and water quality as well as managing waste streams in industry and government. In August 2015, she took a position as an Environmental Engineer at Alcoa Corp.

Antonia Giardina (SES 1998): has worked for the past 15 years for the military to implement and oversee environmental initiatives. She has served as Senior National Program Manager for Sustainability where she was responsible for command and compliance at more than 600 army facilities nationwide. In December, 2016 she was promoted to Deputy Chief of the Environmental Division of the U.S. Army Corps of Engineers.

Greg Henkes (SES 1996): Greg was appointed Assistant Professor at SUNY Stony Brook Earth and Planetary Sciences in 2016. He completed his Ph.D. at Johns Hopkins and a Dryefus Postdoctoral Fellowship at Harvard. Greg first became interested in isotope geochemistry while at Bates College and pursued independent research using stable isotopes to trace wastewater in West Falmouth Harbor during the SES. He uses clumped isotopes to explore climate in deep time.

Eve-Lyn Hinckley (SES 1999): In 2015, Eve-Lyn was hired as Assistant Professor in the Environmental Studies Program and appointed a Fellow of the Institute of Arctic and Alpine Research at the University of Colorado, Boulder. In 2000, Eve won the Rankin Award for best student paper at the annual meeting of the New England Estuarine Research Society based on work initiated during the SES and never looked back. She completed her Ph.D. at Stanford University in 2009 and worked for the National Ecological Observatory Network prior to moving to the University of Colorado.

Carrie McCalley (SES 2001): after the completing the SES, Carrie worked at the Ecosystems Center for two years on projects in the Arctic. This past year, she was appointed Assistant Professor of Environmental Science at the Rochester Institute of Technology. Carrie studies microbial processes in tundra and dessert soils and has published important papers on her work in both *Nature* and *Science*. She was a featured speaker at the MBL Ecosystems Center 40th Anniversary celebration in May of 2015.

Jessie Moravek (SES 2015): a 2016 graduate of Northwestern University, was one of 18 talented young people from around the Nation to be awarded a coveted Luce Fellowship to study and work in Asia. Jessie is the only awardee in Environmental Science and is studying high altitude wetlands in the Himalayas at the NGO Wildlife Conservation Nepal.

Gennie Noyce (SES 2007): obtained her Ph.D in Physical Geography from the University of Toronto in 2016. She is currently a postdoctoral fellow at the Smithsonian Environmental Research Center working on upland forest and wetland ecosystems.

Sophie Parker (SES 1997): after SES, Sophie completed her BA at Wellesley College. She was then hired as a research assistant at the Ecosystems Center to work on a soil warming experiment in Abesko, Sweden. She received her doctorate from the University of California, Santa Barbara in 2006. Since 2008, she has been working for The Nature Conservancy in southern California. She is currently a Senior Scientist at TNC, providing science leadership on the Los Angeles Urban Conservation and Energy Program, the Santa Clara River and Coast Project as well as the Amargosa River Project.

Nick Peng (SES 2008): completed his doctorate from Princeton University in 2015, working on nitrogen cycling in oxygen minimum zones of the ocean and N-cycling in salt marsh sediments. While a graduate student, Nick returned to MBL to take the Advanced Microbial Diversity course and began research at the Great Sippewissett Salt Marsh that resulted in a publication in *Frontiers in Microbiology*. He is now a postdoctoral fellow in the department of Earth Science at the University of California, Santa Barbara.

Tori Ziemann-Forbes (SES 1999): Associate Professor at the University of Iowa (UI), received a prestigious Depart-ment of Energy Early Career Award in 2015 for her work on neptunium, an element derived from the decay of Uranium useful in tracing radioactive waste. Tori came to SES as a chemistry major from Beloit College and returned to work at the Ecosystems Center as a summer REU intern at Toolik Lake, a SES teaching assistant and then as a research assistant at WHOI prior to entering graduate school at Notre Dame. She completed her doctorate there in 2007. In 2013, Tori also received an NSF Career Award for her work on development of metal-organic nanotubes that have novel properties useful in water purification.

Finally, we note with much sadness, the death of Yasuke Kumai in August 2015 while hiking in Scotland. Yasuke was a much loved member of the SES class of 2006. In his too short 29 years, Yasuke had a tremendous impact on others. In spite of being visually impaired, he was a remarkably accomplished and cheerful young man, completing his undergraduate degree at Vassar in 2008 and his doctorate in physiology and biochemistry at the University of Ottawa in 2013. His research resulted in over 20 publications; and he was awarded a prestigious Marie Curie postdoctoral Fellowship to work at the Paris Cardiovascular Research Centre. The University of Ottawa has established a scholarship in his name; for more information, see a moving tribute at:
https://www.uottawa.ca/tabaret/en/content/celebrating-potential

Education Highlights

The Ecosystems Center has a long standing tradition of teaching the next generation of scientists and scientific leaders. The Center provides a unique opportunity for students to learn by working alongside some of our nation's top experts on pressing environmental concerns and ecological issues. In this section, we summarize the many programs that the staff and scientists at the Center have contributed to: Research Experience for Undergraduates (REU), the Brown-MBL Graduate Program in Biological and Environmental Science partnership, the Jeff Metcalf Summer Undergraduates Research Fellowship SURF, the Woods Hole Science and Technology Education Partnership WHSTEP; and of course, community involvement and science outreach.

RESEARCH EXPERIENCE FOR UNDERGRADUATES

Jerry Melillo, William Werner and Michael Bernard mentored two undergraduate students from the Harvard Forest REU Summer Program: Alana Thurston (2015) and Catherine Polik (2016). Alana's project was titled "The effects of soil warming on relative phosphorus availability and mycorrhizal communities"; Catherine's project was titled "Thermal acclimation of soil respiration in response to prolonged soil warming."

Jim Tang welcomed two interns from the Woods Hole Partnership Education Program (WHSTEP). Jim also sponsored Jonathan Ang and Jonathan Gewirtzman from Brown University who were advised by Joanna Carey. Jonathan Ang recorded the fluxes of methane and carbon dioxide in the saltmarsh at the Waquoit Bay National Estuarine Research Reserve as part of a biogeochemistry study of how the marsh may respond to a changing climate. Over two summers, Jonathan Gewirtzman studied silica cycling in Harvard Forest. Specifically, he determined the role that terrestrial vegetation plays in controlling the exchange of silicon at the land-sea interface. Jim Tang mentored other undergraduate students as well: Jasmine Pratt from University of Santa Barbara, Yi-Jia Cheng and Yan-Huei Wu, both from the National Chiayi University in Taiwan.

JC Weber mentored two REU students in the summer of 2016: Leonard Shaw, from the University of Chicago and Emily Maness from the University of Tampa. Emily's project focused on the organic compounds extracted from suspended particles, collected from pump profiles on Oceanic Flux Program (OFP) cruises in April and November of 2015. Emily already worked in the lab as a high school junior and 2016 was her second year as a REU at the Center. Leonard's project focused on the organic compounds extracted from particles collected in the OFP sediment traps in the time period leading up to the pump profiles. Leonard also participated in the April 2015 OFP cruise.

The Ivan Valiela lab hosted a number of undergraduates in 2015 and 2016. In addition to mentoring Metcalf participants, Elizabeth Elmstrom and Javier Lloret mentored four other undergraduate students: Sarah Skelton, Emily DeFries, Clara Maynard and Lindsay Levine. Emily, a REU student from Purdue University, worked on understanding changes in estuarine food webs under the influence of increased nitrogen loads using analysis of carbon and nitrogen isotopic signatures. Sarah, Clara and Lindsay received internships under the Brown-MBL Program as part of the Brown University LINK Award Program.

Sarah examined the effects of eutrophication on the structure of invertebrate food webs in Waquoit Bay. Clara studied spatial-temporal responses of estuarine phytoplankton to changes in nitrogen loads from watersheds. Lindsay worked on atmospheric conditions driving *Zostera marina* recovery and analyzing changes in climatic patterns, atmospheric nitrogen deposition, and wastewater nitrogen loads.

Chris Neill mentored several undergraduates under different programs. In 2015, Lena Champlin, from Brown University, worked on the Naushon Grasslands Project monitoring changes of plant diversity over five years on Naushon Island and investigating the impacts of disturbance by mowing and cattle grazing on the succession of grassland to shrubland through field observations. Eva Kinnebrew, a 2015 Metcalf student, examined the impacts of soil nitrogen levels on species richness in Northeastern grassland and the role of disturbance in mediating the nitrogen-diversity relationship.

Robert Howarth sponsored Jennifer Jackson, an undergraduate student from Cornell University. Jennifer worked alongside Melanie Hayne on lab and field analyses supporting the work in West Falmouth Harbor.

At Toolik Field Station, Thomas Parker mentored four students through Wilkes University as part of the ECOTYPES project. Stephen Turner, from Wilkes University, worked on the ecological controls on leaf toughness in Arctic ecosystems. Darrel Dech, also from Wilkes University, worked on host parasitoid dynamics within the inflorescences of *Eriophorum vaginatum*. Alana Thurston, from Haverford College studied the influence of shrubs and associated mycorrhizal fungi on soil organic carbon storage. Finally, Mayra Melendez, from the University of Texas El Paso worked on remote sensing of the phenology of *Eriophorum vaginatum*.

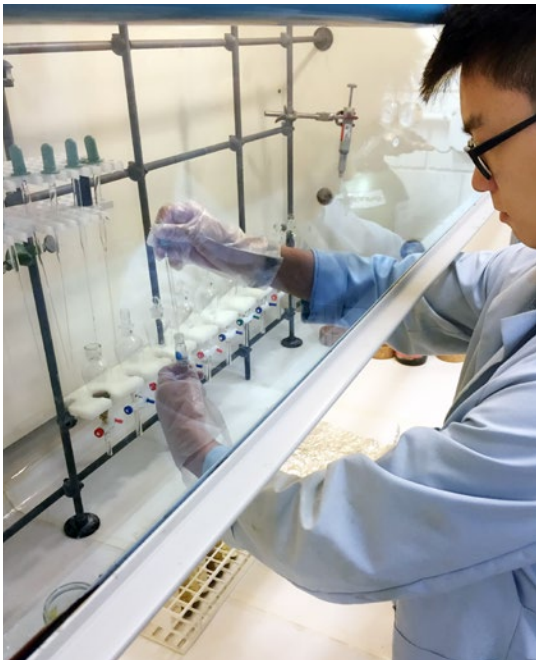
JEFF METCALF SUMMER FOR UNDERGRADUATE RESEARCH FELLOWS (SURF)

Over the last two summers, the Ecosystems Center welcomed five Metcalf SURF students from the University of Chicago. Jonathan Michelsen was sponsored by Jim Tang and was mentored by Mary Heskel on his project on chlorophyll fluorescence at the leaf, canopy and regional scales. Joe Vallino mentored Petra Byl and Ruby An. Petra's project was assessing microbial coordination over time and space in Siders Pond. Ruby, also a 2015 SES student, worked on optimizing the performance of an algae-to-methane coupled bioreactor system through experimental and modeling approaches. Elizabeth Elmstrom, from Ivan Valiela's Lab, mentored Tynan Bowyer who worked on sea level rise and decadal shifts of vegetation composition in the Great Sippewissett Marsh.

BROWN-MBL GRADUATE PROGRAM

Two Brown-MBL Ph.D. students graduated from the program in 2016. Rachel Chelsea Nagy, from the Department of Ecology and Evolutionary Biology (EEB) advised by

Opposite page: SES Students 2015 and Ecosystems Director, Anne Giblin, braving the weather on a kayak trip on Plum Island; Top: Joe Vallino recording early morning data at Siders Pond (Photo:Julie Weber); Bottom left: Foraminifera, pteropord and gastropod fecal pellets collected at 1500m. Botton right: REU Leonard Shaw (University of Chicago/Conte Lab) extracting organics from deep sea particulates collected in Oceanic Flux Program sediment traps (Photos: JC Weber)



Chris Neill and committee member Ed Rastetter, graduated in May 2016 after defending her doctoral thesis "Ecological and biogeochemical consequences of land use change in the Brazilian Amazon." Apollonya Porcelli, a Department of Sociology student in the Brown Open Graduate Program, advised by Linda Deegan and Chris Neill, graduated in May 2016 with a Master's of Science degree after defending her thesis "Relative abundance and feeding ecology of juvenile bluefish (*Pomatomus saltatrix*) in a New England estuary." Anne Giblin is on the committee for two Ph.D students from the program, Will Longo and Will Daniels. Both students are expected to graduate in 2017.

Another partnership between Brown University and MBL is the IGERT program in Reverse Ecology. The IGERT graduate level program in Computational Integration of Genomes, Organisms and Environments ended in July 2015. It included several Ecosystem scientists including Zoe Cardon as the programs co-PI. Over the course of five years, the program trained a cohort of PhDs who integrated information from new technologies into novel insights of how organisms function in their environments. They determined how genomes will be sampled in the future, bridging an intellectual link between ecosystems ecologists, microbial geneticists, biogeochemists and computational biologists.

In addition to graduate students, the Brown-MBL program continued to offer Brown undergraduate students summer MBL internships through the Brown University LINKS Award Program with generous funding from Charles and Phyllis Rosenthal. In 2015 and 2016, nine undergraduates were placed at MBL including Ecosystems Center labs and field sites in Woods Hole, Martha's Vineyard and Nashon Island.

THESIS ADVISING AND COURSES TAUGHT

Anne Giblin traveled to University of Southern Denmark to serve as an external examiner for Elizabeth Robertson. Anne also served on the committee for Ashley Busco-McKim, a graduate student of Jennifer Bowen; as well as on the committee for Stuart Waugh from Stony Brook University.

Ed Rastetter taught a seminar on Kalman Filtering at Boston University. In 2016, Ed sponsored Laura Graham from St Francis Xavier University for her research at Toolik Field Station. Laura's master's thesis was on "Controls on terrestrial CO_2 emissions from seasonally snow-covered ecosystems." She conducted her research through the MBL-Chicago seed grant, along with Sue Natalu (WHRC) and Julie Jastrow (Argonne NL). Ed also served on the committee for doctoral candidate Chelsea Nagy from Brown University under the Brown-MBL Program. Chelsea's modeling manuscript "Nutrient limitation in tropical secondary forests following different management practices"was submitted to the journal Ecological Applications in May 2016.

Linda Deegan served as advisor to Heidi Golden, University of Connecticut, on her research: "Climate Change influences on Arctic Grayling metapopulations."

LOGAN SCIENCE JOURNALISM PROGRAM

Led by Linda Deegan in 2015 and 2016, the Ecosystems Center offered an 11-day hands-on research course as part of the MBL Logan Science Journalism Program. In 2015, the Environmental Fellows were: Carolyn Beeler from WHYY NPR Philadephia; Giovana Girardi, from O Estado de S. Paulo in Brazil; Christopher Joyce, from NPR Washington, D.C.; Amy Quinton, from Capitol Public Radio in Sacramento, California; Yves Sciama, from Science et Vie in France; Christopher Smith Gonzalez, Galveston County Daily News (Texas); Meera

Subramanian, a freelance journalist on Cape Cod; and Michael Werner, a freelance journalist/filmmaker from Seattle. In 2016, the fellows were: Shanna Baker, Senior Editor at Hakai Magazine; Jennifer Barrios, Reporter at Newsday; Bethany Brookshire, Science Education Writer for Science News; Sasha Chapman, Freelance Journalist from Canada; David Levin, Science Editor of Pellet Productions; and Emiliano Rodríguez Mega, Freelance Science Journalist from Mexico.

WOODS HOLE SCIENCE & TECHNOLOGY EDUCATION PARTNERSHIP

JC Weber served as the co-chair of the executive committee for the Woods Hole Science & Technology Education Partnership (WHSTEP), a network connecting area research institutions and the regional K-12 school districts. Lindsay Scott, administrator of the program, organized the mentoring sessions at the Falmouth Lawrence Junior High School Science Fair as part of the WHSTEP program. Hap Garritt, JC Weber, Bonnie Kwiatkowski, Elizabeth de la Reguera, Sam Kelsey and Marshall Otter all served as judges to the fair or mentored the students for their projects.

SCIENCE OUTREACH

The Ecosystems Center continues to enhance literacy in science and technology in the community. In 2015 and 2016, Center staff and scientists participated in a number of educational programs in local classrooms and beyond.

Inke Forbich, JC Weber and Hap Garritt served as judges at the Falmouth Academy Science Fair. Hap Garritt, Suzanne Thomas and Marshall Otter also served as judges at the Massachusetts State Science and Engineering Fair held at MIT. Anne Giblin participated in the Gulf of Maine Institute Summer workshop "Learn to Steward the Gulf" where teachers made plans to implement local place-based activities for their students throughout the Gulf watershed. She also served on the panel of the Salt Marsh Science Symposium in Newbury during which K-12 students presented the findings of their research. In the spring and summer of 2016, JC Weber supervised a junior high school student from the Bourne Public High School. The collaboration rebooted a long standing tradition of having a high school student learn and be a part of the team, which often leads to those very same students returning as REUs.

COMMUNITY INVOLVEMENT

Ecosystems staff and scientists continue to be actively involved in the community through collaborations with NGOs, community organizations and service on town committees.

Anne Giblin served as the Chair of the Gulf of Maine Institute Board. She is also a member of Buzzards Bay Scientific Advisory Committee as well as a member of the Cape Cod Commission 208 Monitoring Subcommittee. Linda Deegan served on the Massachusetts Board of Directors for The Nature Conservancy. JC Weber is a Board member for the Wareham Land Trust. Elena Perez Peredo is an active member of the MBL Postdoctoral Scientists Association. In June 2015, Jim Tang was interviewed for the Falmouth Enterprise for current research on greenhouse gas exchange between the salt marsh and air over time through respiration from four reserve sites including one site at Waquoit Bay National Estuarine Research Reserve.

Opposite page top: Filter fun, SES Project (Photo: Kanaskie, SES 2015); Opposite page botom: Suzanne Thomas, JC Weber, Hap Garritt and Marshall Otter at the Massachusetts State Science & Engineering Fair, MIT 2015; Top: Emi Okikawa, SES 2015, sampling for Pink Berries in salt marshes (Photo: Joe Vallino); Bottom: "You are what you eat. Plus a little more", SES food web project (Photo: Kanaskie, SES 2015)

News 2015–2016

In June 2015 The Ecosystem Center celebrated its 40th anniversary with a special two-day symposium. The keynote address was given by Dr. John Holdren, President Obama's Chief Science Advisor and Director of the Office of Science and Technology Policy. It was followed by a series of presentations including former directors George Woodwell, John Hobbie and Jerry Mellilo; former postdoctoral scientist Suzanne Tank; by former graduate and undergraduate students Breck Bowden, Gillian Galford, Carrie McCalley; and Angela Posada, a MBL Logan science journalism polar fellow. The day ended with a panel discussion on the future of ecosystems science moderated by Jim Metzner who had also been a Logan Science Journalism Fellow. Ian Foster from the University of Chicago, Jerry Melillio and William Schlesinger of the Cary Institute of Ecosystems Studies all participated in the panel.

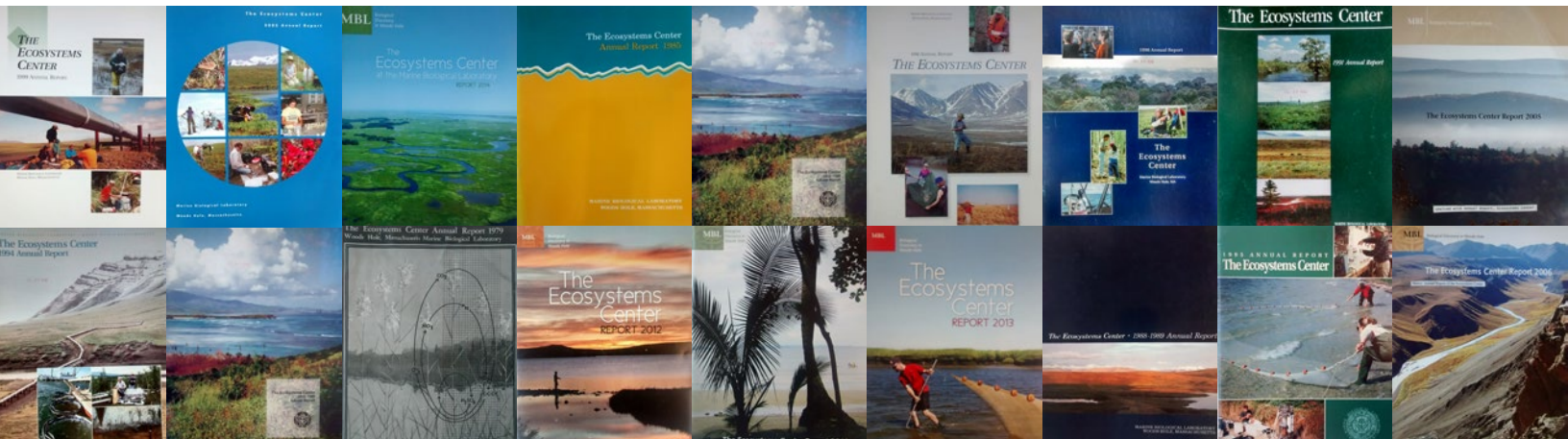
Anne Giblin was named Interim Director of the Center in May 2016, succeeding Christopher Neill. Anne first came to the MBL over three decades ago and has held scientific positions at the Ecosystems Center since 1983. Anne is a principal investigator for several projects including Long Term Ecological Research at Plum Island. Anne serves as a member of the National Estuarine Research Reserves Science Collaborative Advisory Board as well as a member of the LTER Executive Committee. Anne also serves on the planning committee for Coastal and Estuarine Research Federation for the 2017 meeting. She was a panelist on the NSF workshop on Phosphorous in June 2015. She participated in the Environmental Defense Foundation workshop on "Linking Environmental Stressors in Coastal and Marine Ecosystems."

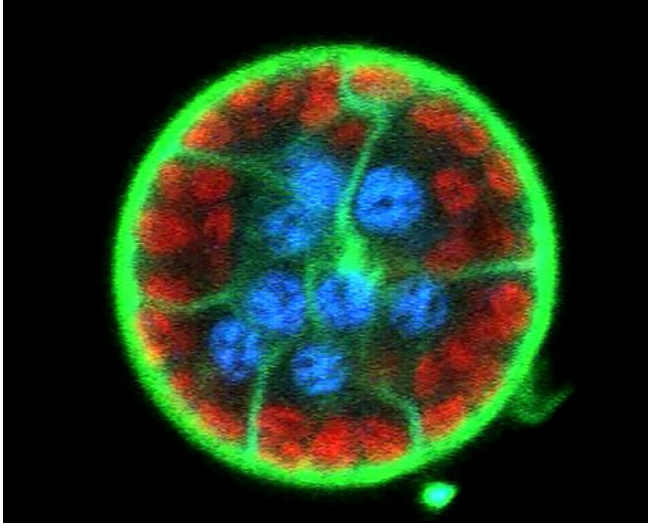
Jerry Melillo serves on the Advisory Committee for three major programs of the National Academy of Sciences: the Gulf Research Program, the US Global Change Research Program and the US National Member Organization for IIASA. Jerry also serves on the Advisory Committee for the International Institute of Applied Systems Analysis (IIASA) as well as the Advisory Committee for the Sustained National Climate Assessment – Federal Advisory Committee. He also served on the Board of Trustee of University Corporation for Atmospheric Research between 2009 and 2016. He continues to sit on the Board of Trustee of the Cary Institute of Ecosystem Studies.

Linda Deegan serves on the NOAA Science Advisory Board for 2014-2017. Linda was also nominated by two federal agencies and was selected to serve on an Expert Panel to provide technical input, review, and guidance to the Louisiana Coastal Protection and Restoration Authority for diverting freshwater and sediment from the Mississippi and Atchafalaya Rivers into adjacent estuarine basins to build, maintain and sustain coastal wetlands. In 2016, Linda was also a member of the Coastal and Estuarine Research Federation, Award Recipient Selection Committee.

Jim Tang has been a member of the Steering Committee of the Global Science and Data Network for Coastal Blue Carbon since 2015. He is a member of the Steering Committee of the U.S. National Ecological Observatory Network-Chinese Ecological Research Network NEON. Since 2011, Jim has been the co-chair of the NEON/Fundamental Instrument Unit Technical Working Group for soils. Jim is also a long-time member of the LTER International Committee.

Zoe Cardon was a member of the review panel for the triennial scientific and program management review for the U.S Department of Energy's program in Biological and Environmental Research at Oak Ridge National Laboratory. She was also a panelist reviewing pre-proposals for NSF Division of Integrative Organismal Systems. Zoe was a guest speaker at the Ignite Session organized by the Ecological Society of America (ESA), Science Committee in August 2015. The session was titled "Advances, Frontiers, Applications, and Challenges within and across Ecological Disciplines: a Celebration of ESA's Centennial, and a Roadmap for the Next 100 Years", at the 100th Annual ESA meeting in Baltimore, Maryland. She was a guest speaker at Harvard University Plant Biology Initiative Symposium, "Plants and Climate ECOSYSTEMS CENTER





REPORT 2015-2016 | Change: From Leaves to Ecosystems." Zoe gave a talk titled "Ebb and Flow in Soil Down Below - The Ups and Downs of Rhizosphere Resource Exchange."

Joanna Carey was elected Rhode Island State Director of the Society of Ecological Restoration, New England Chapter. Joanna also served as the co-chair of the Coastal and Estuarine Research Federation Biennial Conference "Responses of salt marshes to sea level rise" in Oregon in the Fall of 2015. In the field, Joanna spent five weeks in Alaska, along with Elizabeth de la Reguera, driving over 6000 miles on the Haul Road to collect river samples for her NSF Earth Science Fellowship.

Elizabeth Elmstrom received the EPA's Southern New England Coastal Watershed Restoration Program grant for the Ivan Valiela Lab at the Audubon Society in Bristol, Rhode Island.

William Werner presented a poster entitled "Under long term soil warming, trees in a Northeastern Hardwood Forest reallocate carbon from roots to aboveground woody growth" at both the 2016 Annual Harvard Forest Ecology Symposium and the 11th Annual Harvard Plant Biology Symposium.

Thomas Parker coordinated the ECOTYPES project, an NSF project between the MBL, Wilkes University, The University of Texas, El Paso and West Chester University. The project aims to understand how locally adapted populations of the tundra species *Eriophorum vaginatum* respond to rapid climate change in the arctic.

Elizabeth de la Reguera participated in the conference panel on "Measuring and Reducing Campus Nitrogen Footprints", organized by the Association for the Advancement of Sustainability in Higher Education in Minneapolis, 2015.

Opposite page: Celebrating 40 years of the Ecosystems Center, past covers of the Annual Report; Top: Aquatic and desert-evolved algae of genus *Scenedesmus* growing in liquid medium under common garden conditions prior desiccation experiments (Photo: Zoe Cardon lab); Bottom: Confocal image of the green unicellular algae *Scenedesmus rotundus* and its associated microbiota. This alga was isolated from the South Western deserts of the US; it is now maintained in culture at the MBL. The confocal image was generated Zeiss LSM70. The surface was capture using plant autofluorescence fluorescence (cyan). Bacteria are visible on the algal surface, labeled with a DNA stain, SyBr Safe (yellow) which also stained the algae nuclei (Photo: Elena Peredo)

Michael Bernard presented a poster titled, "Sustained, self-reinforcing feedback between terrestrial carbon cycle and climate system based on 24 years of soil warming" at the 2015 Annual Harvard Forest Ecology Symposium. In 2016, Michael presented another poster at the symposium, "Progressive phosphorus limitation after prolonged soil warming at Barre Woods, Harvard Forest."

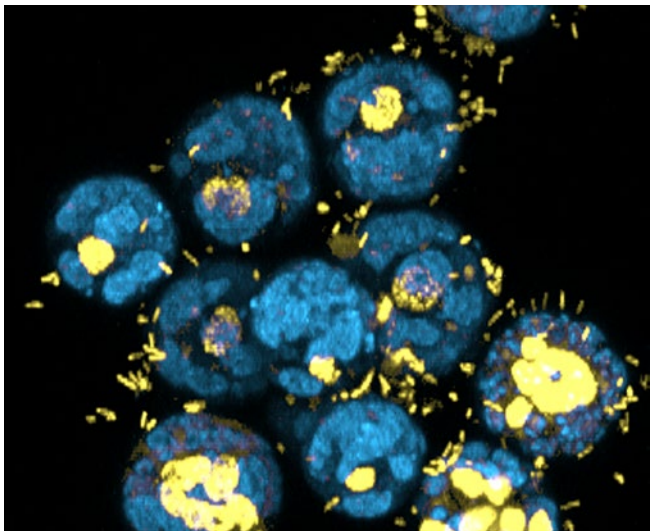
Hap Garritt is a member of the LTER Information Managers Committee.

Suzanne Thomas presented a talk titled "Push-Pull: assays in the field reveal coupled sulfur, nitrogen, and Carbon Cycling in salt marsh sediment" at the Annual Ecological Society of America meeting in Baltimore, Maryland in 2015.

Elena Lopez Peredo participated in the faculty job application writing workshop, organized by WHOI in August and September 2016. In July 2016, Elena also participated in two meetings at the MBL: the Teaching & Mentoring Workshop, and the MBL Summer Postdoc and Graduate Student Seminar Series.

UNIVERSITY OF CHICAGO SEMINARS AND MEETINGS

In July 2016, Jim Tang was invited at the seminar on the phenology and solar induced fluorescence for understanding ecosystem carbon dynamics at Argonne National Laboratory. Joe Vallino attended the Computations In Science Seminar Series at University of Chicago on the topic of "Living systems defined in the context of maximum entropy production and information: a computational approach." Zoe Cardon was an invited contributor on the first annual Quantitative Approaches Bootcamp at MBL, for all incoming Biological Sciences graduate students at the University of Chicago. Zoe was also a guest speaker at the Ecology and Evolution Department Seminar at UChicago, giving a talk on "Dried out but not dead! Green Algal Terrestriality in Desert Microbiotic Crusts."



Postdoctoral Scientists

Faming Wang Wang studies carbon, nitrogene and phosphorus biogeochemical cyclings in forests and salt marshes. He is working with Ecosystems Scientist Jim Tang, and USGS scientist Kevin Kroeger to investigate the changes of greenhouse gas emissions during the saltmarsh restoration in New England.

Javier Lloret works with Distinguished Scientist Ivan Valiela and combines field studies and modeling to investigate how estuarine macroalgal and seagrass beds respond to recent declines in nitrogen deposition from long-range sources and local increases in urbanization.

Joanna Carey's current research examines silicon (Si) cycling in the Arctic, specifically looking at how land cover change and permafrost thaw is altering rates of Si export to coastal receiving waters. To do this, she is examining a suite of rivers encompassing a 700 km North-South transect within the Yukon and North Slope basins of Alaska. Joanna's work is funded by NSF Earth Science Postdoctoral Fellowship.

Mary Heskel is working with senior scientist Jim Tang to measure and model daytime respiration fluxes at the leaf and ecosystem scales across the growing season at Harvard Forest. Mary also contributed to teaching SES students about canopy productivity in deciduous forests. Mary received the Ray Leuning Scholarship to attend a two-week Flux Course in Boulder, Colorado. She was also quoted in multiple press releases, including from the Columbia University Lamont-Doherty Earth Observatory and Australian National University, for a first-authored paper published in PNAS. Mary was quoted in Science for press coverage of a study by Reich et al. titled "Boreal and temperate trees show strong acclimation of respiration to warming."

Thomas Parker is an ecologist working on how changes in arctic plant communities due to climate change will influence ecosystem processes. He is currently working with Ecosystems Center scientist, Jim Tang, and Ned Fetcher at Wilkes University to understand how locally adapted plant populations will respond to environment change.

Xiaoliang Lu works with Distinguished Scientist Jerry Melillo and Research Associate David Kicklighter. He develops land use/land cover datasets to explore how human activities and disturbances affects carbon dynamic of terrestrial ecosystems.

Elena Lopez Peredo works with Senior Scientist Zoe Cardon and uses terrestrial green microalgae isolated from Southwest US desert soils to understand the genetic basis of algal survival in extremely arid environments.

Joanna Carey sampling at Sagavanirktok River or Sag River, in Arctic Alaska

Publications 2015 to 2016

2016

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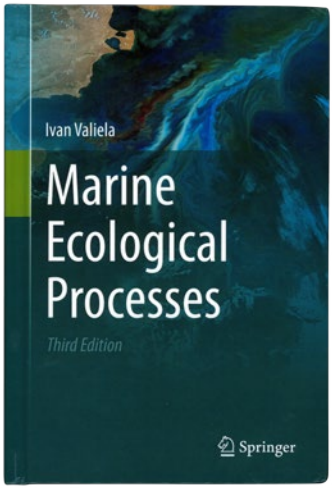

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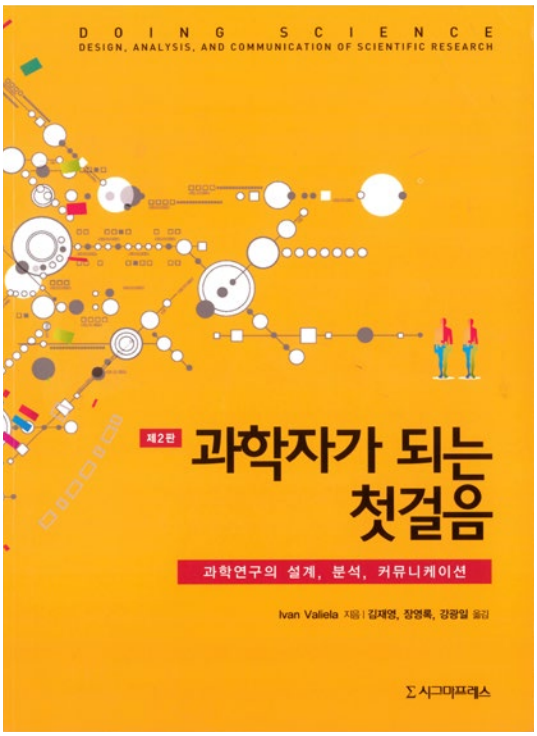

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Opposite page top: Sunrise at Siders Pond, photo taken as part of the project on assessing microbial metabolic function and circadian rhythms over time and space in Siders Pond (Photo: Julie Huber); Opposite page bottom: Plum Island Dunes (Photo: Christian Alexander, SES 2015); Above: Ivan Valiela's text book "Doing Science: Design, Analysis, and Communication of Scientific Research" is published in Korean

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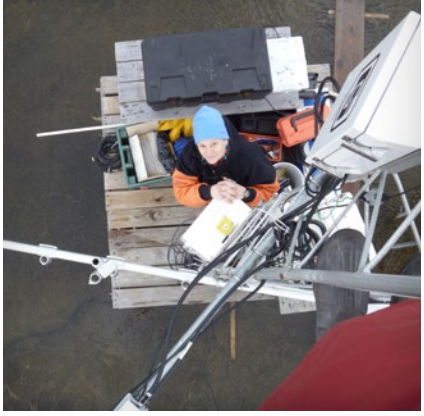

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Opposite page: Estimating water volume during cranberry harvest on Cape Cod (Photo: Lindsay Scott); Top: Jane Tucker at Plum Island, measuring CO_2 fluxes using instrumented towers to determine if marshes can accumulate enough organic matter to keep pace with sea level rise (Photo: Inke Forbrich); Bottom: Rainbow over the mountains, as seen from the Toolik Field Station (Photo: Daniel White)

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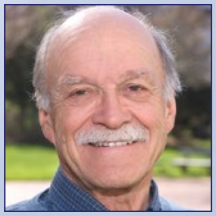

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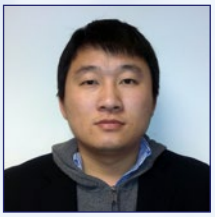

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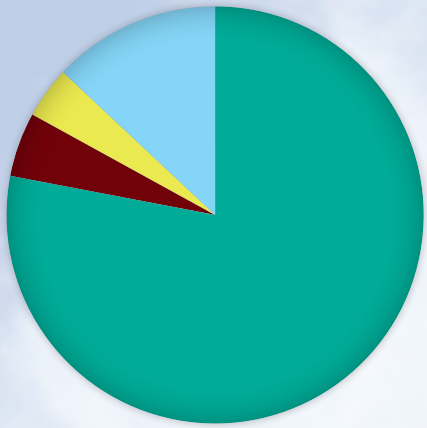
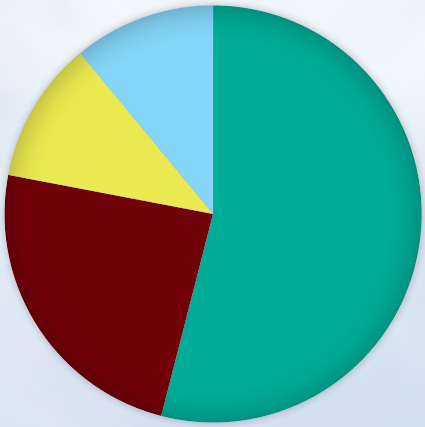
Early June sampling at Toolik Lake. From left to right: Brecia Douglas, Chris Cook, Jason Dobkowski, Graham Stewart, Hank Baker (Photo: Daniel White)

Sources of Support for Research and Education

The operating budget of The Ecosystems Center for the period of January 2015 – June 2016 was $11,915,000. Approximately 78% of the income of the center came from grants for basic research from government agencies, including the National Science Foundation, NASA, the Department of Energy and the Environmental Protection Agency. The other 22% came from gifts and grants from private foundations, including support for the Semester in Environmental Science, as well as from institutional support for administration and income from the center's reserve and endowment funds.

These non-governmental funds provide flexibility for the development of new research projects, public policy activities and educational programs. Income from these funds helps defray the costs of operations, writing proposals, consulting for government agencies and the center's educational programs.





The following donations were made to the Ecosystems Center and the SES Program between January 1, 2015 and June 30, 2016. More information can be found in the MBL annual report.

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