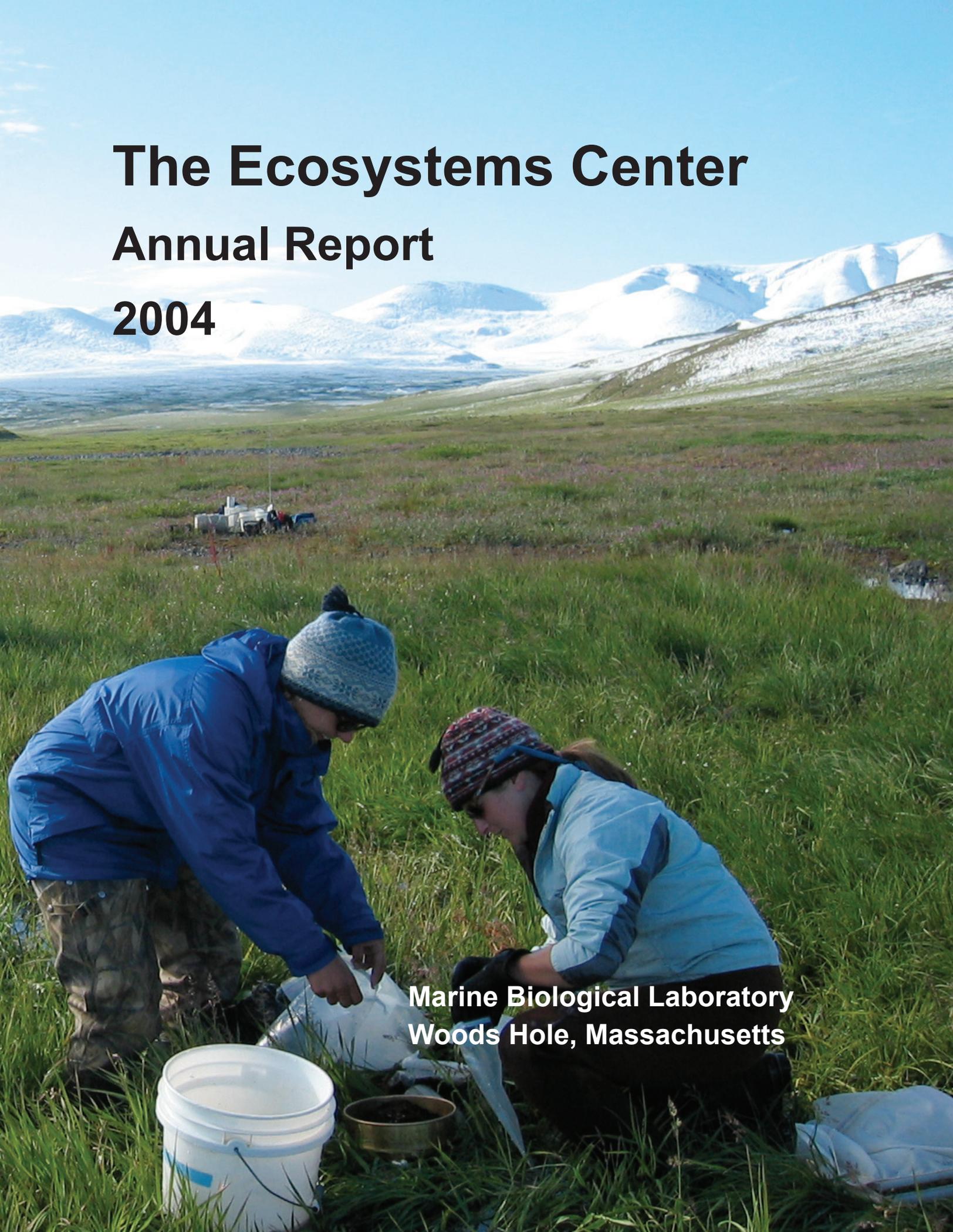


The Ecosystems Center Annual Report 2004

A photograph of two researchers in a field. One researcher is wearing a blue jacket and a grey knit hat, and the other is wearing a light blue jacket and a colorful knit hat. They are both leaning over, working with a white bucket and a small metal bowl on the ground. In the background, there are rolling green hills with patches of snow, and a small white structure is visible in the distance under a clear blue sky.

**Marine Biological Laboratory
Woods Hole, Massachusetts**

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Editor-in-chief: John E. Hobbie
Managing Editor: Deborah G. Scanlon
Printed by: Command Print Solutions, Inc.
Graphics by: Members of The Ecosystems Center staff
Consulting Editor: Martha R. Downs
Designed by: Suzanne J. Donovan

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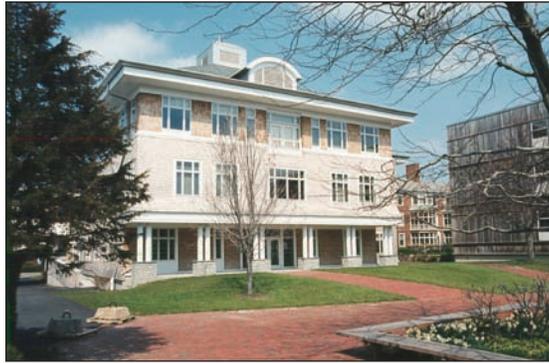
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Introduction to The Ecosystems Center



C.V. Starr Environmental Sciences Building, home of The Ecosystems Center since 2001.

The Ecosystems Center was founded in 1975 as a year-round research program of the Marine Biological Laboratory (MBL). Its mission is to investigate the structure and functioning of ecological systems and to predict their response to changing environmental conditions, to apply the resulting knowledge to the preservation and management of natural resources, and to educate both future scientists and concerned citizens.

The center operates as a collegial association of scientists under the leadership of co-directors John Hobbie and Jerry Melillo. Because the complex nature of modern ecosystems research requires a multidisciplinary and collaborative approach, center scientists work together on projects, as well as 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 questions at field sites ranging from Arctic Alaska, Sweden and Russia to Brazil, from the temperate forests of New England to the estuaries of the eastern United States.

- At the Arctic Long-Term Ecological Research (LTER) site at Toolik Lake in the foothills region of Alaska's North Slope, Ecosystems Center scientists study the effects of warmer temperatures on Arctic ecosystems. Will an increase in the depth of thaw in the permafrost 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 Ecosystem LTER site in northern Massachusetts, researchers ask how changes in rural land use and urban development affect the flow of nutrients and organic matter into New England estuaries. How will they alter the food web and plant growth in coastal waters? What happens to the production of commercially valuable fish as a result?
- In Brazil, scientists investigate the degree to which the clearing of tropical forests in the western Amazon changes the amount of greenhouse gases, such as carbon dioxide and nitrous oxide, that are 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?
- On the continental shelf and slope of the East Coast, scientists study the chemical composition of dissolved organic matter in marine environments. How does it affect our understanding of how and why carbon is stored?
- Studies by center scientists have shown increased freshwater discharge from the Arctic Rivers in Eurasia. If ocean circulation is affected, how might the climate in western Europe 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?
- In virtually all areas of study at The Ecosystems Center, scientists use mathematical models to simulate ecosystem structure and function and to make predictions. Over the next 100 years, will Arctic ecosystems store or release more carbon? In the year 2101, what is the projected deforestation in a coastal New England watershed?
- Computer models at the center are also used to ask questions about the effects of future changes in climate, carbon dioxide and ozone on vegetation productivity and carbon storage world-wide. These models are run at a spatial scale of half degree of latitude and half degree of longitude.

The Ecosystems Center staff currently includes 11 principal investigators and 48 research and administrative staff members. The annual operating budget for 2004 was \$9.1 million. Although research programs are funded primarily by grants from federal and state agencies, additional support for research and education comes from private foundations, corporations and individual donors.

Facilities at The Ecosystems Center include mass spectrometers for stable isotope analysis, chemical analytical laboratories and experimental chambers. Center staff also makes extensive use of the DNA sequencing facilities at the MBL's Josephine Bay Paul Center for Comparative Molecular Biology and Evolution.

In 2003, the MBL and Brown University established a joint Graduate Program in Biological and Environmental Sciences.

Ecosystems Center scientists hold formal appointments at Brown, and graduate students conduct research at both institutions. Brown also joined the Semester in Environmental Science (SES) consortium, allowing Brown students to enroll in SES, The Ecosystems Center's undergraduate educational venture. The program, launched in the fall of 1997, brings undergraduates from a consortium of 60 liberal arts colleges and universities to the MBL campus for an intensive introduction to environmental sciences from the perspective of ecosystem ecology.



Chris Crockett takes water from Toolik Lake, Alaska, to incubate samples at the LTER site.

One of the important reasons for conducting basic research in ecology is the development of a sound foundation for environmental policy and management. Center scientists are actively involved in the application of scientific knowledge to the solution of environmental problems in a variety of ways, including briefing federal and state legislators and administrators, advising resource managers and serving on committees responsible for formulating policy and coordinating research. Researchers also work with non-governmental organizations and government agencies on assessing the impact of development on ecosystems or evaluating the success of various approaches to resource management.

Research Articles: An Overview

The research articles in this year's report focus on the theme of human-related disturbance to ecosystems from two perspectives: consequences and response strategies. In a set of three articles, our scientists report on the consequences of these disturbances on Arctic lakes, temperate forests and tropical rainforests. In two other articles, center scientists describe their research on possible management and restoration strategies for the human-dominated ecosystems of New England.

The human-related disturbances discussed in this year's report are climate change, land-cover and land-use change, and disruption of the nitrogen cycle. The Earth's climate system continues to warm, with global mean surface temperature expected to increase between 1.4 and 5.8°C by the end of the 21st century. This warming and other climate changes are likely to cause functional and structural changes in ecosystems. Functional changes may include changes in the rates of plant production and the cycling of nutrients; structural changes could mean new mixes of plant species.

Center researchers working at Toolik Lake, Alaska, and at the Harvard Forest in central Massachusetts report how they use large field experiments to study the possible functional and structural consequences of climate change. In the Arctic, climate warming sets off a cascade of ecological impacts. When permafrost begins to thaw, soil material that was frozen for many thousands of years begins to weather, releasing phosphate nutrients. Eventually, more nutrients will enter streams and lakes. While nutrients have been added to Arctic lakes in the past, Anne Giblin, Marcus Gay, Ian Washbourne of the center and Gretchen Gettel of Cornell University have carried out an experiment that looks at the impact of nutrients on shallow Arctic lakes versus deep Arctic lakes. In the article titled "Production in Arctic Lakes: Not Just How Much but Where?" Anne discusses how benthic algal productivity, the largest part of lake productivity in the Arctic, is reduced in deep and enhanced in shallow lakes. Productivity was not a linear response to added nutrients.

The article titled "New England's Forests: What Role Does Species Composition Play in Future Carbon Storage?" describes the work

of Ecosystems Center scientists Jackie Mohan, Jerry Melillo, Joe Blanchard, Paul Steudler, center consultant Frank Bowles, and Harvard University scientist Fakhri Bazzaz on the effects of a long-term soil warming experiment on tree species. The remarkable outcome of the experiment was that the dominant red oak trees were being replaced by slower-growing species in the forest understory. The long-term consequence of this change is that forests of the future will be dominated by a new combination of tree species and that these ecosystems may sequester carbon from the atmosphere slower than today's forests, thus leading to a more rapid climate change.

Today, some of the most dramatic land-cover and land-use changes are occurring in the new-world tropics. In the Amazon Basin, forest and savanna areas are being cleared to make way for cattle pastures and mechanized agriculture to cultivate soybean, rice, corn and other lucrative cash crops. These changes affect the ways in which the land is coupled to the atmosphere and freshwaters. Linda Deegan, Chris Neill and Christie Hauptert, all from the center, examine how the conversion of forests to pastures affects stream transport of nutrients. Their article, titled "Land-Use Change: Effects on Nutrient Transport Processes in Amazonian Streams," discusses how the size of the streams relates to export or storage of nitrogen. They also consider the implications of their findings on nitrogen export from the Amazon River. Their study makes use of an experiment in which ¹⁵N-ammonium is continuously added to a stream to measure the nitrogen cycle.

Over the past century, humans have more than doubled the amount of reactive nitrogen that cycles through the biosphere. This doubling is associated with the use of nitrogen fertilizer in agriculture, the planting of leguminous crops and the burning of fossil fuels at high temperature that produces oxides of nitrogen. The reactive nitrogen moves through the environment and creates a host of problems including those associated with nitrogen-enriched groundwater. In the coastal zone, this nitrogen-enriched groundwater flows to coastal estuaries, where it causes algal blooms, reductions in oxygen levels in the water column,



HEDI LUX

Soil warming experimental plots in late winter at Harvard Forest LTER in central Massachusetts.

the destruction of plant habitat and fish kills. The nitrogen in the groundwater is in the form of nitrate from the treatment of wastewater. One way that resource managers may be able to remove nitrate from the groundwater, and thus reduce coastal eutrophication, is to set up belowground, permeable barriers through which the groundwater flows. Within the barriers, the nitrate is changed by bacteria to inert nitrogen gas. Joe Vallino and Ken Foreman of The Ecosystems Center describe their tests of the barrier method on Cape Cod in an article titled “Reactive Barriers: A Nitrogen Shield for Coastal Systems?”

The final article reports on attempts to manage a different type of impact on ecosystems. Sandplain grassland and heathland along the coast of New England are rare habitats that support high biotic diversity. What is the best strategy for managers to use to maintain this habitat now that fire is suppressed and sheep grazing has ended? In their article titled “Maintaining Threatened Ecosystems: Better Information Eases Hard Choices,” Chris Neill,

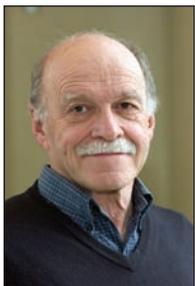
Ann Lezberg and Richard McHorney report on the results of mechanical clearing as a restoration tool and the possible unintended impacts on the nitrogen in groundwater.

Efforts such as this study on Martha’s Vineyard and the nitrogen barrier project on Cape Cod that test ways to mitigate some of the effects of human-related disturbances are important steps in applying knowledge of ecosystems to environmental problems. Equally essential to the goals of The Ecosystems Center are the research projects that provide the understanding of ecosystem processes throughout the world, such as that on algal production in Arctic lakes, or the projects that assess the consequences of human disturbance, such as the conversion of forest to pasture in the Amazon and the warming of forest soils in New England.

The signs of human activities are all pervasive in ecosystems from the Arctic to the Amazon. Predicting impacts of these activities and devising mitigation requires knowledge of the mechanisms of ecosystems that comes from basic research.

From the Directors:

Molecular Techniques, Microbial Ecology and Ecosystems



John Hobbie



Jerry Melillo

Microbes are the least known of all the players in the web of an ecosystem. Yet they are essential to ecosystems; without microbes, organic matter would not decompose and nutrients like nitrogen and phosphorus would not be recycled. All ecosystems

would come to a halt. To predict what ecosystems will look like in the future, we have to know how microbes operate now and how they will respond to changes in climate, nutrients and biota. If future conditions are wetter than the present, for example, then a reduced fungal decomposition would lead to more storage of carbon in the soil.

At the MBL, scientists and staff of The Ecosystems Center interact with the Bay Paul Center, where molecular biology methods at the forefront of science are used to study microbial diversity, evolution and underlying mechanisms of biomedical importance.

The Bay Paul Center is also fostering a project, led by David Patterson, for internet-based documentation of the diversity of microbes based on their microscopic appearance. For the very small bacteria of the plankton, the microscope shows only a few shapes (Figure 1), but in reality, hundreds or thousands of species of bacteria could have the same shape. Microscopic images are more helpful for studying diversity of the larger planktonic protists (Figure 2) that consume bacteria and of the large cyanobacteria (Figure 3) that carry out photosynthesis near the surface of salt marsh sediments.

Over the past decade, methods to study the ecology of microbes have been revolutionized. Scientists have adapted methods of molecular biology used for laboratory cultures to study complex communities from soil and water (Figure 1). These methods use the nuclear material found in cells, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), which together control the formation of proteins. The question is, Do the new methods produce the understanding that ecosystem scientists need in order to predict how microbial organisms function?

The answer is, almost. Tremendous advances in techniques have made the methods of molecular

biology easier and easier to apply. The DNA-based information about microbes in soil and water is flooding in. But the information from DNA is about the metabolic capabilities of bacteria. It is known that most of the bacteria in water and soils are inactive and are not expressing these metabolic capabilities at any given time. Ecosystem science needs to know the next step: which microbes are active and which biogeochemical processes they are actually carrying out. This information will come from RNA measurements, and here the methods and information are just beginning to flow.

Before these new methods were developed, ecosystem scientists could measure microbial processes, including decomposition, the oxidation of ammonia and bacterial growth, but they were unable to link the processes with the microbes. It was as if scientists were dealing with a black box that could not be opened. In the case of a few specialized microbes, such as those that reduce sulfate to hydrogen sulfide in marine sediments, bacteria could be grown in culture and identified. But even here there was no way to know if the cultured species represented one percent or 99 percent of the species actually carrying out the process in nature.

The first molecular tool that ecologists have successfully employed is based on the makeup of genes in a molecule of bacterial DNA. Each gene is a stretch of nucleotides that code for a particular protein. Many of the genes in bacteria are “housekeeping” genes; these are crucial for growth and metabolism and are found in all bacteria. Within these genes, the sequence of



Figure 1. Planktonic bacteria from the Sargasso Sea. The scale bar represents 1 μm .



Figure 2. *Cryptomonas*, on left, is a flagellate with chloroplasts from Toolik Lake, Alaska. This organism, ~30 μm in length, both consumes bacteria and carries out photosynthesis. Right, a ~40 μm long protozoan, *Cryptopharynx*, found in Little Sippewissett Marsh, Massachusetts, consumes bacteria and small algae.

nucleotides in each species of bacteria is very slightly different from that in all other species. These differences can be used to identify the organisms present.

In this method, bacteria are first collected from soil or water and their DNA molecules are extracted. An adequate sample contains 10 to 40 billion bacteria. To get that many bacteria, researchers usually need to collect a few milliliters of soil or up to 40 liters of water. Next, a section of the DNA representing a single gene is amplified by a method called PCR (polymerase chain reaction) to produce hundreds of thousands of exact copies. These copies are then placed in a DNA sequencer machine to determine the sequence of nucleotides that make up the gene.

The particular gene often used to identify microbes defines an RNA molecule that serves a critical role in the cell's protein synthesis machinery. This molecule is so important that its sequence is very similar in all cells on earth. Slight differences from species to species in the sequence of nucleotides can be used to identify the organisms present.

The final step is comparison of the sequence of nucleotides with those found in the large computer bases that now are available on the Internet. Ideally, a close match will lead to identification with a species of bacteria previously cultured in the laboratory. Many types of bacteria, however, are known only from the DNA data and have not been cultured.

An extension of this DNA-based method amplifies genes that are specific for a microbial function, for example, for sulfate reduction or ammonium oxidation. There are slight

differences in the sequence of nucleotides that make up the gene, so these can be used for taxonomic identification.

What microbial data are produced by the DNA-based methods? There are three types of information: microbial species present in a sample, the abundance of each species (using a method called quantitative PCR) and the functional genes present in the microbes.

What ecological use are the DNA-based data? From these studies we now have a general idea about the number of species of microbes in soil and water. The information about the distribution of microbes in aquatic and terrestrial ecosystems is only now beginning to accumulate.

We are also able to make correlations between the various processes and the microbes that are present. For example, in the ocean we can now look for a correlation between the measurement of nitrogen fixation (the conversion of nitrogen gas to a form used by plants and animals) and the types of microbes present that contain the gene for nitrogen fixation to identify microbial species likely to be active.

Another correlation could determine which microbes are likely to be found together in reoccurring communities and which physicochemical parameters structure these communities. A study in the Plum Island Estuary in Massachusetts revealed that a community of bacteria exists that is unique to estuaries.

In the future, scientists will be able to make use of recent advances in rapid DNA sequencing to characterize all the genes in a bacterial community. This will reveal all the potential transformations and greatly improve the ability to investigate correlations of species with biogeochemistry of ecosystems.

The second type of molecular tool that scientists are using successfully is based on the principle that the presence or absence of RNA for a particular gene correlates with the activity of the proteins for a particular function. Scientists can not only measure changes in RNA (which does correlate with gene expression) but also determine which species of bacteria are producing it. To really link microbial taxa with bacterial functioning, RNA may be the key molecule to study.

Although the methods of extraction, amplification and sequencing of the RNA are very similar to the DNA method, in practice they are much more difficult to carry out. One problem is that RNA is comparatively short-lived in the cell so samples have to be rapidly processed and carefully preserved. Another is that many types of RNA have to be examined in order to determine what kinds of functions are changing over a season or as a result of disturbance.



COURTESY OF MICROSCOPE
(WWW.MBL.EDU/MICROSCOPE)

Figure 3. *Lyngbya* is a filamentous blue-green alga (cyanobacterium). This sample was found in the sediments at Plum Island Sound. A filament is ~20 μm in diameter.

One promising new technique is that of microarrays. It is based on hybridization, a property of nucleic acids in which a piece of DNA with a known sequence of nucleotides will bind to a piece of RNA from the same species of microbe. In the microarray technique, a short piece of DNA is spotted on a glass slide. Each piece is a proxy for a gene with a different function. The RNA is extracted from bacteria cells, labeled with a fluorescent molecule, then hybridized to the spots on the slide. The spots that become highly fluorescent under UV light correspond to the RNA with particular functions.

What help are these RNA-based methods? They show which microbial genes are expressed, and that indicates which microbial processes are active at a particular time. In effect, we now have a measurement of an off-on switch of microbial processes.

What ecological use are the RNA-based data? One use is to find out just what microbes are doing in the environment. In an Antarctic lake, DNA measures showed that purple bacteria were present throughout the water column and all had a gene for photosynthesis. However, RNA showed that the gene was expressed only in deeper waters, an unexpected result that will stimulate further research.

Another use is to determine what changes have occurred in a microbial community as a result of disturbance such as long-term fertilization of a forest. In the Arctic, long-term fertilization appears to have dramatically changed the bacterial processes resulting in an unexpected reduction in the amount of soil organic matter. RNA methods should show which genes are now expressed and answer the question, is the microbial system merely more active as a result of fertilization or has the microbial community composition changed to new species? This is an important question for predicting the impacts of warming and the expected increased nutrient supply.

These new DNA-based techniques, and others, have produced new insights and improved understanding of the diversity among microbial communities of soils and water. We can now carry out correlation studies relating species to communities and environmental conditions. However, to add to knowledge of the controls on ecosystem processes, the RNA-based techniques are necessary. These are just beginning to be adapted for ecological studies. We now see a roadmap of how to reach a microbial ecology of ecosystems.

Production in Arctic Lakes: Not Just How Much, but Where?



TOM KLEINDINIST

Anne Giblin

Arctic systems, which are still relatively undisturbed by human influences such as fertilizer use, are ideal sites to study the influences of climate change on ecosystem structure. At Toolik Lake, on Alaska's North

Slope, scientists from The Ecosystems Center have observed increasing nutrient availability in terrestrial systems under experimental warming. If climate warming in the Arctic continues, increased nutrients will begin leaching into lakes and streams, potentially altering these low-nutrient systems in dramatic ways.

The growth of phytoplankton, microscopic plants living in the water column, is commonly very low in Arctic lakes – as little as one-tenth that of unpolluted temperate lakes. However, we know from studies in temperate regions that where water column production is low, benthic, or sediment-based, processes can be much more important. The low concentration of phytoplankton in the water column allows light to penetrate all the way to the bottom and microalgae growing directly on the sediment surface are able to use it effectively.

Studies on the food webs in lakes in the region of the Arctic Long-Term Ecological Research (LTER) at Toolik Lake gave the first indication that benthic processes are very important in these lakes. Many of the dominant consumers, such as insects and snails feed largely on benthic algae. In turn, even lake trout in some lakes feed more heavily on benthic animals than on prey in the water column.

To better determine the importance of benthic algae in fueling Arctic food webs, we have been surveying lakes in the Toolik region. Work begun by George Kipphut at the University of Kentucky and now continued by Anne Giblin, Ian Washbourne and Marcus Gay of The Ecosystems Center with Gretchen Gettel of Cornell University shows that benthic algae in the shallow regions of lakes are very productive (Figure 1). In the shallower lakes, benthic algal production can equal or exceed that of phytoplankton in the water column. In the clearer lakes benthic production

can be significant even at depths of 5 to 7 meters while in other lakes benthic production is limited to the upper 3 to 4 meters.

Although benthic algae form the base of the food webs in these systems, scientists have understood little about what limits their growth. The depth distribution suggests that light is a key control. To understand the relative role of light in benthic production, the team measures the growth of benthic algae under a variety of light conditions. The results show that benthic algae in lakes of the Toolik region are adapted to low light conditions. In most lakes, low light levels (about 10 percent of surface light during the Arctic summer) support maximal growth rates for benthic algae (Figure 2).

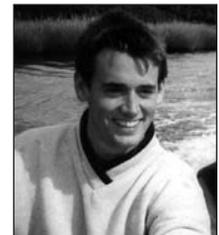
In the low nutrient environment of Arctic lakes, nutrients probably limit algal production, but direct contact with the sediments, where nutrient concentrations are higher than in the water column, gives benthic algae a competitive edge over phytoplankton. As nutrient inputs increase, they stimulate phytoplankton growth, which reduces light availability to benthic algae. This leads to a decrease in benthic production and, in extreme cases, organisms that depend upon benthic algae may be lost from the food web.

Previous experiments on two lakes in the Toolik region both showed a dramatic increase in phytoplankton production with nutrient



SUE DONOVAN

Ian Washbourne



KEN FOREMAN

Marcus Gay



TOM KLEINDINIST

Gretchen Gettel

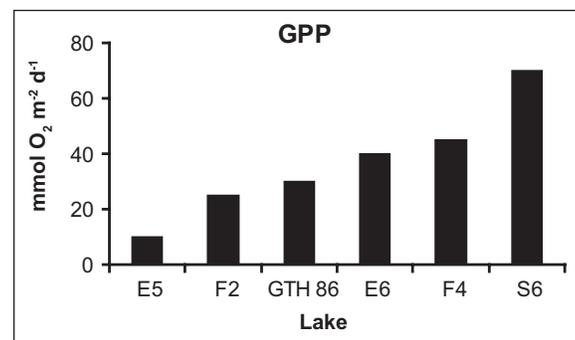


Figure 1. Gross primary production in shallow (less than 3 m) sediments from six lakes in the Toolik region. The oxygen produced in a given area over a given time is used to estimate plant growth or gross primary productivity (GPP). All measurements were made at the same light level (200 μ E). The three deeper lakes (E5, F2 and GTH 86) have lower benthic productivity than the three very shallow lakes (F4, E6 and S6). For comparison, water column GPP ranges from 8 to 50 mmol oxygen (O₂) per square meter per day (m⁻² d⁻¹).

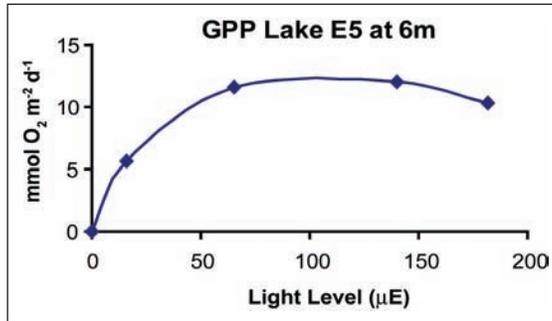


Figure 2. The response of benthic algae in an Arctic lake to light, showing productivity of benthic algae in the deep lake (E5). Maximum rates of growth are achieved at relatively low light levels. For comparison, on a typical summer day in Massachusetts, light levels might reach 3000 μ E.

fertilization. However, these experiments used relatively high nutrient additions and did not monitor the response of benthic algae. Both human disturbance and climate change are expected to increase nutrient delivery to Arctic lakes and algal production – whether benthic or suspended – forms the base of lake food webs. So predicting how Arctic lakes will respond to future changes in climate and to human disturbance requires a clear understanding of the algal response to increased nutrients.

To characterize the response of lakes to smaller nutrient increases, and to directly explore the change in water column versus benthic production, Giblin and colleagues have been fertilizing two small lakes in the Toolik region since 2001. One lake, E5, is relatively deep, about 12 meters, while the other, E6, is very shallow with a maximum depth of only 3 meters. The researchers hypothesized that in the shallow lake the benthic algae would be able to use the added nutrients and that their production would increase more than phytoplankton. In the deeper lake, they predicted that the phytoplankton would increase and that benthic production would therefore decline.

After four years, the response of the benthic algae in the shallower lake, E6, has been fairly clear. Although there has been some light attenuation with fertilization, benthic production in the last two years of the experiment has been higher than in previous years (Figure 3a) and has been accompanied by a dramatic increase in concentrations of chlorophyll *a* (a plant pigment) in sediments (Figure 3b).

The response of the deeper lake, E5, has depended upon depth. Fertilization has also reduced the amount of light reaching the

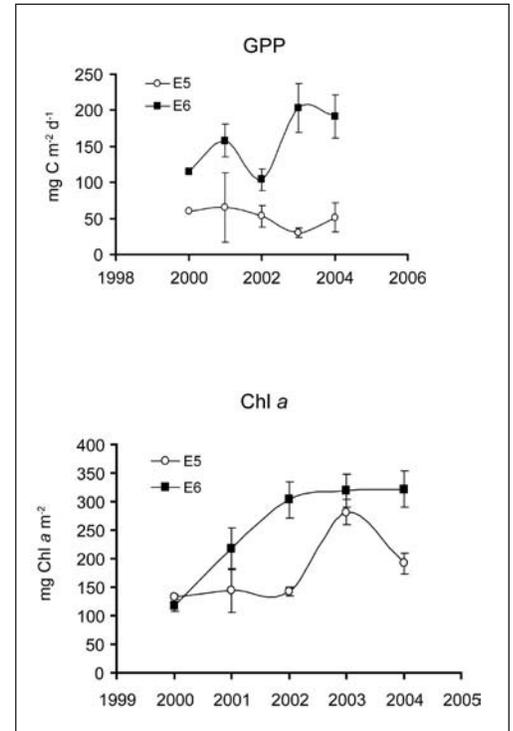


Figure 3a (top). Gross primary production (GPP) of shallow sediments in lakes E5 (deep) and E6 (shallow). **Figure 3b (bottom).** Chlorophyll *a* concentrations in shallow sediments in lakes E5 (deep) and E6 (shallow). Symbols represent the mean and bars represent the standard error of the June-August measurements taken in each year.

bottom in this lake. Before fertilization, benthic productivity was significant to a depth of about 6-8 meters. After fertilization, benthic production is a rare occurrence at those depths. Even at 3 to 4 meters, there is a suggestion of a decline in benthic production (Figure 3a). The amount of plant pigments in the sediments has been quite variable and also shows no clear pattern.

Thus it appears that in shallow lakes, like E6, benthic algae can take full advantage of the added nutrients even though light levels declined with the increase in water column production. The response in the deeper lakes, like E5, suggests a decrease in the energy entering benthic food webs will occur with increased nutrients.

A benthic-based food web encourages the growth of snails, benthic insects and fish such as burbot and lake trout, while a plankton-based food web would better support zooplankton and grayling. Other on-going studies will show whether the changes that researchers have seen in benthic and phytoplankton production in response to fertilization will affect the rest of the food web.

New England's Forests:

What Role Does Species Composition Play in Future Carbon Storage?



TOM KLEINDINST

Jerry Melillo



TOM KLEINDINST

Paul Steudler

The trees and soils of the world's forests account for more than half of the organic carbon stored on land.

Currently, forests of the temperate zone are actively accumulating carbon in large enough quantities to slow the increase of carbon dioxide in the atmosphere.

It is not clear, however, that long-term climate change will produce the same effect.

A number of phenomena may be contributing to this enhanced carbon accumulation, including regrowth of forests on

land cleared for agriculture, carbon dioxide fertilization of photosynthesis and climate change itself.

Climate change has the potential to tip the carbon balance of temperate forests and other land ecosystems, although it remains uncertain whether the forests will release or store more carbon under temperature increases projected to be between 1.4 and 5.8°C. The possible feedback mechanisms include changing plant community composition and biogeochemical processes, such as plant photosynthesis and microbial respiration. Changes in community composition could favor increased or decreased carbon storage, depending on the characteristics of the favored species.

Warming experiments conducted in a variety of ecosystems including forests have shown conflicting trends. Short-term losses of soil carbon in the form of carbon dioxide compete against acceleration of nitrogen cycling rates that can stimulate plant growth and carbon storage in long-lived plant tissues, such as wood. Warming has also been shown to affect plant community composition in bogs and fens, alpine meadows, and sub-Arctic shrub/dwarf birch ecosystems and tundra.

In contrast to the knowledge about the response of these short-statured plant communities, there is little information on the ways communities of large trees in temperate forests may respond to changing climate.

One effect might be to alter plant community composition during forest succession.

Succession is the slow replacement of species as a forest changes from a disturbed state, such as a pasture, to a mature forest. Increases in carbon and/or nitrogen resources could change the competitive dynamics of forest trees – favoring either faster-growing, early successional tree species or slower-growing, later successional species. The rate of carbon sequestration in forest ecosystems is closely linked to successional development. Young forests, dominated by fast-growing, early-successional tree species, exhibit peak rates of carbon accumulation. Over time, altered demographics could affect forest succession and productivity, thus changing future carbon sequestration by temperate forests.

To gather information about changes to forest community composition and other aspects of climate change, Ecosystems Center researchers Jacqueline Mohan, Jerry Melillo, Joe Blanchard, Paul Steudler, center consultant Frank Bowles and Harvard University scientist Fakhri Bazzaz conducted a soil warming experiment at the Harvard Forest in central Massachusetts (Figure 1). Working in a mixed deciduous stand dominated by northern red oak with red maple, they measured the growth responses of juvenile trees to a 5°C increase in soil temperature. As in an earlier, smaller soil-warming study nearby, they used buried resistance cables to heat the soil.



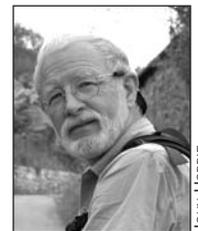
PAUL FRANKSON

Jacqueline Mohan



KATHERINE LEINGIR

Joe Blanchard



JOHN HOBBIIE

Frank Bowles



SARAH MORRISSEAU

Figure 1. Photo of the 30 x 30 m control plot at the soil warming study site in the Barre Woods sector of the Harvard Forest in Petersham, Massachusetts. The mixture of several species of juvenile and mature trees provides an ideal site to study changes in species composition.

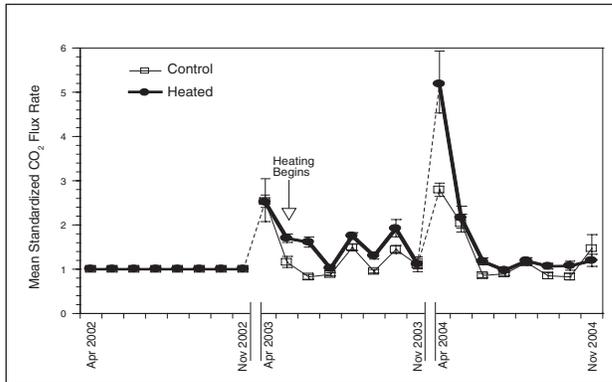


Figure 2a. Soils in warmed plots emit more CO₂ than control plots after heating commences. Error bars represent standard error of nine measurements. Flux rates for warmed and control plots were each standardized to pre-heating flux measurements in individual plots.

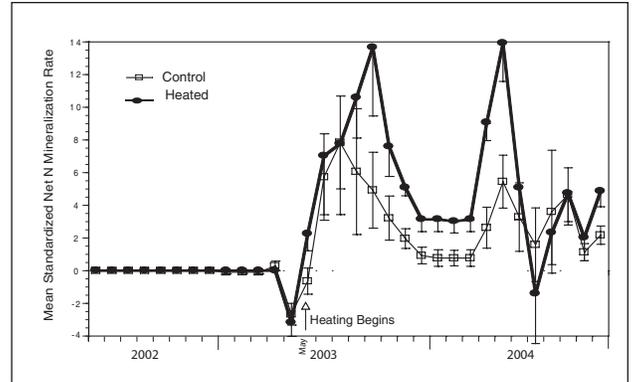


Figure 2b. Mean rates of soil net N mineralization – standardized for pre-treatment 2002 rates – are higher in the warmed plot after heating commences. Error bars represent standard errors of the means.

The researchers made a set of plant-growth and biogeochemical measurements, including carbon dioxide emissions from the soil surface to the atmosphere and net nitrogen mineralization, in warmed and control (unwarmed) plots, each 30 x 30 meters. They measured the growth responses of juvenile trees of 11 species: sugar maple (*Acer saccharum*), eastern hemlock (*Tsuga canadensis*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), striped maple (*A. pennsylvanicum*), red maple (*A. rubrum*), red oak (*Quercus rubra*), black oak (*Q. velutina*), sweet birch (*Betula lenta*), yellow birch (*B. alleghaniensis*), and white pine (*Pinus strobus*). These species co-dominate forests in much of eastern North America. By using bud-scale scars to determine previous years'

terminal heights, they were able to evaluate annual growth rates for each tree. For a total of 401 individuals in the heated and control plots, they compared the growth responses during the treatment year (2003) with those in pre-treatment years (2001, 2002).

During the first year of treatment, warming caused a 22 percent increase in soil respiration (Figure 2a) and a 37 percent increase in net nitrogen mineralization (Figure 2b). These biogeochemical responses are similar to what the scientists observed at the beginning of the earlier warming study at the Harvard Forest. On average, the juvenile trees grew 50 percent faster in warmed plots, but individual species responded quite differently.

The warming most benefited slower-growing species (Figure 3), while the majority of fast-growing species demonstrated negligible responses to warming. Of the six species that exhibited growth enhancements from warming, five were the slowest-growing taxa under control conditions: white ash, eastern hemlock, black oak, sugar maple, and black cherry. One fast-growing tree that did display increased growth under warming was red maple, a species that is becoming increasingly abundant throughout its range.

The findings suggest that the dynamics of regeneration in temperate-zone forests of the future may favor low-productivity species. If so, the rate of carbon assimilation by these forests could be slowed, leading to faster accumulation of carbon dioxide in the atmosphere and increasing rates of global warming in the future.

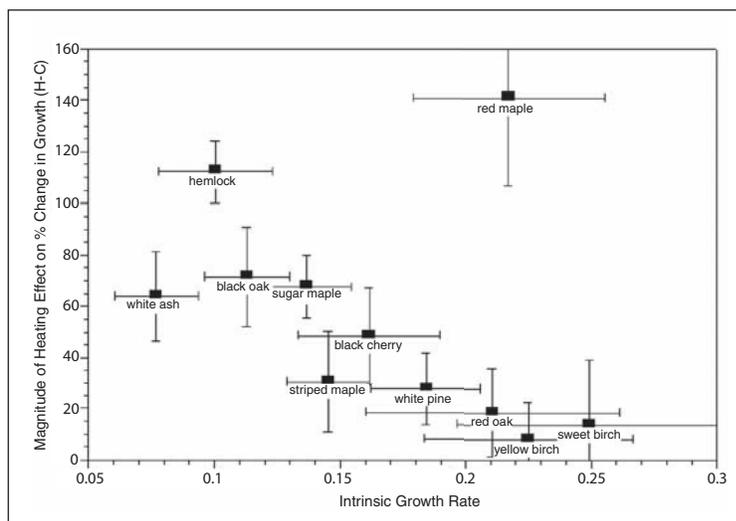


Figure 3. The intrinsic growth rate of various tree species plotted against the heating effect for the same species. A value of zero signifies that growth was the same in the heated treatment as in the control plots. Intrinsic growth rate was calculated as the mean growth rate in the control plot during 2002 and 2003.

Land-Use Change: Effects on Nutrient Transport Processes in Amazonian Streams



Linda Deegan

TOM KLEINDINST

The clearing of lowland Amazon tropical rainforest for pasture represents one of the largest and potentially most important land conversions on Earth. The Amazon contains more than 4 million square kilometers of

tropical forest and the earth's largest river network. The Amazon Basin also has the world's highest rate of forest clearing, primarily for cattle pasture, with more than 600,000 square kilometers of forest cleared in the Brazilian territory alone since 1970.

The Amazon is the most dramatic example of how human activities modify land use over a significant portion of the Earth's surface, altering the ecological functioning of soils and surface waters over large regions and influencing the movements of nutrients and materials among adjoining ecosystems. Small streams are closely connected to the adjacent land and play an important role in nutrient cycling and regulating materials that move downstream and eventually reach larger river channels and the coastal ocean. It is becoming increasingly important to understand stream functioning in these disturbed landscapes, because they now comprise a large fraction of the watersheds in many major river systems.

In the Amazon, small headwater streams dominate the total length of stream channels and account for more than 80 percent of total channel length. Disturbances that influence the biogeochemical functioning of small streams now have the potential to affect most major rivers. But despite the enormity of current land use change in the Amazon (Figure 1), relatively little is known about nutrient cycling in the small streams that serve as the most direct link between upland and aquatic ecosystems.

By using stable isotopes to trace the movement of nitrogen through streams of different sizes in areas with different land uses, Ecosystem Center researchers Linda Deegan, Chris Neill and Christie Hauptert, along with their Brazilian colleagues Reynaldo Victoria, Alex Krusche and Victoria Ballester, are able to decipher how

land use alters the stream nitrogen cycle and ultimately how it changes the balance between storage and export. They added a small amount of ammonium (NH_4^+), which contained ^{15}N as a tracer to identify and follow where the added nitrogen goes in the ecosystem, to two lowland Amazon streams cleared for pasture in central Rondônia. Additions of ^{15}N allow researchers to follow the system's functioning – such as uptake by microorganisms or conversion of ammonium to the more mobile nitrate (called nitrification) – without disturbing it.

The fate of the added ^{15}N clearly indicated that replacing rainforest with pasture leads to dramatic differences in stream function that depend heavily on the size of the stream. The smallest flow of water that runs year-round is called a first-order stream. Two first-order streams come together to make a second-order stream. The combination of two second-order streams produces a third-order stream. In the second-order pasture stream, forest conversion created a channel with extensive infilling of riparian grass, slow moving currents and thick



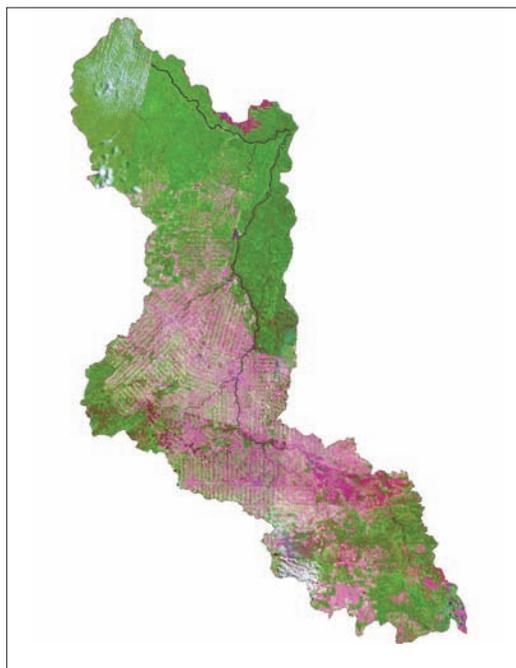
Christie Hauptert

CHRIS NEILL



Joaquin Chaves

TOM KLEINDINST



TROPICAL RAIN FOREST INITIATIVE

Figure 1. Deforestation of lowland Amazon rainforest is widespread in central Rondônia, Brazil. Satellite image shows the extent of conversion of Amazon rainforest to pasture in the Ji-Paraná River basin in Rondônia, part of the Amazon River network. Green indicates forested areas and pink signifies pasture lands.



Figure 2. Second order stream, on left, shows narrowing of channel by grasses and benthic matter. Third-order stream has much less infilling and consequently has faster currents.

deposits of fine and coarse benthic organic matter on the stream bottom (Figure 2). In contrast, in the larger third-order pasture stream, forest conversion led to a more open stream channel where infilling by riparian grass was much less, currents were faster, sand cover was extensive and less organic matter accumulated.

These differences in stream structure resulted in large differences in the nitrogen cycle and a reversal of nitrogen storage and export patterns. Compared to temperate systems, both streams had very long uptake distances, the distance traveled by an ammonium molecule before it is removed from the stream water (Figure 3). A typical temperate stream transforms all the ammonium in less than 200 meters; ammonium travels over 1,000 meters in these tropical streams. In the second-order pasture stream, nitrification did not occur because the process requires oxygen and decomposition of the high accumulations of organic matter consumed all the available oxygen. In contrast, in the third-order pasture stream, a small amount of ammonium was nitrified, but plants or microorganisms did not use the nitrate, which was therefore exported downstream.

The second-order pasture stream retained a large proportion of the nitrogen passing through it, storing almost 80 percent in the riparian grasses and exporting less than 15 percent, predominately as particulate organic nitrogen (PON) (Figure 4). This pattern of storage and export was reversed in the larger third-order pasture stream, where 85 percent of the nitrogen added was exported – about half

as inorganic forms (ammonium and nitrate) and half as particulates. Riparian grasses in this stream stored little nitrogen because the swift current limited their biomass and extension into the stream channel.

These lower-order streams also serve as important habitat for the fish that thrive in the rivers of Amazonia. In addition to their nutrient cycling observations, Deegan, Neill and Haupert found over 35 species of fish in 150 meters of a

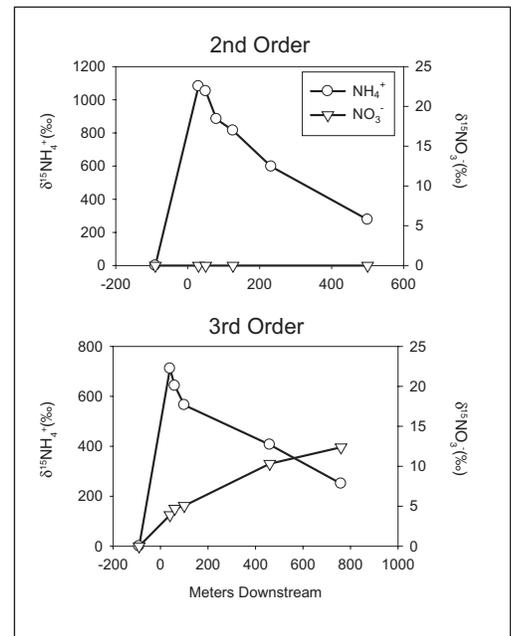


Figure 3. The $\delta^{15}\text{N}$ in ammonium (NH_4^+) and nitrate (NO_3^-) in stream water downstream from the addition point in two pasture streams in the Amazon. In the second-order stream, nitrification did not occur; in the third-order stream, there was some nitrification but most was exported downstream. The ratio of $^{15}\text{N}/^{14}\text{N}$ is expressed as “ δ ” in parts per thousand, which is relative to the ratio of these two stable isotopes in atmospheric nitrogen gas.

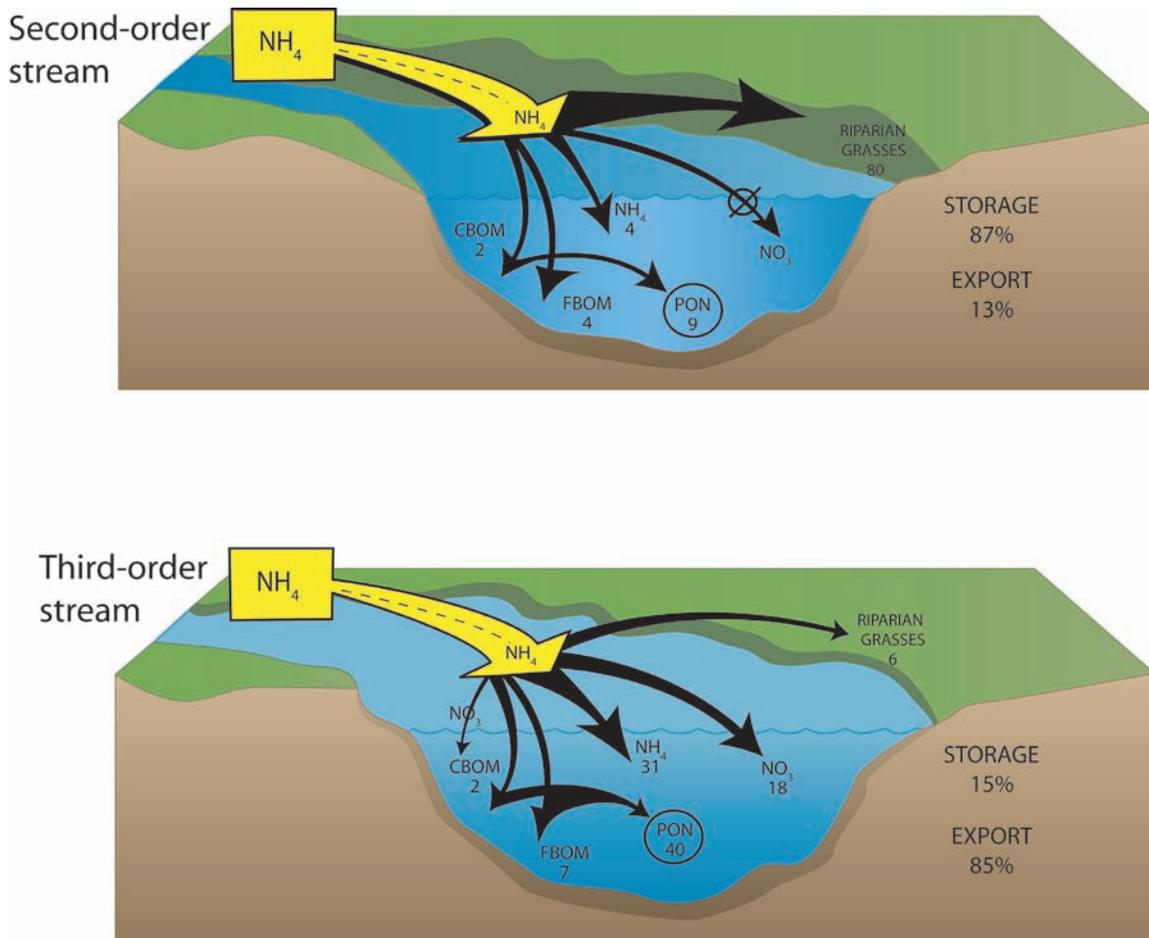


Figure 4. The fate of nitrogen added as ^{15}N - ammonium in a tracer experiment in two pasture streams in the Amazon. The nitrogen moves as ammonium (NH_4^+), nitrate (NO_3^-), particulate organic nitrogen (PON) or is stored in coarse benthic organic matter (CBOM) or fine benthic organic matter (FBOM). In the smaller second-order stream, 87 percent of the nitrogen is stored in the grasses or sediments; in the third-order stream, 85 percent is exported due to the swift current.

typical forest stream. In the second- and third-order pasture streams they studied, only one to three species survived. The fish in the small streams often move out to larger rivers as they grow and become the basis for fisheries.

Small streams serve as a key connection in the landscape, exchanging nutrients and organic matter with the land and serving as habitat for a wide diversity of animals. Moving downstream, these materials and the migrating fish sustain the food webs of larger rivers and eventually coastal waters. In the tropics, forest streams typically export large amounts of nitrogen, but pasture stream systems do not, based on these studies. Even though larger pasture streams transport most of the nitrogen that reaches them, the smaller pasture streams tie up the nitrogen they receive in riparian grasses and stream-bottom

debris, so it never reaches the larger, faster-moving streams.

Researchers are only beginning to explore the linkages to larger streams and rivers, but significant changes to the functioning of stream habitats can hardly leave the higher-order rivers unchanged. The first signs are disquieting. The loss of fish habitat and a large proportion of nutrient inputs may matter little when only a small percentage of the landscape is cultivated. However, as the balance of land use tips toward pasture, rivers and coastal waters may see profound effects on food webs, nutrient cycles, and fish abundance. As pasture conversion continues across the region, studies like this one provide some ability to anticipate the large-scale effects of forest clearing.

Reactive Barriers:

A Nitrogen Shield for Coastal Systems?



Joe Vallino

CINDY VALLINO



Ken Foreman

TOM KLEINDINIST

Increasing nitrogen inputs from wastewater, fertilizer use, and fossil fuel burning are having a significant impact on coastal ecosystems. Excess nutrients from such scattered sources feed algal blooms and alter estuarine food webs.

A new approach to solving the nitrogen problem is to install a permeable reactive barrier (PRB) that will intercept groundwater carrying reactive forms of nitrogen and convert it to harmless nitrogen gas before it reaches sensitive estuaries. Joe Vallino and Ken Foreman, scientists at The Ecosystems Center, are working with Pio Lombardo of Lombardo Associates in Newton, Massachusetts, and Will Robertson from the University of Waterloo to evaluate the effectiveness of PRBs at two sites on Cape Cod. If the barriers prove to be effective and long-lasting, it may turn out to be easier and cheaper to identify and shield sensitive waters than traditional methods of wastewater disposal and treatment.

Recent assessments of our nation's coastal environments have shown that estuaries and embayments face ever-increasing levels of nitrogen enrichment caused by nitrogen loading on land, which is transported to the coast in rivers and groundwater. Nitrogen enters watersheds via three primary routes: 1) wastewater from residential septic systems, municipal facilities, and animal wastes, 2) fertilizer application for agriculture as well as for residential and commercial lawns and 3) combustion of fossil fuels for energy production and transportation, leading to increased atmospheric deposition. This excess nitrogen causes eutrophication of coastal waters, which results in large algal blooms (Figure 1) and changes to food webs that support commercial and recreational fisheries. Decomposing algal blooms can consume oxygen in the water and cause massive mortalities of both finfish and shellfish.

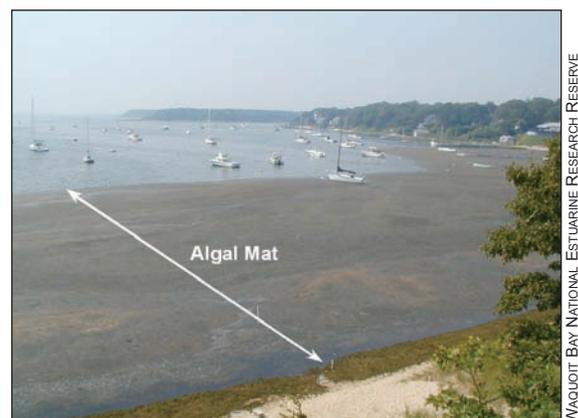
In particular, urbanization on Cape Cod has resulted in elevated nutrient concentrations in groundwater and surface water, and many of Cape Cod's estuaries and bays are exhibiting signs of moderate eutrophication, including replacement of eelgrass by macroalgae (Figure 1), low dissolved oxygen and periodic fish kills.

Traditional approaches to mitigate coastal nitrogen-loading have focused mainly on

reducing fertilizer and wastewater inputs. Where fertilizer use is mainly agricultural – such as in the Mississippi River basin, which contributes to the “dead zone” in the Gulf of Mexico – convincing farmers to adopt strategies including precision fertilization can significantly reduce nitrogen inputs. However, in suburban and urban environments, where the habits and behavior of large numbers of individual homeowners must be altered to achieve meaningful (greater than 20 percent) reductions, the challenge is even greater.

In Waquoit Bay and similar suburbanized coastal pond watersheds, fertilizers account for 15 to 25 percent of the total load, while wastewater accounts for the remainder. Consumer education may reduce the load of fertilizer to watersheds, but nitrogen in wastewater must be actively removed. Fortunately, under the right conditions bacteria can be enlisted to convert nitrogen in wastewater – which plants and algae readily consume – to nitrogen gas, which plants and algae cannot use. Decomposition of organic waste produces ammonium. When oxygen is present, bacteria convert ammonium to nitrate in a process known as nitrification. Both ammonium and nitrate are components of fertilizer and stimulate algal blooms. However, in the absence of oxygen, other bacteria can convert nitrate to nitrogen gas in a process known as denitrification. In denitrification, bacteria use nitrate instead of oxygen to react with organic material and produce energy for growth.

In a few advanced wastewater treatment facilities, oxygen concentrations are adjusted to



WAQUOIT BAY NATIONAL ESTUARINE RESEARCH RESERVE

Figure 1. Example of algal bloom that develops as a result of excessive nutrient runoff from land. Picture taken at the head of Waquoit Bay, Falmouth, Massachusetts.



Figure 2. Proposed locations for installation of the NITREX™ PRB at the head of Waquoit Bay (right) and next to the Childs River (left) in Massachusetts.

encourage bacteria to convert ammonium into nitrate and then nitrate into nitrogen gas, thus removing it from the wastewater. Treatment that removes nitrogen has been effective in reducing nitrogen inputs from some major metropolitan areas (e.g., the Blue Plains treatment plant serving Washington, D.C., and discharging to the Potomac River). However, centralized wastewater treatment requires major investment and is expensive to operate and maintain. It is not cost effective in most rural or suburban areas where housing is spread out. Individual on-site systems that remove nitrogen have been developed, but they are also costly and may not consistently achieve high rates of nitrogen removal. Furthermore, storm water, fertilizers and atmospheric sources usually bypass wastewater treatment facilities, flowing directly into streams and groundwater.

Rather than trying to treat water as it leaves individual properties, scientists have proposed removing the nitrogen just before it enters coastal waters. By passing nitrate-laden water through a reactive material, they can facilitate bacterial denitrification. The material can be quite simple, such as woodchips. The woodchips provide a source of carbon for the denitrifying bacteria, and also cause areas of low oxygen concentration to develop, which is the other necessary requirement for denitrifying bacteria.

When woodchips are placed in the ground in the form of a wall, it is known as a permeable reactive barrier, or PRB. Lombardo Associates has employed the NITREX™ PRB developed by Robertson to remove high concentrations, 30-100 milligrams per liter (mg/L), of nitrate in contaminated groundwater associated with septic leaching fields and other point source releases.

The team, which consists of center scientists Vallino and Foreman, along with Robertson and Lombardo, obtained funding for their study from the Cooperative Institute for Coastal and Estuarine Environmental Technology program, sponsored by the National Oceanic and Atmospheric Administration. They will

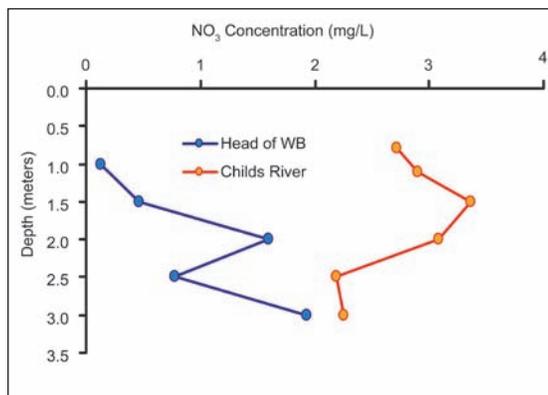


Figure 3. Initial sampling of groundwater nitrate (NO₃⁻) concentration at the head of Waquoit Bay and along the Childs River (See Figure 2).

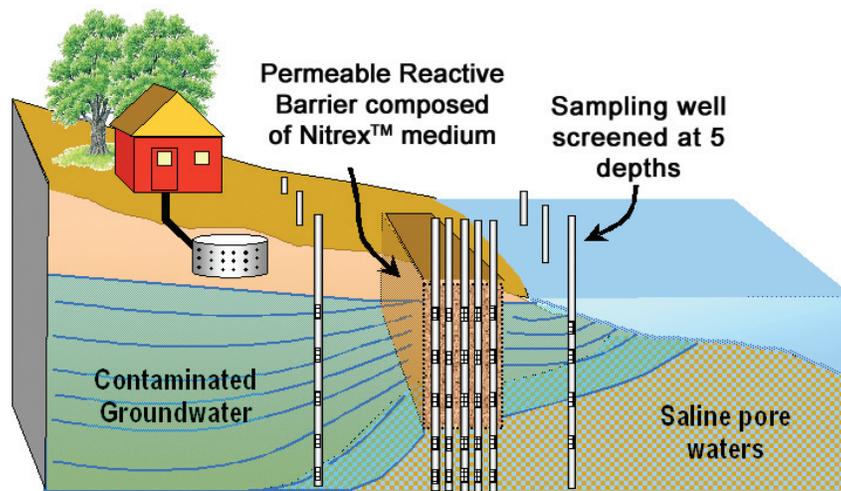


Figure 4. Example installation plan for the NITREX™ permeable reactive barrier along the coast. Samples from wells will help determine the fate of groundwater nitrate as it passes through the NITREX™ medium.

investigate the effectiveness of NITREX™ PRBs at removing low levels of nitrate (1-5 milligrams per liter), from groundwater along the coastline, a more challenging application than previous uses of PRBs. The researchers will install two NITREX™ PRBs in two Cape Cod locations, one at the head of Waquoit Bay in the National Estuarine Research Reserve and the other along the Seacoast Shores development next to the highly eutrophic Childs River (Figure 2). Both sites had high groundwater nitrate concentrations in initial samplings (Figure 3). The PRB will be installed at the interface between the freshwater contaminated with nitrate and the seawater (Figure 4). At the coastline, groundwater is forced to the surface by the denser saltwater, which means the PRBs do not have to be very deep. Initial surveys indicate a depth of approximately two meters should be sufficient to capture all the freshwater.

Using PRBs to remove nitrogen from groundwater along the coast right before it enters estuaries and embayments has promise, but also poses several additional challenges. The barriers would intercept nitrogen not only from septic systems, but also from fertilizer application and from atmospheric deposition, which would be a huge advantage over denitrifying septic systems. The major challenge is in understanding exactly what happens to the nitrate entering the PRB. Groundwater sample wells installed upstream and downstream of the PRB, as well as within

the NITREX™ medium itself (Figure 4), will help the researchers answer that key question. Previous testing makes it clear that nitrate is removed from groundwater, but it could wind up simply stuck to organic matter in the wall or converted to organic forms. In the first case, the PRB would eventually become saturated and begin to leak nitrogen. In the second case, organic nitrogen would be converted back to active nitrogen in the estuary. Only nitrogen gas would actually escape from the system. The low concentrations of nitrate in groundwater (relative to previous uses of PRBs) could also pose problems.

To address these questions the team will use numerous analytical techniques to ascertain the fate of groundwater nitrate as it passes through the NITREX™ PRB. In collaboration with Anne Giblin of the center, they will use a new method, known as membrane inlet mass spectrometry, to directly measure the rate of nitrogen gas production. Nitrogen gas production is difficult to measure because the high background levels of nitrogen naturally present in the atmosphere mask small changes in the samples. The researchers will also investigate how the PRB functions when seawater floods in, which is likely to occur during coastal storms. They hope to show, however, that PRBs may be a cost-effective means to mitigate some of the nitrogen-loading problems facing Cape Cod and other coastal communities.

Maintaining Threatened Ecosystems: Better Information Eases Hard Choices



Chris Neill

TOM KLEINDINST

There is a thin ribbon of land running from Long Island to Cape Cod and the islands of Martha's Vineyard and Nantucket that contains some of the driest and least fertile soils in the Northeast. Here, often within a stone's

throw of the Atlantic Ocean, the woodlands, heathlands, shrublands and grasslands that make up the native vegetation of these coastal sandplain ecosystems contain many species of plants – 20 in Massachusetts alone – that are now considered to be rare or threatened with further declines.

Many of these plants occur nowhere else in the region and others are globally rare. Periodic natural disturbances of wind, salt spray and late frost helped to form and maintain some of these habitats. Human-made disturbances of fire and land clearing also played a historic role in their formation and persistence.

The portion of the landscape covered by the most vulnerable of these systems – the more open grasslands and heathlands – has declined sharply in recent years. Both the expansion of residential development and the accompanying suppression of fires that control the regrowth of woody vegetation are responsible for this trend.

These interacting factors have reduced the area of species-rich sandplains to such an extent that The Nature Conservancy, for example,

now classifies these sandplain ecosystems as a “globally rare” community type.

The threat of losing an important component of regional biodiversity has made management of early successional habitats a priority. Managers are looking for options to maintain existing high-quality early successional habitats and to restore or rebuild them in other locations on the sandplain.

At the same time that coastal sandplain ecosystems support rare species, they also perform the service of reducing the amount of inorganic nitrogen, particularly nitrate, that moves from soils into groundwater and subsequently to shallow coastal bays where nitrogen overenrichment, or eutrophication, now degrades estuarine life. So managers who contemplate changes to land management that expand grasslands, heathlands and shrublands using fire or mechanical clearing face the added challenge of designing conservation plans that do not simply trade off one important ecosystem service, such as support for rare species, for a different value such as clean groundwater.

Ecosystems Center researchers Christopher Neill, Ann Lezberg and Richard McHorney worked with The Nature Conservancy (TNC) on the island of Martha's Vineyard to apply the tools of ecosystem ecology to quantify just this tradeoff. In 2000, Neill and TNC Islands Program Director Tom Chase designed an experiment to determine if mechanical clearing of sandplain oak woodland followed



Rich McHorney

CHRIS NEILL



CHRIS NEILL



CHRIS NEILL

Figure 1. Photographs of oak woodland (left) and the adjacent cleared woodland that has been colonized by native sandplain herbaceous plants (right). Both areas are part of the land manipulation experiment conducted by The Ecosystems Center and The Nature Conservancy on Martha's Vineyard. The study was designed to test methods of promoting the establishment of and maintenance of rare sandplain grassland and shrubland plant communities.

by the sowing of seeds of native grassland and shrubland plants could create a shrubland-grassland mosaic capable of sustaining characteristic sandplain plant species. At the same time, McHorney and Lezberg installed 50 shallow wells to measure the concentrations of nitrate in the groundwater before and after clearing.

The experiment, which lies near the shore of Edgartown Great Pond, began in 2000 with surveys of the initial vegetation in permanent 3×3 meter plots. Early in 2001, trees were cleared with a large feller-buncher machine of the type used in forestry operations. The goal was to use a severe initial disturbance, clearing, to create an open habitat structure. A less severe and easier-to-apply disturbance, prescribed burns in the dormant season, would then be used to maintain the dynamic vegetation mosaic in future years. The summer after clearing, seeds were collected from a diverse, species-rich existing sandplain grassland on Martha's Vineyard and distributed in the cleared area.

Ann Lezberg led crews of summer interns and sampled vegetation plots in the cleared area for four years. They recorded the presence and cover of each plant species. They also noted changes to vegetation in adjacent undisturbed woodland.

Clearing and seeding changed the vegetation from woodland to the desired oak shrub and grass mosaic (Figure 1). It led to a large increase in the number of typical native sandplain herbaceous species, a small increase in the number of native weedy species and the appearance of only a small number of exotic species (Figure 2). Surprisingly, none of tree and shrub species present in the original woodland were lost. In fact several previously unrecorded native woodland species appeared after clearing (Figure 2). The total number of species in the cleared area increased from 30 at the start to 79 three years after clearing. The Ecosystems Center and TNC will continue to track vegetation changes in the coming years, but so far the results indicate this management works well to expand the habitat for native sandplain species.

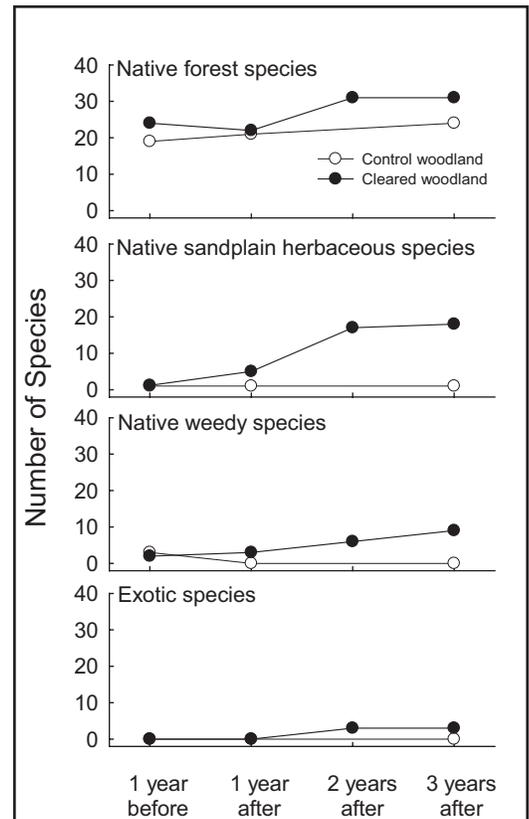


Figure 2. A plot showing the changes to the number of plant species in cleared and control treatments before and after the experimental clearing of oak woodland on Martha's Vineyard. Species were divided up into groups representing native forest species, native sandplain herbaceous species, native woody species and exotic, or non-native species. There was a large increase in the number of native sandplain herbaceous species in the cleared woodland. Species composition changed little in the control woodland.

While this species reorganization was happening, Neill, McHorney and Lezberg measured the amount of ammonium and nitrate (the forms of nitrogen most available to plants) that built up in the soil after the trees were removed. They found that ammonium concentrations increased for two years after clearing and then declined. While nitrate concentrations at the surface did not increase, they measured sharply higher concentrations of nitrate in the groundwater (Figure 3), indicating that ammonium was transformed to nitrate as water worked its way downward through the soil profile. Before the clearing,

nitrate concentrations were very low and typical of the groundwater under undisturbed native woodland. This nitrate apparently hit the groundwater exactly one year after clearing and remained high for three years (Figure 3). What will be the effect of this nitrate that enters the groundwater? By combining the results of the groundwater concentrations, maps of the aquifer depth and a model of total watershed nitrogen loading to Edgartown Great Pond, Neill and McHorney estimated that the total amount of new nitrate contributed to the groundwater by the clearing was 159 kilograms (kg). By assuming that rates of groundwater flow would carry this nitrate to the pond over five years, they compared this annual load of 32 kg per year with the total annual nitrogen load of 10,327 kg per year estimated from watershed nitrogen loading models. Although the increase in nitrate concentrations under the cleared site was significant, it was short lived and small compared with other watershed sources, such as nitrogen deposited in precipitation and nitrate leached from home septic systems. This places the increased nitrate generated by the clearing in perspective — it accounts for less than one percent of the annual nitrogen load to the estuary.

Many factors will guide the selection of methods that landowners and conservation organizations will use to manage their lands in the future. By taking an ecosystem perspective and by teaming with ecologists to perform management experiments and use a variety of methodologies to evaluate the tradeoffs that inevitably occur when changing land use, these groups will be in a better position to choose the methods that lead to the greatest gains in biodiversity protection, while avoiding some of the pitfalls and unintended consequences that might set back future conservation management efforts.

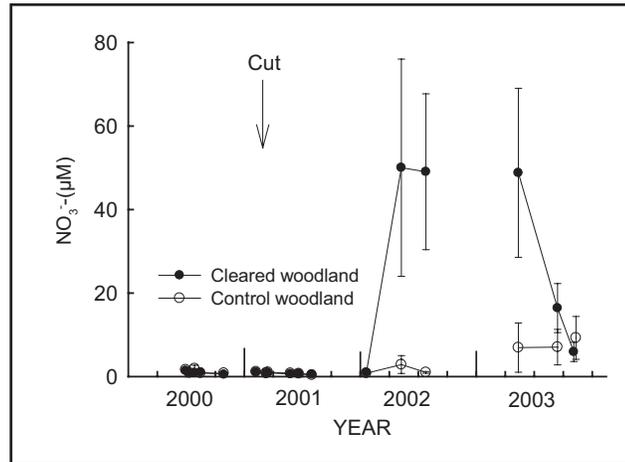
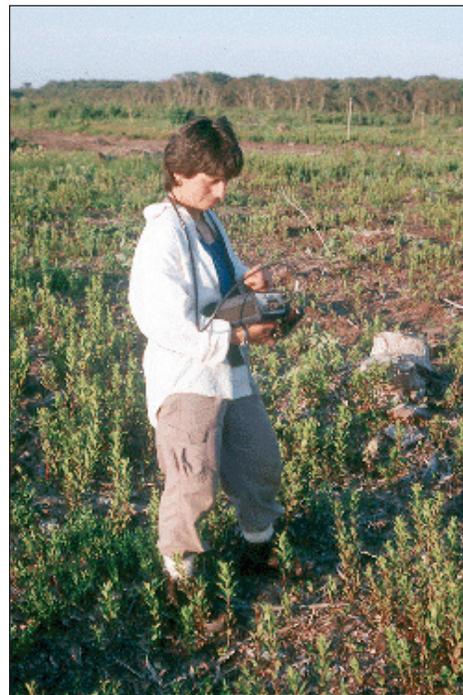


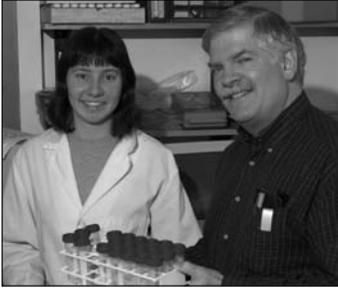
Figure 3. The concentration of nitrate (NO₃⁻) detected in groundwater wells under the cleared woodland and the control woodland during the clearing experiment. Nitrate concentrations increased sharply under the cleared woodland one year after clearing but declined after two years.



Ann Lezberg measures the level of incident light following clearing at the Martha's Vineyard research site.

CHRIS NEILL

Semester in Environmental Science



Allison Burce and Ken Foreman

TOM KLEINDINST

An enthusiastic group of 10 students took part in the Semester in Environmental Science (SES) at The Ecosystems Center in 2004. Two students were from Brown University, the most recent university to join the 60-member SES consortium.

The addition of Brown to the SES consortium has made

it possible for students from colleges and universities that are not affiliated with SES to attend as visiting students at Brown and receive credit from Brown for the semester. This opens the program to qualified students from almost any college or university in the nation.

The goal of SES is to help train the next generation of environmental leaders. SES is not simply a program in marine biology or terrestrial ecology, but integrates and contrasts ecosystems structure and processes across the landscape. Students learn to think critically about scientific information and environmental issues by analyzing and interpreting data they collect for themselves in a diverse array of ecosystems on Cape Cod. SES provides a way for undergraduates to become exposed to and engaged in ecosystem research during the formative stages of their education. Students aspiring to become policy makers and environmental advocates leave SES equipped to understand complex issues.

SES students spend about 20 hours a week in the field and lab, take core courses in terrestrial and aquatic ecosystems science, a science writing seminar and an elective. In 2004, electives offered were Mathematical Modeling in Ecosystems, taught by Ed Rastetter, and Microbial Methods in Ecology, taught by Joe Vallino. During the last five weeks of the program, SES students chose a topic for independent research and work with a mentor from The Ecosystems Center staff to produce a paper and an oral presentation at the semester's end.

The core courses were team-taught by Linda Deegan, Ken Foreman, Anne Giblin, John Hobbie, Chuck Hopkinson, Jerry Melillo, Chris Neill, and Gus Shaver. Course teaching assistants were Ian Washbourne, Rich McHorney, and



Dixie Berthel

SUE DONOVAN



Laura Broughton

COURTESY OF LAURA BROUGHTON

Allison Burce (an SES alumna from 2002). Bonnie Kwiatkowski and Laura Broughton assisted with the elective courses. George Liles of the National Marine Fisheries Service taught the science writing course.

SES makes extensive use of five local field sites to investigate the effects of land-use change and urbanization on ecosystem function: West Falmouth Harbor, Childs River/Waquoit Bay, Johns Pond, Siders Pond, and the experimental forest at Falmouth Wastewater Treatment Plant that is irrigated with treated effluent from the plant.

The Distinguished Scientist Seminar series gives students the chance to interact with leaders in ecology. This year's speakers were Michael Pace, Institute of Ecosystem Studies; John Pastor, University of Minnesota, Duluth; Walter Boynton, University of Maryland; Alan Covich, University of Georgia; Jon Foley, University of Wisconsin, and Pamela Matson, Stanford University.

To date, 121 students have completed the program since it was initiated in 1997. Forty percent of them are currently enrolled in graduate or professional programs in environmental studies.

Many SES students return to The Ecosystems Center as summer research assistants, interns in the National Science Foundation's Research Experience for Undergraduates program, teaching assistants or full-time research assistants. Approximately 20 percent of SES students have worked at the center after participating in the program.



Aimlee Laderman at MBL cedar swamp.

LAURA BROUGHTON

"I've been fortunate to participate in important and exciting projects at The Ecosystems Center, ranging from studies of how Arctic lakes may respond



TOM KLEINDINST

to climate change to measuring the impact of the Boston Harbor cleanup on benthic ecosystems. It's gratifying to be able to apply science to real environmental problems and see the results of my work used to inform policy makers."

*Sam Kelsey, Research Assistant
The Ecosystems Center
SES 1997, Dickinson College 1998*



LAURA BROUGHTON

Joe Vallino explains the chemistry of microbial mats to SES students during a field trip to Little Sippewissett Marsh.

"I had no idea when my advisor convinced me to enroll in SES over going to some exotic country for



TOM KLEINDINST

my semester 'abroad' that SES would open so many doors for me and teach me so much about the scientific process."

*Liz Burrows, Ph.D. student
Oregon State University
SES 2001, Mount Holyoke College 2002*

"Undoubtedly, the experience as an undergraduate that had the most profound effect on my career path was the Semester in Environmental Science....



BONNIE KEELER

While at SES, I found that biogeochemistry, an integrated science drawing on techniques from several subdisciplines, was a good fit to my broad interests and desire to understand nature."

*Corey Lawrence, Ph.D. student
University of Colorado, Boulder
SES 2000, Clarkson University 2001*

Members of the SES Consortium of Colleges

- | | |
|--------------------------------|----------------------------------|
| Allegheny College | Kenyon College |
| Bard College | Lafayette College |
| Bates College | Lawrence University |
| Beloit College | Lynchburg College |
| Birmingham-Southern University | Macalester College |
| Bowdoin College | Middlebury College |
| Brandeis University | Millsaps College |
| Brown University | Morehouse College |
| Bryn Mawr College | Mt. Holyoke College |
| Carleton College | Randolph-Macon Woman's College |
| Centenary College | Ripon College |
| Centre College | Rollins College |
| Claremont McKenna College | Sarah Lawrence College |
| Clark University | Skidmore College |
| Clarkson University | Southwestern University |
| Colby College | Spelman College |
| Colgate University | Trinity College (CT) |
| Connecticut College | Trinity University (TX) |
| Davidson College | University of Mary Washington |
| Dickinson College | University of Richmond |
| Earlham College | University of the South, Sewanee |
| Furman University | Vassar College |
| Franklin & Marshall College | Wabash University |
| Gettysburg College | Washington and Lee University |
| Grinnell College | Wellesley College |
| Hamilton College | Wesleyan University |
| Hampshire College | Wheaton College |
| Harvey Mudd College | Williams College |
| Haverford College | Worcester Polytechnic Institute |
| Hendrix College | |

Education at The Ecosystems Center



BRETT LONGWORTH

Students and faculty from the Arctic Climate and Terrestrial Ecosystems course during a hike on Slope Mountain in Alaska.



TOM KLEINDINST

David Kicklighter



TOM KLEINDINST

Ben Felzer



TOM KLEINDINST

Shaomin Hu

The Ecosystems Center's education activities are varied. In addition to teaching in the Semester in Environmental Science and in the Brown-MBL Graduate Program in Biological and Environmental Sciences, center scientists serve as adjunct professors, guest lecturers and members of doctoral committees at a number of colleges and universities. Senior staff members supervise postdoctoral scientists at the center and undergraduate interns at remote research sites. Visiting scientists and students come to work on projects, some for a week or two and some for a year or more. Staff members work with elementary and secondary school students, serving as mentors and judges in local science fairs.

Research Opportunities for Students and Teachers

Students

With funding from the National Science Foundation, many college students were able to participate in the Research Experience for Undergraduates (REU) program in 2004, working with Ecosystems Center scientists at field research sites. At the Arctic Long-Term Ecological Research (LTER) site at Toolik Lake, Alaska, Andrew Duling of the University of Vermont worked on projects studying the effects of geomorphic disturbance on stream nutrient and sediment transport in Arctic streams.

Joe Powers of Michigan Technological University returned to Toolik Lake for a second summer REU appointment in 2004. Joe continued his research on soil water measurement using Time Domain Reflectometry, and applied his results to analysis of soil water changes following a rare lightning-caused fire in the tundra near Toolik Lake.

Another intern at the Toolik site, Beth Bernhardt of Lawrence University, participated in a survey of carbon dioxide exchange in a range of tundra types at Toolik Lake and nearby Innavait Creek. Her work helped to show how the light response of photosynthesis by whole vegetation canopies varied among vegetation types and in response to fertilizer addition. Beth also participated in a study of the effects of a tundra fire on plant growth and surface energy and water balance.

Paul Falso of Allegheny College was an REU student with the Arctic LTER streams group in 2004. At Toolik Lake, Paul studied the effects of different levels of phosphorus fertilization in streams on the growth of the Chironomid midge, *Orthocladus rivulorum*. Elizabeth Graham of the University of Michigan also conducted a study at Toolik Lake during her REU internship to consider the effects of disturbances such as storms on lake biological processes.

At Plum Island Ecosystem LTER, Jenn Kerry of Gordon College completed a project that investigated the effect of nutrients, salinity, tidal inundation, and vegetation type on invertebrates.

Oliver Monson from the University of California, Berkeley, traveled to Russia to work with Max Holmes on the PARTNERS (Pan-Arctic River Transport of Nutrients, Organic Matter, and Suspended Sediments) project. He collected samples from the rivers for trace metal analyses and co-presented a poster on the research at the American Geophysical Union in San Francisco in December.

Some undergraduate students worked with center scientists through other internship programs or as assistants in the laboratory.

Linda Deegan served as mentor to Erin Greenfield of Tufts University and Sarah Wolskehl of Colorado College, who were coastal interns in the National Oceanic and Atmospheric Administration program, Career

2004: Integrated training in coastal science and management.

Lauren Fety from Swarthmore College was mentored by Ben Felzer and Vinton Valentine during intersession break. Her project examined different land cover data generated from satellite images and aerial photographs.

Abigail Toltin of the University of Massachusetts, Dartmouth, and Andrew Gaylord, University of Massachusetts, Amherst, worked with Maureen Conte and JC Weber. Abby measured carbonate composition of deep particulate material collected in sediment traps off Bermuda; Andy measured carbon content and isotopic composition of vegetation samples from Toolik Lake and Florida.

Nicholas Malizia of Clark University worked with scientists at the Plum Island LTER and was co-author of a research paper, “Visualizing the rate at which the accuracy of a land change prediction decays.”

Teachers

A middle-school teacher from Salisbury, Vermont, accompanied Max Holmes to Russia in May, as part of the Teachers & Researchers Exploring & Collaborating program of the Arctic Research Consortium of the United States. Amy Clapp spent two weeks in Siberia gathering samples on the Lena River for The Ecosystems Center’s PARTNERS project, which studies the flow of freshwater runoff from six Arctic rivers into the Arctic Ocean. Amy sent regular e-mail lessons to her class via satellite phone linked to a laptop computer.

Dora Nelson, an Asheville, North Carolina, high school science teacher, traveled to Barrow, Alaska, to participate in the Arctic LTER Schoolyard project. She and three students sampled Cake Eater Lake to study changes in water chemistry.

Michele Bahr worked with David Patterson and Sarah Roland of the MBL to create an online educational program on Microbiology for teachers and students called micro*scope. The interactive website is designed to help teachers incorporate microbiology into their curriculum.

Schoolyard LTER Projects

Both the Arctic and Plum Island Long-Term

Ecological Research (LTER) projects received supplemental funding from the National Science Foundation for educational activities near their sites.

The Schoolyard Project of the Arctic LTER at Toolik Lake is based in Barrow, Alaska, 250 miles to the northwest of Toolik, since there is no community near Toolik. The program is designed for Barrow students, who are mostly Native Iñupiat Eskimo, in kindergarten through grade 12, their teachers and local residents. It consists of two field activities and “Schoolyard Saturday,” a weekly series of lectures and field demonstrations by visiting and resident scientists.

The first field experiment is a tundra warming experiment in which students study the effects of climate warming on tundra vegetation. A second



Tenth graders from Barrow, Alaska, take ice cores from Cake Eater Lake on the Barrow Environmental Observatory with teacher Tim Buckley and scientist Jerry Brown.

TORSTEN SACHS

experiment, added in 2004, involved measuring changes in lake water chemistry.

Since the program’s inception in 2002, the Saturday lecture series has been offered year-round to the public. In all, 135 talks have been given by local and visiting scientists. In 2004, Laura Broughton of The Ecosystems Center lectured on microbes, and visiting teacher Dora Nelson of North Carolina talked about teaching science.

The program is administered by the Barrow Arctic Science Consortium, with input from Arctic scientist Jerry Brown of Falmouth, Massachusetts, who was instrumental in developing it.



Jon Benstead

TOM KLEINDINST



Jen Bowen

TOM KLEINDINST



Heidi Wilcox

JON BENSTEAD



Michele Bahr

TOM KLEINDINST



Bonnie Keeler

TOM KLEINDINST



Don Burnette

TOM KLEINDINST

In 2004, the Plum Island Ecosystems (PIE) Schoolyard LTER program, which is conducted through the Massachusetts Audubon Society's Salt Marsh Science Project, expanded its presence in the region by adding several urban school districts, including Dorchester, East Boston and Salem, Massachusetts. The Schoolyard Project developed new programs that parallel PIE research projects and continued to provide professional development training for teachers. In all, 1,500 students and 48 teachers have participated in the project.



Yuriko Yano

JIM LAUNDRE

Through another Schoolyard program at PIE, middle and high school students from throughout the region kept up their long-term monitoring of salt marshes for vegetation, invasive species (e.g., *Phragmites australis*), salinity levels and salt marsh fish. At Governor Dummer Academy, high school classes continued to observe spatial patterns in marsh plant community structure as well as changes in numbers and distribution of ribbed mussels and snails in Rowley River tidal creeks.

Science Outreach in the Community

In 2004, many members of The Ecosystems Center staff judged science fairs in kindergarten through grade 12 and assisted students in planning their science projects.

Gus Shaver, Ben Felzer, Hap Garritt and Jane Tucker judged the science fair at Falmouth Academy in February. Michele Bahr and Marshall Otter were judges for the Falmouth Public Schools Science Fair in March. Marshall also judged the Massachusetts State Science Fair at the Massachusetts Institute of Technology in April.

Heidi Wilcox, Laura Broughton, Bonnie Keeler, JC Weber, Sam Kelsey, Michele Bahr and Ben Felzer helped seventh and eighth grade students at Lawrence School, Falmouth's junior high school, as they planned and implemented their science projects. The program is arranged through the Woods Hole Science and Education Technology Partnership (WHSTEP), for which Debbie Scanlon serves as The Ecosystem Center's liaison.

Michele Bahr gave presentations on the importance of microbes in the environment to middle and high school teachers at a Sea

Education Association (SEA) program and at an in-service training session of Cape Cod General Education Development (GED) teachers. She also taught in the MBL course, Living in the Microbial World, an intensive hands-on workshop for teachers.

Falmouth High School science teachers visited The Ecosystems Center for an in-service presentation. John Hobbie and Ed Rastetter gave an overview of their research, and Don Burnette led the teachers on a tour of the Starr Building.

Chris Neill continued to write a nature column for the *Falmouth Enterprise*.

Science Journalism Program/Arctic Climate and Terrestrial Ecosystems Course

The Ecosystems Center participates each year in the MBL's Science Journalism Program. Journalists attend a lecture and laboratory course in Woods Hole in June, co-directed by Chris Neill and Ken Foreman. In 2004, four journalists, John Carey of *Business Week* and freelance writers Rebecca Clarren, Elizabeth Grossman and Eugene Russo, traveled to the Arctic LTER research site at Toolik Lake, Alaska. There, they participated in a workshop on Arctic Climate and Terrestrial Ecosystems, which was sponsored by the International Arctic Research Center (IARC) of the University of Alaska Fairbanks and The Ecosystems Center and organized by John Hobbie.

In addition to the science writers, 23 graduate students enrolled in the workshop, which offered an overview of the controls of ecosystem variability in northern Alaska, from the Alaskan interior to the Arctic. The first week of the workshop consisted of lectures and discussions at the IARC and visits to research sites in the Fairbanks area. During the second week, the students traveled to Toolik Lake, on the North Slope, where the science journalists joined them. Scientists at the LTER site at Toolik demonstrated techniques and models used to study Arctic terrestrial ecosystems in the context of a changing climate. The class took field trips to terrestrial and aquatic experimental sites and traveled up the Dalton Highway to Prudhoe Bay on the Arctic Ocean.



Paul Colinvaux

MIRIAM STEINITZ-KANNAN



Erica Stieve

ERIC CALDWELL

Alaska LTER Interns Study Effects of Rare Tundra Fires

More than six and a half million acres burned in Alaska in 2004, an area larger than the Commonwealth of Massachusetts. The cause was lightning, striking forests and tundra that were especially dry in one of Alaska's warmest and driest summers on record.

While lightning-caused fires are not uncommon, the number of such fires and the vast amount of acreage burned this year are noteworthy.

And, in June, lightning ignited fires on the tundra of the North Slope, a highly unusual event, since the tundra is normally moist at this time of year from melting snow and ice.

Interns in the National Science Foundation (NSF)'s Research Experience for Undergraduates program at the Arctic Long-Term Ecological Research (LTER) site at Toolik Lake, Alaska, quickly set about to study this event. John Hobbie, director of the LTER site, arranged additional funding from NSF for helicopters to take the students to the site. With direction from Sydonia Bret-Harte of the University of Alaska Fairbanks, the students concluded that vegetation in the burned area recovered more quickly than expected, due to regrowth of vascular plants from buds below the ground surface that were protected from the fire. By August, the burned area was considerably greener than the control, though the biomass in the burned area was not as great. The depth of thaw in the burned area was also much greater than in the control because the fire burned away much of the moss and lichen cover. The progressively deepening depth of thaw suggests that burned areas may not rapidly return to their pre-burned state, despite the recovery of the vascular vegetation.



RICHARD FLANDERS

Semester in Environmental Science

The Semester in Environmental Science (SES) program was offered for the eighth year in 2004, directed by Ken Foreman. Dixie Berthel was administrative assistant and teaching assistants were Ian Washbourne, Rich McHorney and Allison Burce.

Other staff members were involved with the SES students, helping them with field work, lab assignments and independent study.

Brown-MBL Graduate Program in Biological and Environmental Sciences

The Ecosystems Center was actively involved in the new Brown-MBL collaboration in education and research. At the undergraduate level, Brown joined the SES consortium and two Brown students were in the SES class of 2004. Four center scientists, John Hobbie, Chuck Hopkinson, Jerry Melillo and Chris Neill, teamed up with Steve Hamburg, associate professor of ecology at Brown, to teach an introductory environmental science course at Brown.

The program accepted its first Ph.D. student into the Brown-MBL graduate program, Gillian Galford. Gillian was graduated in 2004 from Washington University in St. Louis, where she majored in earth and planetary sciences. In the Brown-MBL program, Gillian is working with Jack Mustard, associate professor of geology at Brown, and Jerry Melillo at the center to study the regional and global consequences of the expansion of mechanized agriculture in Brazilian Amazon. She will use a combination of remote sensing, biogeochemistry and simulation modeling in her research.

Four center scientists, Linda Deegan, Chuck Hopkinson, Gus Shaver and

Joe Vallino, were granted joint appointments to the Brown faculty in the Department of Ecology and Evolutionary Biology.

Postdoctoral Scientists

Jon Benstead received his doctorate from the University of Georgia in 2001, where he worked with Cathy Pringle at the Institute of Ecology. His dissertation research examined the consequences of catchment deforestation for stream ecosystems in eastern Madagascar. Since arriving at the center in 2002, he has been working with Linda Deegan and Bruce Peterson on responses of the biota of small Arctic streams to nutrients, recovery of Arctic stream reaches from experimental phosphorus addition, and the factors controlling growth of adult and young-of-year Arctic grayling.

Laura Broughton came to The Ecosystems Center in 2002 to work with Gus Shaver. She has a National Science Foundation Microbial Biology Fellowship to investigate the effects of climate change on the soil microbial community



TOM KLEINDINST

Christian Picard



LAURIE CHASSON

Heidi Lux



KNUTE NADELHOFFER

Neil Bettez



TOM KLEINDINST

Dennis Miller



Vinton Valentine

TOM KLEINDINST

in Arctic systems. Laura received her doctorate in 2001 from Michigan State University, where she studied with Kay Gross at the Kellogg Biological Station. Her dissertation research investigated former agricultural fields and effects of plant communities on soil microbes. At the center, she is studying the effects of warming and fertilization treatments on differences in soil microbial community composition and processes among tundra types at the Arctic LTER site in Toolik Lake, Alaska.



Suzanne Thomas

BRYNNE BRYAN

Al Chan joined the center in 2002. He received his doctorate in 2000 from the Department of Microbiology at Iowa State University and did his research at The National Soil Tilth Laboratory in Ames, Iowa, working with Timothy Parkin. His research focused on the controls of methane cycling in soils. Al worked with Paul Steudler on the Atmospheric Methane Oxidizers in Soil project, investigating the short- and long-term effects of nitrogen deposition on methane oxidation in temperate forests and how they relate to the physiological and molecular diversity of atmospheric methane oxidizers. He is also the creator and webmaster of Microbes.info, a resource for finding information on microbiology topics. Al moved to Melbourne, Florida, in March to become Senior Scientist at AgCert International, a greenhouse gas emissions reduction company.



Jim Galloway

TOM COGILL

Joaquín Chaves received his doctorate in 2004 from the University of Rhode Island's Graduate School of Oceanography, where he worked with Scott Nixon. His dissertation research focused on tracing anthropogenic and oceanic derived nitrogen using stable isotopes in Narragansett Bay, Rhode Island. Since joining the center, he has been working with Chris Neill on nitrogen transport and cycling in small forest and pasture streams in the western Brazilian Amazon basin, focusing on the role of different hydrological flowpaths as vehicles for nitrogen transport to stream channels.



Carrie McCalley

TOM KLEINDINST

Jacqueline Mohan joined The Ecosystems Center in 2004 to work with Jerry Melillo, studying the effects of soil warming on soil biogeochemical processes and tree community composition at the Harvard Forest LTER. Previously, she worked with Fahkri Bazzaz at Harvard University, where she initiated a

study of how climate warming might impact future forest successional dynamics. She earned her doctorate in 2002 at Duke University where she worked with Jim Clark and Bill Schlesinger at the Duke Forest Free-Air Carbon Dioxide Enrichment experiment. As part of her doctoral work she investigated temperate forest tree responses to elevated atmospheric carbon dioxide, and modeled implications for forest succession.

Vinton Valentine came to The Ecosystems Center to work with Chuck Hopkinson in 2003. He received his doctoral degree that year from University of Delaware, where he studied with Vic Klemas at the Center for Remote Sensing in the Graduate College of Marine Studies. His dissertation research investigated the displacement and spatial structure of the scrub-shrub/emergent wetland ecotone along tidal rivers in response to sea-level change and human impacts using remote sensing and GIS technologies. At the center, he is analyzing creek network patterns to develop indicators of condition and stability for tidal marshes facing sea-level rise and other stressors at the Plum Island Ecosystems LTER site in northeastern Massachusetts.

Yuriko Yano joined The Ecosystems Center in 2002 after receiving her doctorate from the Department of Forest Science at Oregon State University, where she studied with Phil Sollins and Kate Lajtha. Currently, she works with Gus Shaver, Anne Giblin and Ed Rastetter on nitrogen cycling and turnover in an Arctic watershed at Toolik Lake, Alaska. The main focus of her research is to determine how nitrogen is retained in soil and/or transported in hydrological flows within the watershed.

Qianlai Zhuang joined the center in 2001 to work with Jerry Melillo in the Terrestrial Ecosystem Model (TEM) group. He completed his doctorate that same year at the Institute of Arctic Biology and Department of Biology and Wildlife of the University of Alaska Fairbanks, where he studied with David McGuire. In his dissertation research, he investigated the effects of changes in permafrost on carbon dynamics in high-latitude ecosystems. He also examined interactions among permafrost changes, water dynamics and fire for their effect on carbon

dynamics. At the center, Qianlai has worked on both a biocomplexity project and a land-use and land-cover change project. His research focuses on the dynamics of soil methane emission and consumption and their feedbacks between terrestrial ecosystems and climate.

Adjunct Scientists

Paul Colinvaux, an adjunct scientist at The Ecosystems Center, came here from the Smithsonian Tropical Research Institute in Panama. He has begun a new collaboration with the Massachusetts Institute of Technology, the University of Arizona, Northern Kentucky University and the Florida Institute of Technology to re-core Galapagos lakes that were cored in 1966 in order to refine the long climatic history of Eastern Pacific Region (EPR) that Colinvaux published in 1972. With new analytical methods, the research offers the potential of the most detailed history of El Niño throughout the Holocene yet obtained. In addition he hopes to test the rival El Niño and La Niña models for the EPR glacial climates. The field work for this project was completed in September 2004.

Robert Howarth, an adjunct scientist at the center, is also a professor of ecology at Cornell University and director of the North American Nitrogen Center, one of five continental-scale centers of the International Nitrogen Initiative. During 2004, he led the efforts of the Millenium Assessment to ascertain possible societal responses to nutrient pollution, and he provided briefings to staff of the U.S. Senate Committee on Agriculture and other policy makers on appropriate measures to reduce nitrogen pollution from agriculture and fossil-fuel combustion in the U.S. He gave one of the plenary addresses at the 3rd International Symposium on Nitrogen held in Nanjing, China, in October, with a talk on policy approaches for reducing nitrogen pollution. Also during 2004 he began work on two new research projects in Woods Hole. One of these, funded by the NSF Biocomplexity program, focuses on the responses of West Falmouth Harbor to increased nitrogen pollution from a contaminated plume of groundwater that originated with the Falmouth wastewater treatment plant. Colleagues on this



Marshall Otter and Paul Stuedler

TOM KLEINDINST



Ai Chan

TOM KLEINDINST

work include Roxanne Marino of Cornell and The Ecosystems Center, Anne Giblin and Ken Foreman of the center, and Karen McGlathery and Peter Berg of the University of Virginia. The other project, funded by Woods Hole Sea Grant, examines the importance of vehicles on Cape Cod as a source of nitrogen pollution to coastal waters, with an emphasis on the atmospheric deposition of nitrogen pollution in the immediate vicinity of roads; colleagues include Roxanne Marino, Eric Davidson of the Woods Hole Research Center and Neil Bettez of Cornell.



Ketil Koop-Jacobsen

TOM KLEINDINST

Maureen Conte joined The Ecosystems Center as a resident adjunct scientist in September. Maureen is an associate scientist at the Bermuda Biological Station for Research, Inc. Her oceanographic and atmospheric studies focus on applications of organic geochemical (and inorganic) tracers to elucidate the processes that control the global carbon cycle. She is the principal investigator of the 27-year Oceanic Flux Program (OFP) sediment trap time series off Bermuda, one of the longest running time-series in oceanography. Her OFP research, funded by NSF, focuses on quantifying material flux to the deep ocean and its variability on time scales of weeks to decades and on using organic geochemical techniques to study the coupled physical and biological processes that control deep ocean particle fluxes. Maureen's atmospheric research, funded through NSF, NOAA and DOE, is using a new method based upon the isotopic composition of plant leaf waxes in aerosols to quantify the spatial and temporal patterns of isotopic fractionation of atmospheric carbon dioxide by terrestrial photosynthesis.



Pat Micks

TOM KLEINDINST



Qianlai Zhuang

TOM KLEINDINST

Ecosystems Center Events and Activities in 2004



Bruce Peterson

MAX HOLMES

Elections and Promotions

Jerry Melillo assumed the presidency of the Ecological Society of America (ESA) at the group's annual meeting in Portland, Oregon, in August. Gus Shaver started his term as vice president for science of the 8,000-member organization.

Jerry is also serving his second term as president of the Scientific Committee on Problems of the Environment (SCOPE), founded in 1969 by the International Council of Scientific Unions to assess information on anthropogenic environmental changes.

John Hobbie finished the final year of his second term as member of Arctic Research Commission. He was appointed to the commission by President Clinton in 1996.

Chris Neill was promoted to the position of associate scientist. Chris came to The Ecosystems Center as a postdoctoral fellow after receiving his Ph.D. from the University of Massachusetts, Amherst.

In the News

Center scientists are often interviewed by media, sometimes for feature stories on their research, sometimes for background information.

The BBC interviewed Bruce Peterson for a program on climate change, while Anne Giblin gave an interview to KTNA, Alaska Public Radio, for a story on the role of benthic production in Arctic lakes. For National Public Radio's "Earth and Sky," Chris Neill was interviewed on his research in the Amazon Basin.

The *Cape Cod Times* wrote a story on the Russian Arctic research project that is being carried out by Bruce Peterson, Max Holmes and Jim McClelland. The story featured Anya Suslova, a teenager from a town on the Lena River in Siberia who helped Max, Jim and Bruce by sending water samples through the winter for their study on freshwater discharge from the Arctic Rivers into the Arctic Ocean.

Science writer Rebecca Clarren's story "Baked Alaska" was featured on Salon.com in September. Rebecca was an MBL Science Journalism Program Fellow who participated in the MBL's program at Toolik Lake.



Max Holmes

JIM MCCLELLAND



Jim McClelland

DEANA ERDMER



Bob Howarth

CORNELL UNIV. PRESS OFFICE



Roxanne Marino

BOB HOWARTH

International Conferences

Linda Deegan, Chris Neill, Christie Hauptert and Paul Steudler attended the Third Large-Scale Biosphere-Atmosphere Science Meeting in Brasilia, Brazil, in July. Linda gave a talk on using ^{15}N to trace nitrogen transport in Amazonian streams, and Chris spoke on soil nitrogen transformations following the clearing of tropical forests for pasture. Christie presented a poster that described their research on how stream size influences the biogeochemistry of nitrogen in pasture stream channels. Paul was co-convenor of a workshop on the intensification of agriculture in the Amazon Basin.

Jerry Melillo served as chair of the regional Millennium Assessment workshop in China in May. He is currently chair of the International Review Committee of the Millennium Ecosystem Assessment for Western China (MAWEC), part of the global Millennium Ecosystem Assessment. The MAWEC studies changes to ecosystems in western China and how these changes affect essential items such as food and clean water.

In June, Jerry traveled to Venice to attend the Massachusetts Institute of Technology's Global Change Forum.

Gus Shaver attended the organizational meeting of the Circum-Arctic Terrestrial Biodiversity project of the European Union at Sweden's Uppsala University in May. He also presented a seminar at Lund University on long-term experiments in the Arctic tundra. In October, he lectured at the University of Edinburgh, Scotland, on carbon-nitrogen interactions in the Arctic tundra.

Ed Rastetter traveled to La Selva, Costa Rica, in February as a consultant on a rainforest canopy project and later visited the Macaulay Institute in Aberdeen, Scotland, in April to work on a carbon-14 labeling experiment.

Long-Term Ecological Research (LTER)

The annual meeting of the Arctic LTER was held in Woods Hole in February, organized by John Hobbie and Debbie Scanlon. Attending from the MBL were Michele Bahr, Jon Benstead, Laura Broughton, Chris Crockett, Linda Deegan, Marcus Gay, Anne Giblin, Adrian Green, Bonnie Kwiatkowski, Jim Laundre, Carrie McCalley,

Bruce Peterson, Ed Rastetter, Gus Shaver, Erica Stieve, Joe Vallino, Ian Washbourne, Heidi Wilcox and Yuriko Yano.

The Plum Island Ecosystems LTER's annual meeting was held in May in Woods Hole. Chuck Hopkinson organized the event, which was attended by Suzanne Thomas, Vinton Valentine, Michele Bahr, Emily Gaines, Jen Bowen, Anne Giblin, Ketil Koop-Jakobsen, Joe Vallino, Hap Garritt, and John Hobbie.

In February, John Hobbie participated in the LTER national executive committee meeting in Washington, D.C., and in April, he traveled to a meeting in San Jose to advise on the organization of a new marine LTER for McMurdo Sound, Antarctica. He helped plan a new LTER program on cross-site research and synthesis at a meeting at Cape Canaveral in November.

As the Arctic representatives to the LTER network coordinating committee, Gus Shaver and John Hobbie attended the committee's meeting in Fairbanks in August, then they, assisted by Debbie Scanlon, led the group on a field trip to Toolik field station and Prudhoe Bay. Gus also represented the Arctic group at the committee's meeting in Santa Barbara in April.

Hap Garritt of the Plum Island LTER and Jim Laundre of the Arctic LTER attended the NSF LTER information managers' meeting in July in Portland, Oregon.

Estuarine Research Federation (ERF)

Linda Deegan is on the governing board of ERF and is president of the New England Estuarine Research Society (NEERS), a regional affiliate society of ERF. In March, she gave a talk on the effects of long-term nutrient addition on a salt marsh community at the spring meeting in Burlington, Vermont. At the same meeting, Linda presented research that she and others have done on mummichogs. Anne Giblin and Jane Tucker also attended.

At the October meeting of NEERS, held on Block Island, Rhode Island, Anne Giblin presented her research on salinity effects on the nitrogen cycle in estuaries. Sam Kelsey, Jane Tucker and Vinton Valentine also attended. Sam and Jane presented posters: Sam's topic was "Boston Harbor sediment improving with reduced sewage loading." Jane's was titled

"Massachusetts Bay: Beginning to see the forest."

American Geophysical Union (AGU)

Chuck Hopkinson was co-organizer of the AGU-sponsored Chapman Conference on Salt Marsh Geomorphology: Physical and Ecological Effects on Landform, held in Halifax, Nova Scotia in October. The purpose of this conference was to summarize current research and research needed in the future to determine the response of coastal marshes to anthropogenic activities. Chuck and Vinton Valentine co-authored a presentation, given by Chuck, on indications of change in coastal intertidal wetlands.

At the AGU annual meeting in San Francisco in December, John Hobbie gave a poster with co-author Erik Hobbie on how mycorrhizal fungi provide nitrogen for Arctic plants. Gus Shaver attended and presented a poster on long-term Arctic tundra experiments. Ben Felzer gave a talk on his research using a biogeochemical model to study the effect of ozone on ecosystem processes. Yuriko Yano gave two presentations, one on nitrogen transformation and transport in an Arctic watershed and the other about detrital controls on dissolved organic matter in soils.

Meetings and Workshops

Joe Vallino attended the Ocean Research Conference sponsored by the American Society of Limnology and the Oceanography in Honolulu in February and gave a talk on modeling biogeochemical processes.

Ben Felzer gave a talk on using biogeochemical models to determine ozone effects on net primary production and carbon sequestration at the 36th Annual Air Pollution Workshop in Rhinelander, Wisconsin, in April.

Vinton Valentine attended the annual meeting of the Atlantic Coast Environmental Indicators Consortium in April at the Institute of Marine Sciences, University of North Carolina-Chapel Hill in Morehead City. Vinton also made a presentation on geomorphometric indicators of tidal marsh condition in Plum Island Estuary at the May Environmental Monitoring and Assessment Program 2004 Symposium of the U. S. Environmental Protection Agency, held in



Ed Rastetter



Bonnie Kwiatkoski



Zy Biesinger



Gillian Galford



Marty Downs



Kelly Holzworth

TOM KLEINDINST

Newport, Rhode Island. Chuck Hopkinson was a co-author.

At the annual meeting of the Arctic Research Consortium of the U. S. in Washington, D. C. in May, John Hobbie spoke about the Arctic research projects that are currently underway at The Ecosystems Center.

Chuck Hopkinson was invited to the Workshop on Ocean Impacts of Climate Change organized by Cleanair – Coolplanet, held in Boston in June. His presentation was on the effects of climate change on coastal ecosystems.



Debbie Scanlon

MARTHA SCANLON

At the North American Benthological Society in Vancouver, B.C., in June, Adrian Green presented a talk on the landscape characteristics of the Upper Kuparuk stream network, North Slope, Alaska. Heidi Wilcox presented a poster on nitrogen retention in mountain and spring Arctic streams. Jon Benstead also attended and presented a poster on stoichiometric interactions in the Kuparuk River food web.

In July, Joe Vallino gave a lecture titled “Is ecosystem biogeochemistry governed by nonequilibrium thermodynamics and resource allocation constraints?” at the Gordon Conference on Metabolic Basis of Ecology, held at Bates College in Lewiston, Maine.



Sue Donovan

BILL DONOVAN

At the Ecological Society of America annual meeting in Portland in August, Jerry Melillo gave a lecture on element interactions at the global scale. John Hobbie attended and gave a paper on comparison of aquatic and terrestrial organic nitrogen use and decomposition. Gus Shaver presented two posters on his Arctic research. Ed Rastetter also attended. Gus traveled to Washington, D.C., to attend meetings of the ESA governing board in May and November.

Bruce Peterson attended the synthesis retreat of the Arctic System Science at Lake Tahoe, California, in August. In September, Chuck Hopkinson attended the Fourth Annual All-Estuarine and Great Lakes Environmental (EaGLE) Centers Conference meeting at the University of Minnesota Duluth, and presented a poster, co-authored with Vinton Valentine, “Geomorphometric patterns of tidal marsh development and degradation.”

Jerry Melillo was chair of the United Nations Environment Programme workshop to design a



Mary Ann Seifert

TOM KLEINDINST

special report on the environment in Washington, D.C., in September.

Anne Giblin organized a session on linkages between upland and coastal ecosystems at the Northeastern Ecosystem Research Cooperative in November in Durham, New Hampshire. Chuck Hopkinson made a presentation on land use effects on the coastal zone.

Chris Crockett, Gus Shaver and John Hobbie attended the annual meeting of Toolik Field Station Steering Committee in San Francisco in December. Following the Steering Committee meeting, John attended a NSF-sponsored workshop on the future directions and needs of scientific research supported by the Toolik Field Station.

At the MBL

Jerry Melillo gave a Friday Evening Lecture at the MBL in June on “Biology, Earth’s Atmosphere and Climate Change.”

Anne Giblin was on the steering committee for the Workshop on Advanced Approaches to Quantify Denitrification, held in May. She also gave a talk on ecosystem-scale measurements using nutrient stoichiometry, mass balance and ¹⁵N tracers and was the discussion leader for the working group on integrating denitrification estimates from fresh to salt water.

The Arctic Flagship Observatories meeting in November was organized by Gus Shaver and attended by John Hobbie, Ed Rastetter and Bruce Peterson. The objective of the workshop was to stimulate researchers and funding agencies to develop integrated and long-term Arctic research observatories, both in the U.S. and internationally.

Chris Neill organized the Coastal Sandplain Science and Conservation Workshop in December, at which he gave a lecture on vegetation and biogeochemical responses to sandplain land management on Martha’s Vineyard, Massachusetts.

Lectures and Seminars

In addition to their lectures at Brown University as part of the Brown-MBL graduate program, center scientists gave presentations on environmental issues to many colleges and universities, local scientific institutions and community groups.

At the University of Massachusetts, Boston, in March, Anne Giblin presented a seminar on freshwater discharge and nitrogen cycling in the oligohaline zone of estuaries. At Vassar College in November, she spoke on eutrophication in a dammed estuary.

Joe Vallino gave lectures on microbial biogeochemistry at the University of New Mexico, Albuquerque, in November and Lawrence Livermore National Laboratory in California in December.

In February, Jerry Melillo spoke at Williams College on greenhouse gas emissions from the Brazilian Amazon. At Auburn University in March, he lectured on nitrous oxide emissions from tropical forests. Later in the year, Jerry spoke on global climate change at the Massachusetts Institute of Technology and Wesleyan University.

In April, Chuck Hopkinson was invited to speak at the Virginia Institute of Marine Science and the Woods Hole Oceanographic Institution (WHOI) on the topic of the stoichiometry of oceanic dissolved organic matter.

Bruce Peterson spoke at Bates College in March on increasing Arctic river discharge and climate change. In May, he made a presentation on denitrification at the Woods Hole Research Center and again on the same subject in November at WHOI. Bruce spoke at Wesleyan and Stony Brook University in October on abrupt climate change.

Gus Shaver gave a seminar on climate change and ecosystem stoichiometry in an Arctic landscape at the University of Massachusetts, Boston, in December.

Chris Neill gave a talk at the Edgartown, Massachusetts, Yacht Club in July on science that supports conservation of Martha's Vineyard's biological diversity. Chris was invited to speak on how deforestation is altering Amazonian stream ecosystems at a lecture at Grinnell College in November.

Ben Felzer lectured at Sea Education Association in Woods Hole on climate change and global warming. Michele Bahr gave an introductory lecture to the microbial world and laboratory exercises on basic microbiology

principles for the course "Planetary Protection: Policies and Practices," held in Santa Cruz, California in April.

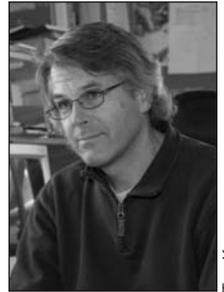
Committee Memberships

John Hobbie is taking part in the newly formed National Ecological Observatory Network (NEON). The NEON Design Consortium is funded by the National Science Foundation to plan a nation-wide network of observatories that would have similar installations and experiments. In July he attended a science workshop in Boulder convened by NEON to write a report on the ecological aspects of biogeochemical cycles. As a representative of the High Latitude Ecological Observatory group, John attended a meeting of the regional NEON group at Bonnevill Hot Springs Resort in Washington in October.

John is chairman of Florida Bay Scientific Oversight Committee. He has also served as a member of the board of trustees of the National Institute for Global Environmental Change.

Jerry Melillo is a board member of the H. John Heinz III Center for Science, Economics and the Environment. He also serves on the external advisory committees of the Directorate for Biological Sciences of the National Science Foundation; the Natural Resources Ecology Laboratory at Colorado State University; the Center for the Study of Institutions, Population, and Environmental Change at Indiana University; and Strategic Analysis, Research and Training (START), an international non-governmental organization that helps scientists from developing countries participate in global-change science.

Chris Neill is a member of the board of directors of Falmouth Associations Concerned with Estuaries and Salt Ponds and of the Association to Preserve Cape Cod. He is also a member of The 300 Committee Capital Campaign Committee, the Coalition for Buzzards Bay Science Advisory Committee, and the executive committees of the Cape Cod Group of the Sierra Club and the Coonamessett River Coalition.



Chuck Hopkinson

TOM KLEINDINST



Jane Tucker

PAUL JOYCE



Hap Garritt

TOM KLEINDINST



Emily Gaines

TOM KLEINDINST



Gus Shaver and Lorna Street

TOM KLEINDINST

Linda Deegan is on the editorial board of *Ecological Applications*. Gus Shaver serves on the editorial boards of *Ecosystems* and *Arctic, Antarctic, and Alpine Research*. He is also on the steering committees of Terrestrial Ecosystem Responses to Atmospheric and Climate Change, the Arctic Climate Impact Assessment panel on Terrestrial Ecosystem responses to Climate Change and UV-B, and is a member of steering committee of the Study of Environmental Arctic Change.

Jane Tucker is chair of the Falmouth Coastal Resources group. Ben Felzer is on the technical review committee of global change and wildlife for The Wildlife Society.

Anne Giblin is chair of the advisory board of the Cooperative Institute for Coastal and Estuarine Environmental Technology.

Ken Foreman is a member of the Town of Falmouth's Nutrient Management Working Group and a member of the Falmouth Ashumet Plume Nitrogen-Offset Committee. Linda Deegan is a member of the Falmouth Conservation Commission.



Maureen Conte, Abigail Toltin and JC Weber

TOM KLEINDINST

MBL Boards and Committees

Jerry Melillo is a member of the search committee for a new director for the MBL. Gus Shaver is a member of the MBL Science Council, while Chris Neill serves on the laboratory's buildings and grounds committee. Joe Vallino is on the computer advisory committee, and John Hobbie is chair of the MBL safety committee, of which Don Burnette and Paul Steudler are members. Anne Giblin serves as chair of the diving control board and Jane Tucker is a member of diving committee and of the laboratory's employee position evaluation committee. Kelly Holzworth and Debbie Scanlon are members of the activities committee.



Chris Crockett, Jim Laundre and Adrian Green

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Mac Lee and Mike Johnson

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Seminars at The Ecosystems Center During 2004

January

- 27 David McGuire, University of Alaska Fairbanks, “Modeling the role of historical forest harvest in the carbon budget of the United States.”

February

- 3 Mark Bertness, Brown University, “Why experimental community ecology matters to conservation biology.”
- 10 Steven Wofsy, Harvard University, “Short term and long term controls on the carbon budgets of forested ecosystems.”
- 17 Heidi Nepf, Massachusetts Institute of Technology, “Flow and transport in aquatic canopies.”

March

- 2 Steven Hamburg, Brown University, “Calcium biogeochemistry in the northern hardwood forest: Trace minerals, land-use history and acid rain.”
- 9 Michael Keller, University of New Hampshire, “Effects of logging in the Brazilian Amazon on biogeochemical cycles.”
- 16 Christopher Neill, MBL, “Land-water nitrogen movement following severe disturbance of a coastal forest: Insights from a conservation management experiment on Martha’s Vineyard.”
- 23 Thomas Jordan, Smithsonian Environmental Research Laboratory, “Changes in nitrogen and phosphorus biogeochemistry along an estuarine salinity gradient.”
- 30 Peter Raymond, Yale University, “Terrestrial atmospheric CO₂ sequestration and rivers: The role of watershed export of dissolved organic and inorganic carbon on regional and global carbon budgets.”

April

- 6 Charles Driscoll, Syracuse University, “Acid rain revisited.”
- 13 Kathleen Weathers, Institute of Ecosystem Studies, “Clouds, fog and the maintenance of ecosystems: Mist opportunities?”
- 20 Stefan Sievert, Woods Hole Oceanographic Institution, “Life at the oxic-anoxic interface: Structure and function of sulfur transforming microbial communities.”
- 27 Ruth Curry, Woods Hole Oceanographic Institution, “Observed ocean salinity changes: Implications for the planetary hydrologic cycle.”



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May

- 4 Julia Jones, Oregon State University, “Seasonal and successional streamflow response to forest cutting and regrowth in the northwest and eastern United States, and some evidence of hydrologic effects on carbon and nitrogen.”
- 11 Timothy Fahey, Cornell University, “Contrasting rhizosphere effects of ectomycorrhizae and arbuscular mycorrhizae of forest trees.”
- 18 John Mustard, Brown University, “Climate, water, and plants: Environmental change in the Great Basin, U.S.”
- 25 Joseph Vallino, MBL, “Optimal resource allocation, distributed metabolism, and microbial biogeochemistry.”

October

- 5 Maureen Conte, MBL, “What organic aerosols can tell you about the terrestrial carbon cycle: Case studies from Maine and Alaska.”
- 12 Lawrence Hurd, Washington and Lee University, “The community niche of generalist predators.”
- 19 Jani Benoit, Wheaton College, “Infaunal burrow densities and sediment methyl mercury accumulation in Boston Harbor.”

November

- 9 Doug Spieles, Denison University, “Mitigation banks: Compensatory creation and restoration of wetlands.”
- 30 Diane McKnight, University of Colorado at Boulder, “Dissolved organic material in aquatic ecosystems: Electron transport reactions transforming trace constituents.”

December

- 7 Changsheng Chen, University of Massachusetts, Dartmouth, “A new estuarine ecosystem modeling system: Application and validation.”

Staff at The Ecosystems Center During 2004

Administrative Staff

John E. Hobbie, Co-Director
Ph.D., Indiana University
Jerry M. Melillo, Co-Director
Ph.D., Yale University
Kenneth H. Foreman, Director of Semester in
Environmental Science Program
Ph.D., Boston University
Dorothy J. Berthel, Administrative Assistant
Suzanne J. Donovan, Graphics and Website
Specialist
Massachusetts College of Art
Kelly R. Holzworth, Research Administrator
University of San Diego
Deborah G. Scanlon, Projects and Publications
Coordinator
B.A., Syracuse University
Mary Ann Seifert, Administrative Assistant
B.A., Alfred University

Scientific Staff

Linda A. Deegan, Senior Scientist
Ph.D., Louisiana State University
Anne E. Giblin, Senior Scientist
Ph.D., Boston University
John E. Hobbie, Senior Scientist
Ph.D., Indiana University
Charles S. Hopkins, Senior Scientist
Ph.D., Louisiana State University
Jerry M. Melillo, Senior Scientist
Ph.D., Yale University
Bruce J. Peterson, Senior Scientist
Ph.D., Cornell University
Edward B. Rastetter, Senior Scientist
Ph.D., University of Virginia
Gaius R. Shaver, Senior Scientist
Ph.D., Duke University
Christopher Neill, Associate Scientist
Ph.D., University of Massachusetts, Amherst
Joseph J. Vallino, Assistant Scientist
Ph.D., Massachusetts Institute of Technology
Paul A. Steudler, Senior Research Specialist
M.S., University of Oklahoma
Benjamin Felzer, Research Associate
Ph.D., Brown University
David W. Kicklighter, Research Associate
M.S., University of Montana
Robert M. Holmes, Research Associate
Ph.D., Arizona State University

Roxanne Marino, Research Associate
Ph.D., Cornell University
James W. McClelland, Research Associate
Ph.D., Boston University

Educational Staff Appointments

Jonathan P. Benstead, Postdoctoral Scientist
Ph.D., University of Georgia
Jennifer L. Bowen, Postdoctoral Scientist
Ph.D., Boston University
Laura C. Broughton, Postdoctoral Scientist
Ph.D., Michigan State University
Alvarus S. K. Chan, Postdoctoral Scientist
Ph.D., Iowa State University
Joaquin E. Chaves, Postdoctoral Scientist
Ph.D., University of Rhode Island
Jacqueline E. Mohan, Postdoctoral Scientist
Ph.D., Duke University
Vinton J. Valentine, Postdoctoral Scientist
Ph.D., University of Delaware
Yuriko Yano, Postdoctoral Scientist
Ph.D., Oregon State University
Qianlai Zhuang, Postdoctoral Scientist
Ph.D., University of Alaska Fairbanks

Technical Staff

Michele P. Bahr, Senior Research Assistant
M.S., University of Hawaii
Zy F. Biesinger, Research Assistant
M.S., Utah State University
Joseph H. Blanchard, Research Assistant
B.S., University of New Hampshire
Allison E. Burce, Research Assistant
B.S., Harvey Mudd College
Donald W. Burnette, Research Assistant
M.S., Southern Illinois University
Elizabeth H. Burrows, Research Assistant
B.A., Mount Holyoke College
Christopher P. Crockett, Research Assistant
M.S., Murray State University
Emily F. Gaines, Research Assistant
B.S., University of Virginia
Robert H. Garritt, Senior Research Assistant
M.S., Cornell University
Marcus O. Gay, Research Assistant
M.S., University College of North Wales,
Bangor
Adrian C. Green, Research Assistant
M.S., University of Alabama

Christie L. Hauptert, Research Assistant
M.S., Massachusetts Institute of Technology/
Woods Hole Oceanographic Institution

Shaomin Hu, Research Assistant
B.S., University of Science and Technology of
China

J. Michael Johnson, Research Assistant
M.S., University of North Carolina at
Wilmington

Bonnie L. Keeler, Research Assistant
B.A., Colorado College

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

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

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

Corey R. Lawrence, Research Assistant
B.S., Clarkson University

William M. Lee, Research Assistant
B. S., The College of William and Mary

Ann L. Lezberg, Research Assistant
M.S., University of Washington

Heidi Lux, Research Assistant
M.S., West Virginia University

Carmody K. McCalley, Research Assistant
B.A., Middlebury College

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

Patricia Micks, Research Assistant
M.S., University of New Hampshire

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

Christian R. Picard, Research Assistant
M.S., University of Akron

Carol Schwamb, Laboratory Assistant
University of Connecticut

Erica L. Stieve, Research Assistant
M.A., Boston University

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

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

Ian J. Washbourne, Research Assistant
M.S., University College of North Wales,
Bangor

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

Heidi S. Wilcox, Research Assistant
M.S., University of Georgia

Consultants

Francis P. Bowles, Research Systems Consultant
Principal, Research Designs
Ph.D., Harvard University

Martha R. Downs
M.S., Boston University

Adjunct Scientists

Paul Colinvaux, Smithsonian Tropical Research
Institute

Maureen Conte, Bermuda Biological Station for
Research

Robert Howarth, Cornell University

Visiting Scientists and Scholars

Neil Bettez, Cornell University

Luc Claessens, University of California, San Diego

Solange Filoso, Cornell University

James Galloway, University of Virginia

Gretchen Gettel, Cornell University

Ketil Koop-Jakobsen, Boston University Marine
Program

Aimlee Laderman, Yale University

Michael Williams, University of Maryland

Brown University-MBL Graduate Program in Biological and Environmental Sciences

Gillian Galford, Ph.D. student

Semester in Environmental Science Students

Lisa Brunie, Mount Holyoke College

Emily DeMoor, Brown University

Sarah Foster, Hampshire College

Sara Hicks, Hampshire College

Kevin Kingsland, Beloit College

Katherine Nolan, Bates College

Rose Phillips, Mount Holyoke College

Noam Ross, Brown University

Emily Sampson, Mount Holyoke College

Chad Yaindl, Lafayette College

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LINDA DEEGAN

Christie Hauptert and Chris Neill prepare an experiment to add staple isotope nitrogen-15 tracer to an Amazonian pasture stream.

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Wilcox, H. S., J. B. Wallace, J. L. Meyer, and J. P. Benstead. Effects of labile carbon addition on a headwater stream food web. *Limnology and Oceanography*.

Williams, M., C. Hopkinson, E. Rastetter, J. Vallino, and L. Claessens. Relationships of land use and stream solute concentrations in the Ipswich River basin, Northeastern Massachusetts. *Water, Air and Soil Pollution*.

Williams, M., L. E. Street, M. van Wijk, and G. R. Shaver. Identifying differences in rates of carbon exchange among vegetation types along an arctic topequence. *Ecosystems*.

Yano, Y., K. Lajtha, P. Sollins, and B. A. Caldwell. Chemistry and dynamics of dissolved organic matter in a temperate coniferous forest on andic soils: Effects of litter quality. *Ecosystems*.

Zhuang, Q., J. M. Melillo, D. W. Kicklighter, R. G. Prinn, A. D. McGuire, P. A. Steudler, B. S. Felzer, and S. Hu. Methane fluxes between terrestrial ecosystems and the atmosphere at northern high latitudes during the past century: A retrospective analysis with a process-based biogeochemistry model. *Global Biogeochemical Cycles*.



Ecosystems Center scientists Chuck Hopkinson and Anne Giblin dive in Boston Harbor to measure biological and chemical changes in sediments, part of a research project to evaluate the recovery of Boston Harbor from earlier sewage additions.

SAM KELSEY

Grants for Research and Education During 2004

I. National Science Foundation

NSF-ATM-0120468

“Biocomplexity: Feedbacks between Ecosystems and the Climate System”

(subcontract from Massachusetts Institute of Technology)

10/01/2001- 09/30/2006

Investigators: Melillo, Kicklighter

\$1,083,333

NSF-ATM-0439620

“Land-Water Interactions at the Catchment Scale: Linking Biogeochemistry and Hydrology”

(subcontract from Georgia Institute of Technology)

01/01/2004 - 08/31/2006

Investigators: Hobbie, Rastetter

\$87,684

NSF-BCS-0410344

“Global Effects of Human and Terrestrial Interactions”

(subcontract from Massachusetts Institute of Technology)

09/14/2004 - 02/28/2009

Investigator: Melillo

\$200,000

NSF-DBI-0301231

“Controlled Environment Facilities for Examination of the Effects of Climate Change and Human Land Use on Terrestrial and Aquatic Ecosystems”

09/01/2003 - 08/31/2006

Investigators: Shaver, Hobbie, Hopkinson, Vallino

\$240,000

NSF-DBI-0330525

“FSML: Planning Proposal for Plum Island Coastal Research Facility”

01/15/2004 - 12/31/2006

Investigators: Deegan, Hopkinson

\$25,000

NSF-DBI-0352466

“A Regional Network to Improve Understanding of the Carbon Cycle: A Workshop Proposal”

10/01/2003 - 09/30/2004

Investigator: Melillo

\$15,000

NSF-DEB-9810222

“The Arctic LTER Project: The Future Characteristics of Arctic Communities, Ecosystems, and Landscapes”

12/15/1998 - 11/30/2005

Investigators: Hobbie, Shaver, Peterson

\$4,498,703

NSF-DEB-0080592

“Harvard Forest LTER Program”

(subcontract from Harvard University)

10/15/2000 - 09/30/2006

Investigators: Melillo, Stuedler

\$749,400

NSF-DEB-0087046

“LTER Cross Site: Interactions between Climate and Nutrient Cycling in Arctic and Subarctic Tundras”

10/01/2000 - 09/30/2005

Investigator: Shaver

\$318,000

NSF-DEB-0089585

“Turnover and Retention of Nitrogen in an Arctic Watershed: Links to Organic Matter Accumulation and Response to Climate”

09/15/2001 - 08/31/2005

Investigators: Shaver, Giblin, Rastetter

\$1,110,892

NSF-DEB-0089738

“Physiological and Molecular Diversity of Atmospheric CH₄ Oxidizers in Soil”

09/15/2001 - 08/31/2005

Investigator: Stuedler

\$1,091,612

NSF-DEB-0108960

“Species-, Community-, and Ecosystem-Level Consequences of the Interactions Among Multiple Resources”

06/01/2001 - 06/30/2005

Investigators: Rastetter, Shaver

\$417,946

NSF-DEB-0111410

“IRCEB: Nitrate Uptake and Retention in Streams: Mechanisms and Effects of Human Disturbances from Stream Reaches to Landscapes”

(subcontract from University of Tennessee)

09/01/2001 - 08/31/2006

Investigator: Peterson

\$486,999

NSF-DEB-0213767

“Trophic Cascades and Interacting Control Processes in a Detritus-based Aquatic Ecosystem”

10/01/2002 - 09/30/2006

Investigators: Deegan, Peterson, Vallino, Hopkinson, Hobbie

\$2,711,971

NSF-DEB-0315656

“Nitrogen Movement from Uplands to Streams in Forested and Deforested Tropical Watersheds”

09/01/2003 - 08/31/2006

Investigators: Neill, Stuedler

\$606,000

NSF-DEB-0423385

“The Arctic LTER Project: Regional Variation in Ecosystem Processes and Landscape Linkages”

12/01/2004 - 11/30/2010

Investigators: Hobbie, Peterson, Shaver

\$4,920,000

NSF-EAR-0420575

“Nonlinear Feedbacks in Coupled Element Cycles During Eutrophication of Shallow Coastal Ecosystems”

(subcontract from Cornell University)

08/15/2004 - 07/31/2009

Investigators: Giblin, Foreman

\$582,169

NSF-MCB-9977897

“Microbial Observatories: Salt Marsh Microbes and Microbial Processes: Sulfur and Nitrogen”

10/01/1999 - 09/30/2004

Investigator: Hobbie

\$999,246

NSF-OCE-9726921

“LTER: Plum Island Sound Comparative Ecosystem Study (PISCES): Effects of Changing Land Cover, Climate and Sea Level on Estuarine Trophic Dynamics”

07/01/1998 - 06/30/2005

Investigators: Hopkinson, Deegan, Giblin, Hobbie, Peterson, Vallino

\$4,859,262

NSF-OCE-0423565

“Plum Island Ecosystem LTER”

08/01/2004 - 07/31/2010

Investigators: Hopkinson, Deegan, Giblin, Hobbie, Peterson, Vallino

\$4,920,000

NSF-OFP-0509602

“Time Series Particle Flux Measurements in the Sargasso Sea”

(subcontract from Bermuda Biological Station for Research)

12/01/2004 - 08/31/2006

Investigator: Conte

\$161,013

NSF-OPP-9732281

“The Response of Carbon Cycling in Arctic Ecosystems to Global Change: Regional and Pan-Arctic Assessments”

03/01/1998- 03/31/2005

Investigators: Hobbie, Rastetter

\$1,000,000

NSF-OPP-9911278

“Aquatic Ecosystem Responses to Changes in the Environment of an Arctic Drainage Basin”

07/01/2000 - 06/01/2005

Investigators: Hobbie, Peterson, Giblin, Deegan, Vallino

\$4,563,868

NSF-OPP-0096523

“Primary Production in Arctic Ecosystems: Interacting Mechanisms of Response to Climate Change”

01/01/2001- 12/31/2004

Investigator: Shaver

\$533,119

NSF-OPP-0229302

“Biogeochemical Tracers in Arctic Rivers: Linking the Pan-Arctic Watershed to the Arctic Ocean”

10/01/2002 - 09/30/2007

Investigators: Peterson, Holmes

\$1,657,491

NSF-OPP-0352897

“Resource Allocation and Allometry of Plant Growth in the Arctic: Key constraints on Change and Predictability of the Arctic System”

05/01/2004 - 04/30/2007

Investigator: Shaver

\$885,102

NSF-OPP-0408371

“Developing Process-Level Understanding of Controls on Belowground Carbon and Nutrient Dynamics in Tundra Ecosystems”

(subcontract from University of Michigan)

02/01/2000 - 01/31/2005

Investigator: Rastetter

\$1,401,232

NSF-OPP-0425045

“Science Journalism Program for the Arctic”

05/01/2004 - 04/30/2007

Investigators: Hobbie, Neill, Foreman

\$164,073

II. National Aeronautics and Space Administration

NASA-NAG5-10135

“Predicting Changes in Regional and Global Biogeochemical Cycles”
(subcontract from University of New Hampshire)
01/01/2001-12/31/2004

Investigators: Melillo, Peterson, Stuedler, Kicklighter
\$540,908

NASA-NAG5-9515

“Biogeochemical Consequences of Agricultural Intensification in the Amazon Basin”
05/01/2000-10/31/2004

Investigators: Melillo, Stuedler, Neill
\$1,410,043

NASA-NAG5-11142

“The Role of Land-Cover Change in High Latitude Ecosystems: Implications for Carbon Budgets in Northern North America”
08/01/2001-07/31/2004

Investigators: Melillo, Kicklighter

NASA-NCC5-690

“Key Connections in Amazonian Stream Corridors”
01/15/2003-01/14/2006

Investigators: Deegan, Neill
\$667,141

NASA-NNG04GH75G

“Understanding the Changing Carbon, Nitrogen, and Water Cycles in the Earth System”
(subcontract from University of New Hampshire)
04/15/2004-04/14/2007

Investigators: Melillo, Peterson, Stuedler, Kicklighter
\$315,250

NASA-NNG04GJ80G

“Testing Trace Gas Flux Models Using In-situ and Remotely-Sensed Data”
(subcontract from Massachusetts Institute of Technology)
05/01/2004-04/30/2007

Investigators: Melillo, Kicklighter, Felzer
\$441,310

NASA-NNG04GM39G

“Linking Multi-Scale Remotely Sensed Data, Field Observations and Biogeochemistry Models to Evaluate Changes in the Terrestrial Ecosystems of China”
(subcontract from Auburn University)
07/01/2004-06/30/2007

Investigators: Melillo, Kicklighter, Felzer
\$380,000

III. National Oceanic and Atmospheric Administration

NOAA-CICEET Program-NA04NOS190109

“Effectiveness of Reactive Barriers for Reducing N-Loading to the Coastal Zone”
09/01/2004-08/31/2006

Investigators: Vallino, Foreman
\$209,397

NOAA-Coastal Ocean Program-NA04NOS4780182

“Career 2004: Integrated Training in Coastal Science and Management”
07/01/2004-06/30/2006

Investigator: Deegan
\$48,270

NOAA-Sea Grant-NA16RG2273

“Effects of Varying Freshwater Discharge on Nitrogen Dynamics in the Oligohaline Regions of Estuaries”
(subcontract from Woods Hole Oceanographic Institution)
03/01/2002-12/31/2004

Investigators: Giblin, Hopkinson
\$112,626

NOAA-NA17RJ1223

“Application of the Leaf Wax-Aerosol Method to Assess Spatial and Temporal Patterns of Carbon Isotopic Fractionation of Atmospheric CO₂ by Terrestrial Photosynthesis”
(subcontract from Bermuda Biological Station for Research)
07/01/2004-06/30/2006

Investigator: Conte
\$277,051

IV. U.S. Department of Energy

DOE-NIGEC-DE-FC02-03ER63613

“Carbon Isotopic Studies of Assimilated and Ecosystem-Respired CO₂ in the Southeastern Pine Forest”
09/01/2004-08/31/2007

Investigator: Conte
\$173,440

DOE-DE-FC02-03ER63613

“Soil Warming and Carbon-Cycle Feedbacks to the Climate System”
(formerly “Global Warming and Carbon Storage in Mid-Latitude Forest Ecosystems”)
09/01/2003-08/31/2007

Investigators: Melillo, Stuedler
\$548,761

DOE-DE-FC03-90ER61010
“Human Influences on Forest Nitrogen Budgets and their Implications for Forest Carbon Storage”
(subcontract from Harvard University)
07/01/1998-06/30/2004
Investigators: Melillo, Steudler
\$1,077,781

DOE-DE-FG02-04ER63893
“Heterotrophic Soil Respiration in Warming Experiments: Using Microbial Indicators to Partition Contributions from Labile and Recalcitrant Soil Organic Carbon”
(subcontract from University of Georgia)
08/15/2004-08/14/2007
Investigator: Melillo
\$216,645

V. U.S. Environmental Protection Agency

EPA-R8267701
“Coastal Wetland Indicators”
(subcontract from University of South Carolina)
07/01/2001-02/25/2006
Investigator: Hopkinson
\$373,723

VI. U.S. Department of Agriculture

USDA-01-CA-11242343-051
“Predicting the Influence of N Deposition on Temperate Forest Carbon Uptake and Storage Using ¹⁵N Tracers” and Modeling
09/01/2001-08/31/2005
Investigator: Neill
\$73,182

VII. Other Research Grants

Commonwealth of Massachusetts - SCENV10003180033
“The Nature Conservancy-Marine Biological Laboratory Sandplain Ecosystem Restoration and Conservation Experiment”
07/30/2002-06/30/2004
Investigator: Neill
\$41,540

Exxon Mobil Corporation
“Investigating the Cycling of Natural and Manmade Nitrogen Compounds”
(subcontract from Bermuda Biological Station for Research)
02/01/97-02/01/04
Investigator: Melillo
\$55,000

Texaco Foundation
“Environmental Fellowship Program”
09/01/90-12/01/04
Investigator: Melillo
\$535,000

The Nature Conservancy
MAFO-07152003
“Hydrological Science to Support Biodiversity Conservation in Massachusetts”
07/01/03-06/01/05
Investigator: Neill
\$95,000

VIII. Grants for Support of Semester in Environmental Science and Facilities

Andrew W. Mellon Foundation
“Semester in Environmental Science”
06/01/96-12/01/04
\$4,821,249

The Starr Foundation
“Semester in Environmental Science”
12/01/97-12/01/04
\$750,000



Anne Giblin and Chuck Hopkinson collect a core sample of sediment from Boston Harbor.

SAM KELSEY

Sources of Support for Research and Education

The annual operating budget of The Ecosystems Center for 2004 was \$9,101,933. Approximately 82 percent of the income of the center comes from grants for basic research from government agencies. The other 18 percent 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.

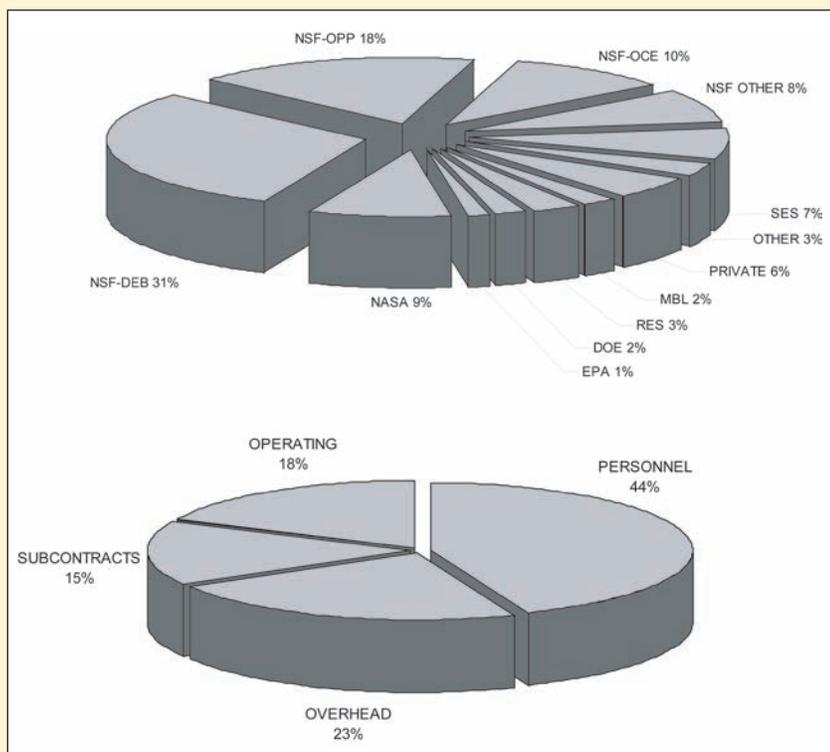
These non-governmental funds provide flexibility for the development of new research projects, public policy activities and educational programs. More information about sources of support appears in Research Grants in Effect in 2004 in this report.

The combined total value of the center's reserve fund and endowment at the end of 2004 was \$5,593,518. 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.

Over the years since it was founded in 1975, the center has received support from these foundations, corporations and industry consortia:

Jessie Smith Noyes Foundation, Inc.
 The Harold Whitworth Pierce Charitable Trust
 The Proctor and Gamble Company
 Rockefeller Brothers Fund
 The Rockefeller Foundation
 Rowland Foundation, Inc.
 Scherman Foundation, Inc.
 Ann Osterhout Edison/Theodore Miller Edison
 and Olga Osterhout Sears/Harold Bright Sears
 Endowed Scholarship Fund
 The Catherine Filene Shouse Foundation
 Bill and Phoebe Speck Fund
 The Seth Sprague Education and Charitable Foundation
 The Starr Foundation
 Surdna Foundation, Inc.
 Sweet Water Trust
 Texaco Foundation
 Wingwalker Initiatives
 The Worthington Family Foundation, Inc.

Atlantic Richfield Foundation
 The Burroughs Wellcome Fund
 Robert Sterling Clark Foundation, Inc.
 The Clowes Fund, Inc.
 Conservation, Food & Health Foundation, Inc.
 The Jessie B. Cox Charitable Trust
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 Arthur Vining Davis Foundations
 Davis Educational Foundation
 Henry L. and Grace Doherty Charitable Foundation, Inc.
 Electric Power Research Institute
 Environmental Data Research Institute
 Environmental Resources Management Group
 ExxonMobil Corporation
 Max C. Fleischmann Foundation
 The Ford Foundation
 General Electric Foundation
 Grace Foundation, Inc.
 The Grass Foundation
 The Harken Foundation
 Charles Hayden Foundation
 International Business Machines Foundation
 Blum Kovler Foundation
 Charles A. Lindbergh Fund
 The Andrew W. Mellon Foundation
 NL Industries Foundation, Inc.





**The Ecosystems Center
Marine Biological Laboratory**

7 MBL Street, Woods Hole, Massachusetts 02543-1301
508 548-3705

The Ecosystems Center home page: ecosystems.mbl.edu
MBL home page: www.mbl.edu