Cover: Adélie penguins on the ice near Palmer Station, Antarctica, site of the newest Long Term Ecological Research project to be based at the Ecosystems Center. (Photo: Hugh Ducklow)
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:

- At the Toolik Lake Arctic Long Term Ecological Research (LTER) site on Alaska’s North Slope and at research sites in Greenland and northern Scandinavia, Ecosystems Center scientists study the effect of warmer temperatures on Arctic ecosystems. Will increased permafrost thaw make more nutrients available to plants? If these nutrients flow into streams and lakes, how will they affect the aquatic food web?

- At the Plum Island Ecosystems LTER site in northern Massachusetts, researchers ask how urban development affects the flow of nutrients and organic matter into New England estuaries. How will they alter the food web and plant growth in salt marshes? What happens to the production of commercially valuable fish as a result?

- At the Palmer Station LTER in Antarctica, Ecosystems Center scientists study the coastal ecosystem along the west Antarctic Peninsula, where sea ice duration has declined by 80 days in response to climate warming since 1975, leading to large-scale declines in animal populations and other changes in the marine ecosystem. Do these changes suggest the fate of more polar regions of the Antarctic continent?

- In Brazil, scientists investigate how the clearing of tropical forests in the western Amazon changes greenhouse gases such as carbon dioxide and nitrous oxide released into the atmosphere. What will the effect be on global climate? How will change in temperature and atmospheric gas concentrations affect the productivity of forests? What effect does the clearing of forest for pasture have on tropical streams ecosystems?

- In Boston Harbor, researchers measure the transfer of nitrogen from the sediments to the water column. How long will it take the harbor to recover from decades of sewage addition?

- In the Arctic rivers of Eurasia, center scientists have conducted research that shows increased freshwater discharge to the Arctic Ocean. If ocean circulation is affected, how might the climate in western Europe and eastern North America change?

- On Martha’s Vineyard, researchers restore coastal sandplain ecosystems with either controlled burning or mechanical clearing. How much will beneficial processes such as groundwater recharge and nitrogen retention increase in restored ecosystems? Will it restore diversity in plant and animal species?

- At the Harvard Forest LTER in central Massachusetts and at the Abisko Scientific Research Station in Sweden, 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?

Scientists in the center use sophisticated computer models to ask questions about effects of future changes in climate, carbon dioxide and ozone on vegetation productivity and carbon storage worldwide. Center researchers collaborate with social and atmospheric scientists at MIT to investigate ecological responses to various scenarios of economic and energy development.
Carbon Through the burning of fossil fuels and the clearing of land for agriculture, we have caused the atmospheric concentration of carbon dioxide (CO$_2$) to increase by more than 30% over the past two centuries, with the current concentration higher than it has been in the last half-million years. Because CO$_2$ is a greenhouse gas — a gas with the ability to absorb heat radiated from the Earth’s surface — its accumulation in the atmosphere is a primary cause of global warming. Projections of population growth and assumptions about energy use in the future indicate that the CO$_2$ concentration will continue to rise, likely reaching between two and three times the late nineteenth century level by 2100. If this happens, the Earth’s surface temperature will likely rise by between about 2°C (4°F) and 5°C (9°F).

Nitrogen Conversion of atmospheric N$_2$ into biologically reactive forms of N has more than doubled as a result of fossil fuel combustion and fertilizer production. In the atmosphere, reactive N is linked to the production of ozone, which reduces growth rates of native vegetation and agricultural crops. Nitrogen deposition to ecosystems alters nutrient ratios in soils and causes surface-water acidification. The effects of increased reactive N fluxes from terrestrial to aquatic environments have been demonstrated in individual small watersheds, regional to continental drainage systems, and at global scales. Enhanced coastal eutrophication and anoxia, changes in water chemistry that favor toxic phytoplankton, and increases in the production of some greenhouse gases are associated with these elevated N fluxes.

Human Activities and Changes in the Life-sustaining Cycles of Carbon, Nitrogen and Water

For millennia, humans have been modifying their local environment in an effort to acquire food, fuel, and fiber. The beginning of the Industrial Revolution marked a shift in the scale of these modifications. Human activities have now significantly altered fundamental earth processes, including the life-sustaining cycles of carbon, nitrogen, and water. The alterations are having major consequences for the future of life on our planet.
Water  Humans rely on water for basic survival and economic development and today control more than half of all accessible water. However, the distribution of water is very uneven, and water resources are often overexploited, with more than one billion people lacking access to clean water and more than two billion without sanitation. Hydraulic engineering is widely employed to augment scarce or mistimed supplies. Its impact on the water cycle is global and substantial: about 200 of the world’s largest reservoirs have residence times greater than one year; and there has been a tripling of the mean time of passage for water since pre-impounded conditions. Irrigated cropland produces more than 40% of the global food supply. While the impact of irrigation on the global water cycle is less than 5% of global runoff, the regional impact of irrigation on hydrology can dramatically alter the flow of large main-stem rivers like the Nile and Indus.

Cycle Interactions  Despite the scientific progress that has advanced understanding of each of these important cycles, it is widely recognized that the carbon, nitrogen, and water cycles interact in a variety of important ways that affect the capacity of ecosystems to support humans. In terrestrial and aquatic ecosystems, these cycles are inextricably linked through many important processes including photosynthesis, transpiration, decomposition, and other microbially mediated carbon and nitrogen transformations. Ecosystems Center scientists are exploring these interactions through a mix of experiments and models.

Humans rely on water for basic survival and economic development and today control more than half of all accessible water.
The year 2007 has been a watershed year for climate change. The United Nations Intergovernmental Panel on Climate Change (IPCC) released its Fourth Assessment Report and shared the Nobel Peace Prize with former Vice-President Al Gore. In Bali, representatives from almost all the nations on our planet gathered to discuss how to move forward from the 1997 Kyoto Accord to mitigate global warming and avoid catastrophic changes to Earth’s ecosystems and society.

With the release of the IPCC Report this year, there is no longer any serious scientific debate regarding the following points about climate change:

- the Earth has warmed over the past century by 0.7°C (1.3°F), and the average annual temperature is now 14°C (57°F), warmer than at any time in at least the past 500 to 1,000 years;

- the warming is the result of greenhouse gas accumulation (primarily carbon dioxide (CO₂) but also methane, nitrous oxide, and chlorofluorocarbons) in the atmosphere, products of human activity;

- the warming will continue;

- impacts of the warming and associated changes will be increasingly severe in the coming decades; and

- a massive global effort is urgently needed to stabilize the level of atmospheric CO₂ and minimize the temperature increase.

We have three ways to respond to climate change: 1) do nothing, 2) adapt to likely changes, or 3) mitigate the future effects by decreasing greenhouse gas emissions. To make informed decisions about adaptation and mitigation, we need better understanding of the impacts and their costs. Fortunately, we do have sufficient understanding to start making responsible decisions now. As a nation, the U.S. makes political, social, and business decisions in the face of uncertainty all the time about national defense, disease control, interest rates, and other areas of national policy. Climate change is no different and no exception.

As the just-released United Nations Human Development Report makes clear, impacts of climate change on wealthy nations will be less than the effects on poorer, less-developed nations in the tropics, which lack the resources to cope with the changes to come. It is going to get warmer, the impacts will be large and expensive, and immediate action is critical to minimize them.
Polar research has been a central focus in the Ecosystems Center for many years. In 2007, with new co-director Hugh Ducklow’s move to MBL, Antarctica was added to the center’s research portfolio. The Palmer, Antarctica, Long Term Ecological Research (LTER) project is the third of 26 research sites in the U.S. LTER network hosted within the Ecosystems Center.

Since 1990, Palmer LTER has been investigating the intimate small- and large-scale links between climate, sea ice, and the Antarctic marine ecosystem. The Antarctic Peninsula is one of the most rapidly warming regions on Earth, having warmed in winter by 6°C (11°F) since 1950. This warming caused the spectacular collapse of the Larsen-B ice shelf in 2002 and is impacting the entire ecosystem from microbes to penguins.

In January of each year, Palmer LTER investigators Ducklow, Matthew Erickson, and Kristen Myers will join colleagues from Lamont Doherty Earth Observatory, Rutgers University, the Virginia Institute of Marine Science, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, and the Polar Oceans Research Group (Montana) for a six-week oceanographic research cruise aboard the U.S. Antarctic Program research vessel Laurence M. Gould. Their mission is to study the distributions and dynamics of sea ice, ocean circulation, primary production and grazing, ocean biogeochemistry, and seabird ecology.

Aboard the Gould, LTER scientists collect information on the vertical distributions of ocean temperature, salinity, nutrient concentrations, dissolved CO₂, rates of primary and bacterial production, krill abundance, and distributions of penguins and other seabirds on a grid of 55 hydrographic stations.

The grid extends from the coast over 200 kilometers to the open sea and over 400 kilometers north-south along the peninsula. The data thus constitute a valuable time series of 3-D views of ocean ecology in the Austral summer over the 1993-2008 period. Long-term data on sea ice extent and duration are collected from satellites.

The spectacular warming in the past half-century has caused almost a 90-day reduction in the duration of sea-ice cover west of the Peninsula. Most species of marine animals and plants, including phytoplankton, krill, fish, seals, whales, and seabirds, have life cycles attuned to the annual rhythm of sea ice advance and retreat. The reduction in sea ice interferes with the life cycles of ice-dependent species forcing them poleward and causing local extinctions. At the same time, subpolar species of seals and penguins have begun to expand their ranges southward, colonizing the Palmer region.

Climate change and ecosystem responses in polar regions are important sentinels of global change that provide opportunities for new understanding of the enormous transformation of our planet by modern civilization.

Ecosystems Center investigators seek a deeper understanding of the processes by which ecosystems across the planet are responding to unprecedented rates of climate warming, from the poles to New England and the rainforests of Brazil.
Earth and its component ecosystems are dominated by two vastly different sets of interacting processes — microbial and human. About half of global photosynthesis is carried out by microscopic phytoplankton in the sea, and most of the decomposition of organic matter back into CO\textsubscript{2} is by microbes. Within the past century, however, many processes on Earth have become dominated by human activities, and their impact is profound. Pollutant compounds pervade the global environment, even in the remotest polar regions and the deep sea. The human population and its social institutions are integral parts of the global environment and all its ecosystems. Human well-being depends on services provided by healthy ecosystems. These essential ecosystem services are degraded and threatened by our activities.

Better understanding of the effects of human impacts on the global environment is needed if we are to formulate effective policies to reverse their effects and manage ecosystems sustainably. The Earth is increasingly well-monitored by local-scale experiments, regional sensor networks and global satellite observations, but observations and experiments alone cannot provide a full understanding of the interactions and dynamics of human activities and ecosystems. Mathematical models of ecosystem processes like plant growth, nutrient cycling and microbial decomposition are powerful tools for testing our understanding and giving us whole-system views of the operation of global ecosystems.

Models are tested against our observations and once validated, can be used to project the outcome of complex feedback processes in the environment. The model described here is one example of the outcome of complicated ecological interactions and human impacts that could not be predicted from observations alone.
Predicting the Effects of Global Environmental Change

In just the 32 years since the founding of the Ecosystems Center, the Earth’s human population has increased by more than 60% — more than two and a half billion people. Accompanying this unprecedented increase in population has been a dramatic increase in industrialization, especially in the developing world. The pressure that this type of growth puts on local ecosystems has long been recognized and has led to legislation like the 1963 Clean Air Act and the 1972 Clean Water Act, aimed at reversing human impacts on the environment. The 1997 Kyoto Protocol and the 2007 Climate Change Conference in Bali — the “Bali Road Map” — have the same aims, but on a global scale.

Even if these efforts at remediation are successful, however, there have already been major changes to the global environment and further changes are inevitable. The Ecosystems Center’s Ed Rastetter and Gus Shaver, along with their colleagues at the Swedish Agricultural University, Stanford University, the University of Oregon, and the U.S. Environmental Protection Agency, have been developing computer models to examine how ecosystems around the world will respond to these changes in the global environment.

Effects of human activities include increasing atmospheric carbon dioxide (CO$_2$), acidification of rainfall and of the oceans, degradation of water quality, increased nitrogen deposition, and global climate change. These impacts are all fairly well understood and are slowly being addressed, at least in isolation from each other. Scientists, however, are just beginning to understand how ecosystems will respond together to all these changes in the global environment. Developing this understanding is a research focus at the Ecosystems Center where we are learning that ecosystem responses to global change are strongly constrained by interactions among the major biogeochemical cycles of essential resources, such as carbon, nitrogen, phosphorus, and water. The interactions among these cycles are far more complex than we at first appreciated.

Rastetter’s model is helping to unravel this complexity. The model is based on an economic analogy in which plants and microorganisms optimize the expenditure of their biotic assets to acquire resources from the environment in the proportions needed to sustain life and to maximize growth. For example, plants require carbon for growth and they can have several responses to elevated CO$_2$ concentrations. Because elevated CO$_2$ makes carbon acquisition easier, many plants reallocate their resources to become more efficient. They slow down leaf growth but increase root growth and thereby increase the uptake of soil nutrients. Within leaves, many plants will reallocate nitrogen from enzymes associated with carbon acquisition to enzymes associated with light capture. Natural selection should strongly favor species able to optimize their resource acquisition in this way.

“This perspective has changed our understanding of how ecosystems respond to global change,” says Rastetter. “For example, even though many ecosystems will sequester carbon rapidly when CO$_2$ concentration is first increased, the long-term rate of sequestration is far less than would be expected because the plants have to slow the rate of CO$_2$ uptake by photosynthesis to match the supply rate of other resources from the environment.”

Many scientists initially believed that the “CO$_2$ fertilization effect” would lead to increased removal of CO$_2$ from the atmosphere, but Rastetter’s model helps explain why this may not hold over the long term. Rastetter and his colleagues are also using the model to examine forest re-growth, for example, to assess the potential for carbon sequestration by planting forests. The rate of carbon sequestration is again tied to how fast other elements accumulate in the ecosystem. “Because of their association with nitrogen-fixing bacteria, some plants can pull nitrogen out of thin air,” says Rastetter, “but phosphorus presents a very different set of problems.”

Resolving these problems will go a long way toward answering the original question: Just how will the biosphere respond to human alterations of the major resource cycles?
Coastal zones face unprecedented pressure from population growth. Watersheds within 30 miles of the ocean support more than 50% of the world’s population, and this percentage is expected to increase dramatically in coming decades, threatening the environmental integrity of coastal ecosystems. The U.S. National Academy of Sciences reports that the greatest pollution threat facing the coastal marine environment comes from nitrogen and phosphorus. These nutrients, from septic tanks and fertilizer use, pollute bays and rivers, fuel algae growth, and smother marine life.

It is well known that the addition of fertilizers can improve crop yields, especially in areas with poor soils that lack either nitrogen or phosphorus. Up until 1910, fertilizer was largely mined or collected from animal waste. In 1910, however, the Haber-Bosch process was invented, which allowed nitrogen fertilizer to be produced from the abundant nitrogen gas in the atmosphere. As a result of widespread use of inexpensive fertilizers that the Industrial Revolution permitted, production of harvestable crops increased dramatically, but extensive fertilizer use has introduced a new problem for coastal environments.

As a fertilizer, nitrogen stimulates aquatic plant growth in the form of phytoplankton and seaweed. The microscopic phytoplankton grow directly in the water, turning it green or reddish brown, thereby blocking sunlight. The result is loss of submerged aquatic plants that provide beneficial habitats for shellfish and finfish alike. Even worse, when the overabundant phytoplankton and algae die, they sink to the bottom where they decompose, removing most or even all the oxygen from the water. This over-fertilization of aquatic environments is known as eutrophication, and is often the cause of fish kills and the loss of commercial and recreational fisheries.

Scientists at the Ecosystems Center are conducting research on ways to mitigate coastal eutrophication and thus restore our coastal zones in communities like Cape Cod, Massachusetts.

Because of their low cost, fertilizers are often used in excess. The nitrogen not consumed by plants makes its way to coastal environments via rivers and groundwater. Even if fertilizers are used sparingly, agricultural crops are exported to coastal communities for livestock and human consumption where the nitrogen is released as animal and human waste. Consequently, a significant fraction of the nitrogen we manufacture using the Haber-Bosch process ultimately makes it into coastal ecosystems.
To prevent nitrogen from reaching the coastal zone, and the eutrophication it causes, large cities install sewer systems that divert wastewater to treatment plants that remove excess nitrogen. In rural areas, the cost of sewering low-density housing is often prohibitively expensive, so septic systems are used that directly release nitrogen into the groundwater, significantly contributing to coastal eutrophication.

In Massachusetts, the effects of eutrophication have been well documented on Cape Cod, and the means to mitigate nitrogen loading are being actively pursued. Recently, Ecosystems Center scientists Joe Vallino and Ken Foreman, in collaboration with Pio Lombardo of Lombardo Associates, have been investigating the use of NITREX™ permeable reactive barriers (PRBs). The barriers are installed along the coast to intercept and remove nitrogen in groundwater before it discharges into coastal embayments. NITREX™ is made predominately from woodchips, which provide a source of food and energy for bacteria that convert nitrate (from fertilizers, wastewater and acid rain) into nitrogen gas that escapes back into the atmosphere in a process known as denitrification.

Vallino and his colleagues installed two pilot-scale PRBs along the beach at the head of Waquoit Bay and along the Childs River in Waquoit, a village of Falmouth, Massachusetts. Situating the PRBs along the beach ensures that all nitrogen in groundwater is intercepted; however, it also means the PRBs can be exposed to seawater during storms and other high tide events. Since PRBs have not been previously installed in coastal environments, our primary research question has focused on the effects of seawater on the bacteria that conduct denitrification.

After two years of monitoring the test PRBs following their installation, Vallino and Foreman have confirmed that the PRBs effectively remove groundwater nitrate. Furthermore, the intrusion of saltwater does not significantly degrade the performance of the PRBs. Ecosystems Center scientists are using the results of this research to convince coastal managers that PRBs are effective means of mitigating coastal eutrophication. Once they sufficiently demonstrate that PRBs work, they may be employed to improve water quality in coastal embayments on Cape Cod and elsewhere.

Recruiting Bacteria To Remove Nitrate from Groundwater Along the Coast

To prevent nitrogen from reaching the coastal zone, and the eutrophication it causes, large cities install sewer systems that divert wastewater to treatment plants that remove excess nitrogen. In rural areas, the cost of sewering low-density housing is often prohibitively expensive, so septic systems are used that directly release nitrogen into the groundwater, significantly contributing to coastal eutrophication.

In Massachusetts, the effects of eutrophication have been well documented on Cape Cod, and the means to mitigate nitrogen loading are being actively pursued. Recently, Ecosystems Center scientists Joe Vallino and Ken Foreman, in collaboration with Pio Lombardo of Lombardo Associates, have been investigating the use of NITREX™ permeable reactive barriers (PRBs). The barriers are installed along the coast to intercept and remove nitrogen in groundwater before it discharges into coastal embayments. NITREX™ is made predominately from woodchips, which provide a source of food and energy for bacteria that convert nitrate (from fertilizers, wastewater and acid rain) into nitrogen gas that escapes back into the atmosphere in a process known as denitrification.

Vallino and his colleagues installed two pilot-scale PRBs along the beach at the head of Waquoit Bay and along the Childs River in Waquoit, a village of Falmouth, Massachusetts. Situating the PRBs along the beach ensures that all nitrogen in groundwater is intercepted; however, it also means the PRBs can be exposed to seawater during storms and other high tide events. Since PRBs have not been previously installed in coastal environments, our primary research question has focused on the effects of seawater on the bacteria that conduct denitrification.

After two years of monitoring the test PRBs following their installation, Vallino and Foreman have confirmed that the PRBs effectively remove groundwater nitrate. Furthermore, the intrusion of saltwater does not significantly degrade the performance of the PRBs. Ecosystems Center scientists are using the results of this research to convince coastal managers that PRBs are effective means of mitigating coastal eutrophication. Once they sufficiently demonstrate that PRBs work, they may be employed to improve water quality in coastal embayments on Cape Cod and elsewhere.
Semester in Environmental Science

Since 1997, the Ecosystems Center has sponsored the Semester in Environmental Science (SES), an academic fall semester, off-campus program for undergraduates. The curriculum provides an intensive field and lab-based introduction to ecosystems science and the biogeochemistry of coastal forests, freshwater ponds and estuaries.

Scientists at the Ecosystems Center serve as faculty for the program. In addition to teaching fundamentals of ecosystems science, they discuss their current research, which touches on important issues of global change including deforestation and urbanization, over-exploitation of resources such as fish and timber, climate change and disruption or alteration of major element cycles. In the lab and the field, students learn first-hand how these global changes are affecting ecosystems on Cape Cod.

The curriculum of structured core courses and electives leads students to develop research questions of their own. Equipped with new knowledge and techniques learned in the first nine weeks of the semester, they pursue independent research during the last six weeks of the program. They report on their findings at a final symposium that is open to the entire Woods Hole scientific community.

To date, 166 students have completed the program. SES alumni are making an ever-larger contribution to the field of environmental science and policy. About half the students eventually go on to professional or graduate school.
SES alums have won a number of significant awards for their work. Most recently, Marselle Alexander-Ozinkas (SES ’03, Bates College ’05) received a NOAA Knauss Fellowship in marine policy. Amanda Spivak (SES ’99, Bryn Mawr College ’01) was honored with the Matthew Fontaine Maury Fellowship Award in 2006 for outstanding graduate work at Virginia Institute of Marine Science. Carmody McCalley (SES ’01, Middlebury College ’03) won the Billings award at the national Ecological Society of America (ESA) meeting in 2006 for her work in the Mojave Desert soils. Carmody is the second SES alum to have received a major award at the ESA in the past four years.

In December 2007, the Davis Educational Foundation awarded SES a three-year grant of $290,000, in part to re-establish our faculty fellowship program. The fellowship will allow a faculty member on sabbatical from a school within the MBL Consortium in Environmental Science, comprised of schools that have approved the SES program for credit, to come to Woods Hole during the fall semester. Fellows are free to develop new ideas, write papers, and conduct research with Ecosystems Center scientists and other colleagues in Woods Hole.

In the past, these visiting fellowships and sabbatical experiences have been enormously successful in fostering collaboration in research and teaching. For example, Peter Siver (Connecticut College, sabbatical at MBL in 1997) successfully developed a joint Research in Undergraduate Institutions (RUI) grant with Anne Giblin of the Ecosystems Center to use a paleolimnological approach to assess the interactive effects of acid deposition and eutrophication in softwater lakes. Tom Millette (Mount Holyoke College, sabbatical at MBL in 1999), a geographer, continues to collaborate with center investigators working on the Plum Island Ecosystems Long Term Ecological Research project on ways to assess sea level rise using remote sensing. In collaboration with center scientist/SES faculty member Linda Deegan, Sallie Sheldon (Middlebury College, sabbatical at MBL in 2001) obtained a NSF-RUI grant that has fostered research opportunities for Middlebury students at the Plum Island LTER. John Hobbie, (Senior Scholar at the Ecosystems Center) and Howard Drossman (Colorado College, sabbatical at MBL in 2005) received NSF funding to study the role of fungi in nutrient cycling in tundra soils.

Altogether, six faculty fellows from consortium schools have spent at least a semester at MBL, and these sabbatical leaves have resulted in 17 scholarly papers and abstracts and submission of seven research grants. Faculty members from the colleges have returned to their institutions energized with new research and teaching ideas, and have encouraged their students to participate in the SES. This fellowship program has helped strengthen the bonds between the Ecosystems Center and colleges and universities within the MBL Consortium in Environmental Science. With the funds provided by the new grant, we will be able to offer this fellowship for the next three years.

For more information about the SES program, please go to the website, http://courses.mbl.edu/SES/. 
Other Educational Programs

The Ecosystems Center is actively involved in education in a variety of ways. In addition to teaching in the Semester in Environmental Science, center scientists serve as adjunct professors and advisors in the Brown University-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.

Brown-MBL Graduate Program in Biological and Environmental Sciences

Graduate students work with Ecosystems Center scientists in the MBL’s graduate program with Brown University. Gillian Galford is studying regional and global consequences of the expansion of mechanized agriculture in the Brazilian Amazon with Jerry Melillo of the Ecosystems Center and Jack Mustard of Brown. She is lead author of an article to be published in Remote Sensing of Environment on the results of a Brown-MBL study, conducted by Gillian and Jerry, John Mustard and Aline Gendrin, both of Brown, and Carlos C. Cerri and Carlos E.P. Cerri, both of Universidade de São Paulo, to track the transformation of forested land to agricultural cropland through space and time.

Angela Allen’s research focuses on understanding the nutrient dynamics of aquatic ecosystems in the context of global climate change. Her advisors are Bruce Peterson of the Ecosystems Center and Osvaldo Sala from Brown. Seeta Sisla works with Melillo and Sala on estimating the contribution of root respiration to total soil carbon dioxide outflow in a temperate forest ecosystem.

Shelby Hayhoe is looking at the effect of land use change on biogeochemical cycling in tropical systems, focusing on agricultural conversion in the Amazon. Her advisors are Christopher Neill of the Ecosystems Center and Stephen Porder from Brown.

Marselle Alexander-Ozinskas completed her Master’s degree in 2007. Her research was on the effects of topography, landscape age, and climate change on biogeochemical nitrogen cycling in the arctic and other arid ecosystems with Gus Shaver of the center and Osvaldo Sala of Brown. She has been selected for a National Sea Grant College Program Dean John A. Knauss Marine Policy Fellowship in 2008. She will work in Washington, D.C., in the office of Guam delegate Congresswoman Madeleine Bordallo, a member of the House Committee on Natural Resources and chairwoman of Subcommittee on Fisheries, Wildlife and Oceans. Marselle completed the Ecosystems Center’s Semester in Environmental Science in 2003.

Kristen Myers and Yawei Luo transferred into the Brown-MBL program from the College of William and Mary when their advisor Hugh Ducklow moved to the Ecosystems Center in May. Kristen is doing her Ph.D. research on bacterial community structure in coastal Antarctica with Ducklow and Brown co-advisor Jeremy Rich. Yawei’s research with Ducklow and Warren Prell from Brown uses numerical simulation models to study plankton dynamics and nutrient cycling, with emphasis on the open ocean.
Undergraduate Internships

With funding from the National Science Foundation (NSF) and other groups, the Ecosystems Center has offered many college students the opportunity to undertake summer projects at research sites. In 2007, undergraduates conducted research projects through NSF’s Research Experience for Undergraduate program. Their projects ranged from a study on the effects of fish and nutrient removal on invertebrates and birds at the Plum Island estuary in northern Massachusetts to a study of denitrification in the Arctic tundra in Alaska to a study of the effects of climate change on the Antarctic Peninsula.

Schoolyard Long-Term Ecological Research Projects

In 2007, the three MBL–based Long Term Ecological Research (LTER) projects again received supplemental funding from NSF to promote educational activities near their sites.

The Arctic Schoolyard LTER is based at Barrow, Alaska, and designed for students, mostly Native American Inupiat, their teachers and local residents. It consists of “Schoolyard Saturday,” a weekly series of lectures and field demonstrations by visiting scientists, and two field activities for Barrow students and teachers. One field experiment measures the effects of climate warming on tundra vegetation; the second experiment measures changes in lake water chemistry.

A major component of the Plum Island Ecosystem (PIE) Schoolyard LTER is a project conducted with the Massachusetts Audubon Society’s Salt Marsh Science Program. This project provides environmental education to more than 700 middle and high school students in the coastal region of northeastern Massachusetts by engaging them in salt marsh research near their homes. Through an additional educational effort, led by Governor’s Academy in Rowley, school students study the distribution of plants and animals at PIE field sites and maintain a long-term database.

The Palmer Station LTER collaborates with a number of educational organizations to create interdisciplinary projects that are based on research by Palmer scientists. Palmer’s program participates in several International Polar Year (IPY) projects, which include video and audio podcasts and a web-based Picture of the Day from their annual research expedition. A children’s book, another IPY project, will be accompanied by an activity guide expanding the concepts in the book to reach a wider audience.

Science Journalism Program

The Ecosystems Center has participated in the MBL’s Science Journalism Program since its inception in 1986. Journalists attend a hands-on training course in ecology in Woods Hole in June, directed by Chris Neill and Ken Foreman. In 2007 the journalists were Anne Bolen, managing editor of *GeoTimes*; Peter Thomson, acting senior producer of Public Radio International’s *Living on Earth*; Andrea Cross, freelance writer; Richard Friebe, *Frankfurter Allgemeine Zeitung* (Germany); Jude Isabella, *YES! Magazine*; Rosanne Skirble, *Voice of America*. Bolen and Thomson spent two weeks at the Ecosystems Center’s Long Term Ecological Research site at Toolik Lake, Alaska, escorted by the project’s principal investigator, John Hobbie. The writers took part in experiments in the streams, lakes and tundra, and interviewed scientists about their research and arctic warming.

Science Outreach in the Community

In 2007, members of the Ecosystems Center staff judged community and state science fairs for students in kindergarten through grade 12 and mentored junior high school students. The center also participated in the Woods Hole Science and Technology Education Partnership, providing assistance to teachers and students in the local school systems. Center scientists and staff helped plan and build the Village Science Playground at Mullen-Hall School in Falmouth, Massachusetts.

Ecosystems Center staff members serve on many town committees, including the Falmouth Planning Board and Falmouth Conservation Commission, Falmouth Associations Concerned with Estuaries and Salt Ponds, the Association to Preserve Cape Cod, the Falmouth Coastal Resources working group, the Nutrient Management working group and the Falmouth Ashumet Plume Nitrogen-Offset Committee.

Andrew Gaylord and Abigail Toltin, interns in the Research Experience for Undergraduate program, prepare sediment trap samples for elemental analysis. The samples are from Maureen Conte’s Oceanic Flux Program, which comprises 30 years of particle flux observation in the deep Sargasso Sea. (Photo: Tom Kleindinst)

Above: Vera Simmonds, a Barrow, Alaska, High School student, monitors plots in the tundra warming experiment of the Arctic Schoolyard Long Term Ecological Research Project. (Photo: Leslie Pierce)
Hugh Ducklow joined the Ecosystems Center in May, succeeding John Hobbie as co-director. Hugh was the Glucksman Professor of Marine Science at the Virginia Institute of Marine Science (VIMS) at the College of William and Mary. His research centers on the interactions between climate change and ecosystem function, especially on the Antarctic Peninsula, where he is lead principal investigator on the Palmer Long Term Ecological Research project. Hugh has two graduate students, Kristen Myers and Yawei Luo, who transferred from the College of William and Mary into the Brown-MBL program.

Two scientists, Zoe G. Cardon of the University of Connecticut and Jianwu (Jim) Tang of the Chicago Botanic Garden, will join the Ecosystems Center staff in 2008.

Zoe Cardon, a terrestrial ecologist and senior scientist, is a nationally recognized ecologist, with expertise in plant physiological ecology and plant-rhizosphere (the interface between roots and soil) interactions. She will collaborate with the MBL’s Bay Paul Center in the Micro-Eco Interface, an initiative that will bridge research of the Ecosystems and Bay Paul Centers.

Zoe comes to the Ecosystems Center from the Department of Ecology and Evolution at the University of Connecticut where she was an associate professor as well as associate director of the university’s Center for Integrative GeoSciences. She spent fall 2003 on sabbatical at the Ecosystems Center and has been an adjunct scientist on the staff since 2006. Zoe received her Ph.D. from Stanford University and her undergraduate degrees in biology and Spanish from Utah State University.

Jim Tang is a soil ecologist and assistant scientist, studying the impact of climate change on ecosystem processes and functions and the feedback of terrestrial ecosystems to climate change. He has developed a novel carbon flux measurement system to simulate carbon and water exchange between terrestrial ecosystems and the atmosphere across various scales.

Jim received his Ph.D. from the University of California, Berkeley, and his undergraduate and master’s degrees from Beijing University in China. He has been at the Chicago Botanic Garden and an adjunct associate professor of biological sciences at Northwestern University.

Charles (Chuck) Hopkinson left the Ecosystems Center at the end of December to become director of the Georgia Sea Grant Program. Chuck started his career at the University of Georgia in 1979 as assistant marine scientist, spent a year at Askö Laboratory, University of Stockholm in 1988, then joined the Ecosystems Center in 1989 as assistant scientist. He was promoted to senior scientist in 1997.

At the center, Chuck was lead principal investigator on the Land Margin Ecosystems Research project at Plum Island Sound, which later became the Plum Island Ecosystems Long Term Ecological Research (PIE LTER) site. Anne Giblin will take over as lead investigator on the PIE LTER.
Ecosystems Center scientists serve on national-level planning committees for science initiatives, on boards and as officers of scientific societies, and as conveners of professional conferences.

**Gus Shaver** organized a symposium, Ecological Foundations of Sustainability in a Constantly Changing World, at the Ecological Society of America (ESA)’s annual meeting. Gus ended his term as ESA’s vice president for science in 2007. Gus was also plenary speaker at the International Workshop on High Latitude Terrestrial and Freshwater Ecosystems in Abisko, Sweden.

**Hugh Ducklow** gave the opening keynote address, “Microbial ecology and the challenge of sustainability,” at the 10th Symposium on Aquatic Microbial Ecology in Faro, Portugal.

**John Hobbie** was chair of a National Research Council committee that met to explore how the U.S. should undertake studies of lakes recently discovered beneath the four-kilometer thick Antarctic ice sheet.

Long Term Ecological Research (LTER) executive committee member **Chuck Hopkinson** co-organized a symposium to inform National Science Foundation (NSF) and other federal agencies of the coupled human and natural systems research being conducted within LTER network.

**Joe Vallino** organized a session at the American Society of Limnology and Oceanography meeting on aquatic ecosystem models. He also participated in the LTER National Network’s decadal planning study.

**Ed Rastetter** serves on the Global Change Experiment Committee of the National Ecological Observatory Network. **Anne Giblin** served on the steering committee of the Estuarine Research Federation’s annual meeting.

**Jerry Melillo** was inducted into the American Academy of Arts and Sciences in 2007. The academy recognized Jerry for his work on soil biogeochemistry, global modeling and applying science to climate policy. Jerry served as the vice chair of the Northeast Climate Impacts Assessment, a project coordinated by the Union of Concerned Scientists. The project report was issued in July and is available at http://www.northeastclimateimpacts.org.

**Linda Deegan** and **Chris Neill** were Fulbright fellows in Brazil at the University of São Paulo. The fellowships were co-sponsored by the Council for the International Exchange of Scholars in the U.S. and by the Research Foundation of the State of São Paulo.

Linda and Chris were also noted in the Scientists and Thinkers category of Cape Cod Life’s 400 People Who Make a Difference issue.

**Ivan Valiela** was appointed Adjunct Scientist at the center and was named 2007 Wiese Distinguished lecturer at the Dauphin Island Sea Laboratory.

**In the News**

**Joe Vallino** and **Ken Foreman** were interviewed by National Public Radio’s Cape and Islands station on their research project that examines the use of permeable reactive barriers for removing nitrate from groundwater.

**Hugh Ducklow** was featured in the Cape Cod Times’ article on species that are dying off due to climate change in Antarctica. Hugh was also quoted in a Washington Post article on global warming in the polar regions.
Publications 2007


Maureen Conte walks along a canopy walkway high above the rain forest floor near the Nouragues field camp in French Guiana. (Photo: JC Weber)


**January**

9 William McDowell, University of New Hampshire, “Biogeochemistry of suburban basins: Putting people into the landscape.”

30 Paul Colinvaux, MBL, “History of the Amazon forest: The disproval of the refuge hypothesis and the consequent problem of diversity.”

**February**

13 Lauren Mathews, Worcester Polytechnic Institute, “Cryptic biodiversity and phylogeographic patterns in a snapping shrimp species complex.”

20 Ivan Valiela, Boston University, “Macroalgal blooms: control mechanisms in Venice Lagoon and the coasts of the world.”

27 Mirta Teichberg, Boston University, “Local and global comparisons on macroalgal response to nutrient enrichment.”

**March**

6 Stephen Porder, Brown University, “What do chronosequences tell us about ecosystems?”

13 Georgia Carvalho, Woods Hole Research Center, “A comparison of land use policies in Bolivia, Brazil, Peru and Colombia: Opportunities for conservation in the Amazon.”

20 Jen Culbertson, Boston University, “Effects of chronic petroleum hydrocarbon exposure on salt marsh grass biomass.”

27 Shufen Ma, University of Delaware, “Using voltammetric solid-state microelectrodes for the analysis of chemical speciation in a variety of sediment and water environments.”

**April**

3 Steve d’Hondt, University of Rhode Island, “Microbial activities in deep subseafloor sediments.”

10 Jennifer Jenkins, University of Vermont, “The biochemistry of suburbia: Controls on carbon cycling in residential systems.”

**May**

1 Ylva Olsen, Boston University, “Experimental manipulation of sediment nutrient concentrations and grazing on a tropical seagrass meadow in Jobos Bay, Puerto Rico.”

8 Maureen Conte, Bermuda Institute of Ocean Sciences/MBL, “Assessing large-scale regional and temporal patterns of terrestrial ecosystem discrimination using molecular tracers in continental aerosols.”

15 Heidi Geisz, Virginia Institute of Marine Sciences, “Current levels and long-term trends of persistent organic pollutants in seabirds breeding in Antarctica.”

**June**

26 Zoe Cardon, University of Connecticut, “Resource exchange in the rhizosphere: Life in the swoosh and ooze.”

**July**

14 Mike Behrenfeld,* Oregon State University, “New insights into global ocean primary production.”

28 Tim Fahey,* Cornell University, “Energy Supply for the below-ground community.”

**August**

17 Arthur Gold, University of Rhode Island, “Small town science: Constraints and successes in ecosystem management.”

24 Sophia Fox, Boston University, “The relative role of bottom-up and top-down controls on macrophyte and consumer community structure in Waquoit Bay, Massachusetts.”

**September**

10 Jennifer Jenkins, University of Vermont, “The biochemistry of suburbia: Controls on carbon cycling in residential systems.”

**October**

2 Hugh Ducklow, MBL, “Particle export and microbial activity at Palmer Station, Antarctica.”

16 Michael Allen, University of California, Riverside, “Mycorrhizae and C/N dynamics in semiarid ecosystems: Integrating rapid sensor, pattern analysis, and isotopic data.”

**November**

2 Kristina Sundback,* Göteborg University, Sweden. “Role of benthic microalgae in nutrient cycling and resilience in shallow water sediment systems.”

27 Anne Giblin, MBL, “Nitrogen cycling in a dammed estuary: Lessons from the Parker River.”

**December**


11 Joe Vallino, MBL, “Use of the maximum entropy production principle for modeling microbial biogeochemistry.”

18 Gus Shaver, MBL, “Changing views of a changing Arctic tundra.”

* SES Distinguished Scientist Seminar Series
Hugh W. Ducklow  
Senior Scientist,  
Co-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.

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.

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.

Charles S. Hopkinson  
Senior Scientist  
Ph.D., Louisiana State University  
Chuck’s work focuses on the coastal zone, examining the effects of climate change, land use change and sea level rise on estuaries and continental shelves and the ecosystem services they provide.

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.

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.
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.

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.

Zoe G. Cardon  
University of Connecticut  
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.

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

Maureen’s research specialty 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.

Ivan Valiela  
Boston University Marine Program  
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.
Jennifer S. Barkman  
Research Assistant  
B.S., Auburn University

Dorothy J. Berthel  
Administrative Assistant

Donald W. Burnette  
Research Assistant  
M.S., Southern Illinois University

Sarah M. Butler  
Research Assistant  
M.S., University of Maine

Timothy Cronin  
Research Assistant  
B.A., Swarthmore College

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

Benjamin Felzer  
Research Associate  
Ph.D., Brown University

Sophia E. Fox  
Postdoctoral Scientist in Residence  
Ph.D., Boston University

Clara S. Funk  
Research Assistant  
B.A., Wesleyan University

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

Melanie Hayn  
Research Assistant  
B.S., Cornell University

Kelly R. Holzworth  
Research Administrator  
University of San Diego

Jennifer E. Johnson  
Research Assistant  
B.A., Swarthmore College

Samuel W. Kelsey  
Research Assistant  
B.S., Dickinson College

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

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

Brown-MBL Graduate Program in Biological and Environmental Sciences

Marselle Alexander-Ozinskas
B.S., Bates College

Angela Allen
M.S., University of Rhode Island

Gillian L. Galford
B.A., Washington University

Yawei Luo
M.S., Peking University

Shelby Hayhoe
B.A., Grinnell College

Kristen M. S. Myers
B.A., College of William and Mary

Seeta Sistla
B.A., Swarthmore College

Visiting Graduate Students

Neil Bettez
Cornell University
M.S., University of North Carolina, Greensboro

Lindsay D. Brin
Boston University Marine Program
B.A., Swarthmore College

Erin L. Kinney
Boston University Marine Program
B.A., Dartmouth College

Ketil Koop-Jakobsen
Boston University Marine Program
M.S., Roskilde University, Denmark

Ylva Olsen
Boston University Marine Program
M.S., University of Plymouth, UK

Consultants

Francis P. Bowles, Research Systems Consultant
Alina S. Cushing
Heidi Golden

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

Staff who left in 2007

Jennifer L. Bowen, Teaching Fellow, Princeton University
Joaquin E. Chaves, Post-doctoral Associate, Brown University
Suzanne J. Donovan, Freelance Graphic Designer
Deanne C. Drake, Research Scientist, National Institute for Water and Atmospheric Research, New Zealand
Robert C. Hanifin, Biological Science Technician, U. S. Department of Agriculture, Davis, California
Lora A. Harris, Assistant Professor, Chesapeake Biological Laboratory, University of Maryland
W. McDonald Lee, Laboratory Specialist, Virginia Commonwealth University
Katherine J. Lenoir, Graduate Student, Boston University
Jacqueline E. Mohan, Assistant Professor, University of Georgia
Christian R. Picard, Biologist, Springborn Smithers Laboratories, Wareham, Massachusetts
Laura E. Wittman, Graduate Student, Duke University
Sources of Support for Research and Education

The annual operating budget of the Ecosystems Center for 2007 was $7,040,000. Approximately 78% 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 22% 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 2007 was $5,600,000. 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 the following corporations and foundations over the past five years:

Arthur Vining Davis Foundation
Blum-Kovler Foundation, Inc.
The Clowes Fund, Inc.
ExxonMobil Foundation
Harken Foundation
Horizon Foundation, Inc.
The Kohlberg Foundation, Inc.
Massachusetts Environmental Trust
The Andrew W. Mellon Foundation
The Harold Whitworth Pierce Charitable Trust
The Starr Foundation

Ecosystems Center scientists study the effect of land use, such as farming, on the transport of materials in streams such as this at Long Meadow Brook, Appleton Farms, Ipswich, Massachusetts (Photo: Kate Morkeski)