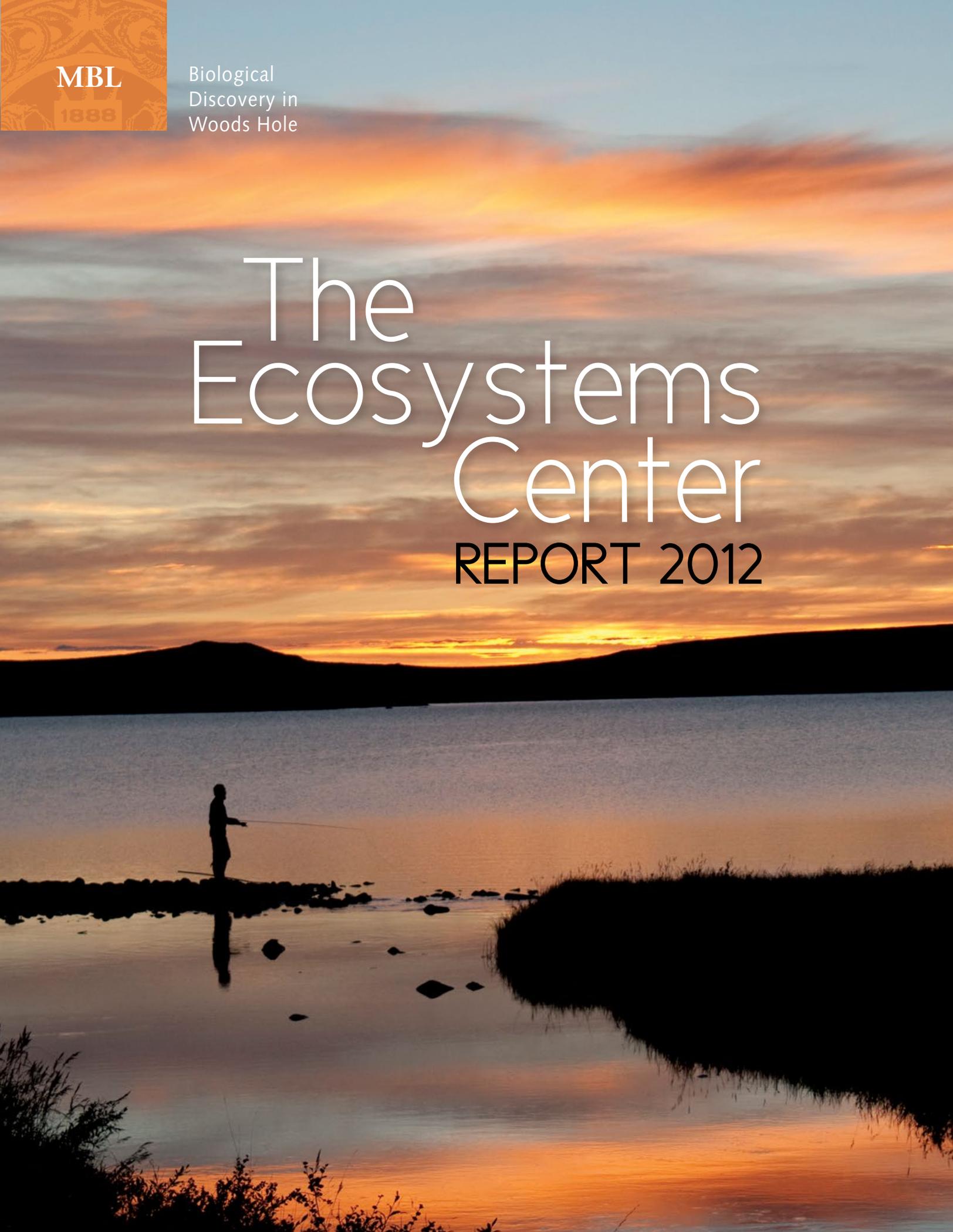




MBL

Biological
Discovery in
Woods Hole



The
Ecosystems
Center
REPORT 2012



Cover photo Michael Kendrick, Ph.D. student at the University of Alabama fishing for arctic grayling (*Thymallus arcticus*) at Toolik Field Station, Alaska, in August. The Fishscapes project, under the direction of Ecosystems Center Senior Scientist Linda Deegan and Alex Huryn, Professor of Biological Sciences at the University of Alabama, is examining how changing climate affects the migration and life-cycle of grayling populations in the Kuparuk River on the north slope of Alaska.

This research is based out of Toolik Field Station, home of the Arctic Long Term Ecological Research (LTER) site (68°38'N, 149°36'W). The Arctic LTER project is maintained by the Ecosystems Center and was established to understand and predict the effects of environmental change on arctic tundra and freshwater.
(Photo: Jessica Drysdale)

This page Woods Hole Partnership Education Program student Jessica Eason (in blue) and collaborators measure gas fluxes and salt marsh sediment properties alongside Sage Lot Pond in Mashpee on Cape Cod.
(Photo: Kate Morkeski)

Editors Christopher Neill
and Deborah G. Scanlon

The Ecosystems Center
MBL
Woods Hole, MA

Ecosystem Science

FOR ENVIRONMENTAL SOLUTIONS

By Christopher Neill



I took over as Director of the Ecosystems Center in December 2012. I did it for one simple reason. I believe that ecosystem science—the study of complex biological systems and their interaction with the physical environment—will help solve environmental problems and ensure that our future balances human needs with the sustenance of the astonishing range of natural ecosystems from tundra to rainforest that are our planetary life support systems.

I grew up beside the Hudson River. When I first explored its banks in the early 1960s, the river was pretty much an open sewer. My friends and I joked that the river would change color depending on what color the GM plant was painting cars that day. Today the Hudson is a different place, and that change is a testament to our collective ability to solve environmental problems. Modern sewage treatment plants that New York City built in the 1980s improved water quality. And industrial pollution was curtailed even before that auto plant in North Tarrytown closed for good in 1996.

Today fixing our environmental problems requires more than building treatment plants and shutting off discharge pipes. Problems are complex and more global. They require teams of scientists to understand and solve—exactly the approach that the Ecosystems Center takes to environmental science. This report describes the tip of the iceberg of that remarkable work.

Close to home, Ecosystems Center scientists identified over many years the damage that the excess nitrogen from thousands of backyard septic systems causes in Cape Cod estuaries. Center scientists now conduct cutting-edge experiments, such as experimentally adding nitrogen to whole saltmarsh creeks at Plum Island, to examine the mechanisms that cause the marsh to degrade (pages 4-5). Then they translate this understanding into watershed models that can both predict future change and evaluate actions to prevent nitrogen from reaching coastal waters.

In the Arctic, rising temperatures caused by global releases of greenhouse gases are transforming the tundra. Thunderstorms that were almost unheard of several decades ago are now common in mid summer. With those storms comes lightning and lightning-ignited wildfires. Higher temperatures also bring earlier snowmelt and low August river flows that can block migration of fishes. Ecosystems Center scientists synthesize Arctic change (pages 6-7) and lead investigations of these new global Arctic phenomena. They study the ways that fire might accelerate further change—like initiating thawing of permafrost that might cause large additional releases of carbon on dark burned surfaces. And they use new technology to track how fish move in response to river flows.

Ecosystems Center scientists reach across disciplinary boundaries to advance basic understanding of ecosystems. The MBL's open culture and the access to cutting-edge tools in genomics and microscopy provided by MBL's position as a world crossroads for biological research help incubate these interactions. This allows Ecosystems Center scientists to look at problems, like water uptake into roots in the world's drylands (pages 8-9) in new and exciting ways.



At the global scale, one of humanity's grand challenges is to produce more food for a growing and more affluent population while growing more "biofuel" to replace energy from coal, oil and natural gas. One solution is to produce more food and fuel on each acre of land—but this requires large amounts of fertilizer and other inputs that can damage the environment. In the globalized industrial soybean fields of the Brazilian Amazon and on farms in East Africa, Ecosystems Center scientists study how emerging intensive agriculture might be modified to protect fresh waters and conserve adjacent wild lands. They also construct global models to predict where conflicts between the demands for food and fuel are most likely to arise.

We know that solving global environmental problems and speeding a transition to a more sustainable world requires more than doing science. It requires translating science into a form where it changes national and global policy. This year, the Ecosystems Center's Jerry Melillo took on the challenge of leading the US National Climate Assessment's Development Advisory Committee. Jerry organized and oversaw more than 240 authors who documented how climate change impacts different regions and different economic sectors such as water resources, agriculture, energy and urban infrastructure. The Assessment also outlines options for adapting to the now-unavoidable changes that climate change will bring.

It is a great honor to lead such a talented group of scientists and staff that make the Center a global leader in ecosystem science. As climate change accelerates and global economic and ecological forces transform the Earth's coasts, tundra, rain forests and remaining wild places, the work of the Ecosystems Center is more valuable than ever.

Researchers hike into Atigun Gorge, an entry point into the Arctic National Wildlife Refuge, about 20 kilometers south of the Toolik Field Station, base of the Arctic Long-Term Ecological Research project
(Photo: Jessica Drysdale)



Coastal Wetlands

IMPLICATING NITROGEN IN SALT MARSH COLLAPSE

Worldwide, salt marshes are disappearing. Reduced sediment supply, coastal development, sea-level rise, pollution and overgrazing all may contribute to the problem. Salt marshes are vital to the health of our coasts. They protect inland areas from storms, provide habitat and nursery ground for fish and birds, and filter nutrients from water and thus protect other nutrient-sensitive coastal ecosystems such as seagrass beds. They also store carbon and provide recreation and scenic vistas.

Our coasts will look—and work—very differently with less salt marsh.

In 2002, Ecosystems Center Senior Scientist Linda Deegan and a team of collaborators began a one-of-a-kind experiment in Massachusetts' Great Marsh in the Plum Island Estuary, north of Boston, to try to understand how salt marshes respond to higher amounts of nutrients that now reach shorelines from fertilizer and wastewater, funneled from watersheds to estuaries via groundwater and rivers. By dripping fertilizer into small marsh creeks on incoming tides since 2004, they artificially created “nutrient-enriched” creeks that they compared with unfertilized creeks. When their work started, the prevailing wisdom was that salt marshes were nutrient filters that had a vast capacity to take up nutrients year after year without harm. Eight years later, their results show this idea needs a thorough re-evaluation.

The largest salt marsh in New England is the spectacular setting for the Plum Island Long-Term Ecological Research Project.
(Photo: David Johnson)

RESEARCH IN THE MARSH

As May arrives in the marshes of the Plum Island Estuary, so do the scientists. For the past decade Linda Deegan, MBL Research Associate David Johnson and their colleagues from the TIDE Project (Trophic Interactions in Detritus-Based Ecosystems), set out for their research sites along the marsh-bordered Rowley River. By comparing whole fertilized and unfertilized reference “creeksheds” that include marsh channels and the marsh platform itself, they can examine the effects of nutrients on the entire marsh system—from bacteria to birds to fish and even the geomorphology of the marsh itself.

Previous work from small fertilized plots in salt marshes suggested that more nutrients would stimulate aboveground plant biomass, which would in turn increase sediment trapping and increase marsh accretion. While the TIDE experimental fertilization did increase aboveground biomass as predicted, it did not increase the stem density of marsh grass or increase sediment trapping. The fertilization did, however, cause the creek-bank salt marsh grass, *Spartina alterniflora*, to invest less biomass in the belowground roots and rhizomes that build the marsh’s peat soils and bind sediments—perhaps not surprising because more nutrients were now supplied in the incoming water. Fertilization also stimulated the sediment microbes that consume buried organic matter.

The net result was that after four years of fertilization, the banks of the fertilized creeks began cracking, and eventually slumping, calving off of the creek banks in sofa-sized chunks. The fertilization increased decomposition of plant litter and increased nitrogen loss by denitrification in marsh sediments. It changed the structure of marsh creeks by increasing the density and length of marsh-edge cracks, the number of slumps and the amount of fine sediment in marsh creeks. There were no equivalent changes in the reference creeks. These results, reported in the journal *Nature*, show that responses to changes at the scale of whole ecosystems can be quite different than those obtained from small plots because ecosystems have interacting physical and biological parts. While the marsh retained much of the added nutrients, the nutrients in turn altered the marsh. The concentrations of nutrients added to the marsh by the TIDE team were the same as found in some nutrient-enriched estuaries or likely to

occur on others in the future. This requires rethinking the idea that salt marshes can withstand almost any nutrient loads our increasing coastal population might throw at them.

While the TIDE Project was the first to demonstrate nutrient-driven marsh loss experimentally, these findings do not appear to be unique to Plum Island. Jamaica Bay, New York, for instance, receives nutrient concentrations similar to the TIDE experiment because four wastewater treatment plants discharge nutrient-rich water into the bay. Jamaica Bay also shows marsh loss with similar patterns of decreased belowground biomass, increased microbial respiration, and marsh edge collapse.

The dramatic geomorphic response of marshes to nutrients demonstrated by the TIDE Project may not occur in every marsh. Different coastal regions have combinations of characteristics including temperature, sediment supply, geomorphology, and tidal flushing. However, given the increasing availability of nitrogen that now flows from watersheds into coastal waters, marshes worldwide may be susceptible.

Many questions remain unanswered. For example, the TIDE team now plans to examine how these geomorphic changes affect marsh food webs. How will habitat change affect small fish that rely on the creek-bank habitat for spawning and feeding? The creek bank is also a “hotspot” for microbial processes such as nitrogen removal by denitrification, and creek bank loss may lower the ability of marsh creeksheds to remove nitrogen from the water, further diminishing the marsh’s ecological service as nutrient filter.

Eight years of experimental nutrient additions changed the structure of marsh creeks by increasing marsh-edge cracks and creek slumping. (Photo: Christopher Neill)



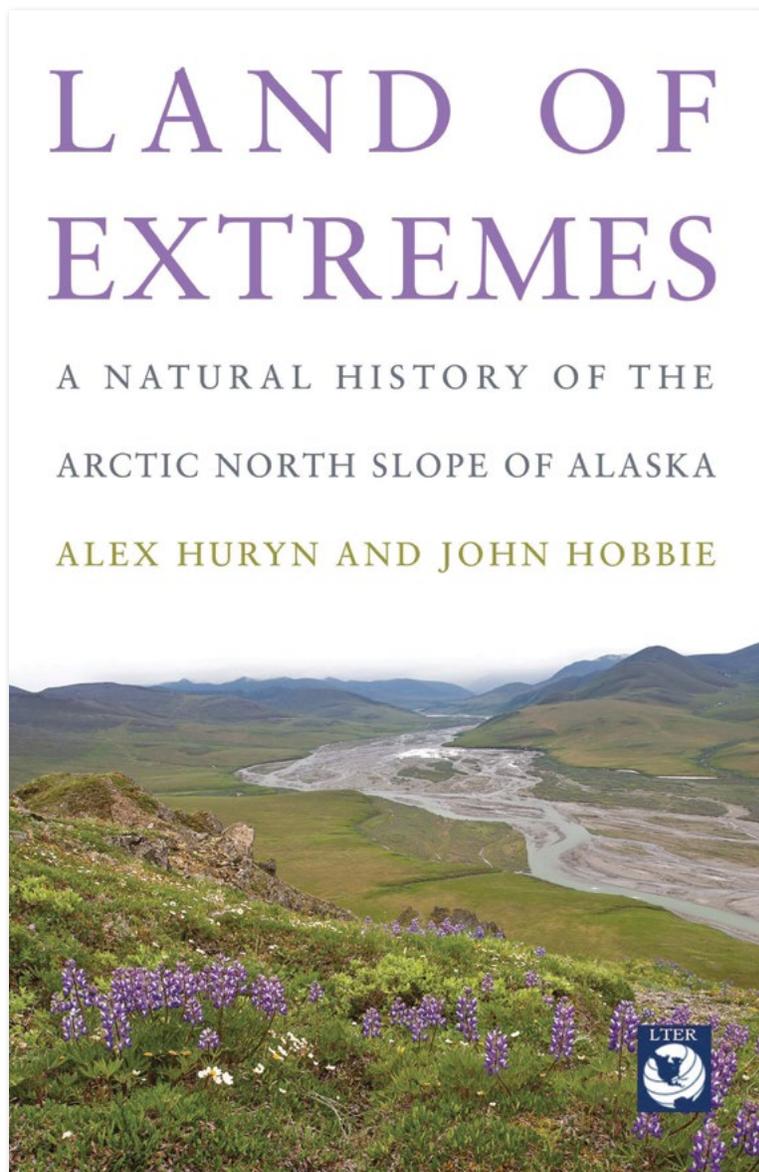
Arctic Change

SYNTHESIZING TWO DECADES OF RESEARCH

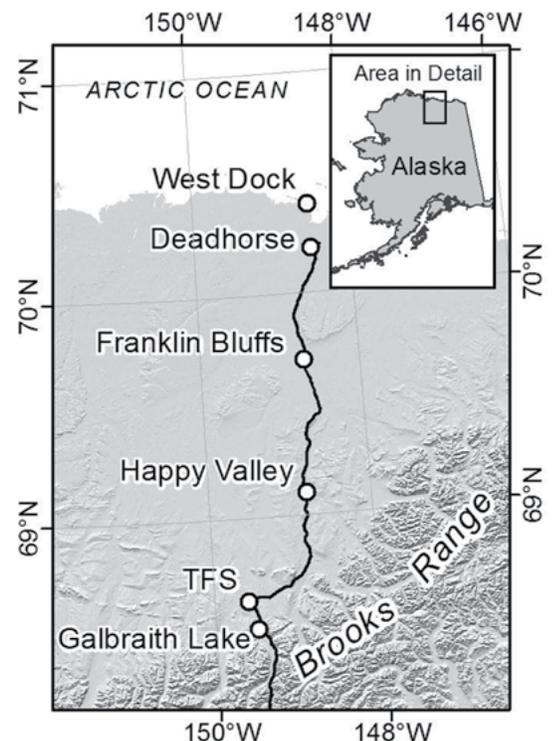
Scientists from the MBL's Ecosystems Center have investigated arctic ecology in a variety of sites for nearly 40 years: Abisko in northern Sweden, Svalbard (north of Norway), Russia and Alaska. Most of the research has taken place near Toolik Lake in the Arctic foothills of the North Slope of Alaska where the research facility has grown from a few tents and surplus pipeline construction trailers to the University of Alaska's laboratory and dormitory buildings for 125 scientists. The centerpiece of the research is the continuing Arctic Long Term Ecological Research, or LTER project, that investigates the climate and ecology of the streams, lakes and

tundra accessible from the Toolik Field Station. Since 1975, the Arctic LTER has archived data on the climate, geology, soils, microbes, plants and animals of the region. The Arctic LTER has also carried out experiments, such as field manipulations of temperature, light, and nutrients that aim to discover the controls of species presence, productivity and survival. This wealth of detailed knowledge generated by the LTER—which makes the area around Toolik Lake one of the best-studied Arctic locations in the world—attracts a wide assortment of researchers from the Ecosystems Center and elsewhere, who use this base of information to launch new studies.

The concentration of so many arctic experts in one place each summer led Arctic LTER scientist Alex Huryn (University of Alabama) and former LTER lead scientist John Hobbie (MBL) to write a book that brings together the information about the ecosystems of this region and of the North Slope collected from hundreds of papers and theses. The book, "Land of Extremes: A Natural History of the Arctic North Slope of Alaska" (University of Alaska Press), illustrates this natural



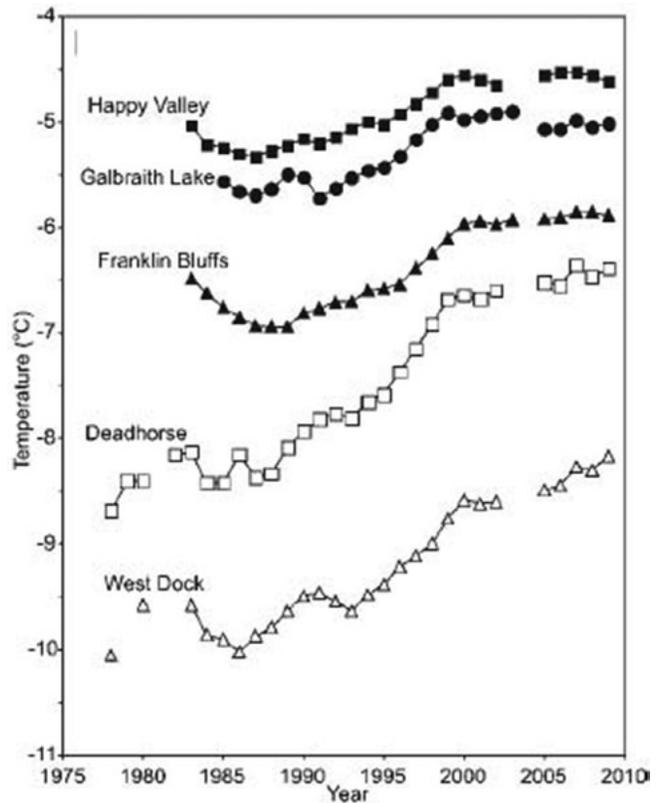
The Toolik Field Station (TFS) lies between Happy Valley (to the north) and Galbraith Lake (to the south)



history through stories, anecdotes, and color photos about the geology, plants, animals, and human occupation of Arctic Alaska. The book is aimed at both scientists and ecotourists encountering the Arctic for the first time—people who do not know a patch of auffs from a pingo. The book includes a mile-by-mile natural history of the Arctic 170 miles of the Dalton Highway, the road that parallels the Alaska oil pipeline from Fairbanks to Prudhoe Bay.

John Hobbie and Arctic LTER scientist George Kling (University of Michigan) recently sent off for publication another book, titled *A Changing Arctic: Ecological Consequences For Tundra, Streams, and Lakes* (In Press. Oxford University Press). There was another motivation for the second book—each LTER project is obligated to summarize and synthesize the detailed knowledge gained about the current ecology of their study system and predict the ecological future. Chapters, written by 58 co-authors, cover present and past vegetation, climate, the ecology of streams, lakes, and tundra, and mercury cycling as well as a final synthesis chapter.

The 24 years of year-round climate observations at the Toolik site revealed that the mean annual temperature showed no long-term change. Yet long-term observations of ecosystems themselves indicate changes consistent with warming. Careful measures of 156 separate plots, each 1 m by 1 m and measured 4 times since 1989, revealed that grasses and forbs increased in height and biomass. Satellite reflectance measures reveal the same pattern, which is likely caused by slight warming of the soils and an increase in microbial breakdown of nutrients bound up in organic compounds in tundra soil. More evidence was that the chemistry of streams and lakes has changed since 1975; the alkalinity of the water has doubled as if there has been thawing of the permafrost and increased weathering of soil previously frozen for nearly 10,000 years. The final evidence comes from 20 m deep in the permafrost near Toolik; from 1983 to 2011 the temperature increased by 1.0° C—but this does yet not imply an imminent loss of permafrost because the 2011 temperature is still -4.8° C. If the warming of the climate continues at the same rate, the prediction laid out by the LTER scientists is for a longer growing season and increased growth of plants. This means that vegetation will slowly become shrubbier. The largest change in topography and hydrology will occur if and when the permafrost thaws but at current rates this will take several hundred years.



Top: Hobbie: Time series of permafrost temperatures measured in boreholes drilled into permafrost in northern Alaska showing warming trends between 1983 and 2011. Measurements are at 20 m depths at five sites along the Dalton Highway. (Source: Romanovsky and Osterkamp 2012)

Bottom: Musk Ox sampling fireweed (Photo: John Hobbie)

Going to Extremes

STRESS MANAGEMENT BY MICROBES

Microscopic bacteria, fungi, archaea and other tiny organisms house the molecular “machines” that sustain life on Earth. On land and in the sea, microbes decompose the dead, recycling the nutrient building blocks of life essential for growth of new generations. In the ocean, photosynthesis by microbes fuels food webs that support fisheries. Microbes are also critical reservoirs of biological know-how, actively transforming pollutants and providing new sources of fuel. For all these reasons and more, Ecosystems Center scientists are intensifying their focus on natural microbial communities at the heart of ecosystem functions, including ecosystem services sustaining humanity, all around the globe.

How microbes survive under extreme environmental conditions, and even continue to carry out fundamental ecosystem functions, remains a mystery in many ecosystems. Famously colorful blooms of microbes populate the near-boiling hot springs of Yellowstone National Park. Rod-shaped microbes live in (and help generate) the extreme acidity and very high

toxic metal concentrations at acid mine drainage sites dotted across the Western US. Soil microbes in the Arctic prepare for winter by adjusting their metabolism before the deep freeze that will persist for nine months of the year.

But such obviously severe examples are not the only challenging environments for microbial life. In seasonally dry ecosystems such as the semi-arid Great Basin of the US, even the predictable annual soil drought exposes microbes in upper soil layers to extraordinarily stressful conditions. Do soil microbes simply become dormant during drought and wait until conditions improve? Or can they continue to function in special microsites created either by their own activities or by neighboring plant roots? Since climate warming and precipitation decline in portions of the western US are expected to lead to intensified soil drought in the future, answers to these basic questions are essential for understanding whether and how belowground ecosystem functions can be maintained.

Sagebrush steppe field site on Bureau of Land Management grazing land in northern Utah, seen from a distance (Photo: Zoe Cardon)



MANNA FROM MICROBES IN THE HIGH AND DRY

Senior Scientist Zoe Cardon and her colleague John Stark of Utah State University have been working in northern Utah's seasonally dry sagebrush steppe to explore soil microbial activity, and its implications for plant nutrient availability, during the driest portions of summer. Productivity of this ecosystem is limited by both water and soil nitrogen availability, and sagebrush are dominant plants in this and many landscapes of the western US. The deep root systems of sagebrush serve as conduits for water flow from deep, moist soil to extremely dry surface soil, even during the depths of drought. This "hydraulic lift" of soil water, through plant roots as pipes, has been detected in many seasonally dry ecosystems of the world. Water moves through roots upward from deep moist soil and is deposited in shallow parched soil at night, only to be taken up again by plant roots the following morning to support leaf function.

Prior to being re-commandeered by plants in the morning, however, the redistributed water has already moistened the thin sleeve of "rhizosphere" soil around plant roots for hours, providing a slightly wetter nighttime niche for rhizosphere microbes. Since the fresh leaf and root litter available for microbial processing is also predominantly found in surface soil layers, upward hydraulic lift of small amounts of water to those layers, even for just a few hours each night, may help maintain recycling of nutrients from decomposing plant litter in transiently moistened microsites.

Cardon and Stark tested this idea on grazing land managed by the Bureau of Land Management near Laketown, Utah. They installed instruments to measure soil moisture at multiple depths around sagebrush that were and were not carrying out hydraulic lift. In early August, when soils were very dry after two months of drought, they assayed microbial nutrient cycling and avail-

ability of nitrogen to the sagebrush using a new technique they developed specifically for exploring nitrogen cycling in very dry soil. They injected very small amounts of ammonia gas labeled with the stable isotope tracer ^{15}N into surface soil around sagebrush, and watched its transformation and uptake by plants and microbes over 48 hours.

These assays using injected gas clearly showed that sagebrush-mediated hydraulic lift increased rates of microbially-controlled nitrogen cycling in surface soil around the shrubs during deep summer drought, and enhanced uptake of nitrogen by the sagebrush themselves at exactly the time they are flowering and setting seed. Though microbes seem "high and dry" in surface soils in late summer, hydraulic lift delivers sips of sustaining water to fine roots and rhizosphere microbes, potentially supporting improved sagebrush seed set and even plant productivity in this nitrogen and water-limited ecosystem.

Building on this work, Cardon and colleagues are now using greenhouse experiments, field data, and mechanistic and earth system modeling to evaluate the ecosystem-level impact of this vital plant root-soil-microbe connection in a range of seasonally dry ecosystems, from Washington State, California, and Arizona, to the Brazilian Amazon.

Sagebrush with buried ring underneath for measuring soil respiration
(Photo: Zoe Cardon)



Semester in Environmental Science

In Fall 2012, the 16th Semester in Environmental Science (SES) hosted 17 students from 15 colleges and universities. The 15-week semester program teaches theory and methods of ecosystems research. SES is the only academic year educational program for undergraduates at any of the research institutions in Woods Hole.

SES students learn from their own hands-on collection and analysis of data as much as from lectures and readings by the Ecosystems Center faculty. During core courses, students sampled freshwater, estuarine and terrestrial ecosystems where they measured species composition and biomass of plants, animals and microbes and the physical factors such as light, salinity, and soil characteristics, that drive photosynthesis, respiration, and nutrient cycling. SES students employ many of the same approaches to understanding ecosystem structure and function as Ecosystems Center research staff use at field sites across the globe. Students use their own data and

data of their student colleagues to build a picture of how the diverse land and aquatic ecosystems found in the Woods Hole region work. In addition to core courses, the students enroll in either mathematical modeling of ecosystems or microbial methods in ecology. During the last six weeks of the program students pursue independent research projects and present their findings at a public symposium in December.

Fifty-seven colleges participate in MBL's SES consortium and approve SES for credit. Students from non-affiliated colleges and universities may receive credit through Brown University as part of the Brown-MBL Partnership.

Marty Rivera of the University of Puerto Rico prepares an oak leaf for photosynthesis measurement with research assistant Laura van der Pol, SES '06. (Photo: Jen Reeve)

Teaching assistant Alice Carter, SES '10, on right, helps Liz de la Reguera of Dickinson College with data in the SES lab (Photo: Shelly Xia)



The training that SES students receive and the professional connections they make prepare them for research internships after the program ends. In the summer of 2012, nine students—40 percent of the class of 2011—conducted research with scientists at sites throughout the country.

Anika Aarons (Mount Holyoke College) participated in a cruise aboard the R/V Atlantic Explorer to the Ocean Flux Program (OFP) sediment trap deployment site located 75 km SE of Bermuda. Under the guidance of Maureen Conte, who leads the NSF-funded OFP, Anika studied carbon transport to the deep sea.

Fiona Jevon (Harvard University), Hansen Johnson (Bates College) and Andrew Miano (Connecticut College) all traveled to the Long Term Ecological Research site at the Toolik Field Station in northern Alaska. Fiona worked with Gus Shaver to study changes in shrub canopy caused by climate change; Hansen worked with Shaver on the effects of recent tundra wildfires, and Andrew looked at how changing hydrology alters the migration of arctic grayling, a fish in Arctic rivers, under the guidance of Linda Deegan.

Collin Knauss (Connecticut College) worked with Ken Foreman to study innovative ways to clean up nitrate-contaminated groundwater on Cape Cod.

Sarah Nalven (Colby College) worked with Julie Huber of the Bay Paul Center at MBL to study the ecology of the specialized microbes that inhabit deep-sea hydrothermal vents.

Jehana Samaha (Brown University) and Elisabeth Ward (Brown University) followed up on their SES project that looked at how suburban landscapes shape soils and plant communities. They worked with Chris Neill to collect soils and survey plants in the Boston metropolitan region as part of a larger nationwide effort to see how suburbanization is reshaping the nation's ecological landscape.

Xiao Yang (Grinnell College) studied greenhouse gas emissions from salt marshes at Waquoit Bay on Cape Cod under the guidance of Jim Tang.



Top: Senior scientist Gus Shaver and former SES student and research assistant Laura van der Pol work with colleagues on a chamber used for measure plant photosynthesis. (Photo: Jessica Drysdale)

Left: Former SES students Will Longo, Carrie Harris and Hansen Johnson conducted research at the Toolik Lake LTER site in Alaska last summer. (Photo: Will Daniels)

STUDENTS FOR THE 2012 SEMESTER

Julia Adams (Wellesley College), Kara Anonni (University of Minnesota Duluth), Ashley Brooks (Bates College), Tanner Cunningham (Bates College), Elizabeth de la Reguera (Dickinson College), Katherine Ann Glover (Sewanee University), Arianna Goodman (Oberlin College), Alexandra Guest (Skidmore College), Johanna Jensen (Colorado College), Michael Marty-Rivera (University of Puerto Rico), Margaret Notopoulos (Skidmore College), Kim Ohnemus (Skidmore College), Zach Pinto (Middlebury College), Aliza Ray (Bard College), Jennifer Reeve (Haverford College), Shelly Xia (Franklin & Marshall College), Joo Young Yim (Grinnell College).

DISTINGUISHED SCIENTIST GUEST LECTURERS

Sarah Hobbie (University of Minnesota) "*Biogeochemical fluxes through neighborhoods and households in the Twin Cities, Minnesota*"

Mark Kurz (Woods Hole Oceanographic Institution), "*Noble gases from the deep Earth, cosmogenic nuclides and landscape evolution (Why biologists should care)*"

Christine Goodale (Cornell University) "*Nitrogen-deposition effects on forest carbon sequestration*"

Russell Schmidt (University of California, Santa Barbara) "*Abrupt state change and resilience in marine ecosystems: What coral reefs are telling us*"

SES FACULTY

Linda Amaral-Zettler, Maureen Conte, Linda Deegan, Hugh Ducklow, Kenneth Foreman, Anne Giblin, John Hobbie, Julie Huber, George Liles, Jerry Melillo, Chris Neill, James Nelson, Bruce Peterson, Edward Rastetter, Gus Shaver, Jianwu Tang, Joseph Vallino

RESEARCH AND TEACHING ASSISTANTS

Richard McHorney, Bonnie Kwiatkowski, Carolyn Harris, Victor Schmidt, Alice Carter

Education Highlights

Ecosystems Center scientists teach undergraduates in the Center's fall semester Semester in Environmental Science program, and they advise and mentor graduate students, postdoctoral scholars and undergraduate research interns from a variety of institutions. The Center has a special research and educational partnership with Brown University. Center scientists advise and co-advise 11 Brown PhD students. In 2012, they also mentored five Brown undergraduates who participated in Center research projects. Center scientists also judge local science fairs, mentor middle and high school students and take part in a range of other activities to increase public understanding of science.

HIGHLIGHTS FROM THE BROWN/MBL PARTNERSHIP

Shelby Riskin defended her dissertation in 2012. She was advised by Christopher Neill at MBL and Stephen Porder at Brown. Her dissertation, "The Hydrological and Biogeochemical Consequences of Conversion to Soybean Cultivation on the Amazonian Agricultural Frontier," received support from a Watson Fellowship from MBL and a Cogut Fellowship from the Brown Center for Latin American and Caribbean Studies during her last year of study.

Catherine Luria journeyed twice to Palmer Station, Antarctica, to study how ocean microbes respond to rapidly warming temperatures. Cat works with Hugh Ducklow and Linda Amaral Zettler. Her science and field experience was featured in the jobs and careers section of *Nature*.



Xi Yang found that the New England spring, as measured by plant phenological changes, arrives as much as a week earlier today than it did fifty years ago. Yang and his colleagues at the MBL Ecosystems Center, Brown University's Department of Geological Sciences, and the University of Minnesota's Department of Soil, Water, and Climate used remote sensing, weather data and models to construct plant phenology in New England between 1960 and 2010.

Christopher Neill of the Ecosystems Center is the program's director. Other center scientists with Brown appointments are Zoe Cardon, Linda Deegan, Hugh Ducklow, Anne Giblin, John Hobbie, Jerry Melillo, Bruce Peterson, Edward Rastetter, Gus Shaver, Jim Tang and Joseph Vallino.

Ed Rastetter taught "Ecosystem Modeling for Non-Programmers" in January on the MBL campus. Christopher Neill taught "The Natural and Social Dynamics of Land Use Change," a spring semester course of the Partnership for International Research and Education (PIRE) that focused on the environmental effects of the New Green Revolution in Africa. Zoe Cardon, Anne Giblin and Joseph Vallino participated in "IGERT Reverse Ecology Immersion," a core graduate course that is part of an innovative NSF-sponsored Integrated Education and Research Traineeships project that focuses on using genomic information to shed light on ecosystem functioning.

Students advised by Ecosystems Center scientists

- ▶ Maya Almaraz, Ecology and Evolutionary Biology, advised by Christopher Neill
- ▶ Lindsay Brin, Ecology and Evolutionary Biology, advised by Anne Giblin
- ▶ Sarah Corman, Ecology and Evolutionary Biology, advised by Linda Deegan
- ▶ Mengdi Cui, Geological Sciences, advised by Jim Tang
- ▶ Will Daniels, Geological Sciences, advised by Anne Giblin
- ▶ Shelby Riskin, Ecology and Evolutionary Biology, advised by Christopher Neill
- ▶ Catherine Luria, Ecology and Evolutionary Biology, advised by Hugh Ducklow
- ▶ Marc Mayes, Geological Sciences, advised by Jerry Melillo
- ▶ Chelsea Nagy, Ecology and Evolutionary Biology, advised by Christopher Neill
- ▶ Appollonya Porcelli, Sociology, advised by Christopher Neill
- ▶ Xi Yang, Geological Sciences, advised by Jim Tang

Brown-MBL student Shelby Riskin samples water from an Amazon stream. (Photo: Christopher Neill)

UNDERGRADUATE EDUCATION

Five Brown undergraduate students participated in summer research with Center scientists. Harriet Booth worked with Linda Deegan and David Johnson at the Plum Island Long Term Ecological Research site on how increasing nutrient loads affect salt marsh food webs. Jehane Samaha, Elisabeth Ward and Emma Dixon worked with Christopher Neill on a project titled, "The Ecological Homogenization of Urban America." They examined species diversity, vegetation structure and carbon stocks in Boston suburban ecosystems to test the idea that suburban ecosystems across the US have similar ecological structure. Michael Menesses traveled to the Millennium Village of Sauri, Kenya to work on the Partnership for International Research and Education Project with Brown MBL graduate student, Maya Almaraz. Jehane and Elisabeth were supported by Brown UTRA fellowships, Harriet received a Brown LINK fellowship and Emma Dixon was a Brown Beckman Scholar.

Research Experience for Undergraduates

The Ecosystems Center gives many college students the opportunity to pursue research projects in the laboratory and at field sites in many places around the world. With funding from the National Science Foundation and other sources, undergraduate students in 2012 participated in projects with center scientists. Their internships ranged from spending the summer on the North Slope of Alaska at the Arctic Long-Term Ecological Research project, studying the effects of the increased number of tundra fire to measuring and characterizing particle flux in the deep Sargasso Sea.

Schoolyard LTER and other LTER Educational Programs

Plum Island Ecosystem's (PIE) Long Term Ecological Research (LTER) Schoolyard Program collaborates with the Massachusetts Audubon Society, the Gulf of Maine Institute and the Governor's Academy in Newbury, Massachusetts. Current K-12 education programs reach more than 1,000 students a year. Elizabeth Duff of Mass Audubon leads a Salt Marsh Science Project in which students work with teachers and scientists to learn about the expansion of the invasive common reed (*Phragmites australis*) into salt marshes. Each year one to three students from The Governor's Academy in Newbury, Massachusetts, take part in field and lab work with teachers from the school and PIE scientists. During the school year, teachers and students conduct marsh vegetation transect surveys in a marsh near their campus. Students from the Governor's Academy fished for striped bass with teacher John Pirie and worked with



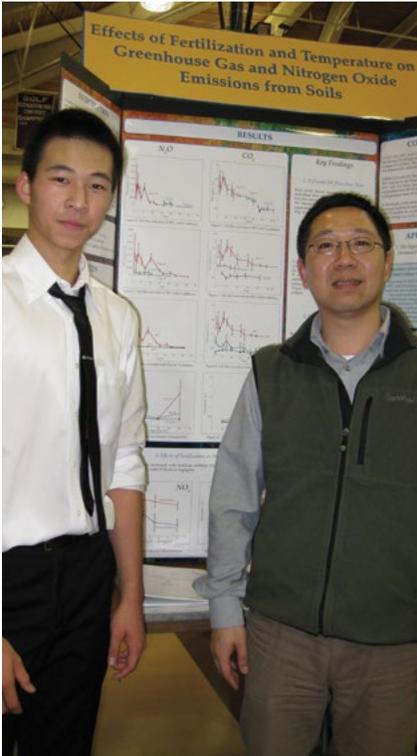
Top: From left, Jehane Samaha, Elisabeth Ward and Emma Dixon identify plant species in suburban lawns of the Boston metropolitan region (Photo: Chris Neill)

Bottom: JC Weber explains long-term ocean research to students from the New York Harbor School (Photo: Debbie Scanlon)

PIE scientists to understand striped bass movements and how they affect the distribution of the small fish they prey on.

The Arctic Schoolyard LTER program in Barrow, Alaska replicates some of Arctic LTER experimental and monitoring activities such as measuring the effects of climate warming on tundra vegetation and measuring changes in lake water chemistry and sponsors a weekly lecture series, called "Schoolyard Saturday." Eve Kendrick, a teacher in Tuscaloosa, Alabama traveled to Anaktuvuk Pass to present a lesson plan in the schools there. She developed the plan from her experiences working with the streams group at Toolik.

The Antarctic Palmer LTER Education and Outreach program sponsored Jo Blasi, a teacher at the New England Aquarium in Boston, to join a research team aboard the R/V



Top: Lauren Alteio, REU student, on left, and Lindsay Scott, research assistant, collect soil samples for enzyme analyses at the Harvard Forest LTER site. (Photo: Chelsea Baldino)

Bottom: Vincent Lin, of Falmouth High School, was advised by Jim Tang. His award-winning 2012 science project was on the effects of fertilization and temperature on greenhouse gas and nitrogen oxide emissions from soils. (Photo: Debbie Scanlon)

Lawrence M. Gould. Five schools and hundreds of students communicated via the Palmer LTER blog: Tracking Change and the New England Aquarium Explorers blog. A new penguin webcam, a gift to Palmer LTER outreach, was installed and pilot tested on Torgersen Island, near Palmer. It generated more than 10,000 hits. Teacher Nell Herrmann organized gifted students in grades 9-12 called "Polar Ambassadors" from State College Area High school, in Pennsylvania.

Science Journalism Program

Six science journalists in MBL's Logan Science Journalism Program spent three days at the Harvard Forest LTER site in Petersham, Massachusetts, and then eight days at MBL during mid-May, working alongside Harvard Forest and Ecosystems Center scientists to investigate how global changes are changing the forests of eastern North America.

Madeleine Amberger from Austrian Broadcasting, Karin Klein from the Los Angeles Times, Maggie Koerth-Baker from BoingBoing.net, Eric Niiler from Discovery News, and freelance writers Kathiann Kowalski and Virginia Carmichael counted hemlock woolly adelgid, measured tree seedlings in herbivore exclosures, quantified carbon dioxide fluxes from a soil warming experiment, and cored down to ice-aged sediments in the Black Gum Swamp.

Christopher Neill and Richard McHorney designed and taught the course to highlight LTER global change research and give journalists a hands-on window into the scientific process. The Ecosystems Center's Jerry Melillo, Harvard Forest's David Foster and David Orwig, and Highstead scientist Ed Faison mentored the journalists through the experiments. The journalists collected field data, analyzed the information, then distilled that work into short presentations. Ecosystems Center research assistants William Werner and Chelsea Baldino helped with the program in the field.

Community Outreach

Every year, Center scientists and research assistants volunteer to mentor junior high school students and judge system-wide science fairs. In 2012, Kate Morkeski, Suzanne Thomas, Sam Kelsey and JC Weber helped students to develop their science projects. Jim Tang, Kenneth Foreman and Melanie Hayn advised high school students, who went on to win top prizes in Falmouth and regional science fairs. Projects such as the mentoring program are organized by the Woods Hole Science and Technology Educational Partnership (WHSTEP). Ecosystems staff members JC Weber, Debbie Scanlon and Kate Morkeski serve on WHSTEP's board and act as liaisons to respond to requests from teachers and students and to provide outreach events and family science nights. Ecosystems Center staff members who judged community and state science fairs included John Hobbie, Marshall Otter, JC Weber, Suzanne Thomas, Jim Tang and Hap Garritt.

Ecosystems Center staff members take an active role in town activities, serving on both non-profit private groups and Falmouth committees and as town meeting members. Hugh Ducklow and Matthew Erickson provide nutrient analyses for the Baywatchers Program of the Buzzards Bay Coalition. Ducklow, Maureen Conte and JC Weber serve as volunteers in the program, carrying out weekly observations on water quality at nearby sites around the bay. Christopher Neill is president of Falmouth Associations Concerned with Estuaries and Saltponds.

Anne Giblin presented talks to policy makers and the public on climate and sea level change. She spoke at the Essex County Greenbelt annual meeting, the Parker River Wildlife Refuge Climate Adaptation Strategies workshop, the Great Marsh Coalition 2012 Symposium on sea level adaptation, and the Northeast Climate Center outreach and science planning meeting.

News 2012

Christopher Neill was named director of the Ecosystems Center in December. Chris studies ecosystem responses to deforestation and land use change and has a long-standing research program that investigates the watershed-scale consequences of deforestation for agriculture in the Brazilian Amazon. Chris first came to MBL as a student in the summer Marine Ecology course in 1983. He joined the MBL as a post-doctoral research associate in 1991. Chris directs the Hands-on Environmental Laboratory for the MBL's Logan Science Journalism Program, and has written a column on ecology and the environment for The Falmouth Enterprise newspaper. He was awarded a Bullard Fellowship by Harvard University in 2010 and a Fulbright Fellowship to Brazil in 2007. Chris is also the Phyllis and Charles M. Rosenthal Director of the Brown-MBL Partnership and director of the Brown-MBL Graduate Program in Biological and Environmental Sciences. Chris succeeds Hugh Ducklow, who held the post since 2007, and has moved to the Department of Earth and Environmental Sciences at the Lamont-Doherty Earth Observatory at Columbia University.

The **MBL** is part of a seven-university consortium that won the competition to host the US Department of Interior's Northeast Climate Science Center (CSC). The center is part of a federal network of eight Climate Science Centers created to provide scientific information, tools, and techniques that managers and other parties interested in land, water, wildlife and cultural resources can use to anticipate, monitor and adapt to climate change in the Northeast region. The CSC is headed by the University of Massachusetts Amherst and includes Columbia University, the University of Wisconsin, the College of Menominee Nation, the University of Minnesota and the University of Missouri.

Bruce Peterson was named the winner of the Alfred C. Redfield Lifetime Achievement Award by the Association for the Sciences of Limnology and Oceanography. The award honors major, long-term achievements in limnology and oceanography and singled out Bruce for his "innovative and transformative studies of carbon, nutrient, and water cycles at process, ecosystem, and global scales."

Jerry Melillo was named chair of the National Climate Assessment Development and Advisory Committee and leads preparation of the US National Climate Assessment. The

Top to bottom and left to right: Christopher Neill; Rapidly rising tide catches researchers by surprise (Photo: Elizabeth Forbes); Carrie Harris collects water sample on Toolik Lake in Alaska (Photo: Will Daniels); Helicopter landing on the Alaskan tundra to transport scientists to camp. (Photo: Carrie Harris); Bruce Peterson (Photo: Max Holmes)



Assessment compiles and analyzes the latest science and information about current and projected effects of climate change across the United States. It is the most comprehensive evaluation of the national and regional scale impacts of climate change on the US environment and economy ever undertaken. Jerry serves on the Board of Trustees of the University for Atmospheric Research (UCAR), the parent organization of the National Center for Atmospheric Research in Boulder, Colorado, which advances the understanding of weather and climate to benefit society. He serves on the Board of Trustees of the Cary Institute of Ecosystem Studies in Millbrook, New York, where he is the Board's Vice-Chair, and was appointed to the Executive Committee of The Mistra Council for Evidence-Based Environmental Management (EviEM) headquartered in Stockholm, Sweden, which tries to improve the science basis for decisions in Swedish environmental policy.

Hugh Ducklow was appointed to the US Antarctic Program Blue Ribbon Panel to examine the status and capabilities of the US Antarctic program in anticipation of the renegotiation of the Antarctic Treaty.

Ecosystems Center Administrator **Kelly Holzworth** was appointed to the board of the National Council of University Research Administrators and serves on the board's Pre-Award subcommittee.

Linda Deegan leads the MBL participation in the newly-awarded Northeast Climate Science Center, a consortium of seven institutions led by the University of Massachusetts Amherst. Linda also serves on the board of the Massachusetts chapter of The Nature Conservancy.

Jerry Melillo and **Gus Shaver** were named Fellows of the Ecological Society of America. They are in the first group to be named to the new Fellows program by the 10,000-member society, the world's largest organization of professional ecologists.

Gus Shaver served on the National Academy of Sciences Polar Research Board, Department of Energy's Biological and Environmental Research Advisory Committee, the Scientific Steering Committee of the International Study of Arctic Change, and the Executive Board of the US LTER Network. He also spent seven months at University of Edinburgh.

Joe Vallino was a member of the NSF site review team in June that visited and reviewed the Center for Coastal Margin Observation and Prediction (CMOP), a NSF Science and Technology Center.

Anne Giblin is a member of the board of the Gulf of Maine Institute.

Jim Tang serves on the Long Term Ecological Research International Committee, the National Ecological Observatory Network/Fundamental Instrument Unit Technical Working Group for soils.

Linda Deegan and **David Johnson** were interviewed by many media outlets for their article that appeared in Nature, "Coastal Eutrophication as a Driver of Salt Marsh Loss." They included Scientific American, Quirks and Quarks (CBC), NPR, Boston Globe, Yale 360, Cape Cod Times, NSF's Science360 News Service and the Boston Herald.

Left top: Chelsea Baldino measures tree diameter at the Harvard Forest LTER site. (Photo: Lindsay Scott)

Left Bottom: Researchers sample the water in lakes near the Toolik field station in Alaska (Photo: Carrie Harris)

Below: David Foster (right), director of the Harvard Forest LTER, explains the future of eastern hemlock forests to journalists in MBL's Logan Science Journalism Program. From left, Maggie Koerth-Baker (BoingBoing.net), Virginia Carmichael and Kathiann Kowalski (freelance), Madeline Amberer (Austrian Broadcasting), Karin Kline (Los Angeles Times) and Eric Niiler (Discovery Press). (Photo: Christopher Neill)



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Caribou walk a ridgeline near Toolik Field Station (Photo: Carrie Harris)

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Seminars 2012

JANUARY

- 17 Juliette Rooney-Varga, University of Massachusetts-Lowell. "Relationships between soil organic matter, nutrients, bacterial community structure, and the performance of microbial fuel cells."
- 31 Stephen Frolking, University of New Hampshire. "Peatlands in the 21st century climate system: State of knowledge and a modelling perspective."

FEBRUARY

- 7 Sergio Fagherazzi, Boston University. "The coupled morphological and biological evolution of intertidal landscapes."
- 14 Erik Hobbie, University of New Hampshire. "Bomb carbon and FACE studies reveal widespread organic nitrogen use by mycorrhizal fungi."
- 21 Inke Forbrich, MBL Ecosystems Center. "Upscaling of methane emissions in a boreal peatland – observations and modeling."
- 28 Karina V. Schäfer, Rutgers University. "Temporal and spatial dynamics of CO₂ and CH₄ fluxes in temperate urban wetlands."

MARCH

- 6 Eri Saikawa, Massachusetts Institute of Technology. "Process modeling of global soil nitrous oxide emissions - past, present, and future."
- 13 Maureen Conte, MBL Ecosystems Center. "Weather in the ocean abyss: Particle rain, storms and hurricanes in the deep Sargasso Sea."
- 20 Christopher Algar, MBL Ecosystems Center. "A maximum entropy production (MEP) based model of nitrogen cycling processes in anoxic marine sediments."
- 27 Pete Countway Bigelow Laboratory for Ocean Sciences. "Diversity and function of microbial eukaryotes at deep-sea hydrothermal vents."

APRIL

- 3 Roisin Commane, Harvard University. "Forest fluxes of carbonyl sulfide: Balancing photosynthetic and soil uptake."
- 11 Scott Ollinger, University of New Hampshire. "Sources of variability in canopy spectra and the convergent properties of plants."

- 17 Erika Sudderth, Brown University. "Understanding links among soil, plant, and ecosystem responses to climate change."
- 24 Nuria Fernandez Gonzalez, MBL Ecosystems Center and Bay Paul Center. "Testing the theory of maximum entropy production using methanotrophic microbial communities: A mesocosm approach."

MAY

- 1 Peter Raymond, Yale University. "Controls on regional and global riverine carbon fluxes."
- 8 Wally Fulweiler, Boston University. "A different kind of dam: The influence of terrestrial vegetation on silica export to coastal waters."
- 15 Kevin Kroeger, USGS. "Dinitrogen, denitrification and anammox in submarine groundwater discharge zones."

SEPTEMBER

- 14 *Mark Kurz, Woods Hole Oceanographic Institution. "Noble gases from the deep Earth, cosmogenic nuclides and landscape evolution (Why biologists should care)."
- 18 Ed Rastetter, MBL Ecosystems Center. "Resource optimization and the response of forests to disturbance."
- 21 *Christine Goodale, Cornell University. "Nitrogen-deposition effects on forest carbon sequestration."
- 25 Gary Schultz, Marshall University. "An assessment of bacterial diversity in the Ohio River using pyrosequencing."

OCTOBER

- 5 *Russell Schmidt, University of California at Santa Barbara. "Abrupt state change and resilience in marine ecosystems: What coral reefs are telling us."
- 9 Colleen Hansel, Woods Hole Oceanographic Institution, "How minerals shape microbial communities and biogeochemical pathways."
- 16 Katherine Mackey, MBL and Woods Hole Oceanographic Institution. "Environmental and physiological factors influencing *Synechococcus* biogeography."
- 26 *Sarah Hobbie, University of Minnesota. "Biogeochemical fluxes through neighborhoods and households in the Twin Cities, Minnesota."

NOVEMBER

- 13 Todd Lookingbill, University of Richmond. "Landscape analysis of Civil War battlefield parks."

DECEMBER

- 11 Rachel Stanley, Woods Hole Oceanographic Institution. "High Resolution Underway O₂/Ar Records-What are they telling us?"

*SES Distinguished Scientist Seminar

Mangroves occupy the land-water edge on the Pacific coast of Panama (Photo: Ivan Valiela)



Senior Scientific Staff



Zoe G. Cardon
Senior Scientist
Ph.D., Stanford University



Linda A. Deegan
Senior Scientist
Ph.D., Louisiana State University



Hugh W. Ducklow
Senior Scientist
Ph.D., Harvard University



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



Anne E. Giblin
Senior Scientist
Ph.D., Boston University



Jerry M. Melillo
Senior Scientist
Ph.D., Yale University



Christopher Neill
Director, Senior Scientist
Ph.D., University of
Massachusetts Amherst



Bruce J. Peterson
Senior Scientist
Ph.D., Cornell University



Edward B. Rastetter
Senior Scientist
Ph.D., University of Virginia



Gaius R. Shaver
Senior Scientist
Ph.D., Duke University

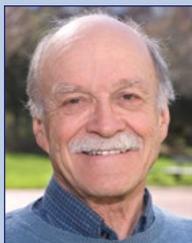


Jianwu Tang
Assistant Scientist
Ph.D., University of California,
Berkeley



Joseph J. Vallino
Senior Scientist,
Ph.D., Massachusetts Institute
of Technology

Senior Scholars



John E. Hobbie
Senior Scholar
Ph.D., Indiana University



Paul A. Stuedler
Senior Research Scholar
M.S., University of Oklahoma



Ivan Valiela
Senior Research Scientist
Ph.D., Cornell University

Adjunct Scientists



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



Robert Howarth
Cornell University
Ph.D., Massachusetts Institute
of Technology/Woods Hole
Oceanographic Institution

Research Associates



David S. Johnson
Research Associate
Ph.D., Louisiana State University



David W. Kicklighter
Research Associate
M.S., University of Montana



Adrian Rocha
Ph.D., University of California,
Irvine

Postdoctoral Scientists



Christopher Algar
Ph.D., Dalhousie University,
Canada



Nuria Fernandez Gonzales
Ph.D., Universidad Autonoma de
Madrid, Spain



Inke Forbrich
Ph.D., University of Greifswald,
Germany



Yueyang Jiang
Ph.D., Purdue University



Claire Lunch
Ph.D., Stanford University



Xiaoliang Lu
Ph.D., Purdue University



James A. Nelson
Ph.D., Florida State University



Marjan van de Weg
Ph.D., University of Edinburgh,
Scotland

Visiting Scientists

Merryl Alber
University of Georgia

Natalie Boelman
Lamont-Doherty Earth
Observatory

Shaomin Hu
Purdue University

Morten Larsen
University of Southern Denmark

Roxanne Marino
Cornell University

Kate Salmon
The Open University, UK

Qianlai Zhuang
Purdue University

Staff



Chelsea L. Baldino
Research Assistant,
B.A., Northwestern University



Megan K. Bartholomew
Research Assistant
B.S., Iowa State University



Andrew Binderup
Research Assistant
M.S., University of Georgia



Samantha Bond
Research Assistant
B.S., University of Maine



Melissa Campbell
SES Recruiter
B.A., Clark University



Jessica A. Drysdale
Research Assistant
M.S., Queen's University, Canada



Matthew Erickson
Senior Research Assistant
M.S., University of Wisconsin-Oshkosh



Elizabeth Forbes
Research Assistant
B.A., Vassar College



Robert H. Garritt
Senior Research Assistant
M.S., Cornell University



Carolynn Harris
Research Assistant
B.A., Bates College



Melanie Hayn
Research Assistant
M.S., Cornell University



Jill V. Holdren
Brown-MBL Coordinator
M.S. University of Hawaii, Manoa



Kelly Holzworth
Center Administrator
University of San Diego



Samuel Kelsey
Research Assistant
B.S., Dickinson College



Bonnie L. Kwiatkowski
Research Assistant
M.S., University of New Hampshire



James A. Laundre
Senior Research Assistant
M.S., University of Connecticut



Cameron MacKenzie
Research Assistant
M.S., Simon Fraser University, Canada



Linda Martini
SES Program Coordinator
B.A., RMIT University, Australia



Richard McHorney
Senior Research Assistant
M.S., University of Pennsylvania



Kate Morkeski
Research Assistant
M.S., Virginia Polytechnic
Institute and State University



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



Timothy Savas
Research Assistant,
B.A., New York University



Deborah G. Scanlon
Communications Coordinator
B.A., Syracuse University



Lindsay Scott
Research Assistant
M.S., Ohio University



Mary Ann Seifert
Staff Coordinator
B.A., Alfred University



Suzanne M. Thomas
Research Assistant
M.S., University of Pennsylvania



Jane Tucker
Senior Research Assistant
M.S., University of North Carolina



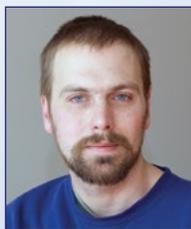
Laura van der Pol
Research Assistant
B.A., Wellesley College



J.C. Weber
Senior Research Assistant
M.S., University of Delaware

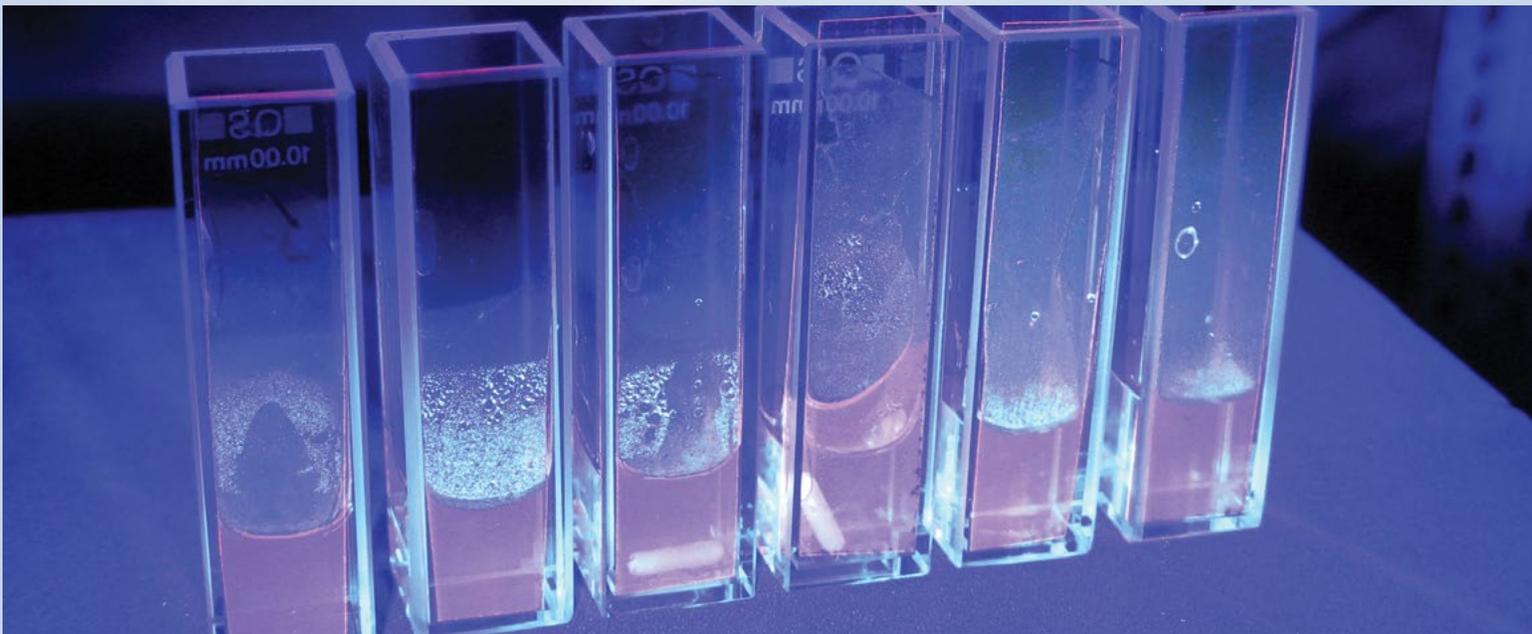


William Werner
Research Assistant
B.S., Beloit College



Daniel White
Research Assistant
M.S., State University of New
York at Brockport

A new technique for measuring oxygen concentration in water relies on pink fluorescence. (Photo: Zoe Cardon)



Brown-MBL Graduate Students



Maya Almaraz
B.A./B.S. University of California,
Berkeley



Lindsay Brin
B.A., Swarthmore College



Sarah Corman
M.S., University of Rhode Island



Mengdi Cui
B.S., Peking University



William Daniels
B.A., Lawrence University



Marc Mayes
M.S., University of Wisconsin,
Madison



Rachel Chelsea Nagy
M.S. Auburn University



Apollonya Porcelli
B. A. Cornell University



Shelby Riskin
B.A., Grinnell College



Xi Yang
M.E., Beijing Normal University

Summer Staff

Anika Aarons, Summer Research Assistant; **Louise Beveridge**, Summer Field Assistant; **Alice Carter**, Teaching Assistant; **Patrick Farrell**, RAHSS; **Ana Gordon**, REU; **Zak Gratton**, Summer Field Assistant; **Jessie Gunnard**, Summer Research Assistant; **Christopher Haight**, Summer Field Assistant; **Mollie Henry**, RAHSS; **Lacey Harris-Coble**, REU; **Gregory Hill**, Summer Field Assistant; **Fiona Jevon**, Summer Field Assistant; **Hansen Johnson**, REU; **Timothy Krikorian**, REU; **Sarah Lapierre**, Summer Research Assistant; **Susanna Michael**, Summer Field Assistant; **Sarah Nalven**, SES Summer Assistant; **Lisle Snyder**, Summer Field Assistant; **Katherine Stout**, REU

High School Students

Jessica Freedman, Falmouth High School; **Kenna Garrison**, Sandwich High School

Consultants

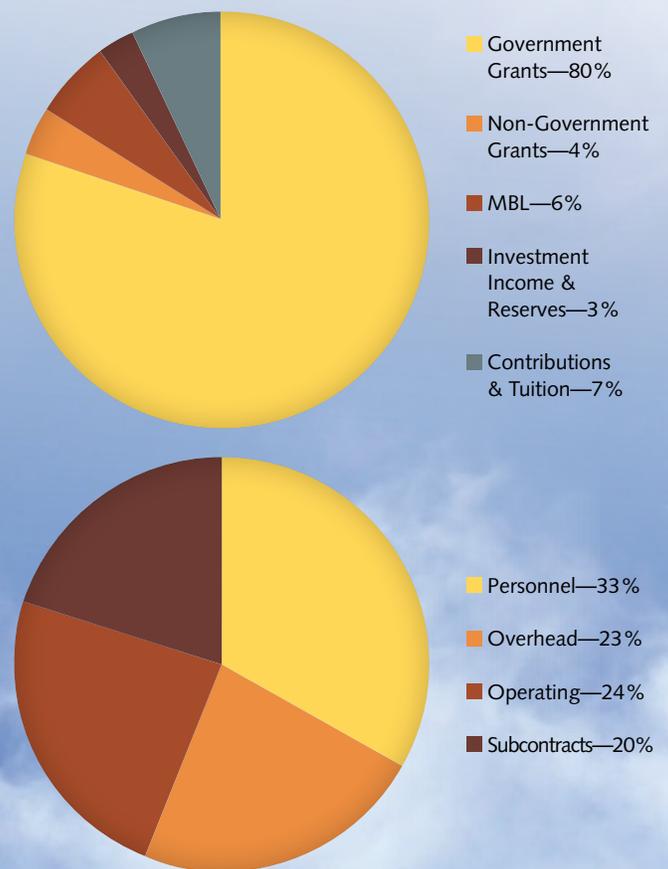
Francis P. Bowles, **Roberta Lombardi**, **Pamela Polloni**, **John T. Finn**, **Christopher Sterpka**

Sources of Support for Research and Education

The annual operating budget of The Ecosystems Center for 2012 was \$7,348,000. Approximately 80% 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 20% comes 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.

The combined fund market value of the center's research and education endowments at the end of 2012 was \$5,572,000. Income from these funds helps defray the costs of operations, writing proposals, consulting for government agencies and the center's educational programs.



Inke Forbrich and Sam Kelsey set up flux tower at Plum Island research site.
(Photo: Samantha Bond)



The Ecosystems Center
MBL
7 MBL Street
Woods Hole, MA 02543-1301
www.mbl.edu

