MBL

Catalyst

Biological Discovery in Woods Hole

Founded in 1888 as the Marine Biological Laboratory

Spring 2011
Volume 6, Number 1

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From the Director

MBL Catalyst

Spring 2011 Volume 6, Number 1

MBL Catalyst is published twice yearly by the Office of Communications at the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts. The MBL is dedicated to scientific discovery and improving the human condition through research and education in biology, biomedicine, and environmental science. Founded in 1888, the MBL is an independent, nonprofit corporation.

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About the cover: An iceberg near Palmer Station, Antarctica. Photo by Jason Orfanon.

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Dear Friends,

We live in an age when environmental issues—from oil spills to toxic algal blooms to global warming—are regularly headline news. Ecosystems science is extremely important in separating fact from fiction in many of these issues. But it is also clear that ecosystems science must be broadly interactive, if those facts are to be put to practical use. As this issue of *MBL Catalyst* highlights, our Ecosystems Center scientists collaborate with many kinds of people in diverse ways that extend the ultimate impact of their research on society. From volunteering for a local environmental group, to advising national and international policymakers on global climate change, Ecosystems Center scientists are making sure their research makes a difference.

When I look at the outstanding body of research that our Ecosystems Center is producing, two important themes stand out. One is long-term polar research. The Arctic and Antarctic are changing faster in response to climate warming than all other regions on earth. Shrinking glaciers, loss of sea ice, and thawing permafrost are visibly apparent to our scientists who have been working for decades at the National Science Foundation's Long Term Ecological Research (LTER) sites at the two poles. Given their combined expertise in Arctic and Antarctic ecosystems, they are currently considering the merits of a "bi-polar" research approach to identify common patterns and critical "tipping points" in polar environmental change.

Another important theme at our Center is the cycling of nitrogen through the Earth's soil, water, and atmosphere. Why should we care about nitrogen? One reason is global warming. More than a third of the nitrous oxide—a powerful greenhouse gas—being emitted to the atmosphere is due to human activities, mainly the use of nitrogen-based fertilizer. A second reason we must care is the runoff from fertilizer, combined with inadequate sewage treatment, means our coastal waters are being overloaded with nitrogen, which debilitates marine habitats and threatens their survival. Nitrogen loading has become a major economic issue facing all coastal communities, including Woods Hole. The Ecosystems Center has world-recognized expertise on the nitrogen cycle and its role in critical environmental issues.

I'd like to extend a warm thank you to Hugh Ducklow, director of our Ecosystems Center, who not only ably guides the Center but found time to serve as guest editor for this issue of *MBL Catalyst*. Hugh directs the Antarctic LTER, which complements the Arctic LTER originally directed by John Hobbie and now led by Gaius Shaver, both of the Center.

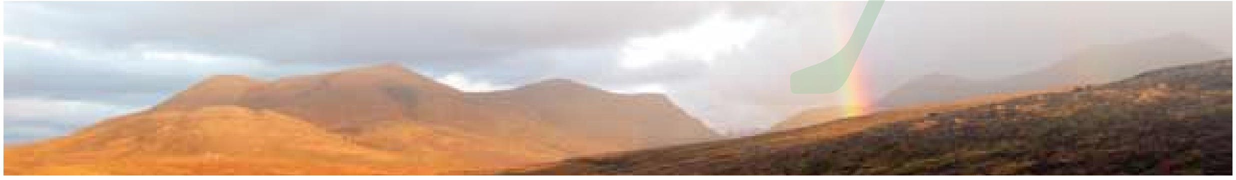
The stresses and challenges our planet faces are not small. But the dedicated scientists at the MBL Ecosystems Center are providing valuable information that helps build a firm foundation as society finds ways to turn the tide.

Gary Borisy

Gary Borisy
President and Director

Catalyst

In this Issue



MBL

Earth in the Balance

Restoring our planet to health

The web of people who are concerned about how we are changing our planet just keeps widening. In the Arctic, native people tell scientists what the polar landscape was like generations ago, before the ice started to melt. In Africa, farmers stop to consider how to best apply crop fertilizer in a way that does minimal harm to the environment. On the Massachusetts coast, citizens band together to find workable solutions to the nitrogen pollution that threatens the harbors and bays.

Top: Maize harvest in Mbole, Tanzania. Staple crop yields in Mbole and other African Millennium Villages have nearly tripled over the past three years, due to the introduction of high-yield seeds and fertilizer.

Middle: MBL scientists and colleagues deploy a mooring in high seas during a research cruise of the *Laurence M. Gould* to Palmer Station, Antarctica.

Right: A citizen volunteer measures water conditions for the Coalition for Buzzards Bay, an environmental advocacy group based in New Bedford, Massachusetts.

Inside this intricate web is where MBL Ecosystems Center research translates into action. It is where the years of patient scientific observation of environmental change become a firm foundation for citizen and political action at all levels, from towns to regions to nations. It is where fishermen, schoolchildren, retirees, global leaders, policymakers, artists, all types of people converge with scientists in the strong desire to bequeath our planet in a healthy state to future generations.

This issue of *MBL Catalyst* explores the connections between Ecosystems Center scientists and some of the environmentally aware people they encounter in their daily work. Together, they are delivering a powerful message: We need a better understanding of how ecosystems operate in the face of climate change and pollution, and we need to act now to create a sustainable future for our planet and its people.

Left: Annual reindeer census near Zhigansk, Siberia.

Right: Chinstrap penguin, Antarctica.

Bay Watch

MBL scientists team with citizens to reduce nitrogen pollution in Buzzards Bay

"MBL is always interested in going upstream, to the source of the nitrogen pollution. It's a unique niche for them. Other institutions are interested in sampling out in the bay, but that's the end of the tailpipe."

— Mark Rasmussen, president, Coalition for Buzzards Bay

The conversation started, as many do, at a social event on a summer evening. Hugh Ducklow had just arrived as the new director of the MBL Ecosystems Center in 2007 when, at a party, he met Mark Rasmussen, president of the Coalition for Buzzards Bay. This citizens group is devoted to protecting the bay and its watershed, which includes more than a dozen towns in southeastern Massachusetts. Its central program is Baywatchers, a team of 135 volunteers who regularly collect samples from the bay's coves and harbors to monitor them for changes in water quality.

I thought, "I can do that. I live right near the bay," says Ducklow. So he signed up to be a Baywatcher. Two mornings a week during the summer, Ducklow leaves for work a little early and stops by his sampling station in Fiddler's Cove in North Falmouth. It takes about a half hour, he says, to record several weather and water conditions, including dissolved oxygen which, if low, can indicate deterioration in water quality.

"It's fun," Ducklow says. "The only time I get to do sampling for my own work is once a year, when I go on a [research] cruise to Antarctica." More to the point, he says, "Environmentally, this is an important issue and organization."

Since then, the ties between MBL and the citizens group have only strengthened. Two years ago, the Ecosystems Center signed a contract to perform ongoing analysis of some of the Baywatchers samples. More importantly, some of its scientists are increasingly active as coalition advisors.

"The MBL is not just running sample analyses and sending us the data on a disk," says Rasmussen. "The relationship is more like science advisors and collaborators. MBL scientists such as Anne Giblin, Chris Neill, and Hugh Ducklow are guiding how we conduct the Baywatchers program: what are the right stations to monitor; what aspects of our data are beginning to tell a story that leads to new questions we want to answer. They really are a guiding force."

The Coalition and the Ecosystems Center share a strong interest in the issue of nitrogen pollution of coastal waters. In Buzzards Bay, excess nitrogen gets into the water mainly because Title V septic systems, which predominate in the region, were not designed to remove nitrogen. Another major source is runoff from fertilizers used in cranberry bogs and on golf courses and private lawns. Too much nitrogen causes excessive algae growth, which depletes the water of oxygen, depriving fish and other organisms of a place to survive.

Giblin is well aware of these problems as an expert on nitrogen cycling through soils and sediments. And, like most Cape Cod residents, she knows the towns are struggling with the fact that revamping their inadequate wastewater treatment systems will cost millions or billions of dollars. Giblin also directs the Plum Island Long Term Ecological Research project on the northern Massachusetts coast. There, too, scientists are interacting with citizens groups, including the Ipswich River Watershed Association, on the pressing issue of nitrogen loading in the salt marsh and bays.

"As a scientist, I can say we have a real problem with nitrogen loading to our bays," Giblin says. "But how do we solve it? Well, we can build big municipal sewer systems that remove nitrogen. We can try alternative technologies. We can change zoning and not let anyone live in certain areas. All of these options have major social and financial implications. And as a scientist, I am not necessarily the best person to make those judgments. That's why it's good to have citizens groups involved. Scientists can provide information on the causes and consequences of excess nitrogen loading and suggest alternatives. Citizens groups can push for action and help bring together citizens, regulators, and policy makers to achieve a solution."

In its daily work, the Coalition for Buzzards Bay advocates for regulatory solutions to the nitrogen problem within town halls, in state legislatures, and if necessary in the courts. But Rasmussen, along with the Ecosystems Center, is also considering alternative approaches, such as "whether we can achieve nitrogen reductions by managing small streams in the upper watershed before the nitrogen even has a chance to reach the bay." With scientific advice from Chris Neill, the Coalition has started talking to cranberry growers in the upper Buzzards Bay watershed about potential ways to manage water flows to reduce the nitrogen load from fertilizers.

"MBL is always interested in going upstream, to the source of the nitrogen pollution," Rasmussen says. "It's a unique niche for them. Other institutions are interested in sampling out in the bay, but that's the end of the tailpipe."

Giblin, who along with MBL scientists Linda Deegan and Ivan Valiela has interacted with the Coalition for Buzzards Bay since it was founded in the mid-1980s, sees much value in the ongoing relationship. "With a program like Baywatchers, every one of those citizen volunteers not only collects samples, they go out and talk to their friends about the nitrogen issue. That is a huge public education benefit. By making sure those volunteers are well educated in the scientific facts, you get this tremendous informal education program going."

Ducklow agrees that scientists should actively support and interact with groups like the Coalition for Buzzards Bay. "If we are not going to stand up for environmental quality in the region, who is?" he says. • — DK

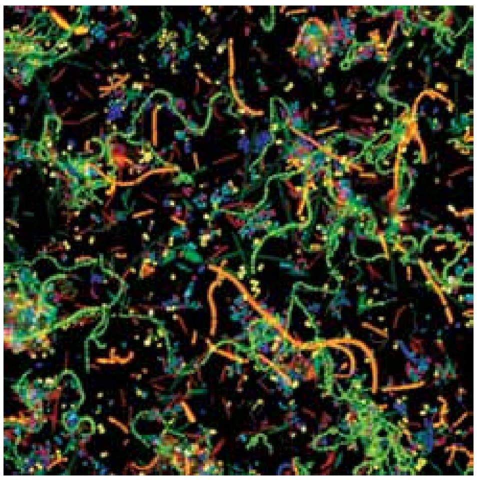
"With a program like Baywatchers, every one of those citizen volunteers not only collects samples, they go out and talk to their friends about the nitrogen issue. That is a huge public education benefit. By making sure those volunteers are well educated in the scientific facts, you get this tremendous informal education program going."

— Anne Giblin, Senior Scientist, Ecosystems Center

Global Rivers Emit Significant Levels of Nitrous Oxide, A Potent Greenhouse Gas

River and stream networks are the source of 10 percent of the nitrous oxide emissions that are due to human activities, report MBL Senior Scientist Bruce J. Peterson and collaborators in a global-scale study. Nitrous oxide (N_2O) is a potent greenhouse gas that contributes to climate warming and destruction of ozone in the stratosphere. "Over the past 50 years, humans have doubled the load of nitrogen to the biosphere primarily through applying nitrogen fertilizer to crops and burning fossil fuels," Peterson says. "One consequence is more nitrogen gets into streams, lakes, and estuaries, which can lead to low-oxygen conditions harmful to aquatic life. But this study shows another consequence is a flux of N_2O from the rivers and streams to the atmosphere," he says. "While carbon dioxide is the most abundant greenhouse gas in the atmosphere, N_2O is 300 times more potent, molecule per molecule." This calculation of nitrous oxide flux from river networks, which the scientists derived from research on 72 streams across the United States, is three times the amount previously estimated by the Intergovernmental Panel on Climate Change. Peterson's research for the study was performed on the Ipswich River watershed at the Plum Island Long Term Environmental Research site in Massachusetts (*PNAS* 108: 214-219, 2011). •

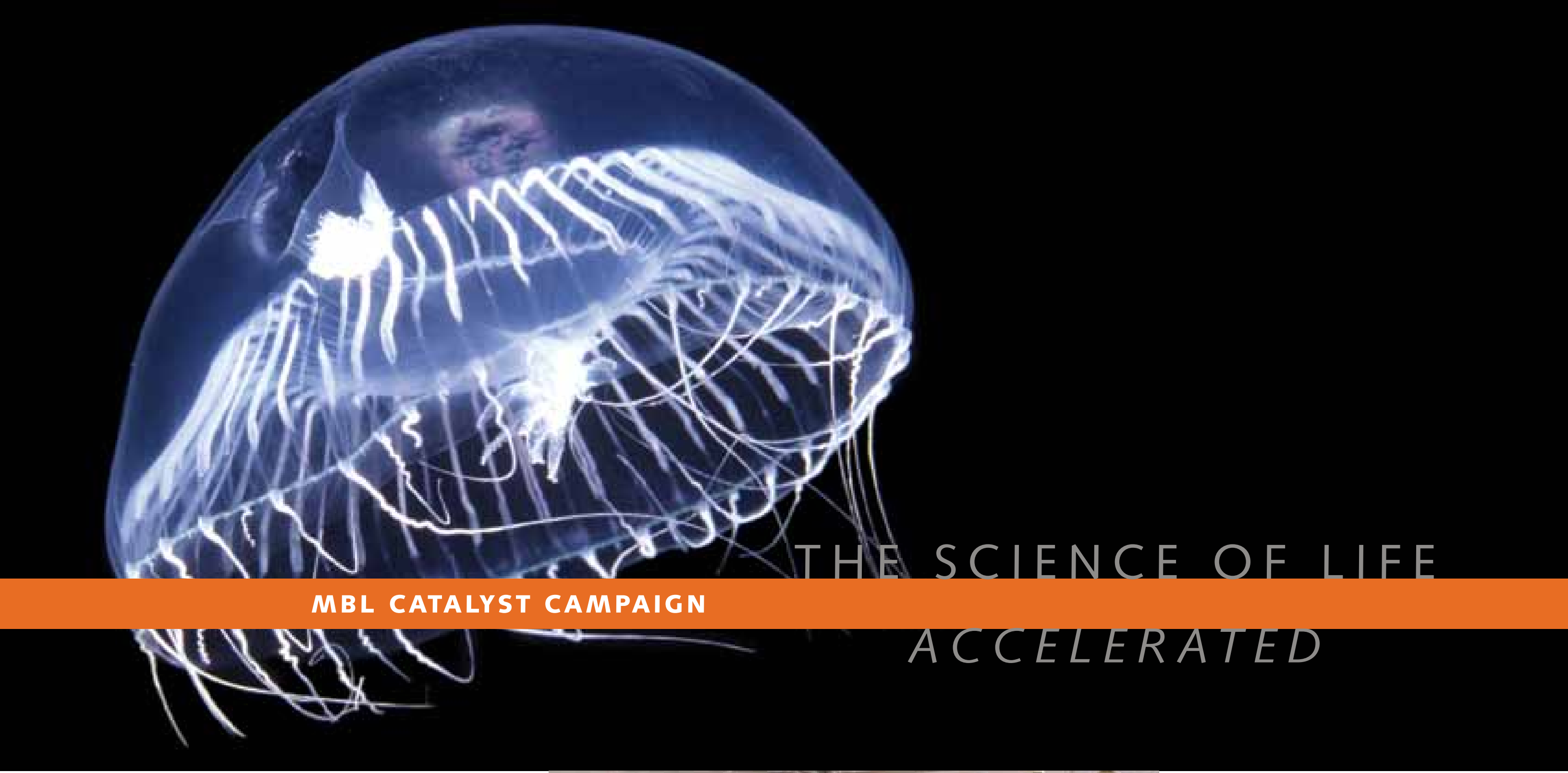
That is One CLASI-FISH



A new microscopy technique developed by seven MBL scientists allows one to see the spatial arrangement of up to 28 differently labeled microbes in a single field of view. Previously, only two to three kinds of microbes could be visually distinguished at once. The developers of the technique, who include MBL President and Director Gary Borisy, Brown-MBL Ph.D. student Alex Valm, MBL scientists Jessica Mark Welch and Rudolf Oldenbourg, and Floyd Dewhirst of the Harvard School of Dental Medicine, used it to analyze dental plaque, a complex biofilm that contains at least 600 species of microbes. They were able to visually discriminate 15 different microbial types, and to determine which two types showed the most interspecies associations. "When we can see where [in a community] the microbes like to hang out, that has implications for how they function," Borisy says. The technique is called CLASI-FISH (combinatorial labeling and spectral imaging fluorescent *in situ* hybridization), and the scientists are now using it to study human microbial populations in the guts of mice. "It's very possible that this technology will enable a new kind of clinical diagnostic procedure," Borisy says. (*PNAS* 108: 4152-4157, 2011). •

MBL Scientists Reveal Findings of World Ocean Microbe Census

The International Census of Marine Microbes (ICoMM) delivered its conclusions last fall at the culmination of the Census of Marine Life, a ten-year endeavor funded by the Alfred P. Sloan Foundation to reveal what, where, and how much lives in the world's oceans. Among the leaders of ICoMM were Bay Paul Center Director Mitchell Sogin and Assistant Scientist Linda Amaral-Zettler, who served as ICoMM's program manager, and education and outreach lead. Over the past seven years, ICoMM amassed more than 25 million genetic sequences from microbes living in 1,200 sites around the Earth. A recent finding from sampling in the North Atlantic Ocean found that distribution of bacteria correlated with different water masses (areas defined by properties such as temperature and salinity). Other key contributions of ICoMM include a diversity estimate for marine microbes (up to 38,000 different kinds in a liter of seawater); the discovery that most marine microbes are rare in abundance; and Sogin's invention of a DNA sequencing technology, called Pyrotag sequencing, which has now revolutionized all fields of microbial ecology, including studies of human health. ICoMM is unique in that it collected both genetic data on marine microbes and contextual data on their habitats. This has led directly to the development of standards at the Genomic Standards Consortium for the minimal contextual information for characterizing sites. •



MBL CATALYST CAMPAIGN

THE SCIENCE OF LIFE *ACCELERATED*

Last summer, during the fanfare of the ribbon-cutting ceremony for the renovated Loeb Laboratory, MBL Trustee and Campaign Chairman Jeffrey Pierce announced the public launch of the MBL Catalyst Campaign. This $125 million fundraising campaign, the largest in MBL history, will increase the pace of discoveries in the life and environmental sciences. It runs through 2012.

The goals of the Catalyst Campaign are to raise endowment and operating support for the MBL's outstanding research and educational programs. Whether you are interested in assuring the health of the planet, training the next generation of leaders in the life sciences, or improving our campus infrastructure, the Catalyst Campaign offers funding opportunities for everyone who values the MBL's transformative work. •

MBL Catalyst Campaign Chairman Jeffrey Pierce speaks at the 2010 Loeb Laboratory ribbon-cutting and campaign kick-off ceremony.

CAMPAIGN PRIORITIES

Ecosystems	$15 million
Microbes	$15 million
Biodiversity	$10 million
Transformative Laboratory Courses	$20 million
Brown/MBL Partnership	$ 5 million
Whitman Center Research Catalyst	$10 million
Regenerative Biology & Medicine	$10 million
Marine Resources	$ 5 million
Cellular Dynamics	$ 5 million
Capital Projects	$25 million
Annual Fund	$ 5 million
TOTAL	$125 million

To receive regular updates on the progress and impact of the campaign, sign up to receive the MBL Accelerate newsletter by sending an e-mail to Dina DiCarlo, ddicarlo@mbl.edu

To learn more about the MBL Catalyst Campaign, contact:
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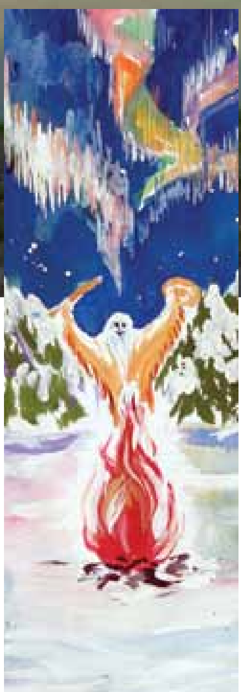
or visit **mbl.edu/catalystcampaign**

Old Worlds and New

IN THE ARCTIC,

nature balances on the freezing point of water



Climate-change inspired artwork by Kolya Kolesov, 15 years old, of Zhigansk, Siberia.

In this cold, circumpolar landscape, climate change is not a vague concept. It's not something to think about another day. People in the eight countries above the Arctic Circle are watching as one world slips away, and a new one forms.

The rise in planetary surface temperature of about 1˚F since 1900 may not yet be noticeable in the "Lower 48." But in the Arctic, an entire ecosystem is thawing, melting, and reshaping.

"Everything is changing," says Senior Scientist Bruce Peterson of the MBL Ecosystems Center, who has studied river ecology at Toolik Field Station on Alaska's North Slope since 1975. "The glaciers at Toolik have shrunk; you can see it from the camp. In some places, the ground ice is melting out. It's not being replaced; it's just disappearing. There is a major transformation taking place as the cryosphere [frozen layer] is going away. "

Others who take watchful notice are the residents, including members of the Yukon River Intertribal Watershed Council in Arctic Alaska and Canada. This coalition of First Nations and Tribes formed to preserve and protect the 1,980-mile river that not only gives them sustenance and livelihood, including a commercial salmon fishery, but is a sacred waterway in their culture. The council's long-range goal is "To be able to drink water directly from the Yukon River."

In a convergence of common interests, Woods Hole scientists and the Yukon River Council are intersecting in a long-term research effort called the Arctic Great Rivers Observatory (GRO).

"We have learned a lot by talking to the indigenous people in the Arctic," says Senior Scientist Max Holmes of the Woods Hole Research Center, who along with Peterson is one of the principal investigators of the Arctic-GRO. "The indigenous people have a long-term perspective. They know when the ice used to break up [seasonally] at the mouth of a river, for instance, and they know when it happens now. They can offer qualitative information that may indicate patterns we already suspect, and we can try to confirm with satellite data. Their anecdotes can even point us in new directions."

Beyond the sharing of traditional ecological knowledge, the Yukon River Council is woven into the fabric of the Arctic-GRO through another route: river sampling. The council, with help from the U.S. Geological Survey, has set up a water quality observation program along the Yukon that involves regular sampling at 39 sites. Some of these samples are being handed off to the Woods Hole scientists for analysis, and this exchange is expected to grow in the coming years.

It's no small gesture, since Holmes, Peterson and their colleagues are keenly interested in the chemistry of the Yukon and the five other biggest Arctic rivers—and especially how that chemistry is changing as the climate warms.

"The beauty of any river system is that its discharge [into a larger body of water] integrates processes that are occurring throughout the whole watershed," Holmes says. "We go down to the mouths of these really big rivers where they empty into the Arctic Ocean, sample and measure all kinds of chemicals, and use that information to learn about changes going on in the watershed, such as permafrost thaw or forest fires. The analogy is like a doctor taking a blood sample to learn about the health of the whole organism. We are not so much interested in the rivers per se, but what the river chemistry can tell us about changes on land."

PEOPLE IN THE EIGHT COUNTRIES ABOVE THE ARCTIC CIRCLE ARE WATCHING AS ONE WORLD SLIPS AWAY, AND A NEW ONE FORMS.

Peterson and Holmes are particularly interested in what the rivers can explain about Arctic carbon, which in the atmosphere forms the greenhouse gas carbon dioxide (CO_2).

"There is a huge amount of carbon locked up in Arctic permafrost—twice as much as in the atmosphere," says Holmes. "Now, the permafrost is starting to thaw and the organic matter in there is becoming active. It's like you unplugged your freezer and the food in there is starting to rot. It's decomposing, and releasing CO_2 and methane. That has started to happen in the Arctic, and presumably its only going to accelerate as the climate warms."

The release of ancient carbon from permafrost thaw would leave its chemical "fingerprint" on the Arctic rivers as they pass through their watersheds. It's too early to tell yet if this is happening on a widespread scale. But last summer, in the Kolyma River in Siberia, Holmes found carbon that was 30,000 years old, whereas previous carbon samples from the area were at most 6,000 years old. "That was exciting. That was direct evidence of mobilization of ancient organic matter with permafrost thaw," he says.

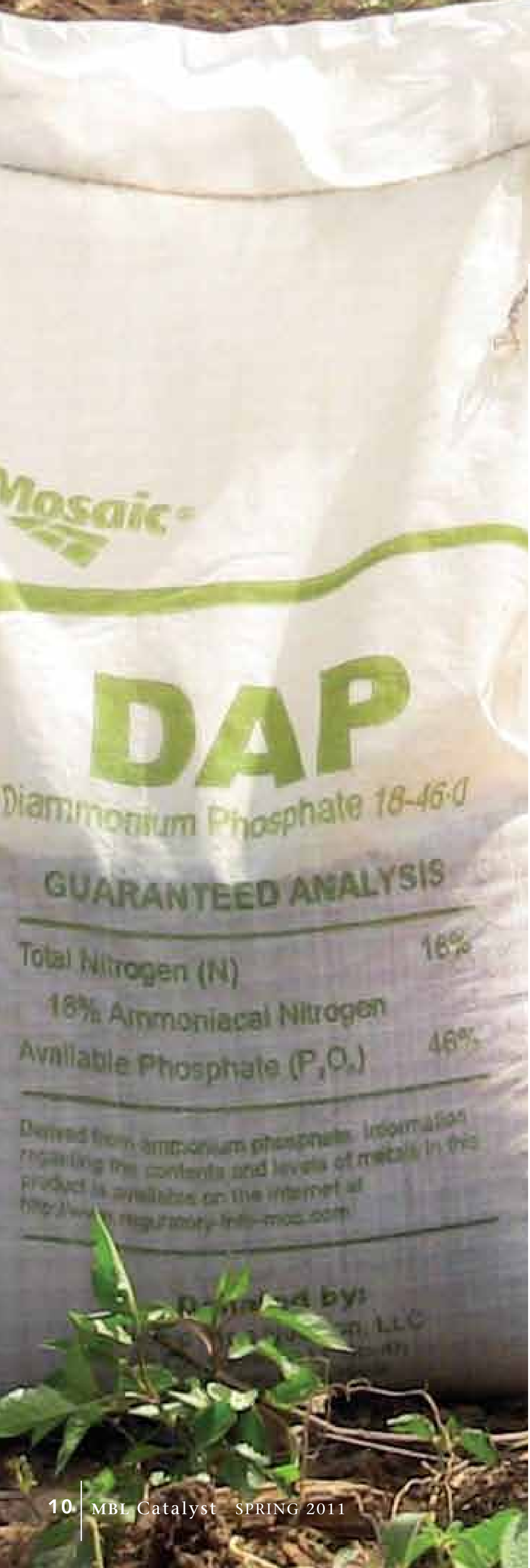
Holmes has attended meetings of the Yukon River Intertribal Watershed Council, where he was deeply impressed by the stories he heard told. "It is really powerful to see how they relate to the river, its importance to them," he says. Holmes and Peterson, also, are listening to the rivers, but as environmental scientists would do. "The strength of the Arctic rivers study," Holmes says, "is as a signal of widespread terrestrial change." • —DK

Top: Herding reindeer for annual census, Zhigansk, Siberia.

Left: Jon Waterhouse (foreground), director of the Yukon River Intertribal Watershed Council, and Max Holmes (left) with elders and community leaders in Zhigansk, Siberia, one of the sampling sites on the Lena River for the Arctic-GRO project.

As Africa Goes gree

New Brown-MBL Parternship project



Passionate social revolutions and long-range planning don't always go hand in hand, but sometimes the opportunities arise to make wise choices in the midst of great change.

Such is the case with the African Green Revolution, which is the new wave of the agricultural revolution that swept Asia and Latin America in the 1940s to 1960s.

"African farmers, having missed the Green Revolution of the 20th century, are now beginning to add substantial amounts of fertilizer to their crops," says Distinguished Scientist Jerry Melillo of the MBL Ecosystems Center. The short-range benefits are tremendous: Farmers are suddenly tripling their harvest yields in a nation where nearly a third of the people live in extreme poverty, and the soil and climate for agriculture are poor.

Yet as the first Green Revolution has shown, the intensification of agriculture, with its high inputs of fertilizers, pesticides, herbicides, and water to obtain maximum crop yields, can have complex consequences for the land and its sustainability.

"Intensive agriculture often drives farmers to specialize. It can also make them money," says Chris Neill, senior scientist in the MBL Ecosystems Center and director of the Brown-MBL Partnership. "Some people argue that that is a good thing. If the U.S. Midwest is good at producing corn, for example, then it should focus on producing corn very efficiently and sell it to the rest of the world. Other people think that is a nutty system. We should be focused on feeding people, producing a wide variety of crops, using less inputs to the land, transporting produce shorter distances."

What path the farmers in Africa will take as their own Green Revolution unfolds is of great interest to Neill, Melillo, and a group of their colleagues at the MBL, Brown University, and Columbia University as well as at Moi University in Kenya and Sokoine University in Tanzania.

Neill heads up a new collaboration between these institutions: the Partnerships for International Research and Education (PIRE). Funded by the National Science Foundation, PIRE will examine how targeted interventions to increase crop yields in the Millennium Villages in Africa influence the health and well-being of local farmers—and impact the environment.

The Millennium Villages are 14 rural communities that are receiving interventions to lift them out of deep poverty and create sustainable economies based on agriculture. The ten-year project, which began in 2006, operates out of Columbia University's Earth Institute and is supported by a long list of private foundations.

"The idea of the Millennium Villages is, instead of providing direct food aid to people who are undernourished by shipping

n

surveys the unfolding of an agricultural revolution

food in, you provide them with the tools to grow more food on their small acreages. That means giving them hybrid seed for fast-growing, high-yield crops, fertilizers, and information to improve farming practices," Neill says. These interventions have already occurred in the African Millennium Villages. The PIRE project will now examine the farmers'—and the land's—responses.

"Ultimately, we want to know: Does intensifying agriculture save land for nature?" Neill asks. "If we increase the yield on village plots that were already used for agriculture, does that take off the pressure to convert remaining natural land to cropland? Or is it the opposite? When farmers have a small plot of land, and suddenly through these interventions they can grow food for themselves plus have a little extra to sell, what will they do? Will they diversify? Instead of just growing maize, will they want to grow cabbages, too? Will they invest in other plots of natural land and convert them to farmland?"

To explore these and other questions, such as the impact of intensified agriculture on soil fertility and greenhouse gas emissions, PIRE will focus on two of the Millennium Villages: Mbola in Tanzania, which still has a lot of undeveloped woodland, and Sauri in Kenya, which "is deforested and densely agricultural, with fields of maize packed in like postage stamps," says Neill.

Using tools such as household surveys, satellite data, soil and atmospheric analyses, and ecological models, Ph.D. students from the Brown-MBL Graduate Program and from Columbia University will study the effects of the intensification interventions on the people and the land. The students will team with scientists from the African universities.

"We want to see the health responses in the villages," says Neill. "Can this be a model for solving Africa's food problems? And we want to see the environmental changes. Over the coming decades, intensive agriculture could totally transform Africa. If you make Africa look like the American Midwest, there will be new environmental consequences to consider." • —DK

REVOLUTION REDUX

Many industrialized nations enjoyed surpluses in food production by the mid-20th century, thanks to scientific breakthroughs that brought dramatic increases in crop yields. Still going hungry, though, were most of the nations in Asia, Latin America, and Africa. As their populations grew, so did widespread malnutrition, hunger, and reliance on food aid. To respond, the Rockefeller and Ford Foundations set up an international research network in the 1960s that was designed to transfer agricultural advances to the developing world. Now called the Green Revolution, this investment introduced high-yield seeds, industrial fertilizers, irrigation, and mechanized agriculture to impoverished nations, with an initial focus on wheat and rice. The economic benefits were enormous. India, for instance, went from the brink of famine in the 1960s to being one of the world's leading rice exporters today. Between 1970 and 1990, yields of rice and wheat virtually doubled in Asia and Latin America.

Yet in this same time, food yields in Africa remained virtually unchanged. Several obstacles, including poor infrastructure, stymied the Green Revolution in Africa, such that African farmers in the 21st century were still largely stuck in subsistence farming and dire poverty. That began to change in 2006 with the establishment of the Alliance for a Green Revolution in Africa (AGRA), with major funding from the Rockefeller and the Bill and Melinda Gates Foundations. AGRA is ensuring that African farmers have access to fertilizer and seeds, irrigation, transport, and information, and is committed to making Africa food-self-sufficient and secure.

Top: Farmers in Sauri, Kenya.

Left: MBL Ecosystems Center scientists Linda Deegan and Chris Neill (fourth and fifth from left) with PIRE colleagues in Sauri, Kenya.

Living in a Climate-Changed World

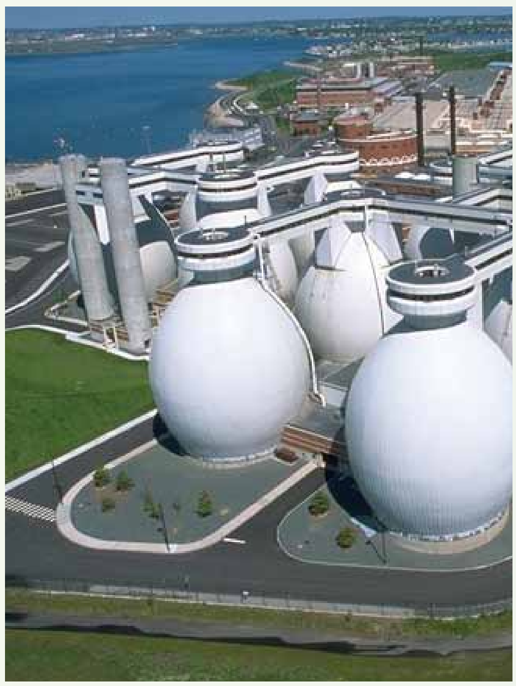
MBL Moment

with ...
Jerry Melillo
Distinguished Scientist, MBL Ecosystems Center

Jerry Melillo is a distinguished scientist and former co-director of the MBL Ecosystems Center, and a professor of biology at Brown University. In 2009, he co-authored the landmark federal report to Congress, "Global Climate Change Impacts in the United States." Melillo was a lead author on both the 1990 and 1995 Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC), and he served in President Clinton's Office of Science and Technology Policy from 1996 to 1997. His research focuses on the impacts of human activities on the biogeochemistry of terrestrial ecosystems, which he has studied in numerous sites around the globe. Melillo collaborates with researchers at MIT on the Integrated Global Systems Model, a comprehensive tool to analyze the feedbacks and impacts of climate change based on various economic, climate, and land-use scenarios. He holds a B.A. and a M.A.T. from Wesleyan University and a M.F.S. and Ph.D. from Yale University.

"Climate changes are underway in the United States and are expected to grow," was the firm conclusion of a major federal report in 2009, co-authored by the MBL's Jerry Melillo. All observations point to the facts: Rising temperatures over the past century have brought on changes such as more heavy downpours in the Northeast and Midwest; more days of drought in the Southwest and Great Plains; rising sea levels, especially on the Atlantic and Gulf coasts; and a loss of glaciers, snow cover, and sea ice in Alaska. Global warming has primarily been induced by human activities, the report affirms, but that means the die is not cast. Given the political will, we can mitigate the degree of global warming by reducing greenhouse gas emissions, as well as adapt to the climate changes that are already in place. Melillo has just been appointed by the U.S. Secretary of Commerce to serve on the National Climate Assessment Development and Advisory Committee. Below, he reflects on what may be the next steps.

MBL: Do you think society is more receptive to climate change adaptations—such as farmers preparing for more days of drought—than to mitigation measures, such as enforced restrictions on fossil-fuel burning?



JM: There is a growing recognition that we have to put adaptation measures in place because we are already experiencing climate changes, and we want to minimize adverse effects in the future. People at the local and regional levels are starting to incorporate climate change adaptation measures into their plans. Examples include farmers switching to crop varieties that are better suited to warmer or drier conditions, and communities altering zoning and building codes to put fewer

structures in harm's way, and make them less vulnerable to damage from floods, intense winds, and other extreme events. A terrific example of climate change adaptation is the Deer Island sewage treatment plant in Boston Harbor (lower left), which was built about two feet higher to take into account projected sea level rise by 2050, the planned life of the facility.

Getting the world's nations to agree on mitigation actions to reduce emission of greenhouse gases, such as carbon dioxide, has been difficult. In the United States, communities, states, and regions are showing leadership on mitigation by looking for win-win situations that make good economic sense and at the same time reduce emissions of heat-trapping gases. Many of these win-win cases involve improving the efficiency of energy use. Beefing up insulation in our homes and businesses, switching to more energy-efficient lighting, and buying higher-efficiency cars are all steps in the right direction.

MBL: As an expert in ecological modeling, do you find that people are confused about the use of models to project future scenarios for climate change?

JM: Helping the public understand what the climate change models can and cannot do is an important challenge for the scientific community. We have to do a better job of explaining the benefits and limitations of these models. They help us think more clearly about the complex interactions among the atmosphere, the ocean, and the land that influence the planet's climate. They also help us to quantify the uncertainties associated with the climate projections. The public needs to be reminded that all of us make many decisions in our daily lives that factor in uncertainty. The military, the business community, governments—all of them use "what if" exploration tools (models) to look into the future and to manage uncertainty.

MBL: Like scientific theories, models might be distrusted because they aren't "facts."

JM: That's why we have to work at linking model projections with our observations of climate trends. A focus on observations allows us to talk about facts. Last spring, for instance, I gave a presentation on climate change to a business group in Rhode Island. We discussed how our observations over the last 30 years show a 70 percent increase in heavy downpours in the Northeast, and our models project this will continue. So how we adapt is a very practical issue, and at the meeting we talked about options like rebuilding the storm drain infrastructure. Three weeks later, there were torrential downpours

that led to extensive flooding in Rhode Island. After that, I got a number of calls from meeting participants who wanted a copy of my Power Point presentation. It's not that I was prescient. It's just that there have been these observations that tell us something, and if we are smart, we will pay attention.

MBL: Do you still encounter people who do not believe climate change is happening, or who do not believe it is primarily caused by human activities?

JM: Yes, but I also find surprising levels of awareness in places you might not think about. For example, the Department of the Navy is very interested in the climate change issue, particularly sea level rise. They have hundreds of bases around the world and they are very concerned about that infrastructure being in harm's way. And they see that this situation will not go away, and that flooding and storm surge problems will likely increase over the century. Hopefully the new Congress will have a dialogue with some of the people in the military who have serious concerns about climate change, and think it could become an important national security issue.

MBL: Are you optimistic that we can mitigate and adapt to climate change before it is too late?

JM: Yes, but I am hoping we do it soon enough so that there aren't really large unintended consequences for society. I have been working with a group at MIT on an integrated assessment model for climate change. Fifteen years ago, when we began this endeavor, we were the only game in town. Now, efforts like these are springing up all over the world. Governments want to think about climate change in this holistic way. In the end, I am optimistic that we will think our way through parts of this problem. We may do some creative things on a global scale, like using land in ways that store more carbon. We can move away from fossil fuels and enter a carbon-light economy through a combination of understanding how nature works and using new energy technologies. I have to be optimistic. We can't give up. We have only one planet. •

Gifts & Grants

The **National Science Foundation** awarded $5.9 million in support of the Arctic Long Term Ecological Research (LTER) project. Gaius Shaver is the principal investigator.

The **Howard Hughes Medical Institute** awarded $3.2 million to support the MBL's Advanced Education Program. William Reznikoff is the principal investigator.

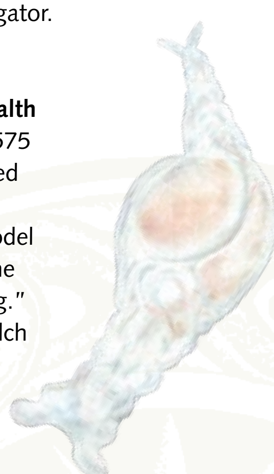
The **National Science Foundation** awarded $1.9 million in support of the Plum Island Ecosystems LTER. Anne Giblin is the principal investigator.

Dart Neuroscience LLC provided $1 million to support research in Rowe Laboratory in the area of learning and memory.

The **Department of Energy** awarded $508,000 for a project titled "Long-term Soil Warming and Carbon Cycle Feedbacks to the Climate System." Jerry Melillo is the principal investigator.

The **National Institutes of Health** awarded $795,575 for a project titled "Monogonont Rotifers as a Model to Investigate the Biology of Aging." David Mark Welch is the principal investigator.

The **National Institutes of Health** awarded $770,610 for a project titled "The Role of the Gut Microbiota in Ulcerative Colitis." Mitchell Sogin is the principal investigator.



Accolades

Loeb Laboratory received Gold Certification from LEED (Leadership in Energy and Environmental Design). LEED is a third-party certification program and nationally accepted benchmark for the design, construction, and operation of high-performance green buildings.

Julie Huber, a microbial oceanographer and assistant scientist in the Josephine Bay Paul Center, was awarded the Neal Cornell Career Development Award. The three-year award is for scientists in the early stage of their research careers at MBL. Cornell was a biochemist and senior scientist at the MBL from 1988 to 2000, and prior to that was a longtime Whitman Investigator.

Linda Deegan, senior scientist in the Ecosystems Center, was appointed to the Science and Engineering Special Team, a Gulf Coast task force that will advise the Obama administration on emerging issues such as a restoration plan for the Gulf Coast ecosystem in the wake of the Deepwater Horizon oil spill.

The **MBLWHOI Library** and the **Biodiversity Heritage Library** received the John Thackray Medal from the London-based Society for the History of Natural History. The medal is awarded for significant achievement in the history of the biological or earth sciences.

Former Trustee **Robert Haselkorn** was named a Senior Scholar in Aging by the Ellison Medical Foundation. These awards are given to established investigators to conduct basic biological research relevant to understanding life-span development processes and age-related diseases and disabilities.

Former Trustee **Gerald Weissmann** received the Master Educator and Mentor Award from New York University School of Medicine. He was also appointed jury chairman of the first Prix Galien International (for pharmaceutical research) presented in the United States.

Jane Maienschein, adjunct scientist, MBL Center for Library and Informatics, was named 2010 Arizona Professor of the Year by the Carnegie Foundation for the Advancement of Teaching and the Council for Advancement and Support of Education.

How Do Your **Greenhouse** *Gases Grow?*

Not so long ago, a farmer wouldn't think twice about liberally applying fertilizer to his or her fields. It could easily triple crop yields, because fertilizer gives the plants nutrients, especially nitrogen and phosphorus, that the soil may lack.

But farmers are increasingly aware that using nitrogen fertilizer brings the bad with the good. "There are a number of unintended consequences, one being the release of nitrous oxide to the atmosphere, a greenhouse gas that is much more powerful than carbon dioxide," says MBL Distinguished Scientist Jerry Melillo.

So how much agricultural fertilizer is just right: Enough to get the desired yield but, in the interest of managing global warming, no more? One hundred pounds per acre? Two hundred pounds?

"We don't know that yet," says Ecosystems Center Assistant Scientist Jianwu (Jim) Tang.

But he is finding out. Tang has taken one instrument from here, another one from there, and combined them in what he calls the Greenhouse Gas Flux Measurement System. When placed in an open field, the system's laser-based sensors automatically measure the fluxes of three greenhouse gases (nitrous oxide, carbon dioxide, and methane) from the soil into the atmosphere every 30 minutes.

"We want to know the response curves. How do the gas fluxes change when we add fertilizer? We are trying both industry-made and organic fertilizer. Also, how do weather conditions—rainfall or temperature for example—affect the fluxes?" Tang says. "After we know the responses, we can build a model to forecast what will happen with fertilization on a larger scale, over bigger regions. Then we will know the right amount of fertilizer we should add to farms."

Right now, the system is being tested in a research cornfield at University of Massachusetts, Amherst. But after it tests well, it will be moved to MBL research sites in Brazil and Africa. "Agronomists in Africa are just beginning to think about how to manage fertilizer applications so they minimize unintended consequences," says Melillo, who is involved in the Millennium Villages project (see p. 10). As Africa transforms to an agricultural economy, Tang's system could be a useful tool indeed.•

What's for Dinner?

The foodchains are changing in a warmer climate

By Hugh Ducklow with Scott Doney

Environmental change can be gradual or—if an ecosystem reaches a "tipping point" with a sudden shift in its species or processes—it can be abrupt. Even abrupt change, though, might only be recognized after some prolonged period of observation.

As I write this, I am aboard the icebreaker *Laurence M. Gould* during our annual research cruise to Palmer Station, Antarctica. Along with other scientists, we're discovering that the foodchains in Antarctica and the Arctic are transforming in response to a climate that's warming as fast or faster than anywhere on the planet. Although our observations started in 1993, some changes are just now becoming apparent.

The large decline in the local Adélie penguin population was recently described by Fen Montaigne in his book, *Fraser's Penguins*, which was widely discussed (even on "The Colbert Report"!). Detecting change in penguins is relatively straightforward because their colonies are at fixed locations, and the birds' behavior is predictable. Changes in other species are more complicated, often masked by large annual variations that make the longer-term trends hard to spot. For example, we documented a change in the phytoplankton (the "producers" at the base of the marine foodweb) along the Antarctic Peninsula, but it took 30 years of satellite data to nail it down.

Another case is even more elusive. Antarctic zooplankton populations are dominated by krill—small, shrimp-like animals that are the principal food of penguins, seals, and whales. Another zooplankton group, the gelatinous salps, is also present. Salps are voracious grazers and have few predators—they're a sort of dead end in the marine foodweb. We used to believe that krill lived in the sea ice, but salps avoided it. The two groups were seldom found together. But this year, we've found salps in nearly every net tow we've collected, including the samples with abundant krill and even in pack ice. Are we seeing a change in the ecosystem and its foodchain? Time will tell. Replacement of krill by salps would have important repercussions for the diet of larger predators.

Observations alone seldom reveal the full story. Observations are often sparse in space and time and complicated by technical difficulties in remote, harsh regions like the polar seas. To get more value from our data, we're building mathematical models of Antarctic marine foodchains, using the data we collect to calibrate and correct the model findings. Our WHOI colleague Sevrine Sailley is using a technique called inverse modeling to incorporate our observations into foodchain models that yield estimates of key ecosystem processes such as photosynthesis, feeding, respiration, and growth rates of krill, salps, penguins, and bacteria. The emerging picture is surprising: It suggests that krill are a relatively minor part of the foodchain, lending support to the idea that they're being replaced by salps.

Why do we care about foodchains so far away? The changes we're seeing presage equally large changes closer to home. We will experience high CO_2 in our atmosphere and a warmer planet for centuries to come. Everything we can learn about the changes an altered climate brings will help us adapt to an uncertain future. •

Hugh Ducklow is a senior scientist and director of the MBL Ecosystems Center. He also directs the National Science Foundation's Long Term Ecological Research (LTER) Project at Palmer Station, Antarctica, a collaborative endeavor with nine other principal investigators and staff to study and understand the Antarctic marine ecosystem. A biological oceanographer and expert on polar climate change, Ducklow's research focuses on the roles of bacteria in the ocean carbon cycle and the responses of the continental shelf sea ice zone ecosystem to rapid climate warming. Ducklow received an A.B. with a concentration in History and Science from Harvard College, and a Ph.D. in Environmental Engineering from Harvard University. He is a member of numerous national and international organizations, panels, and societies and has served on a number of National Academy of Sciences panels.

Scott Doney is a senior scientist at Woods Hole Oceanographic Institution (WHOI), where he holds the W. Van Alan Clark Senior Chair. He is also a principal investigator at the Palmer Station Antarctica LTER, where his research focuses on modeling of ecosystems processes and change. Among his numerous professional affiliations and honors, Doney is chair of the Scientific Steering Committee of the U.S. Ocean Carbon and Biogeochemistry Program. He received his Ph.D. in Chemical Oceanography from the MIT-WHOI joint graduate program in 1991.

An Early Wake-Up Call

The gray, shingled house perched high on a dune at Great Sippewissett Marsh in Falmouth, Massachusetts, was an appealing retreat in the early 1970s. Unfortunately, the house has since slipped into Buzzards Bay due to coastal erosion driven by sea-level rise. MBL scientists first began research in the Great Sippewissett Marsh in 1971, making it an early site for their long-term studies of salt marsh function. In that decade, MBL scientist Ivan Valiela and colleagues, including John Teal of Woods Hole Oceanographic Institution, discovered that nitrogen is a critical factor regulating the "metabolism" of salt marsh ecosystems. Teal and Valiela, who co-taught the MBL Summer Course on Marine Ecology for seven years, published the seminal paper on the subject, "The nitrogen budget of a salt marsh ecosystem," in 1979 in the journal *Nature*. After 40 years of concerted study, Valiela says, it is clear that salt marshes are providing a vital service to the environment by intercepting land-derived nitrogen before it reaches fragile coastal ecosystems. The years of observation also have revealed how salt marshes, and the houses near them, are vulnerable to global changes such as sea level rise.—DS

Great Sippewissett Marsh, along Buzzards Bay north of Woods Hole, in the early 1970s. Photo courtesy of Ivan Valiela.

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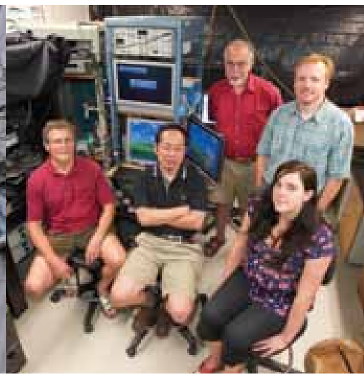

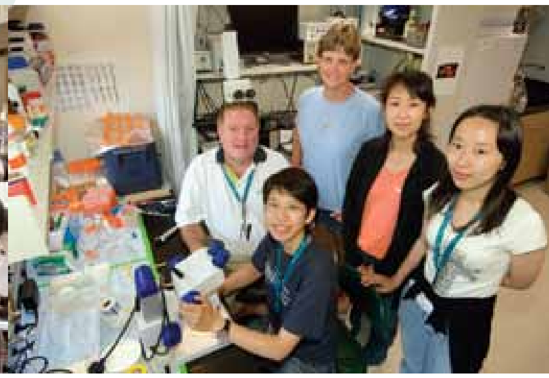

The Whitman Center for Research and Discovery

Hundreds of scientists from around the globe come to the MBL each year, eager to try out their best ideas for creative experiments that, often, can only be done in Woods Hole. They bring their top graduate students and post-docs, quickly set up shop in Rowe Laboratory or elsewhere on campus, meet up with their collaborators from other institutions, and dive into an intense period of scientific inspiration and discovery. The next issue of *MBL Catalyst* will explore the Whitman Center's illustrious history and ongoing mission of conducting important research with high-impact results.