Cover photo: Climate change has increased the number of disturbances such as wildfires in the Arctic. Here, fire burns the tundra near the Sagavanirktok River on the North Slope of Alaska. (Photo: Richard Flanders)
The Ecosystems Center was founded in 1975 as a year-round research center of the MBL. Its mission is to investigate the structure and functioning of ecological systems, predict their response to changing environmental conditions, apply the resulting knowledge to the preservation and management of natural resources, and educate both future scientists and concerned citizens.

Ecosystems Center scientists work together on projects, and collaborate with investigators from other centers at the MBL and from other institutions, combining expertise from a wide range of disciplines. Together, they conduct research to answer a variety of scientific questions:

In both the Arctic and Antarctica, Ecosystems Center scientists in the Toolik Lake and Palmer Long Term Ecological Research (LTER) Projects study the effect of climate change on polar ecosystems. Will increased permafrost thaw make more nutrients available to plants? If these nutrients flow into streams and lakes, how will they affect aquatic food webs? In Siberia, center scientists show how increased freshwater discharge from the arctic rivers may affect ocean circulation and climate. In the coastal ecosystem along the west Antarctic Peninsula, sea ice duration has declined by 80 days in response to climate warming since 1975, leading to large-scale declines in plant and animal populations and other changes in the marine ecosystem.

In New England and around the world, scientists from the Ecosystems Center and their colleagues and students investigate the links among climate and land-use change, urban development, and the hydrology and ecology of watersheds, estuaries and coastal zones. Researchers at the Plum Island Ecosystem LTER site in northern Massachusetts ask how urban development affects the flow of nutrients and organic matter into New England estuaries. In Boston Harbor, researchers measure the transfer of nitrogen from the sediments to the water column to find out how long it will take the harbor to recover from decades of sewage addition. On Martha’s Vineyard, researchers restore coastal sandplain ecosystems with controlled burning or mechanical clearing. Will these changes restore diversity in plant and animal species? In mangrove estuaries of Panama, Ecosystems Center scientists study how watershed deforestation affects water flow from land into the mangroves and how mangrove removal alters the function of tropical coastal ecosystems.

The center’s scientists study the effects of land-use change in temperate and tropical forest ecosystems. In tropical Brazil, scientists investigate how the clearing of tropical forests in the western Amazon affects the release of greenhouse gases such as carbon dioxide and nitrous oxide. How will nutrient and organic matter flows in streams, rivers and watersheds change as Brazil converts more forest into pasture for soybean agriculture? Ecosystems Center scientists are beginning to team with social scientists and economists to explore how large-scale changes in the global economy affect tropical forest ecosystems and how these changes in turn affect climate and the global socioeconomic system. At the Harvard Forest LTER in central Massachusetts, scientists use soil-warming experiments to assess how forests would respond to climate warming. How much carbon might be released as temperatures increase? How will warming change the types of trees in forests of the future? Will changes in nitrogen cycling affect carbon storage in plants?

In our laboratories in Woods Hole, Ecosystems Center scientists analyze thousands of samples generated in field sites around the world and conduct experiments on microbial systems, roots, soils and sediments to understand the ecological processes governing global biogeochemical cycling of carbon, nutrients and greenhouse gases. Scientists use sophisticated computer models to ask questions about effects of future changes in climate, land use, carbon dioxide, ozone, water and nutrients on vegetation productivity, carbon storage and nutrient cycling. Center researchers collaborate with social and atmospheric scientists at MIT to investigate ecological responses to various scenarios of economic and energy development.
As our annual report was going to press in May, two events again seized the attention of citizens in Massachusetts, across our nation and around the world. One is the enormous and still-growing oil spill in the Gulf of Mexico, now washing ashore in the nation’s richest coastal marshes, and endangering wetlands and fishing grounds vital to the national economy. The other event was Interior Secretary Ken Salazar’s approval of Cape Wind, the nation’s first offshore wind farm, capable of supplying three-quarters of Cape Cod’s electricity needs in the next decade. The world’s energy sector – and the environmental concerns it generates – converge in the coastal zone. This is hardly surprising. More than half the world’s population lives within 100 miles of a coast. Most people now live in coastal cities. So this long (300,000-mile), narrow (100-mile) and fragile strip of intensely used land and sea carries much of the burden of the entire planet’s environmental problems.
The interests of Ecosystems Center scientists reflect the importance of the world’s coastal regions. Much of our work and attention is focused in our own backyard: the marshes, dunes and cities of Massachusetts north to Plum Island Sound and southwest across Buzzards Bay into coastal Rhode Island. In particular, we’re interested in how to apply ecological knowledge to design and restore sustainable coastal ecosystems in New England, and eventually, around the world. This work is spearheaded by Ecosystems Center scientists in the Plum Island Ecosystem Long Term Ecological Research Site. The center’s Plum Island group and their colleagues in the social sciences are investigating how urbanization and suburbanization – conversion of forests and croplands into urban landscapes – alter the flows of water, nutrients and sediments from the uplands through the coastal plain and into the sea. An important lesson from this research is that we can’t study coastal zones in isolation from either land or sea. The Ecosystems Center’s work in Massachusetts and around the world emphasizes the need for an inclusive approach that links upland forests and watersheds, wetlands, rivers and estuaries, the coastal ocean and even the open sea. Center scientists have developed a suite of mathematical ecosystem models to connect these components of the upland-coastal-ocean-social system and integrate processes across boundaries.

Problem-solving research tests our understanding in new and interesting ways. For example, in partnership with the Coalition for Buzzards Bay, we’re beginning to consider new, holistic approaches to recommending how coastal villages and towns in southern New England should set nutrient discharge limits, decisions with million dollar price tags. Considering the towns in a watershed as urban ecosystems in the coastal landscape is the starting point for rebuilding sustainable coastal cities.

Locally and globally, coastal zone cities and ecosystems are on the front lines of global change, and so are we.
Changing Disturbance Regimes Add to Effects of Climate Change in Arctic Landscape

Tundra and freshwater ecosystems of the Arctic cover more than 2.7 million square miles (7 million square kilometers), about 6% of Earth’s land surface. The climate of this cold, northern landscape is now warming rapidly, with manifold impacts on populations, communities, ecosystems, and people already apparent. It is clear that the response of the Arctic landscape to warming has the potential to influence future climate change, especially through changes in carbon cycling, hydrology, and the exchanges of energy and CO₂ with the atmosphere.

These changes are occurring in a region that provides a unique suite of ecosystem services to both Arctic peoples and the global human population. In the United States, the Arctic and boreal regions of Alaska are the only places where traditional, subsistence use of the land is common and extensive, where the largest wilderness areas are currently preserved, and where mineral, fossil energy, and biological resources are abundant but largely unexploited.

The changes to the Arctic include a general “greening” of the landscape, changes in species distributions and abundance, and changes in geophysical and biogeochemical processes and cycles at local and regional scales. These changes have been studied by Ecosystems Center scientists for more than 30 years. Increasingly, however, it is apparent that climate warming in the Arctic is accompanied by dramatic changes in the frequency of disturbances such as thawing of permafrost, a surprising increase in wildfires, and changes in the seasonality and synchrony of ecosystem processes. These disturbances, in addition to having major impacts on biogeochemistry, populations, and communities, also lead to major changes in surface energy balance, surface temperatures, water balance, and heat transfer into the permafrost that lies beneath the tundra, lakes, and streams. The result is a much more dramatic and rapid change in communities and element cycles than is predicted in response to warming alone. In the long term, warming-related changes in disturbance regime, the pattern of disturbances that shape the ecosystem over a long time scale, may be more important than the direct effects of warming on arctic tundra and freshwater ecosystems, and on the entire Arctic.
On July 17, 2007, a lightning strike started a fire on the tundra of the North Slope of Alaska near the Anaktuvuk River. The fire burned until it was extinguished by October snowstorms, eventually covering 401 square miles (1039 square kilometers), an area the size of Cape Cod. The Anaktuvuk River wildfire created a unique opportunity to observe the response of a pristine landscape to a major disturbance. As the burned area recovers over time, observations of changes in terrestrial and aquatic ecosystems will afford insights into how these systems function in small watersheds. Because the area burned is so large, it provides an opportunity for measuring change at a scale that is directly relevant to large-area, Pan Arctic modeling and prediction.

Researchers in the Arctic Long Term Ecological Research (LTER) project, led by Gus Shaver, were able to study the recovery of this burned landscape from the very beginning of its emergence from the winter snow cover in May 2008. With support from three NSF grants, through the summers of 2008 and 2009 the group has maintained a monitoring program documenting the recovery of element cycles and communities in lakes, streams, and tundra of the burned area.

One impact of the fire was a darkening of the earth surface, with important consequences for the permafrost that underlies the burned area. Postdoctoral scientist Adrian Rocha showed that immediately after snowmelt in 2008, the blackened surface of severely burned areas (more than three-quarters of the total area) reflected only about 4% of incoming solar radiation in contrast to 18% reflectance (albedo) in unburned areas. With much more solar energy absorbed, the ground thawed more deeply in the burned area, leading to an increase in thermokarst (slumps and slides due to the melting of ground ice). A second major impact of the fire was on terrestrial carbon balance. Combustion of vegetation and soil organic matter in the fire released almost two million tons of carbon to the atmosphere, according to an estimate by Michelle Mack of the University of Florida. Following the burn, Rocha showed that over the summers of 2008-2009, respiration of the burned soils led to a continuing net release of carbon to the atmosphere while photosynthesis on the burned sites was greatly reduced. Photosynthesis did recover slowly, however, so that even in severely burned sites there was a net carbon gain by the end of the summer of 2008, and in 2009.

A third impact was on the biogeochemistry of whole burned watersheds. In this case, George Kling of University of Michigan showed that concentrations of the elements nitrogen and phosphorus in streams draining the burned site were higher than in unburned sites. These changes were exacerbated by the greater total water losses from burned watersheds.

What do these changes mean for the overall changes occurring on the North Slope of Alaska and throughout the Arctic? The 2007 Anaktuvuk River wildfire covered only about 0.5% of the total area of the North Slope of Alaska. Yet combustion alone in this fire released about 30% of the total carbon and nitrogen stocks within the annually thawed active layer above the permafrost. This huge carbon loss is about 10 times the net annual loss of carbon from the adjacent Kuparuk watershed, which is 10 times larger. Clearly, an increase in the frequency and area burned by tundra wildfires may mean that changes in carbon balance on burned areas could become a dominant component of carbon exchange with the atmosphere, much more important than relatively small changes in carbon balance due to gradual climate warming.
Sea Level Rise: How Much and How Quickly?

Sea level is expected to rise significantly over the next century due to global climate change. The 2007 Intergovernmental Panel on Climate Change estimated that average global sea level would rise between 7.5 inches (190 mm) and 23 inches (590 mm) by 2100, but the predictions are very uncertain. Some scientists, in fact, have predicted that sea level rise may be much greater, perhaps 3 to 7 feet. How does this compare to what has happened in the past? We know from the geologic record that sea level has changed dramatically over time. During the last glaciation, 18,000 years ago, sea level was more than 300 feet lower than it is today because water from the oceans was tied up as ice on land. Sea level rose rapidly when the ice on land melted and flowed back into the ocean.

Local records suggest that over the last century sea level rose a little more than 10 inches (Figure 1). Relative sea level rise, that is the relationship between the height of the ocean and the land, can vary considerably from place to place. This is because in some areas the land may be either rising or sinking relative to sea level. At high latitudes the land surface has changed as the crust adjusts to the loss of the great weight of the ice present on land from the ice ages. In spite of these complications, local records can be compiled from areas of geologically stable environments to gain a picture of how sea level is changing globally. More recently satellites have been also used to measure sea level changes over time.

Global sea level change, or “eustatic” sea level change, is believed to be due to two causes. The first is the thermal expansion of the volume of the oceans due to warming (a kilogram of warm water takes up more space than the same mass of colder water). The second is an increase in the volume of water in the oceans due to the melting of ice on land, such as the Greenland and the Antarctic Ice Sheets. The melting of ice on the oceans, such as the northern polar ice cap, has little impact on sea level since the weight of the ice already impacted sea level, and the water is already in the ocean (like ice melting in your drink doesn’t overflow the glass).

How much will sea level continue to rise and how fast will it rise? This is an important question for coastal communities. Rising sea levels increase the damage from storms and threaten coastal infrastructure. These impacts will be even more severe if coastal marshes, which can buffer storms, are lost.
Coastal Marshes May Keep Pace with Rising Seas

Coastal marshes lie within a few feet of sea level. They could be particularly vulnerable to rising sea level if they remain at the same elevation. But by trapping sediments from land and the ocean, and by accumulating organic matter below ground, the height of the marsh platform can increase as water levels rise. For the past 15 years, Anne Giblin and Hap Garritt of the Ecosystems Center and colleagues Chuck Hopkinson of the University of Georgia and Jim Morris of the University of South Carolina have been making measurements of the height of coastal marshes to determine whether they have been keeping up with sea level rise or if they are sinking relative to the height of the ocean. This work is taking place at the Plum Island Ecosystem Long Term Ecological Research (PIE-LTER) project in northern Massachusetts.

Because changes in the height of the marsh are extremely small, these measurements need to be made at a wide variety of places. The measurements are made using a sediment elevation table (SET). Pipes are driven many feet through the marsh until they hit a solid substrate so they will remain stable. Then a carefully leveled arm is placed on the pipe and the height of the sediment relative to the arm is measured at about 80 places around the arm. Currently these measurements are being made at approximately 20 locations in the Plum Island marshes. At the same time the SETs were installed, Giblin and colleagues put in a marker layer of feldspar to color the surface of the sediment. Then, by carefully taking a small section of the sediment, they can measure how much new material is accumulating on top of the marsh surface. By comparing the two measurements they can better understand the sources of sediment and the losses.

The measurements on the marsh platform show that currently in some areas the marshes of Plum Island are accreting material fast enough to keep up with sea level rise, while others are falling behind. Sea level is rising at about 0.1 inch/year (2.66 mm/year) and accretion rates in those areas that are accreting most rapidly are rising a little more than 0.2 inch/year (6mm/year) (Figure 1). There are areas, though, where the marshes are “ponding” and losing elevation relative to sea level. Overall the results suggest that the PIE marshes are keeping up with current rates of sea level rise, but are probably close to their limit.

To better understand the long term implications of changing sea level on marsh survival, Jim Morris and his technician Karen Sundberg have planted salt marsh cord grass at different heights in the tidal range and measured their growth. They have found that the salt marsh grasses grow better at an elevation considerably lower than the current marsh platform. This suggests that PIE marshes are actually a bit higher than optimum relative to sea level and that at least for the short term, should not be threatened by current rates of sea level rise.

![A sediment elevation (SET) table at Plum Island. Boardwalks are used to prevent any compaction due to walking on the marsh near the SET. (Photo: Jim Morris)](image)

Figure 1: Measurements of relative mean sea level taken at the NOAA Boston tide station. Sea level shows considerable year to year variation but overall has been rising at a rate of about a tenth of an inch per year, or just over 10 inches over the last century.
Climate change is predicted to play a major role in the carbon cycle of temperate forests and other ecosystems by altering biogeochemical processes such as plant photosynthesis and microbial respiration. Warming experiments conducted in a variety of ecosystems including forests have examined the effects of climate change on the carbon cycle, specifically the short-term losses of CO$_2$ from soil to the atmosphere. But carbon isn’t the only element we need to know about.

Various aspects of the nitrogen cycle have been studied in soil warming experiments, but it is only recently that scientists have begun focusing on linked plant-soil responses to warming-induced changes in the nitrogen cycle. Nitrogen is one of the most important nutrients in terrestrial ecosystems, essential for all living organisms, and it is often the major factor limiting productivity in eastern forests. The carbon and nitrogen cycles are tightly coupled in these systems. If nitrogen is made more available for plant uptake, the plants are able to increase their CO$_2$ uptake. This can lead to an increase in carbon storage, resulting in a negative feedback to the global carbon cycle.

The amount and form of available nitrogen (for example, ammonium versus nitrate) also can affect plant-species composition in the forests of the northeastern United States. Alterations in the nitrogen cycle in these forests in response to climate change may play an important role in inter-species competition over the 21st century.
In a world warmed by climate change, will red maples and oaks dominate the forests of the northeastern United States?

Ecosystem Center scientists working at the Harvard Forest in central Massachusetts, Jerry Melillo, Sarah Butler, Chelsea Vario and Rose Smith, have been studying how warming will affect the nitrogen cycle and forest species composition in the long-term in deciduous forests of the Northeast.

Since 2003, they have been warming the soil in a large (30m X 30m) plot 5°C above ambient soil temperature using resistance cable buried in the soil. Over the first six years of this soil warming study, they have observed significant changes to the nitrogen cycle with potential consequences for the tree species composition. Since the start of the experiment, they have seen a 49% increase in the rate at which organically bound nitrogen is transformed to ammonium, a common form of inorganic nitrogen taken up by trees in the Northeastern U.S. They have also observed an increase in the amount of ammonium that is transformed to nitrate in a process known as nitrification. Nitrate is a very mobile form of inorganic nitrogen that can be used by some tree species, leached from an ecosystem, or transformed to a nitrogen gas such as nitrous oxide. Nitrification rates have grown from less than 5% of the total nitrogen mineralized at the beginning of the experiment to 25% in year six.

Increased nitrogen availability has resulted in increases in the relative growth rate of red maples and a sustained dominance of oak trees in the forest. Based on assays of leaf enzymes involved in nitrogen metabolism, oaks appear to be the dominant users of the growing nitrate resource. These early results suggest that because of their complimentary abilities to compete for nitrogen, both the red maples and the oaks may thrive in a warmer world.

Projections of the future species composition in forests the Northeast have been done with models that use variables such as temperature, precipitation, elevation, soil type and properties, and land use and fragmentation. Ecosystems Center research at the Harvard Forest site suggests that scientists may be able to better predict the composition of our future forests by incorporating nitrogen into species distribution models.
Semester in Environmental Science

The Semester in Environmental Science (SES) at the MBL is currently the only academic year educational program available for undergraduates at a research institution in Woods Hole. Over the past 13 years, 200 students have completed the program and about half have gone on to receive advanced training in environmental science, policy or engineering. Nearly 70% of SES alumni remain involved in fields related to environmental science and management. SES students are having an impact in their fields. Notably, this year, three SES alums published important scientific findings in the prestigious journal, *Science*.

In 2009, we admitted 16 students to the SES program from a variety of U.S. schools, including Bates, Brown, Colby, Connecticut College, Colorado College, Haverford, Kenyon, Lawrence University, Mt. Holyoke, Northwestern University and SUNY-Environmental Science and Forestry School.

To help provide all students with equal access to the program, we offered $28,509 in financial assistance this year. This scholarship aid was derived from two major sources: gifts from individual donors and endowment income from the Osterhout Edison Sears Endowed Scholarship Fund and the Bill and Phoebe Speck Fund dedicated for undergraduate financial aid at the MBL. During 2009, the SES also received several generous gifts and pledges to help build an endowment for the program. Together with existing endowment this brings the SES endowment to nearly $1 million.

During the first 10 weeks of the program, students completed a set of structured lab and field exercises as part of the core courses. They visited a variety of freshwater, estuarine and terrestrial sites where they measured ecosystem structure (e.g., species composition and biomass of plants, animals and microbes present; light; salinity; soil characteristics) and function (e.g., photosynthesis, respiration, nutrient cycling and release). Students reported their findings at weekly or bi-weekly discussion sessions and prepared written lab reports. They also completed an elective course in either mathematical modeling of ecosystems or microbial methods in ecology. During the last six weeks of the program, after the formal coursework ended, students pursued independent research projects and presented their findings at a public symposium held in December. Results from this work are submitted as final written project reports that are posted to our website, http://courses.mbl.edu/SES/.

For more information about the SES program, please go to the website, http://ecosystems.mbl.edu/SES
I absolutely cannot summarize this experience in words—it is just too big on so many levels. But, as the adventure comes to an end, I would like to highlight some of the unforgettable moments and try to express what this place has meant to me.

My favorite memories will be not only the extraordinary moments, but will also include the plainer routines that made up my daily experience. Sampling in the Zodiac will stay with me as one of my favorite routines. My colleague Alice and I would quietly go about our respective tasks and as I was sitting in the back of the boat, I would look around and experience how each day was different. Sometimes it snowed, sometimes — in rough seas — we had to hold on tight, sometimes the sun peeked through the clouds and reflected brilliantly off the mountains.

One aspect of this landscape that will stay with me is its expansiveness. Perhaps it was so evident because it was framed by tall mountains. Maybe it was because you can look to the horizon and envision it as your wild domain – one of the last untamed, undeveloped places on Earth. The mountains alone were a highlight. Never did I imagine seeing such huge, tall peaks covered in snow and surrounded by water. Completely captivating.

Something else I will unquestionably take with me is all of the wildlife that gives personality to the landscape. I cannot believe all of the marine animals I saw and got close to. The whales, the penguins, the seals... all of it was awesome.

A last feature of the landscape that I loved was the sunsets. Perhaps because they were rare in the Antarctic summer, or perhaps because sunsets are something that everyone can relate to, I'm not sure which. What made these sunsets special, though, were the icebergs that littered the foreground and how the low-lying clouds around the peaks were tinted orange. Sometimes the sunset glued all of the pieces together in my mind — the water, the ice, the rocks, the mountains, and our place in it.
The Ecosystems Center is actively involved in education in a variety of ways. In addition to running the Semester in Environmental Science program for college undergraduates, center scientists serve as professors and advisors in the Brown-MBL Graduate Program, members of doctoral committees, and mentors for postdoctoral scientists and undergraduate interns. The center staff also takes part in a range of community outreach activities to increase public understanding of science.

Schoolyard LTER Program

Plum Island Ecosystem’s Schoolyard Long Term Ecological Research (LTER) project collaborates with both the Massachusetts Audubon Society and the Governor’s Academy in Byfield, Massachusetts. Teachers at Governor’s Academy work to implement science modules for high school students, helping students to monitor ribbed mussels and intertidal marsh plant distribution. Mass Audubon has implemented a science education program for grades 5 to 12 called the Salt Marsh Science Project (SMS), in which students monitor vegetation transects and measure porewater salinities to relate them to vegetation patterns. SMS serves an average of at least 1,000 students per year and 50 teachers from 10 schools. In 2009, Mass Audubon’s education coordinator and LTER representative, Elizabeth Duff, was honored with the 2009 Visionary Award from the Gulf of Marine Council for her work in training teachers in field protocols, classroom lessons, data entry and analysis procedures.

The Arctic Schoolyard LTER program focuses on the community of Barrow, Alaska, the closest large town to the LTER site at Toolik Lake. The activities include two main components: field work that 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 a weekly lecture series, called “Schoolyard Saturday,” on a wide range of scientific topics. The Barrow Arctic Science Consortium has supplemented these Schoolyard activities with additional funds and actively manages both the in-school activities and the public lectures. In addition, each year several Arctic LTER scientists visit Barrow to lecture in the “Saturday Schoolyard” series and in the public schools.

The Palmer Station, Antarctica, LTER program partners with state-wide and international organizations, educational professionals, kindergarten to grade 12 educators, and formal and informal science programs to promote ocean literacy and improve public awareness and understanding of polar ocean science along the western Antarctic peninsula. The Palmer Schoolyard LTER draws upon site research to offer learning opportunities for those interested in professional development through our Research Experience for Teachers program, helping educators create better instructional materials and more dynamic learning experiences for their students in classrooms, libraries, museums and informal learning centers.
Undergraduate Programs

With funding from the National Science Foundation (NSF) and other groups, the Ecosystems Center has offered many college students the opportunity to undertake research projects in the lab and at field sites. In 2009, six undergraduates conducted research projects through NSF’s Research Experience for Undergraduate program. Their projects ranged from studying the diet and growth of Arctic grayling in streams on the North Slope of Alaska, to research on the molecular and isotopic composition of leaf waxes in Holocene lake sediments in French Guiana, to participating on an oceanographic cruise in Antarctica.

Science Journalism Program

From the Arctic to the Antarctic, journalists in the MBL Science Journalism Fellowship Program were able to view first hand the effects of climate change in areas that are warming faster than anywhere else in the world. In June, 10 journalists, accompanied by Chris Neill and Rich McHorney from the Ecosystems Center, traveled to the Arctic LTER at Toolik Lake, Alaska. There, the fellows participated in a weeklong hands-on course, taught by Neill, focusing on key science questions in polar research. Following the course, the journalists teamed up with research scientists to work side-by-side with them in the field and laboratory for a week. In November, three Polar Fellows spent a month with Chris Neill and other scientists studying the effects of climate change and ecosystem function at Palmer Station on the Antarctic Peninsula. For three weeks, the journalists worked closely with scientists at Palmer Station, receiving hands-on training in some of the methods of ecosystems science from Chris Neill. They also accompanied the three LTER teams in residence at Palmer as they studied microbial processes, phytoplankton ecology and penguin foraging and breeding.

Community

Ecosystems Center staff members serve on many town committees, including the Falmouth Zoning Board, the Falmouth Coastal Resources working group, the Falmouth Solid Waste Advisory committee, and the Falmouth Wastewater Technical Advisory Committee, as well as non-profit private groups, Falmouth Associations Concerned with Estuaries and Salt Ponds and the Association to Preserve Cape Cod. Hugh Ducklow’s lab now provides analytical services to the Baywatchers Program of the Coalition for Buzzards Bay. In addition, Chris Neill writes a monthly column on environment for The Falmouth Enterprise.

Brown-MBL Graduate Program

Four students are working with Ecosystems Center scientists in the MBL’s graduate program with Brown University. Shelby Hayhoe is studying the effect of land use change on biogeochemical cycling in tropical systems, focusing on agricultural conversion in the Amazon. Her advisors are Chris Neill of the Ecosystems Center and Stephen Porder from Brown. Lindsay Brin is examining how temperature influences nitrogen pathways in estuaries and mangroves. Her advisors are Anne Giblin from the center and Jeremy Rich from Brown. Sarah Corman is working with Linda Deegan of the Ecosystems Center and Heather Leslie at Brown. Sarah is
interested in the impact of multiple stressors, including climate change on coastal marine ecosystems, particularly rocky shores and salt marshes. Xi Ying is looking at the interdisciplinary research of remote sensing, terrestrial ecosystem ecology and climate change. His advisors are Jim Tang of the center and John Mustard from Brown.

Gillian Galford and Yawei Luo received their doctoral degrees in 2009 and Kristen Meyers received her Master’s degree.

MBL Ecosystems Center Staff Donates Books to Schoolchildren

Molly Bang, well-known author and illustrator from Woods Hole, and Dr. Penny Chisholm, a senior scientist at the Massachusetts Institute of Technology, published Living Sunlight: How Plants Bring the Earth to Life earlier this year. The book is geared for elementary schoolchildren and focuses on photosynthesis. School budget constraints made it unlikely that area school systems would be able to purchase the books so Ecosystems Center employees raised enough money to buy two books per school for each of the 10 elementary and middle schools in the Falmouth, Bourne and Mashpee school districts. Ms. Bang then was able to offer a workshop, with the assistance of the Woods Hole Science and Technology Education Partnership (WHSTEP), for Falmouth, Bourne and Mashpee teachers to help them explain the concept of photosynthesis to children. Teachers were enthusiastic about both the workshop and the book.

PEP Program

Scientists at the Ecosystems Center mentored two participants in the newly formed Partnership in Education program (PEP), launched this year by a consortium of Woods Hole scientific institutions – MBL, NOAA National Marine Fisheries Service, Sea Education Association, U. S. Geological Survey, Woods Hole Oceanographic Institution and Woods Hole Research Center. The goal is to increase diversity in the science community.

Amias Polk and James Shelton of Arkansas State University had internships at the Ecosystems Center. Polk worked with stable isotopes to study nitrogen cycling in the northeast Amazon of French Guiana with adjunct scientist Maureen Conte, while Shelton researched soil respiration on Martha’s Vineyard with assistant scientist Jim Tang.
Jerry Melillo was co-chair and co-editor of the report, *Global Climate Change: Its Impacts in the United States*, commissioned by the U.S. Government’s Global Change Research Program.

Melillo was elected to the Board of Trustees of the University Corporation of Atmospheric Research (UCAR), which is the parent organization of the National Center for Atmospheric Research headquartered in Boulder, Colorado. He was also elected to the Board of Trustees of the Cary Institute of Ecosystem Studies located in Millbrook, New York.

Melillo retired as co-director of the Ecosystems Center in 2009, but continues his many projects as senior scientist.

Zoe Cardon is serving as president of the Physiological Ecology Section of the Ecological Society of America. She is also on the editorial board for the journal *Oecologia*.

Linda Deegan is program director and chair of the steering committee for Comparative Analysis of Marine Ecosystem Organization (CAMEO). She also attended the UN Climate Change Conference (COP15) in Copenhagen with MBL director Gary Borisy and members of the Woods Hole Consortium.

Chris Neill was named Bullard Fellow in Amazon Ecology at Harvard University for 2009-2010. He is conducting research at the Harvard Forest LTER in Petersham, MA.

**Research Grants Received in 2009**

- **NATIONAL SCIENCE FOUNDATION AMERICAN RECOVERY AND REINVESTMENT ACT OF 2009 (ARRA)**
  - Collaborative research: Using biogeochemical and genetic tools to unravel the environmental controls of nitrogen fixation and denitrification in heterotrophic marine sediments. Principal Investigator: Anne Giblin ($262,558)
  - Collaborative research: Shifting seasonality of Arctic river hydrology alters key biotic linkages among aquatic systems. Principal Investigator: Linda Deegan ($1,317,687)
  - Collaborative research: The changing seasonality of tundra nutrient cycling: Implications for ecosystem and Arctic system functioning. Principal Investigator: Edward Rastetter ($180,926)
  - Effects of lengthening growing season and increasing temperature on soil carbon fluxes and stocks in Arctic tundra. Principal Investigator: Jianwu Tang ($89,879)

- **NOAA**
  - Alternative nitrogen cycling pathways: When does nitrate disappearance alleviate eutrophication? Principal Investigator: Anne Giblin ($135,899)

- **EPA**
  - Biofuel trade-offs: Fuels, forest, and food. Principal Investigator: Jerry Melillo ($54,000)

- **NASA**
  - Changes of land cover and land use and greenhouse gas emissions in Northern Eurasia: Impacts on human adaptation and quality of life at regional and global scales. Principal Investigator: Jerry Melillo ($189,999)

- **ETBC: Feedbacks between nutrients enrichment and intertidal substrates: erosion, stabilization, and landscape evolution. Principal Investigator: Linda Deegan ($469,074)

- **Comparative Analysis of Marine Ecosystem Organization (CAMEO): Program office support and steering committee workshop. Principal Investigator: Linda Deegan ($55,095)

- **THE DAVID AND LUCILE PACKARD FOUNDATION**
  - Biofuels production, disruption of the nitrogen cycle and other ecological effects. Principal Investigator: Jerry Melillo ($600,000)

- **COALITION FOR BUZZARDS BAY**
  - Baywatchers: A long-term ecological monitoring program for Buzzards Bay. Principal Investigator: Hugh Ducklow ($396,328)

- **PAINE CONSERVATION TRUST**
  - River otters as bioindicators and sentinels for coastal habitat and water quality. Principal Investigator: Christopher Neill ($10,000)

- **THE NATURE CONSERVANCY**
  - Herring Creek restoration project. Principal Investigator: Christopher Neill ($30,000)

- **HARVARD UNIVERSITY**
  - Bullard fellowship in Amazon ecology at Harvard Forest. Principal Investigator: Christopher Neill ($40,000)
Publications 2009


Suzanne Thomas prepping samples of diverse green algae cultured from desert microbial crusts of the southwestern United States. (Photo: Tom Kleindinst)


Vallino, J. J. Ecosystem biogeochemistry considered as a distributed metabolic network ordered by maximum entropy production. Philosophical Transactions of The Royal Society B.


York, J. K., G. Tomasky, I. Valiela and A. E. Giblin. Isotopic approach to determining the fate of ammonium regenerated from sediments in a eutrophic sub-estuary of Waquoit Bay, MA. Estuaries and Coasts.
JANUARY
27 Andrew Richardson, University of New Hampshire
“Vegetation phenology at scales from organism to biosphere: Why it matters in a changing world”

FEBRUARY
3 Zoe Cardon, Ecosystems Center, MBL
“Hydraulic redistribution of water by sagebrush in northern Utah”

10 Edward Rastetter, Ecosystems Center, MBL
“Canopy N distributions: Leaf-level or canopy-level optimization?”

17 Matthew Wallenstein, NREL at Colorado State University
“Soil microbial physiology: Linking microbial communities to ecosystem function”

24 Robert Humston, Washington and Lee University
“Using chemistry of fish otoliths to track recruitment exchange in river-tributary networks”

MARCH
10 Anne Bernhard, Connecticut College
“Diversity and distribution of ammonia oxidizing archaea in a salt marsh”

17 Eric Kasischke, University of Maryland
“Vulnerability of Alaskan black spruce forests to variations in climate and the fire regime”

31 Pamela Templer, Boston University
“Fate of nitrogen in terrestrial ecosystems: A synthesis of 15N studies”

APRIL
7 Scott Goetz, Woods Hole Research Center
“Implications of recent changes in fire disturbance and vegetation productivity at high latitude”

21 Compton Tucker, NASA Goddard Space Flight Center
“A 27-year NDVI photosynthetic capacity climatology from satellite data: Trends, anomalies, and weirdness”

MAY
5 Erika Edwards, Brown University
“Why do C-4 grasses live where they do? Discriminating physiological factors from historical contingency”

12 Erin Kinney, Ecosystems Center, MBL
“Nitrogen loading to Great South Bay, NY: Land use, sources, and transport from land to Bay”

SEPTEMBER
15 Jackie Collier, SUNY Stony Brook
“Diversity and abundance of Labyrinthulomycetes, the most important marine decomposers you’ve (probably) never heard of”

18 Mark Serreze, Cooperative Institute for Research in Environmental Sciences, National Snow and Ice Data Center, University of Colorado
“Environmental impacts of a shrinking Arctic sea ice cover”

22 Mirko Lunau, Ecosystems Center, MBL
“Microbial short time response to changes in aquatic environments”

25 Peter Groffman, Cary Institute of Ecosystem Studies
“Exotic earthworm invasion and soil carbon in forests”

29 Neil Bettez, Cary Institute for Ecosystem Studies
“Impact of near source deposition of mobile source emissions on forest N cycling in a coastal watershed”

OCTOBER
6 Manuel Lerdau, University of Virginia
“The MEP/DOXP pathway, plant stress, and atmospheric chemistry”

23 George Kling, University of Michigan
“Using ecosystems science to solve problems: The case of killer lakes in Africa”

NOVEMBER
3 Dan Ardia, Franklin and Marshall College
“Golondrinas de las Americas: Geographic variation in life history evolution in Tachycineta swallows”

6 Bess Ward, Princeton University
“Biogeochemistry and molecular ecology of the marine nitrogen cycle”

15 Jackie Collier, SUNY Stony Brook
“Diversity and abundance of Labyrinthulomycetes, the most important marine decomposers you’ve (probably) never heard of”

17 Erika Sudderth, Brown University
“Soil type modifies the impact of changing precipitation patterns on plant productivity and carbon and water exchange in Avena barbata grasslands”

DECEMBER
1 Beverly Johnson, Bates College
“Establishing ‘baseline conditions’ in Gulf of Maine coastal ecosystems using isotopic analyses of ancient fish bone proteins”

8 Hank Loecher, National Ecological Observatory Network (NEON)
“What is NEON Project Science? And what does it mean for scientists?”

* SES Distinguished Scientist Seminar Series
Hugh W. Ducklow  
Senior Scientist,  
Director  
Ph.D., Harvard University  
Hugh is a biological oceanographer focusing on the roles of bacteria in the ocean carbon cycle. His research in Antarctica looks at the responses of the continental shelf sea ice zone ecosystem to rapid climate warming.

Zoe G. Cardon  
Senior Scientist  
Ph.D., Stanford University  
Zoe’s research focuses on microbial activity in soil around plant roots (the rhizosphere), including how water fluxes driven by plants affect resource availability, local conditions, and biogeochemistry in the rhizosphere.

Linda A. Deegan  
Senior Scientist  
Ph.D., Louisiana State University  
Linda is interested in the relationship between animal populations and ecosystems because animals can strongly influence community composition and ecosystem nutrient cycles and productivity.

Kenneth H. Foreman  
Director of Semester in Environmental Science  
Ph.D., Boston University  
Ken’s principal research area is the coastal zone. In recent years, he has been studying the effects of nutrient loading on benthic and water column communities and processes.

Anne E. Giblin  
Senior Scientist  
Ph.D., Boston University  
Anne’s major research focus is the cycling of elements in the environment, especially the biogeochemistry of iron, sulfur, nitrogen and phosphorus in soils and sediments.

Jerry M. Melillo  
Senior Scientist,  
Co-Director  
Ph.D., Yale University  
Jerry is interested in how human activities are altering the biogeochemistry of terrestrial ecosystems and especially how global changes are affecting the chemistry of the atmosphere and the overall climate system.

Bruce J. Peterson  
Senior Scientist  
Ph.D., Cornell University  
Bruce focuses on understanding aquatic productivity and global change by studying the cycles of water, carbon and nitrogen at the ecosystem and global levels.

Edward B. Rastetter  
Senior Scientist  
Ph.D., University of Virginia  
Ed synthesizes field and laboratory data using simulation models to study how plants and microbes optimize their use of resources like carbon, nitrogen, light and water, and how that optimization might influence the response of ecosystems to global change.

Gaius R. Shaver  
Senior Scientist  
Ph.D., Duke University  
Gus’s research is focused on the role of plants in ecosystem element cycles, especially in Alaskan tundra ecosystems, where low temperatures, low light intensities, low nutrient availability, and a short growing season all interact to limit plant growth.

Christopher Neill  
Associate Scientist  
Ph.D., University of Massachusetts, Amherst  
Chris investigates how ecosystems cycle nutrients and organic matter and how changes in land use, such as deforestation in the tropics, alter the structure and biogeochemistry of ecosystems.

Jianwu (Jim) Tang  
Assistant Scientist  
Ph.D., University of California, Berkeley  
Jim’s research focuses on soil biogeochemistry and soil-plant interactions, particularly on carbon and nitrogen cycles through ecosystems processes.

Joseph J. Vallino  
Associate Scientist  
Ph.D., Massachusetts Institute of Technology  
Joe’s research employs thermodynamics to examine how microbial metabolic networks organize and evolve to utilize energy and resources in the environment.
Senior Staff

Paul Colinvaux
Senior Research Scientist
Ph.D., Duke University

Paul studies past climates and vegetation from the Amazon to the Arctic through analysis of air-borne pollen trapped in lake sediments.

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

As an aquatic ecologist, John identifies the factors controlling decomposition and productivity in aquatic ecosystems, especially the role that microbes play.

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

Paul is interested in the responses of temperate and tropical forest and agricultural ecosystems to disturbances like hurricanes, nitrogen and sulfur additions, forest cutting and regrowth, and increased temperature.

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

Ivan is interested in the coupling of land use on watersheds and coastal ecosystems in the larger context of global change.

Adjunct Scientists

Maureen H. Conte
Adjunct Scientist in Residence
Bermuda Biological Station for Research, Inc.
Ph.D., Columbia University

Maureen’s research speciality is trace level molecular and isotopic organic geochemistry. Research focus areas include deep ocean particle flux and the organic geochemistry of biogenic aerosols.

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

Bob’s long-term interest is in environmental management and the effects of nutrients and pollutants on aquatic ecosystems. His scientific approach is through biogeochemistry, particularly nitrogen, phosphorus, and sulfur cycling and export from land to waters.

Sophia E. Fox
Ph.D., Boston University

Postdoctoral Scientists

Claire Lunch
Ph.D., Stanford University

Mirko Lunau
Ph.D., University of Oldenbourg, Germany

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

Suzanne Tank
Ph.D., Simon Fraser University

David S. Johnson
Ph.D., Louisiana State University
Graduate Students

Brown-MBL Graduate Program in Biological and Environmental Sciences

Lindsay D. Brin  
B.A., Swarthmore College  
Advisors: Anne Giblin, Ecosystems Center  
Jeremy Rich, Brown University

Sarah S. Corman  
M.S., University of Rhode Island  
Advisors: Linda Deegan, Ecosystems Center  
Heather Leslie, Brown University

Shelby Hayhoe  
B.A., Grinnell College  
Advisors: Christopher Neill, Ecosystems Center  
Stephen Porder, Brown University

Xi Yang  
M.E., Beijing Normal University  
Advisors: Jim Tang, Ecosystems Center  
John Mustard, Brown University

Visiting Graduate Students

Erin L. Kinney  
Ph.D. Candidate  
Boston University  
B.A., Dartmouth College

Rita Oliveira Monteiro  
Ph.D. Candidate  
State University of New York ESF  
M.S., Université de Liége, Belgium

Consultants

Francis P. Bowles  
Carlos E. P. Cerri  
Alina S. Cushing  
Heidi Golden  
Luane Johnson

Visiting Scientists and Scholars

Peter Berg, University of Virginia  
Thomas Duncan, Nichols College  
James Galloway, University of Virginia  
Roxanne Marino, Cornell University  
Karen McGlathery, University of Virginia  
Xelu Morán, Instituto Español de Oceanografía  
Barbara Ondiviela, Universidad de Contrabria  
Yumei Zhou, Chinese Academy of Sciences

Staff who left in 2009

Dorothy Berthel – Administrative Assistant, MBL Development Department  
Donald Burnette – Retirement  
Timothy Cronin – Graduate student, Massachusetts Institute of Technology  
Troy Hill – Graduate student, Yale University School of Forestry  
Christina Maki – Cross-country bike trip  
Jennifer Peters – Graduate student, University of Canterbury, New Zealand  
Gillian L. Galford, Ph.D., Brown-MBL – Postdoctoral Scientist, Lamont-Doherty Earth Observatory  
Yawei Luo, Ph.D., Brown-MBL – Postdoctoral Scientist, Woods Hole Oceanographic Institution  
Kristen M. S. Myers, M.S., Brown-MBL – Research Technician, Portland State University  
Neil Betze, Ph.D., Cornell University – Postdoctoral Scientist, Cary Institute of Ecosystems Studies  
Ketil Koop-Jacobsen, Ph.D., Boston University – Postdoctoral Scientist, Max Planck Institute, Bremen  
Ylva Olsen, Ph.D., Boston University – Research Lecturer, University of Bangor, Wales
The annual operating budget of The Ecosystems Center for 2009 was $9,894,000. Approximately 77% of the income of the center comes 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 23% 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 total value of the center’s reserve fund and endowment at the end of 2009 was $3,602,639. Income from the reserve fund and endowment helps defray the costs of operations, writing proposals, consulting for government agencies and the center’s seminar program.

The Ecosystems Center is grateful for the support it has received from all its individual donors as well as the following corporations and foundations over the past five years:

The Arthur Vining Davis Foundations
The Clowes Fund, Inc.
Davis Educational Foundation
The Dorr Foundation
Harken Foundation
The William H. Harris Foundation
Mayer and Morris Kaplan Family Foundation
The Andrew W. Mellon Foundation
Mid-American Water of Wauconda, Inc.
Mills Family Charitable Foundation
North Star Financial Services Corp.
The David and Lucile Packard Foundation
Michael R. Paine Conservation Trust
Sugar, Friedberg & Felsenthal

Research assistants Maya Wei-Haas, Alea Tuttle, Jeff Kampman, Max Resin and Dan White celebrate the completion of a fish weir at the Arctic LTER site at Toolik Lake, Alaska. The water temperature in the Kuparuk River that August day was about 3°C or 37°F. (Photo: Elissa Schuett)