MBL

Biological
Discovery
in Woods Hole

The Ecosystems Center at the Marine Biological Laboratory

REPORT 2014

Cover photo
A camera mounted to a balloon tethered at the MBL's Rowley Field house captures the salt marsh in the Plum Island Estuary in Rowley, MA. Plum Island's salt marshes are the prime focus of the Plum Island Ecosystem Long-Term Ecological Research (PIE LTER) Project led by the Ecosystems Center. The PIE LTER strives to understand the long-term response of the coupled watershed, marsh and estuarine system to changes in climate, land use and sea level. Photo by James S. Aber, Susan W. Aber and Vinton Valentine.

This page
Soil warming experimental plots at Harvard Forest in Petersham, MA viewed from a nearby tower in late March, 2014. This 24-year experiment led by Distinguished Scientist Jerry Melillo examines how climate change affects carbon balance of forest ecosystems. Similar soil warming experiments have now been installed in dozens of locations around the world. Photo courtesy of Audrey Barker-Plotkin.

About MBL
The Marine Biological Laboratory (MBL) is dedicated to scientific discovery and improving the human condition through research and education in biology, biomedicine, and environmental science. Founded in Woods Hole, Massachusetts, in 1888, the MBL is a private, nonprofit institution and an affiliate of the University of Chicago.

Editors
Christopher Neill and Fiona Jevon

Ecosystem Science

AT THE FRONTIERS OF CHANGE

By Christopher Neill

During 2014, the average temperature across the globe was the highest in the entire 135 years of the modern climate record back to 1880. According to the National Oceanic and Atmospheric Administration's National Climate Data Center, high temperatures spread around the world, from the western United States to eastern Russia and from Alaska to the interior of South America. The World's oceans, including the Northwest Atlantic out my window in Woods Hole, were a record 1.03°F above their 20th century average. Nineteen out of the 20 warmest years ever recorded have occurred in the last 20 years. Nobody born after 1975 has ever experienced a year with temperatures that were cooler than the1900 to 2000 average. A warmer planet is the new normal.

The Ecosystems Center of the Marine Biological Laboratory develops new understanding of how climate change shapes the Earth's most important ecosystems and then applies that knowledge to environmental policy. Across the US and the world, Ecosystems Center scientists are at the frontiers of that change—in the Alaskan Arctic, along our coastlines, and in the Amazon. The Center's scientists conduct experiments and build tools to predict how ecosystems respond to climate change and how climate will interact with global cycles of water, carbon and nutrients to accelerate—or perhaps buffer against—further planetary change. In 2014, Center Distinguished Scientist Jerry Melillo led the scientific team that produced the US National Climate Assessment, the most thorough examination ever conducted of how US climate has changed and how warmer temperatures and more variable weather influence the nation's regions and economy.

The year also brought exciting exploration of how we can strengthen our science and expand our impact with the MBL's new institutional partner, the University of Chicago. University of Chicago faculty, Ecosystems Center scientists and scientists from other MBL centers held two retreats, one in Chicago and one in Woods Hole, that identified specific areas—such as computing or arctic research—that could transform our current research capacity. A new program of seed grants seeks to accelerate those synergies. We also explored ways that the MBL's unique educational programs, such as the Ecosystems Center's Semester in Environmental Science or other new programs built along that model, could serve University of Chicago students while maintaining their historic role in serving a broad national and global audience.

The Ecosystems Center received an exciting infusion of young talent in 2014 thanks to both a generous gift from Charles and Phyllis Rosenthal and new research projects. Eleven postdoctoral scholars brought new energies to work that spans modeling of Arctic wildfires, to unraveling the physiology and evolution of plant tolerance to drought, to measuring how marshes keep up with sea level rise and how increased fertilizer use increases greenhouse gas emissions from Amazon agriculture.

This year's Ecosystems Center Report highlights the scope and depth of the Ecosystems Center's research. It showcases new work that captures in ecological models how arctic tundra responded and then partially recovered from an unprecedented wildfire that in 2007 burned an area the size of Cape Cod near the Center's Arctic Long-Term Ecological Research (LTER) site. It also explains how continuous measurements of carbon dioxide exchange over salt marshes in the Center's Plum Island Ecosystems LTER provide clues to if and how coastal marshes will keep pace with accelerating sea level rise. A third report explains how national actions—in this case the passage of air pollution laws—can help to reduce stresses on coastal waters.

Recovery from Arctic Fire

The Anaktuvuk River fire site seen from a helicopter. White cottongrass flowers outline the burned sections of tundra. Photo by Chris Neill. Inset: Cottongrass, *Eriophorum vaginatum*, blooms at the site of the 2007 Anaktuvuk River fire. Photo by Jessica Drysdale.

Ecosystems Center Distinguished Scientist John Hobbie explains that when he first visited the Trans-Alaska Pipeline camp on Toolik Lake in 1975 and saw its potential for ecosystems-scale research on tundra, lakes and rivers, thunderstorms simply never occurred.

Fast-forward almost 40 years. Thunderstorms at Toolik's 68°N latitude, borne from a warmer and more energized continental atmosphere, now occur most summers. These storms bring a dramatic and important change—fire.

In 2007, a July lightning strike started the Anaktuvuk River fire, which burned until early October and blackened 1039 square kilometers (400 square miles) a short helicopter ride from Toolik Field Station. That fire reshaped the tundra landscape by consuming vegetation and burning down into the peat soils that comprise more than 95% of the tundra's total stored carbon.

Today, Ecosystems Center Postdoctoral Scientist Yueyang Jiang, working with Center Senior Scientists Edward Rastetter and Gus Shaver, uses this historic event to study and model how fast the tundra can recover from fire and how long it will take for the tundra to rebuild its stocks of carbon in vegetation and soils. This work is important because quantifying how tundra recovers from this new kind of disturbance in the Arctic's changing climate will help predict the Arctic's future role in the Earth's carbon cycle.

One key question is, how soon after the fire will the tundra return to its original role as a site of net uptake of carbon dioxide from the atmosphere? Jiang constructed a simulation model and then compared the model against direct measurements collected by former Ecosystems Center Postdoctoral Scientist Adrian Rocha (now an assistant professor at Notre Dame University). Both the model and observations showed that vegetation, and

its ability to photosynthesize, recovered rapidly. Net uptake of carbon dioxide increased during each year after the fire and equaled that of unburned tundra after three years (Figure 1). It then exceeded that of unburned tundra for at least two years thereafter. This was consistent with satellite images that showed the greenness of the tundra also recovered within about three years and exceeded that of unburned tundra for the next several years (Figure 2).

The model also showed that a fertilizing effect of nutrients left in the ash after the fire contributed to the tundra's high photosynthetic capacity. In addition, both the dark charred surface and the removal of the insulating moss and peat layer caused the soil to warm, which accelerated the release of nutrients from soil organic matter and further stimulated plant growth.

A second key question is, how long will it take the tundra to re-accumulate the soil organic carbon lost in the fire? Jiang's model indicated that about half of the soil organic carbon lost during the fire was recovered in about 30 years, but there was very little further accumulation thereafter. This "unrecovered" carbon was equal to about 1 kilogram for every square meter of burned tundra surface. The reason for this slow accumulation was the loss of nutrients during the fire. After the fire, the vegetation lacked sufficient nutrients to sustain higher growth, and thus higher carbon accumulation. Because the rate of nutrient inputs to tundra in northern Alaska is very slow, Jiang's simulations predict that, under today's conditions, it will take thousands of years to re-accumulate the nutrients and carbon lost in the fire.

Ironically, the climate warming that is increasing the frequency of tundra fires might also help to speed recovery of carbon losses. That is because warming accelerates the rate at which nutrients are released from the soil organic matter, which then causes greater plant growth. The ratio of carbon to nutrients in vegetation is about twice that in soil organic matter. Therefore, when nutrients move from soil into the vegetation, carbon storage increases. In Jiang's simulations, this redistribution results in recovery of total ecosystem carbon stocks to the pre-fire level within a few hundred years.

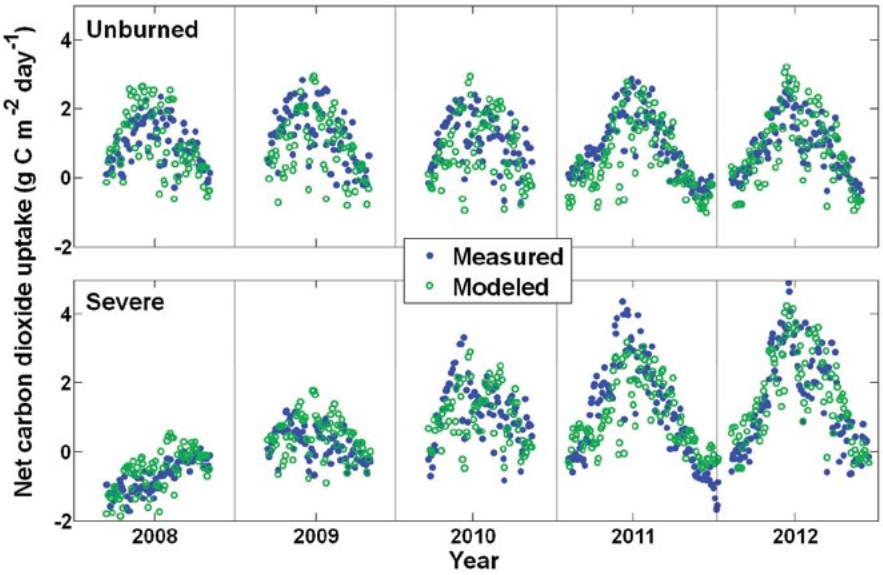


Figure 1: Measured and modeled daily net carbon uptake (positive numbers) or release (negative numbers) during the growing season from 2008 to 2012. The fire occurred in 2007.

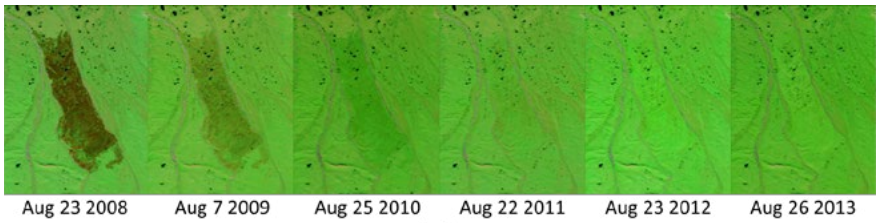


Figure 2: Moderate Resolution Imaging Spectroradiometer (MODIS) images for the Anaktuvuk River fire from 2008 to 2013, showing rapid recovery of the tundra vegetation.

Research assistants of the Arctic LTER Jason Dobkowski, Mike Finnegan and Chris Cook look out over a thermokarst by Wolverine Lake on the North Slope of Alaska. Photo by Sarah Nalven.

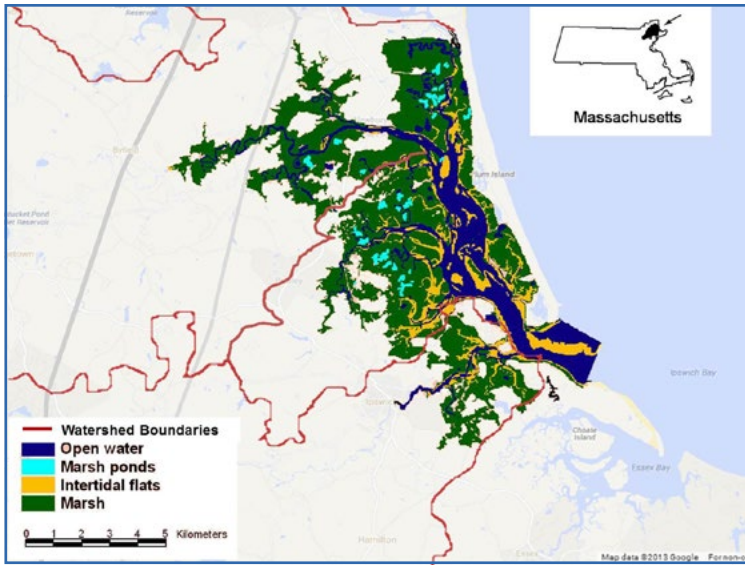
Racing Against Sea Level Rise

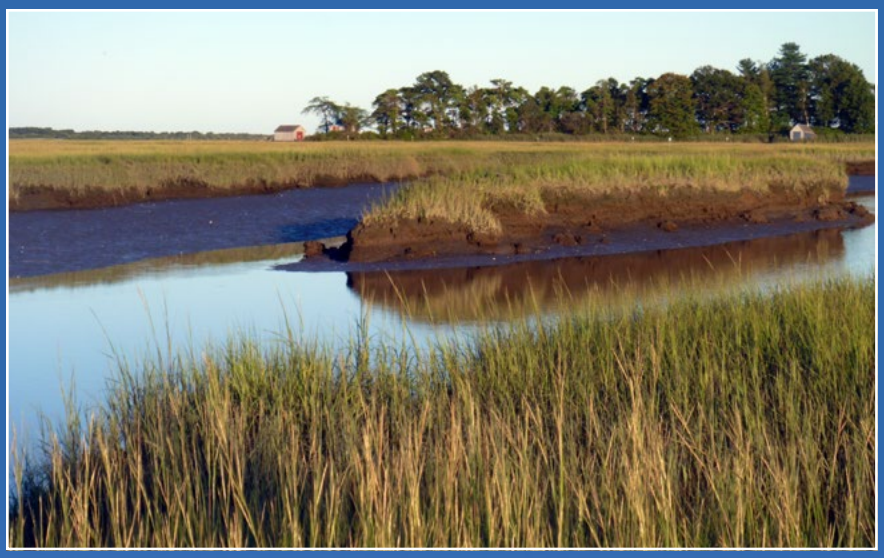
Early settlers to the New England coast cleared land for timber and farms. In some places this flurry of clearing increased the sediment that moved from coastal watersheds into marshes and estuaries. But less than a century later, the industrial revolution transformed New England into the center of American manufacturing. Dams large and small, built to power mills and factories, sprouted on nearly every stream and river. Those dams, most of which are still standing, have an important legacy—they slow water flow and trap sediments that would otherwise reach the coast.

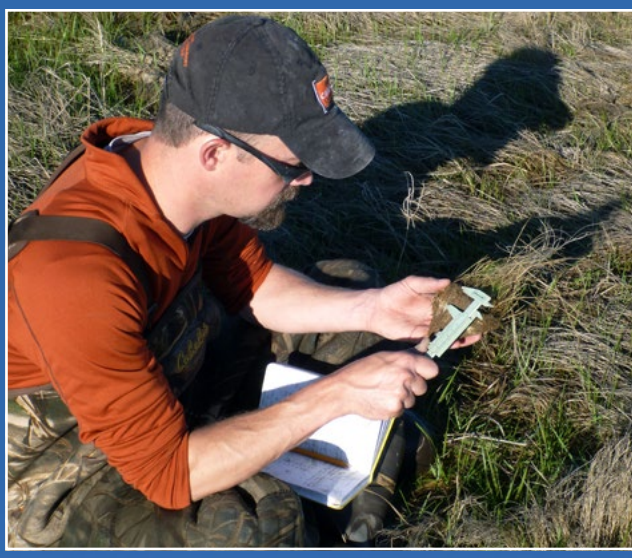
These man-made controls on sediment delivery are important because sediment plays a role—but not the only role—in allowing marshes to maintain their elevation relative to sea level rise. Some of this elevation comes from sediment trapped by stems of marsh grasses, but another important contribution comes from the vertical accretion of organic material produced by the marsh itself. This elevation may be getting harder to maintain. New England's salt marshes—one of the region's critical buffers against coastal storms—developed in a time of fairly stable sea level. But since regular measurements began in Boston in 1920, sea level has risen 25 cm (10 inches) and models predict that future increases could be as high as 2.0 meters (6.6 feet) by 2100. The two main causes are the expansion of the volume of water in a warmer ocean and an increase in ocean volume from the melting of ice stored on land in glaciers and ice sheets.

To measure how much organic matter salt marshes produce each year and how organic matter accumulation contributes to the stability of marshes, Ecosystems Center Postdoctoral Scientist Inke Forbrich and Senior Scientist Anne Giblin installed two tower-mounted atmospheric eddy flux monitoring systems that record how much carbon dioxide moves into and out of salt marshes within the Plum Island Ecosystem Long-Term Ecological Research (LTER) project each year. The goal is to measure the hard-to-find portion of carbon produced by marsh grasses that does not decompose but contributes to elevation gain. University of South Carolina scientist and Plum Island Ecosystem LTER collaborator James Morris contributed measurements of sediment deposition and aboveground vegetation production. In combination, their work showed that a large percentage of the carbon fixed by salt marsh grasses is stored belowground. Morris also showed that aboveground productivity tends to be greater in years when natural cycles makes sea level slightly higher. The eddy flux system will test whether this also occurs for belowground production, where it has the greatest effect on marsh elevation.

Left: Inke Forbrich downloads data from the eddy flux tower at Plum Island. Photo by Tyler Messerschmidt. Right: Map of Plum Island Ecosystem LTER site. Map courtesy of Sam Bond.







To further assess the amount of carbon stored in the soil, Forbrich and Giblin collected cores and measured carbon content at different depths. Their data suggest that carbon has accumulated at 75 grams per square meter per year. This carbon "sink" was lower than their estimates of annual net carbon exchange determined from the atmospheric fluxes. This might be because carbon was lost as dissolved inorganic carbon in the horizontal movement of tidal floodwaters or because large portions of marsh biomass were transported away each year as piles of dead vegetation, or wrack.

So far, the atmospheric measurements show that growth of salt marsh grasses varies substantially over fairly short time periods within years of relatively average and stable mean sea level. This indicates that short-term controls on plant growth—factors such as temperature and light—also influence total marsh annual carbon accumulation.

While challenges remain to completely "close" the marsh carbon budget, the high temporal resolution of the atmospheric measurements (fluxes are calculated at 30-minute intervals) provides important "real-time" estimates of carbon uptake and release. This information will help determine if the ability of marshes to grow faster and store material belowground can compensate for regional reductions of coastal sediment supply—and maintain a feedback that will allow marshes to persist under faster sea level rise.

Left: Plum Island estuary at mid-tide. Photo by Sam Bond.

Right: Research Assistant Sam Kelsey measures marker horizons on a marsh platform core. Photo by Sam Bond.

Below: This eddy flux tower constantly monitors carbon dioxide exchange between the marsh and the atmosphere. Photo by Inke Forbrich.

Declining Nitrogen Deposition

Fossil fuel burning, fertilizer production and the cultivation of legume crops have increased the releases of plant-available nitrogen by about five-fold since 1940. Once emitted to the atmosphere, this nitrogen is transported and then deposited over land and oceans. Atmospheric nitrogen deposition, at rates that now occur in industrialized North America, Europe and East Asia, degrades many aquatic ecosystems. The effects are particularly great along the coast, where nitrogen inputs from deposition combine with nitrogen carried from land by rivers and groundwater. This can deliver an amount of nitrogen hundreds of times greater than what estuaries and coastal ecosystems experienced less than a century ago.

Work by Ecosystems Center scientists Ivan Valiela, Linda Deegan, Anne Giblin and others has shaped current understanding of the ways that increased nitrogen delivery to estuaries stimulates phytoplankton and macroalgae, eliminates eelgrass and other submersed plants, and reduces fish and shellfish. Valiela also developed models that use nitrogen deposition and watershed characteristics to predict the amount of nitrogen (or the nitrogen load) that reaches coastal waters from different sources, typically deposition, wastewater and fertilizer used on lawns and farm fields. Several states now use versions of these models to identify policy options for removing nitrogen and restoring estuaries.

Ecosystems Center Postdoctoral Scientist Javier Lloret and Valiela recently compiled data on the different forms of reactive nitrogen in precipitation collected from hundreds of stations across the world's temperate regions. The data show substantial decreases (up to 50%) in nitrogen deposition over Eastern North America and Central Europe since 1985 (Figure 1). Most of this decrease occurred since 2000, after strict air pollution controls went into effect. In North America, Congress passed amendments to the Clean Air Act in 1990 that required electricity-generating power plants to reduce emissions in two phases. The first phase went into effect in 1995, the second in 2000. The law permitted utilities to buy or sell pollution allowances, which encouraged rapid adoption of new technologies. In Europe, the Convention on Long-range Transboundary Air Pollution was signed in 1979 and entered into force in 1983.

A 44-year nitrogen fertilization experiment in Great Sippewissett Marsh in Falmouth, MA shows how added nitrogen (center of photo) alters plant species composition. Photo by Ivan Valiela.

Reduced nitrogen emissions and lower nitrogen deposition are particularly important for the Northeastern US, where decreases in deposition are large and where many densely populated coastal communities now face difficult and expensive choices about how to reduce nitrogen reaching estuaries. For some coastal bays and sounds, particularly those with small watersheds and large areas of open water where atmospheric deposition is the largest single nitrogen source, lower deposition will make restoration easier and cheaper (because

less nitrogen will have to be removed from wastewater or fertilizer sources). For other coastal waters, where contributions from dense urban development or agriculture are large, reduced deposition will influence restoration strategies and costs far less.

Lloret and Valiela use their synthesis of continental nitrogen deposition patterns to investigate both how observed changes relate to emissions regulations, as well as to changes in agriculture and climate patterns that alter the geography of air-sheds that bring deposition of particular forms of nitrogen to specific areas. They also estimate how reduced nitrogen deposition influences restoration plans for specific Northeast estuaries.

The Waquoit Bay watershed in southern Cape Cod. Approximately one third of total nitrogen entering Waquoit Bay comes from atmospheric deposition. Photo courtesy of Waqouit Bay Reserve Foundation.

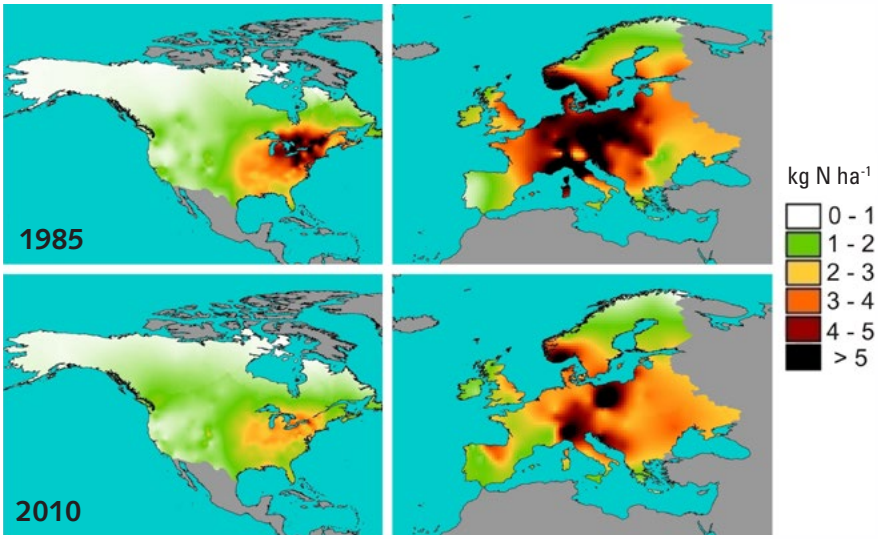
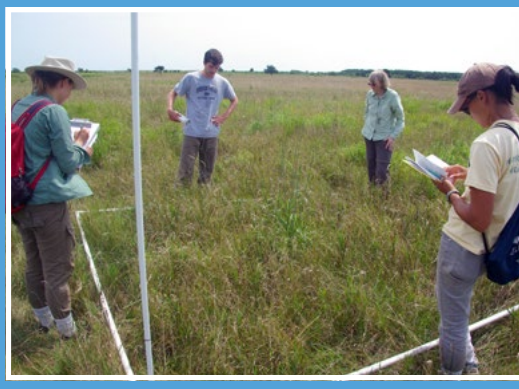


Figure 1. Distribution of nitrate deposition in 1985 (top panel) and 2010 (bottom panel). Nitrate is transported long distances and makes up the largest portion of nitrogen deposition in most places. Data were compiled from the US Atmospheric Deposition Program and the European Monitoring and Evaluation Program.



(L to R) Megan Wheeler, Forrest Carroll, Pamela Polloni, and Katie Surrey-Bergman measure plant diversity in the sandplain grassland restoration project on Martha's Vineyard. Photo by Chris Neill.

NITROGEN DEPOSITION AND TERRESTRIAL ECOSYSTEMS

Over-enrichment from nitrogen deposition can also alter terrestrial ecosystems, particularly in low-nutrient settings where higher nitrogen reduces biodiversity by favoring fast-growing but often non-native plants. Coastal grasslands on nutrient-poor soils harbor many regionally rare and declining plants and may be particularly sensitive to higher nitrogen.

Ecosystems Center Senior Scientist Christopher Neill and Research Assistant Megan Wheeler tested how soil nitrogen influenced plant diversity during experimental establishment of coastal sandplain grassland on an old agricultural pasture on Martha's Vineyard. They increased available nitrogen by adding fertilizer and then added sawdust to reduce nitrogen available to plants (the extra carbon favors nitrogen uptake by microbes but not plants). To their surprise, they found that the level of nitrogen had almost no effect on native plant species diversity. Other factors, like removing existing non-native vegetation and the availability of native seeds, were far more important predictors of native plant establishment. The results are encouraging because they indicate that current levels of nitrogen deposition are not high enough to threaten coastal grassland biodiversity or inhibit conservation management aimed at increasing grassland habitat.

A New Partnership for the MBL

THE UNIVERSITY OF CHICAGO

Ecosystems Center scientists at the MBL use isotopes of nitrogen to study how runoff from urban lands works its way into New England's coastal food webs. An ocean away, University of Chicago faculty use similar methods to trace how naturally-occurring high nitrogen levels from upwelling in the coastal Pacific end up in the mussels that attach themselves to Washington State's rocky coast.

In the foothills of the Brooks Range at Toolik Lake, Alaska, Ecosystems Center scientists model releases of carbon dioxide from tundra soils then match their predictions against long-term measurements of soil carbon under warmer or more nutrient-rich conditions. In the flat and northern expanse of Alaska's coastal plain near Barrow, scientists at the University of Chicago's affiliate Argonne National Laboratory construct comprehensive models of organic carbon storage and release that can be applied to tundra worldwide.

On a small computer cluster in the Starr Building, Ecosystems Center scientists use a global ecological model to predict where on Earth biofuel crops will likely expand and what natural ecosystems and food crops they will displace. In the University of Chicago's Computation Institute, scientists use slightly different models—and the University's state-of-the-art supercomputers—to ask similar questions about where water is sufficient to expand crop irrigation.

Everywhere you look, this web of interaction between the Ecosystems Center and the MBL's new University of Chicago partner is growing. Formalized on July 1, 2013, this partnership is still young, but its potential is beginning to take shape and to enhance both institutions.

At the MBL, Senior Scientist Linda Deegan and the University of Chicago's Cathy Pfister led a September 7-13 Coastal Nitrogen Workshop that examined how animals and their associated microbes influence element cycles. Senior Scientist Edward Rastetter, Argonne National Laboratory scientist Julie Jastrow and Susan Natali from the Woods Hole Research Center received a collaboration grant to improve models of soil carbon emissions from arctic soils and then test them against field measurements. And Yuki Hamada of Argonne National Laboratory and Associate Scientist Jim Tang will explore how the fluorescence of chlorophyll and reflectance spectra from leaves can be used to quantify photosynthesis and carbon exchange in forest canopies.

The MBL and the University of Chicago also seek to expand joint educational activities. University of Chicago undergraduates will be eligible to attend the Ecosystems Center's Semester in Environmental Science for the first time in 2015, and three University of Chicago undergraduate Metcalf fellows spent the summer working with Ecosystems Center scientists. The affiliation brings great potential to develop new programs across the range of ecosystems science, global change and public policy.

Top: Attendees from the MBL and the University of Chicago gather by a statue of Rachel Carson at the Coastal Nitrogen Workshop, which was jointly led by MBL's Linda Deegan and the University of Chicago's Cathy Pfister. Back row (L to R): Maureen Coleman (UChicago), Orissa Moulton (UChicago), Joe Vallino (MBL), Mike Beman (UC Merced), Jack Gilbert (Argonne), Nick Bouskill (Lawrence Livermore Labs), Bess Ward (Princeton), Meaghan Lyons (UChicago), Cathy Pfister. Front row (L to R): Caroline Owens (UChicago), Rachel Folz (UChicago), Ivan Valiela (MBL), Anne Giblin (MBL), Javier Lloret (MBL), Linda Deegan, Rachel Carson, Mitch Sogin (MBL), Mark Altabet (UMass Dartmouth), Jennifer Bowen (UMass Boston). Photo by Chris Neill.

Bottom: University of Chicago students Rachel Folz and Caroline Owens spent the summer of 2014 studying local salt marshes under the mentorship of Ivan Valiela. Photo by Daniel Cojanu.

Other Partnerships

USING ECOSYSTEM SCIENCE TO SOLVE PROBLEMS

The Ecosystems Center maintains its partnership with Brown University that provides unique research experiences to graduate and undergraduate students. The Ecosystems Center also partners with other organizations to apply ecosystem science to management and conservation. One of these partnerships is the *Northeast Climate Science Center* (NECSC), created by the Department of Interior to provide scientific information, techniques and tools to help land managers anticipate and adapt to climate change, protecting land, water, wildlife and cultural resources. The Ecosystems Center works with the NECSC to understand the physical controls on salt marshes and estuarine food webs and how they will respond to climatic change. Assistant Research Scientist James Nelson was a NECSC Fellow and contributed to a report *The Effects of Changing Climate from the Headwaters to the Coasts: A Test Case for Managing in the Face of Climate Change Uncertainty.* The NECSC is led by the University of Massachusetts and includes Columbia University, the College of Menominee Nation, the University of Minnesota, the University of Wisconsin and the University of Missouri.

The Ecosystems Center also collaborates with the Buzzards Bay Coalition (BBC) to conduct one of the longest and largest citizen science water quality monitoring projects in the US. The BBC's Baywatchers program has been documenting change to Buzzards Bay since 1992. Samples collected by Baywatchers volunteers from more than 180 sampling sites in 30 estuaries are analyzed at the Ecosystems Center under the direction of Senior Scientist Christopher Neill. Ecosystems Center scientists collaborate with the science and outreach staff of the BBC to document trends and make these data available to residents and policymakers.

In the Plum Island Ecosystem Long-Term Ecological Research project, Senior Scientist Anne Giblin partners with Massachusetts Audubon's Elizabeth Duff and Robert Buchsbaum to run educational programs that get middle school students out in the field to study how invasive species and sea level rise affect coastal habitats. On Cape Cod, Ecosystems Center scientists and National Park Service scientists at the Cape Cod National Seashore use the Center's Mass Spectrometry Laboratory to measure stable isotopes of carbon, nitrogen and sulfur in the food web of the Herring River in Wellfleet, MA to document conditions before a planned dam removal that will be the largest salt marsh restoration project in New England. On Martha's Vineyard and on the Elizabeth Islands,

Top:Ecosystems Center Assistant Research Scientist James Nelson (far left) talks about his project assessing the vulnerability of salt marshes to climate change at Plum Island with NECSC fellows from across the Northeast US. Photo by Chris Neill.

Inset: Ecosystems Center Research Assistant JC Weber collects water from the "Baywatchers" stations in Onset, MA. Photo courtesy of JC Weber.

Bottom: Nature Conservancy volunteers spread sawdust and seed to test methods for restoring native species in a sandplain grassland experiment on Martha's Vineyard. Photo by Chris Neill.

Christopher Neill works with The Nature Conservancy and local landowners to design science experiments to guide management and restoration of coastal grasslands and shrublands that are among the Northeast US's most important biodiversity hotspots.

Semester in Environmental Science

In 1997, the Ecosystems Center launched the Semester in Environmental Science, a fall semester-long program that provides undergraduates a hands-on immersion in ecosystem and global change ecology. During the past 18 years, SES has served 295 undergraduates from 68 colleges and universities. In 2014, SES hosted 21 students from 15 schools.

For the first ten weeks at the MBL, SES students participate in lectures and field trips to Cape Cod's varying aquatic and terrestrial ecosystems. They then spend hours in the laboratory to master fundamental research techniques that ecologists use to answer questions about the natural world. Students sample the physical and chemical properties of water and sediment in local ponds and estuaries, measure changes to oxygen and carbon dioxide concentrations to estimate the productivity of phytoplankton and forests, use stable isotopes to trace aquatic food webs, and build models to scale field measurements to the ecosystem level.

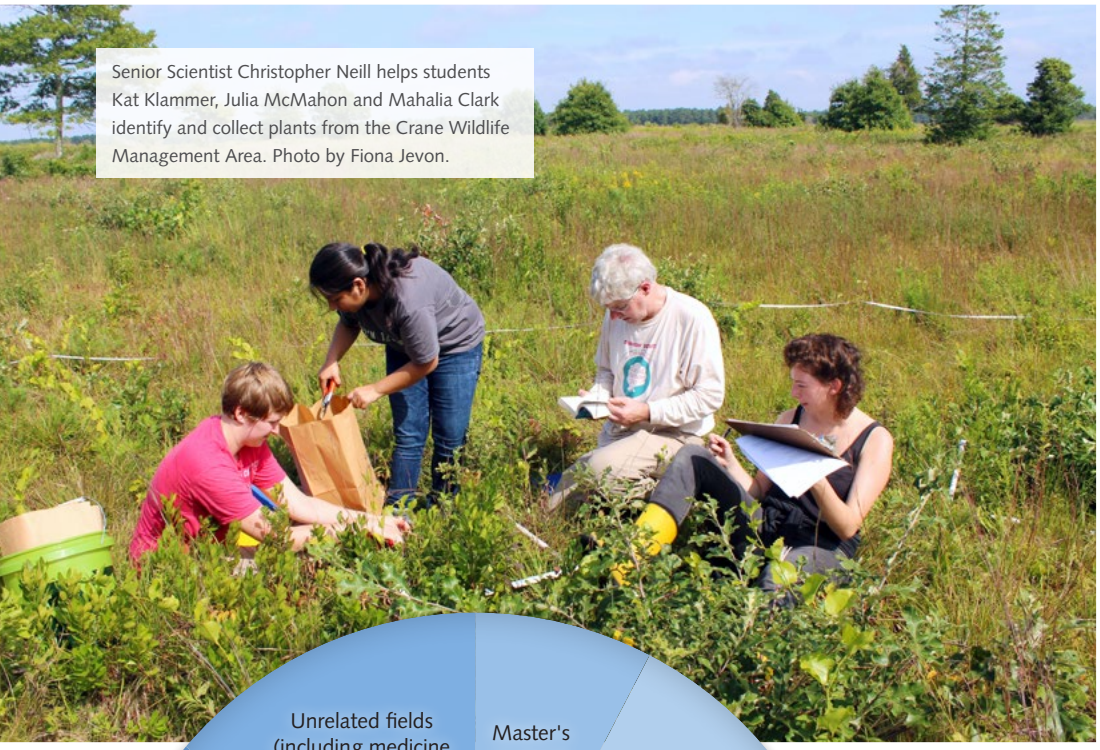
SES student Mahalia Clark lowers a Hydrolab sonde into Waquoit Bay to measure temperature, salinity and dissolved oxygen. Photo by Fiona Jevon.

Students use the techniques learned in the first 10 weeks of the program to develop independent research projects. Topics in 2014 included measuring the effect of beavers and their dam construction on stream and forest food webs, quantifying pharmaceuticals and personal care products in local wastewater and groundwater, assessing the effectiveness of salt marsh restoration projects, and examining the effect of a soil warming experiment at the Harvard Forest on the activity of enzymes associated with soil mycorrhizae. SES students were mentored by Ecosystems Center scientists and by visiting scientist John Schade (St. Olaf College), Julie Huber of MBL's Bay Paul Center and Joel Llopiz of the Woods Hole Oceanographic Institution. Students presented their findings to the Woods Hole scientific community at an end-of-semester symposium. For a complete list of student projects, visit http://www.mbl.edu/ses/courses/projects/.

OTHER SES HIGHLIGHTS FROM 2014 INCLUDED:

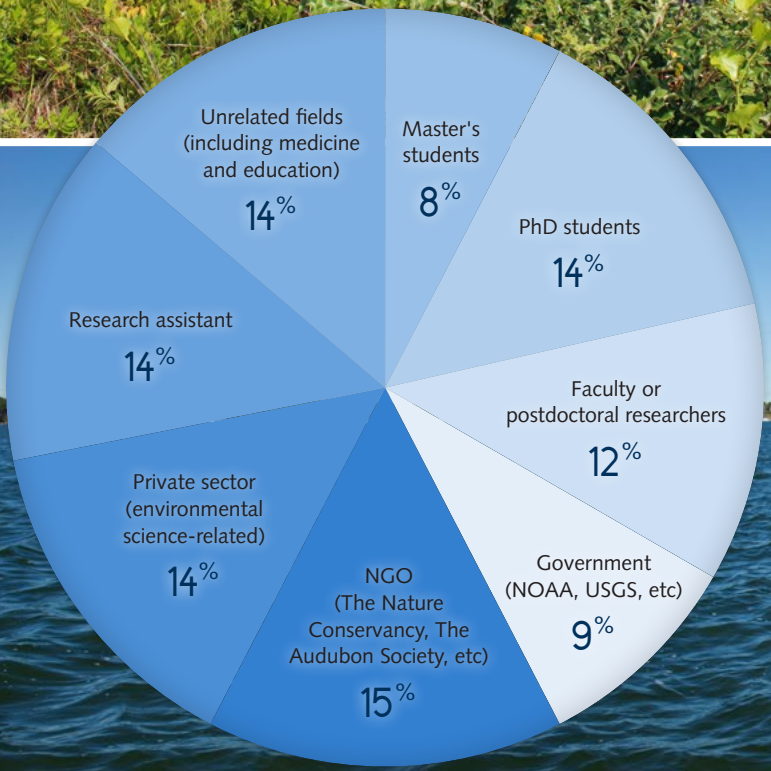
- Kelsey Gosselin (SES 2013) returned to Woods Hole as a summer intern at WHOI with Amanda Spivak, another SES alumna (SES '99). Kelsey studied sediment biogeochemistry and continued as a visiting student in the fall.
- Sarah Nalven (SES 2011, SES TA 2013) began work on a Master's degree at Oregon State University, where she studies the microbial communities in arctic lakes at Toolik Field Station with former Ecosystems Center Postdoctoral Scientist and Arctic LTER collaborator Byron Crump.
- Greg Henkes (SES 2006) began a post-doc in microbial biogeochemistry at Harvard University.
- Carrie McCalley (SES 2001) was first author on a paper published in *Nature* that showed that shifts in soil methane-producing microbes are good predictors of the amount of carbon dioxide and methane produced in thawing arctic permafrost. Carrie is now a Postdoctoral Research Associate at the University of New Hampshire's Earth Systems Research Center.
- David Butman (SES 1999) was appointed Assistant Professor at the University of Washington in the Department of Civil and Environmental Engineering and the School of Environmental and Forest Sciences.

Students seine for fish in an inlet of Waquoit Bay (L to R: SES TA Fiona Jevon, students Madeline Gorchels, Alana Thurston, Christian Daniell and Michelle Pombrol). Photo by Tom Kleindinst.



Senior Scientist Christopher Neill helps students Kat Klammer, Julia McMahon and Mahalia Clark identify and collect plants from the Crane Wildlife Management Area. Photo by Fiona Jevon.

Student Delaney Gibbs samples water from a beaver pond near Plum Island. Several SES students did independent projects on the influence of beavers on the stream ecosystems and the foodwebs of streams and adjacent forests. Photo by Mairi Poisson.



Current activities of SES graduates from 1997 to 2011.

SES students Ben Henry and Delaney Gibbs deploy a plankton net in Waquoit Bay to sample plankton. Photo by Tom Kleindinst.

Education Highlights

BROWN MBL PARTNERSHIP

The MBL maintains a strong partnership with Brown University that began in 2003. Ecosystems Center scientists hold joint academic appointments at Brown and participate by mentoring graduate and undergraduate students and conducting joint research with Brown faculty.

Sarah Corman Crosby defended her dissertation *Salt Marshes in a Changing Climate* on August 25th in the Department of Ecology and Evolutionary Biology. Sarah was advised by Assistant Professor Heather Leslie at Brown and Senior Scientist Linda Deegan and now directs Harbor Watch at Earthplace in Westport, CT.

Xi Yang defended his dissertation *The Times They Are A-Changin': Scaling Seasonality of Plant Physiology from Leaf to Satellite and Implications for Terrestrial Carbon Cycle* on April 28th in the Department of Earth, Environmental and Planetary Sciences. Xi was advised by Associate Scientist Jim Tang and Jack Mustard at Brown. Xi is now a postdoctoral researcher at Brown and works on Amazon vegetation-atmospheric interactions.

REU Jamie Goethlich catches an arctic char to examine how climate changes on Alaska's North Slope may affect fish populations. Photo courtesy of Jamie Goethlich.

Chelsea Nagy studies how riparian forests and soils respond to intensification of Amazon agriculture and she is advised by Senior Scientist Christopher Neill and Stephen Porder at Brown, who also collaborate on Amazon research.

The Ecosystems Center also hosted research by Brown undergraduates Hank Baker, Lia Tosiello and Adam Bouché.

UNDERGRADUATE RESEARCH

For the first time in 2014, the Ecosystems Center hosted students in the Jeff Metcalf Summer Internship Program. This program supports college students from the University of Chicago who conduct summer research at the MBL. Shaunae Alex examined the forms of phosphorus in sinking marine particles in the Sargasso Sea, Rachel Folz investigated the effects of nutrient enrichment and sea level rise in the Great Sippewissett Salt Marsh, and Caroline Owens modeled nitrogen loads to Waquoit Bay.

Each year, the Partnership Education Program in Woods Hole sponsors students who are members of groups traditionally underrepresented in Science, Technology, Engineering and Mathematics fields. The Ecosystems Center hosted Angelique Taylor from Florida Agricultural and Mechanical University and Ola Olawoyin from Philander Smith College.

The Ecosystems Center sponsors many summer undergraduate student researchers through the NSF's Research Experience for Undergraduates (REU) program. Jon Whitcomb from Clarkson University measured dissolved inorganic carbon transport in salt marshes. Alison Hall of Carleton College studied the effect of diet on growth efficiencies in mummichogs, *Fundulus heteroclitus*. At Plum Island, Bethany Williams from Florida State University studied the effect of climate change and sea level rise on the coffee-bean snail, *Melampus bidentatus*. The Arctic LTER hosted two REU students at the Toolik Field Station. Mitch Rasmussen from Utah State University measured the energy balance of arctic streams, and Jamie Goethlich of Northland College studied the effect of experimental lake fertilization on the diet and condition of Alaskan sculpin, *Triglops metopias*.

Other undergraduate researchers at the MBL in 2014 included Levi Simmons from Utah State University who monitored experimental lakes near Toolik Field Station, and Hannah Buesseler from the University of North Carolina, Asheville, Luke O'Brien from Boston College and Emma Sheffield from Eckerd College, who studied the effects of cattle on the vegetation composition of coastal grasslands on the Elizabeth Islands. Two high school students, Pai-Lin Hunnibell from Falmouth Academy and Emily Maness from Falmouth High School helped prepare marine particle samples for analysis of carbonate.

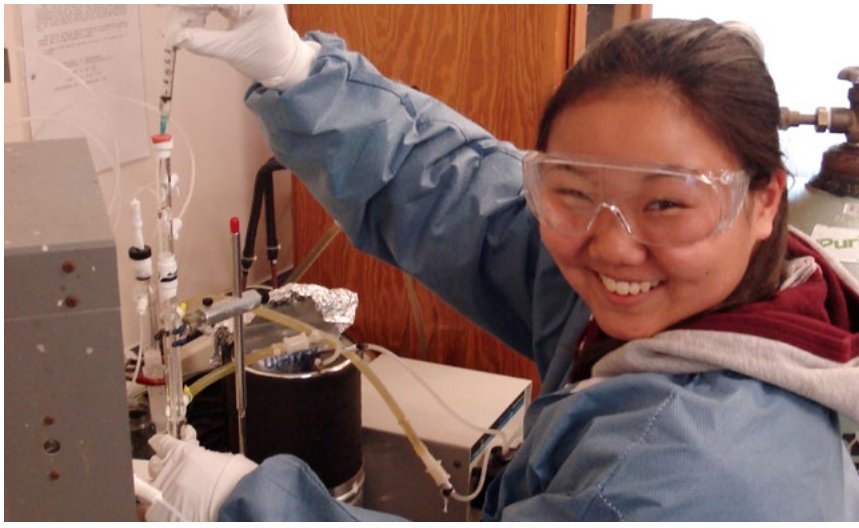
LOGAN SCIENCE JOURNALISM PROGRAM

The Ecosystems Center hosts fellowships and hands-on research experiences for mid-career journalists each year in MBL's Logan Science Journalism Progam. This year journalists

traveled to the Baltimore Ecosystem Long-Term Ecological Research (LTER) Project where they worked with leading urban ecologists in the Baltimore LTER to examine water quality, the distribution of mosquitos that carry West Nile Virus and the aquatic communities in urban ponds and catch basins. Participants were Nick Clark (*Al Jazeera*), Sarah Webb (*Chemical and Engineering News*), Codi Yeager Kocazek (*Circle of Blue*), Fabien Tepper (*Christian Science Monitor*), Susan Phillips (*NPR*) and Catalina Martinez (*EFE News*, Spain). Senior Scientist Christopher Neill and Research Assistant Richard McHorney led the program.

COMMUNITY OUTREACH

Every year, MBL scientists share their knowledge with the local community. Alice Carter, JC Weber and Suzanne Thomas mentored students at the Lawrence Middle School, and Richard McHorney mentored a Falmouth High School student. Alice, JC and Suzanne, Hap Garritt and Marshall Otter, judged the Falmouth Public Schools Science Fair and JC, Marshall and Suzanne also judged the Massachusetts State Science and Technology Fair. Senior Scientist John Hobbie judged the Falmouth Academy Science Fair. JC Weber Co-chaired the Woods Hole Science & Technology Education Partnership (WHSTEP) Executive Committee and organized events to connect local educators with Woods Hole scientists. Kate Morkeski also served on the WHSTEP board. JC, Marshall, and Maureen Conte volunteered as "baywatchers" with the Buzzards Bay Coalition.



Top to bottom:

Senior Research Assistant Rich McHorney demonstrates water filtration to the Logan Science Journalism course in Baltimore. Photo by Chris Neill.

Interns and RAs filling "Frank the Tank", a system that adds nitrogen to Plum Island marshes as part of the TIDE project. From L to R: Olivia Bernard, Bethany Williams, Kailani Acosta, David Behringer. Photo by David Johnson.

Falmouth High School student Emily Maness analyzes the carbonate concentration of deep ocean particles collected by the Oceanic Flux Program. Photo by JC Weber.

(L to R) Megan Wheeler, Emma Sheffield, Hannah Buesseler, Suzanne Spitzer and Luke O'Brien by a fenced enclosure they constructed to test how cattle grazing shapes the sandplain grassland vegetation of the Elizabeth Islands. Photo by Chris Neill.

Postdoctoral Scientists

The Ecosystems Center hosted eleven post-doctoral scientists in 2014. These young scholars work alongside Ecosystems Center scientists and contribute exciting new expertise, skills and ideas to the Center's wide range of research projects. Support for the Center's postdocs was made possible, in part, by a generous gift from Charles and Phyllis Rosenthal.

Chris Algar (PhD, Dalhousie University, 2009) studies how the supplies of oxygen and carbon in marine sediments influence the nitrogen transformations and the populations of microbes that utilize competing nitrogen cycling pathways. He works with Senior Scientist Joe Vallino and the Bay Paul Center's Julie Huber to match biogeochemical observations to biogeochemical models.

Joanna Carey (PhD, Boston University, 2013) is a Powell Center post-doctoral fellow. She works with Senior Scientist Jim Tang, Kevin Kroeger of the US Geological Survey and Pamela Templer of Boston University to quantify how climate change is altering greenhouse gas fluxes from Cape Cod salt marshes.

Ciniro Costa Junior (PhD, University of São Paulo, 2014) models how the spread of intensive agriculture across the Amazon Basin affects emissions of greenhouse gases. He works with Senior Scientist Christopher Neill, Marcia Macedo and Michael Coe at the Woods Hole Research Center and Gillian Galford at the University of Vermont.

Inke Forbrich (PhD, University of Greifswald, Germany, 2011) uses eddy flux measurements to create a detailed carbon budget for coastal salt marshes at Plum Island in Massachusetts and to predict how marshes will respond to rising sea level. She works with Senior Scientist Anne Giblin.

Mary Heskel (PhD, Columbia University, 2014) works with Senior Scientist Jim Tang at the Harvard Forest and at Toolik Lake, Alaska to link canopy-scale productivity measured by eddy-covariance and canopy fluorescence to leaf-level measures of photosynthesis and respiration.

KathiJo Jankowski (PhD, University of Washington, 2014) works with Senior Scientists Christopher Neill and Linda Deegan and conducts field studies to quantify the fate of nitrogen fertilizer in intensifying Amazon crop agriculture and to understand the effects of agriculture on tropical streams.

Yueyang Jiang (PhD, Purdue University, 2012) investigates carbon and nutrient fluxes in arctic tundra following fire and permafrost thawing. He works with Senior Scientist Edward Rastetter and applies the Multiple Element Limitation biogeochemistry model to the North Slope of Alaska.

Javier Lloret (PhD, University of Murcia, Spain, 2012) combines field studies and modeling and works with Distinguish Scientist Ivan Valiela to investigate how macroalgal and seagrass beds control how estuaries respond to warmer temperatures caused by climate change and to declines in nitrogen deposition.

Elena Lopez Peredo (PhD, University of Oviedo, Spain, 2008) studies terrestrial microalgae, isolated from the biological soil crusts in Southwest US deserts, to understand the morphological, physiological and genetic traits that led algae to occupy terrestrial environments. She works with Senior Scientist Zoe Cardon.

Xiaoliang Lu (PhD, Purdue University, 2012) works with Distinguished Scientist Jerry Melillo and Research Associate David Kicklighter and uses the Terrestrial Ecosystem Model to ask questions about how climate, land use change, ozone, nitrogen deposition and disturbance influence the Earth's terrestrial ecosystems.

Or Shapira (PhD, Hebrew University of Jerusalem, 2013) studies the mechanisms by which salinity and drought influence photosynthesis. He works with Senior Scientist Zoe Cardon.

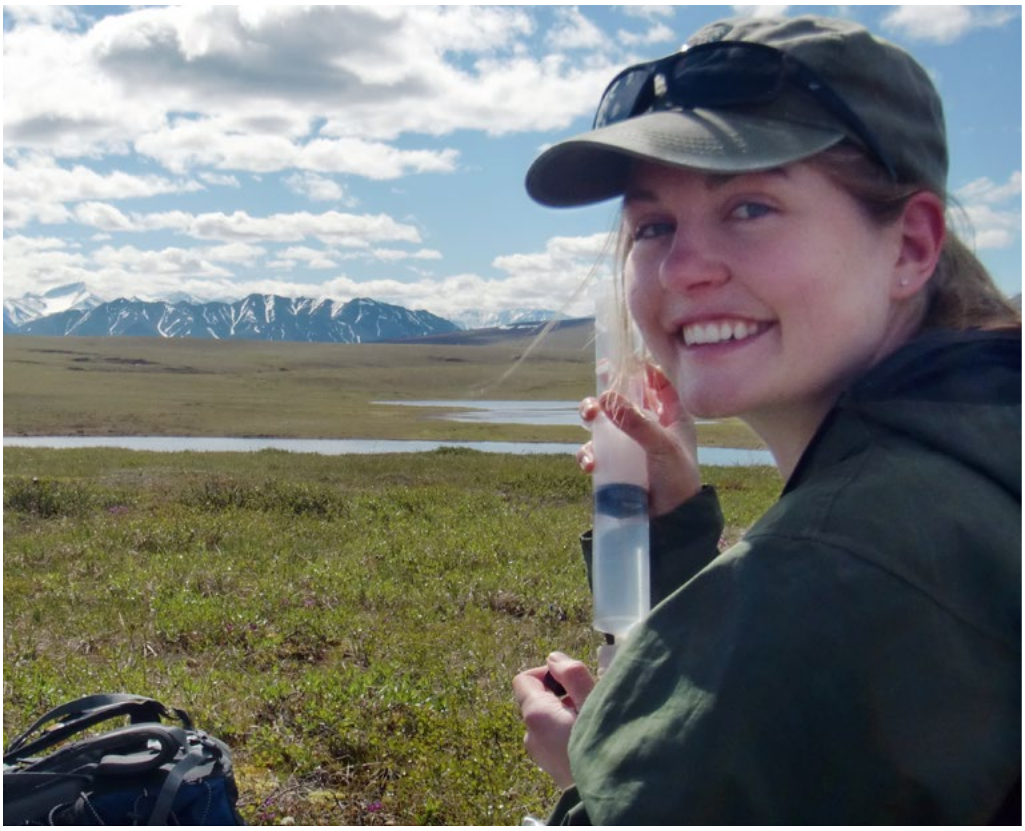
Top: Mary Heskel uses a shotgun to sample canopy leaves at Black Rock Forest in New York to study the relationship between leaf chemistry and photosynthesis. Photo courtesy of Mary Heskel.

Left: Joanna Carey at Toolik Field Station, AK. Photo courtesy of Joanna Carey.

Left top: Elena Lopez Peredo explores how the microscopic green algae that live in desert crusts protect themselves during desiccation. Photo courtesy of Elena Lopez Peredo.

Left Bottom: KathiJo Jankowski takes stream measurements in the Brazilian Amazon state of Mato Grosso, as part of research that looks at how the intensification of farming practices influences nutrient loads to tropical streams. Photo by Chris Neill.

News 2014



In May, Distinguished Scientist Jerry Melillo was elected to the National Academy of Sciences. This honor recognizes Jerry's groundbreaking research in forest ecology and his extraordinary record of public service. Jerry currently chairs the federal advisory committee that prepared the Third US National Climate Assessment, which was released in the spring of 2014. Jerry was a lead author of reports for the first and second Intergovernmental Panel on Climate Change (IPCC) and served as Associate Director for Environment in the Office of Science and Technology Policy in the mid-1990s.

Jim Tang was promoted from assistant scientist to associate scientist. Jim also co-chaired the National Ecological Observatory Network's Fundamental Instrument Unit Technical Working Group on soils.

Senior Scientist Linda Deegan spent 2014 as a Program Officer in the National Science Foundation's Division of Environmental Biology in Arlington, Virginia. At NSF, Linda was the lead contact with the Advisory Committee on Environmental Research and Education, which provides recommendations and oversight for NSF's environmental research and education activities.

Adjunct Associate Scientist Maureen Conte celebrated her 20th year of leading the Oceanic Flux Program, a 37-year time-series that measures particle fluxes to the deep ocean in the Sargasso Sea off Bermuda.

Assistant Research Scientist David Johnson was hired as an Assistant Professor at the Virginia Institute of Marine Science. David is now an Adjunct Assistant Scientist at the Ecosystems Center where he continues to contribute to coastal research at Plum Island.

James Nelson was promoted to Assistant Research Scientist at the Ecosystems Center.

Postdoctoral Scientist Chris Algar was hired as Assistant Professor in the Department of Oceanography at Dalhousie University.

Top left: Research Assistant Alice Carter filters water for the Lakes team of the Arctic LTER on the North Slope of Alaska. Photo by Lauren Watel (PolarTREC 2014) Courtesy of ARCUS.

Top right: Senior Research Assistant Richard McHorney explains how to analyze water for nitrate concentrations during the Logan Science Journalism Program. Photo by Fabien Tepper.

Bottom: Distinguished Scientist Jerry Melillo lead the production of the most recent National Climate Assessment. Photo by Tom Kleindinst.

Senior Scientist Edward Rastetter was awarded a MBL-UChicago/Argonne Collaboration Award together with Julie Jastrow of Argonne National Laboratory and Susan Natali of the Woods Hole Research Center. The team will develop a model of Pan-Arctic ecosystem respiration.

Distinguished Scientist John Hobbie co-edited *A Changing Arctic: Ecological Consequences for Tundra, Streams and Lakes*, published by Oxford University Press. The book highlights science from Toolik Field Station. Senior Scientist Gaius Shaver co-authored the chapter on terrestrial ecosystems. Gus served on the Long Term Ecological Research Network Executive Committee, the US National Academy of Sciences Polar Research Board, and the US Department of Energy's Biological and Ecological Research Advisory Committee.

Director and Senior Scientist Christopher Neill served as the chair of the Science Advisory Committee for the Buzzards Bay Coalition. He and Distinguished Scientist Ivan Valiela also served on the committee that advised the Cape Cod Commission on its 208 Water Quality Plan.

Senior Scientist Anne Giblin joined the National Estuarine Research Reserve's Science Collaborative Advisory Board.

Senior Scientist Zoe Cardon served on the triennial site review panel that evaluated productivity and operations of the Joint Genome Institute.

Natalie Boelman, Assistant Research Professor at the Lamont Doherty Earth Observatory of Columbia University, joined the Ecosystems Center as an adjunct scientist.

Top to bottom, left to right

A group of MBL and UChicago scientists and students hit the beach after a three-day workshop on coastal nitrogen. L to R: Orissa Moulton, Anne Giblin, James Nelson, Javier Lloret, Rachel Folz, Meaghan Lyons, Cathy Pfister, Linda Deegan and Caroline Owens. Photo by Ivan Valiela.

Research Assistant Will Werner turns on the cables that control soil temperature at the Harvard Forest soil warming experiment. Photo by Sarah Nalven.

Four generations of teaching assistants for the SES program unite with Senior Scientist Anne Giblin at the Toolik Field Station in Alaska. L to R: Sarah Nalven (SES TA, 2013), Anne Giblin, Alice Carter (SES TA, 2012-2013), Fiona Jevon (SES TA 2013-2014), Maya Wei-Haas (SES TA, 2009). Photo courtesy of Sarah Nalven.

Maureen Conte oversees the recovery of the Oceanic Flux Program mooring off of Bermuda. Photo by JC Weber.

Summer Research Assistants Alice Carter and Levi Simmons sample Toolik Lake as part of the Arctic LTER. Photo by Sarah Nalven.

SES Director Ken Foreman helps SES student Christine McCarthy use a hydrolab to measure salinity, temperature and dissolved oxygen in Johns Pond. Photo by Jessica Beach.

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Sinking foraminifera shells at 500m depth, collected by the Oceanic Flux Program (OFP) sediment trap mooring offshore Bermuda during the summer of 2014. Photo courtesy of JC Weber.

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Research Assistants Emma Sheffield, Suzi Spitzer, and a cow sample the vegetation on Naushon Island. Photo by Megan Wheeler.

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Right: Atlantic Silversides, striped killifish, mummichogs, and a green crab are just a few of the things SES students caught with this seine in Waquoit Bay. Photo by Alana Thurston.

Below: Senior Research Assistant Rich McHorney demonstrates the proper way to filter water during the annual Science Journalism course in Baltimore, MD. Photo by Fabien Tepper.

Seminars 2014

JANUARY

14 Herb Wilson, Colby College. "Patterns of arrival dates of Maine migratory breeding birds."

21 Yongsong Huang, Brown University. "Progress in applying lacustrine alkenones as a quantitative continental paleotemperature proxy."

28 Michael Dietze, Brown University. "The PEcAn Project: Accessible ecoinformatic tools for carbon-cycle model-data analysis and assimilation."

FEBRUARY

4 Becca Ryals, Brown-MBL Post Doc. "What to do with all that poo? A nitrogen perspective on poultry manure management in the Chesapeake Bay Watershed."

11 Jaclyn Hatala Matthes, Dartmouth College. "Managing, measuring, and modeling wetland carbon flows: Lessons from the California delta."

18 Georgiana Conti, Marine Biological Laboratory. "Carbon storage & plant functional diversity - an empirical test in semiarid forest ecosystems."

25 Elizabeth Wolkovich, Harvard University. "Community assembly and disassembly under global change."

MARCH

4 Matthew Long, Woods Hole Oceanographic Institution. "Ecosystem metabolism in challenging environments using eddy correlation: Seagrass beds, coral reefs, and arctic ice sheets."

18 Doug Frank, Syracuse University. "Grazing ecology of Yellowstone National Park."

25 Oliver Sonnentag, University of Montreal. "Establishing a meso-network of eddy covariance towers to measure carbon, water and heat fluxes along a 1,000-km permafrost gradient in the Northwest Territories, Canada."

APRIL

1 Louisa Bradtmiller, Macalester College. "Not your grandmother's earrings: What opal tells us about the carbon cycle and the trade winds."

8 Kendra McLauchlan, Kansas State University. "Reconstructing nutrient cycling in the paleorecord to assess current global changes."

15 Jim Tang, Marine Biological Laboratory. "Plant physiological constraints of terrestrial carbon fluxes."

22 Chelsea Nagy, Brown-MBL Graduate Student. "Ecological and biogeochemical consequences of agriculture in the Brazilian Amazon."

29 Jennifer Fraterrigo, University of Illinois at Urbana-Champaign. "Cross-scale controls on the impacts of non-native invasive species."

MAY

6 Stefano Allesina, University of Chicago. "The stability of large ecological systems."

20 Mark Bradford, Yale University. "Climate and litter decomposition: the ecological fallacy of a dominant paradigm in ecosystem ecology."

SEPTEMBER

9 Eric Roy, Brown ECI. "Estuarine ecosystem response to large-scale Mississippi River diversions: A synthesis of recent research in the Pontchartrain Estuary."

12 *Cathy Pfister, University of Chicago. "Productivity on rocky shores: from microbes to animals."

19 *John Blair, Kansas State University. "Assessing multiple controls of primary productivity in tallgrass prairie: The Konza prairie LTER program."

23 Cathy Wigand. US EPA. "Multiple stressor effects on salt marsh systems."

30 Anne Bernhardt, Connecticut College. "From shore to shore: A story of salt marsh nitrifiers from the Gulf of Mexico to New England."

OCTOBER

10 *Jill Baron, Colorado State University. "Double whammy: both reactive nitrogen in deposition and climate change influence in high elevation Rocky Mountain ecosystems."

14 Dali Guo, Chinese Academy of Sciences. "Advances and prospects of root ecology. "

21 Sue Natali, Woods Hole Research Center. "Ecological feedbacks to climate change: Shifting carbon dynamics in the Arctic."

24 *Daniel Conelly, Lund University, Sweden. "Is "geo-engineering" an acceptable solution for Baltic Sea eutrophication?"

28 Maryanne Moore, Wellesley College. "Dimensions of biodiversity in Russia's Lake Baikal."

NOVEMBER

4 Maureen Conte, Marine Biological Laboratory. "Linkages between upper-ocean physical forcing, biogeochemical cycles and the elemental composition of the deep particle flux in the oligotrophic Sargasso Sea."

18 Tarik Gouhier, Northeastern University. "Coral-microbial interactions under climate change."

DECEMBER

2 Michael McKormick, Hamilton College. "Geochemical and microbial characterization of Antarctic sediments previously covered by the Larsen A ice shelf."

12 Semester in Environmental Science final student research symposium.

*SES Distinguished Scientist Seminar

Sunset over Toolik Lake, AK.
Photo by Jessica Drysdale.

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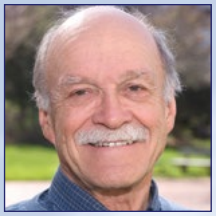

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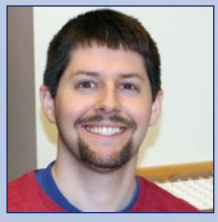

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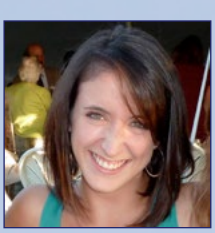

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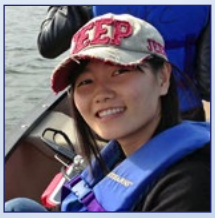

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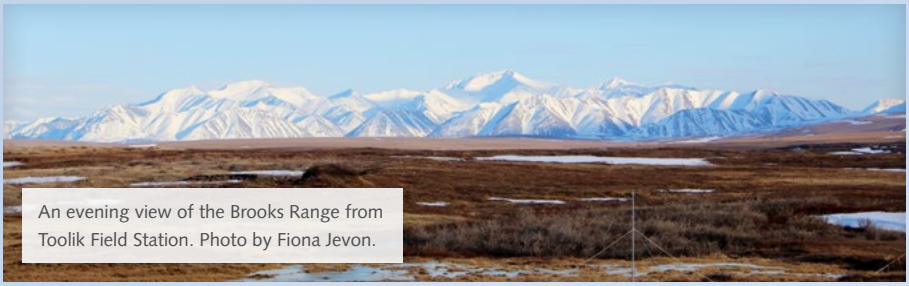
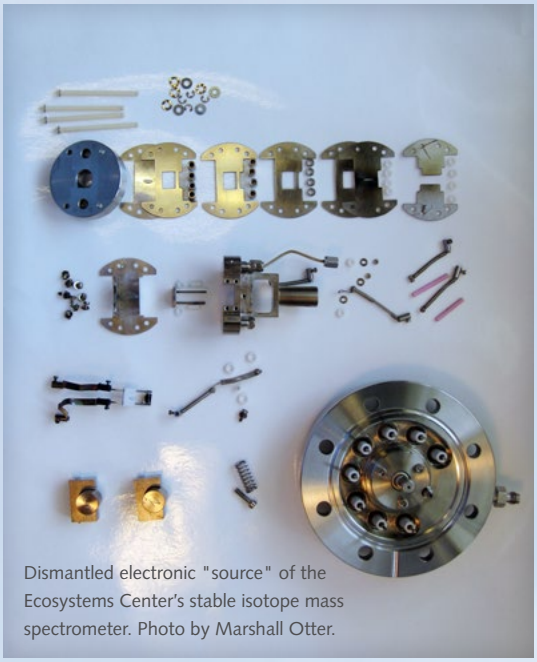


An evening view of the Brooks Range from Toolik Field Station. Photo by Fiona Jevon.



Dismantled electronic "source" of the Ecosystems Center's stable isotope mass spectrometer. Photo by Marshall Otter.

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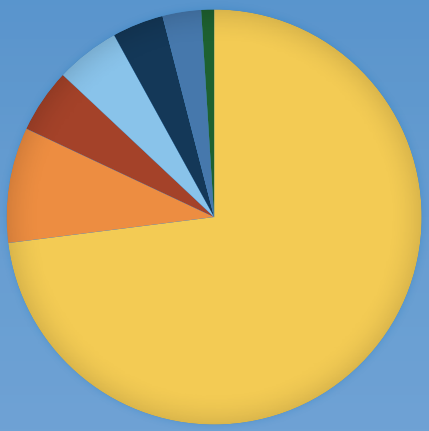
Jonathan Whitcomb
Clarkson University, REU
Bethany Williams
Florida State University, REU

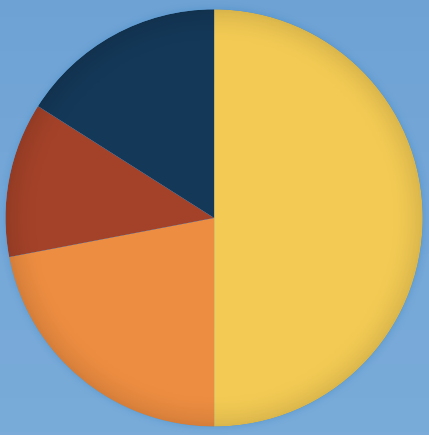
Mangrove trees occupy the land-water edge on the Pacific coast of Panama. Photo by Ivan Valiela.

Sources of Support for Research and Education

The annual operating budget of the Ecosystems Center for 2014 was $7,666,000. Approximately 73% of the Center's income 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 20% 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. Non-governmental funds provided valuable flexibility to develop new research projects, public policy activities and educational programs.

The combined fund market value of the Center's research and education endowments at the end of 2014 was $6,353,000. Income from these funds helps defray the costs of operations, writing proposals, consulting for government agencies and educational programs.





NEW SUPPORT

Beech Tree and Michael R. Paine Conservation Trusts
Robert Burton
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Andrew and Amy Feinberg
Christopher Foreman
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Christopher Freeman
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Lubin Family Foundation
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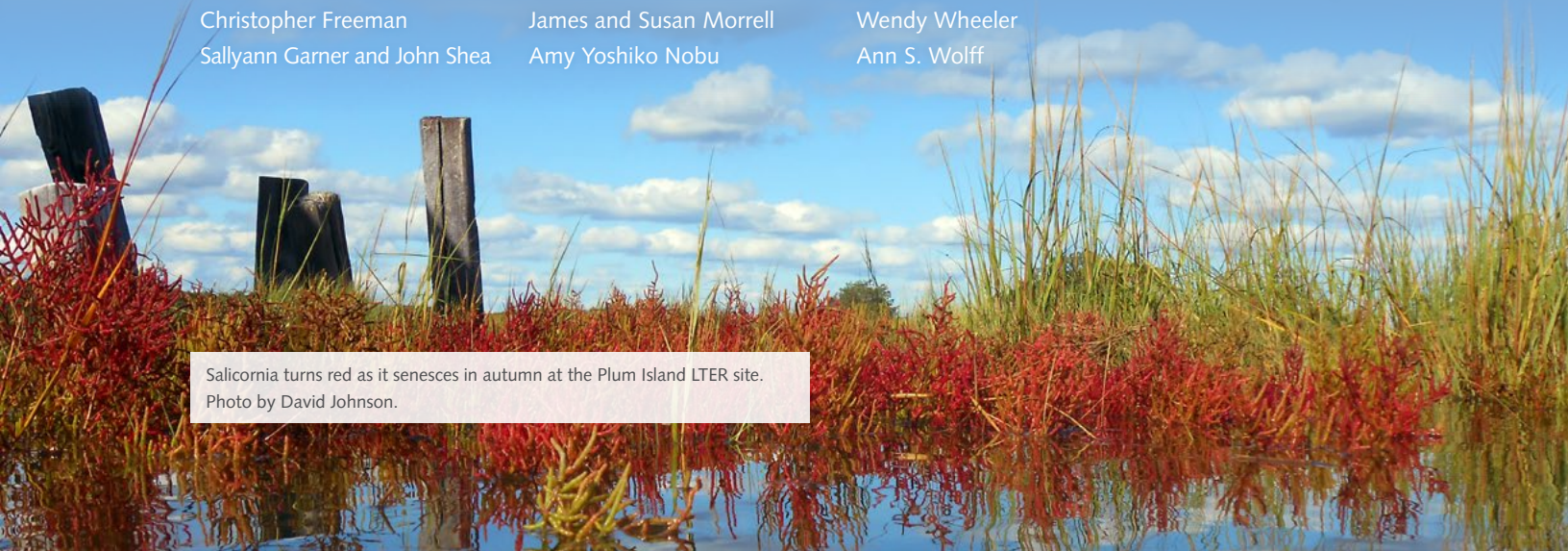

Salicornia turns red as it senesces in autumn at the Plum Island LTER site. Photo by David Johnson.

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