



Cary Institute of Ecosystem Studies

The science behind environmental solutions

Annual Report 2011

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Letter from the President

Every year I am overwhelmed by the breadth, depth, and impact of the scientific research conducted at the Cary Institute. This year is no exception. From Charles Canham's analysis of the potential for northeastern forests to supply wood for energy and the impacts associated with such harvest, to Richard Ostfeld's continuing work on the ecology of Lyme disease and how we might reduce our risk in regional forests, Cary scientists are addressing the environmental issues that matter.

We continue to provide wise counsel on the ecological consequences of mountaintop-removal mining and the need for adequate regulation of hydraulic-fracture extraction of natural gas from the Marcellus shale. Meanwhile, Stuart Findlay and Victoria Kelly have helped local communities to reduce their use of road salt to save money and minimize environmental impacts.

This year also saw an expansion of the Cary Institute's public programming. We are rapidly becoming the "hot ticket" for Friday night in Millbrook, with speakers such as environmentalist and 350.org founder Bill McKibben, Climate Central scientist Heidi Cullen, author Simon Winchester, Natural Resources Defense Council President Frances Beinecke, and our own scientists Emma Rosi-Marshall and Peter Groffman. With every presentation, we seek to translate the best, current science on important environmental issues to the public.

This emphasis on communicating cutting-edge science also drives our K-12 education programs for local schools. The popularity of those programs, as well as the Ecology Camp held on our grounds, attests to meeting a public need. And, of course, we also advise and mentor a large number of undergraduate, graduate, and postdoctoral students. This year we also offered several classes in our cooperative program of teaching at Bard College.

With Steward Pickett serving as President of the Ecological Society of America, Kathleen Weathers working as a Program Director at the National Science Foundation, and Jonathan Cole's election as a Fellow of the American Geophysical Union, the Cary Institute continues to see its scientific staff represented at the highest levels of major scientific societies. Many of our scientists are asked to give significant time to boards and advisory committees for a wide variety of institutions.

The Cary Institute depends upon donations from generous people who care about the environment and who hope that the best scientific knowledge underlies environmental regulations and policy. We provide that science.

Read about us within these pages; you'll like what you see! Then, if you are not already a member, consider joining the Aldo Leopold Society, a group of our most committed donors.



William H. Schlesinger
President

Stay abreast of Cary Institute happenings, from events to breaking science, by signing up for our e-newsletter (www.caryinstitute.org) or following us on Facebook and Twitter.



Letter from the Chairman of the Board

The Cary Institute has earned its reputation as a world-class environmental research organization based on the strengths of its science. For nearly thirty years, its staff has been at the forefront of research into freshwater, air pollution, forest health, and disease ecology. The Cary Institute also plays a major role in training the next generation of ecologists, through hands-on field opportunities and graduate study.

Under Bill Schlesinger's leadership, the Cary Institute has strengthened its commitment to translating science to citizens and policymakers. Since Bill's arrival in 2007, the organization has expanded its portfolio of public offerings, becoming a community resource for environment-themed lectures, weekend education programs, and management workshops on regionally-relevant topics, such as freshwater and land use. It has also teamed with media outlets, most notably the *Poughkeepsie Journal*, to convey environmental science to citizens at large.

As I read about the past year's endeavors at the Cary Institute, I am struck by not only the achievements realized by the members of this organization but also the questions they pursue. From protecting freshwater to promoting the study of cities as ecosystems, the research here is rich with innovative thinking, and its findings contribute to our ability to preserve and protect the ecosystems that support life.

The Cary Institute's research discoveries provide policymakers and citizens with information that is essential to sound environmental decision making, whether on personal or governmental levels. Such knowledge also gives human society the best chance to steward the planet's natural resources for our children and grandchildren.

It is a privilege to serve on the board of the Cary Institute, and my fellow board members join me in asking you to participate with us in supporting the internationally recognized research that is conducted here.



Irene W. Banning
Board Chair

Institutional Profile

Founded in 1983, the Cary Institute of Ecosystem Studies is one of the world's leading independent environmental research organizations. For more than twenty-five years, our team of 16 Ph.D.-level scientists has been investigating the complex interactions that govern the natural world. Their objective findings lead to more effective policy decisions and increased environmental literacy for people of all ages. Areas of expertise include freshwater ecosystems, the ecology of infectious disease, forest response to environmental change, invasive species, conservation biology, and alternative energy sources.

Studies by our scientists have been instrumental in informing the Clean Air Act, the Intergovernmental Panel on Climate Change, and environmental management practices throughout the Northeast, including the Hudson River, New York's Catskill and Adirondack forests, and the watershed of Baltimore, Maryland. Hallmark projects include studies of the impact of acid rain on forests and freshwater ecosystems, unraveling the relationship between biodiversity loss and emerging infectious diseases, and tracking how climate change influences the spread of invasive species.

The Cary Institute's main campus is situated on 2,000 acres in the Hudson Valley village of Millbrook, New York. The site is home to a research complex, analytical laboratories, an environmental monitoring station, classrooms, an education program, and a 150-seat auditorium. The grounds are a laboratory for field research, with extensive on-site studies investigating the ecology of Lyme disease.

Education and public outreach are integral to the Cary Institute's mission. Our scientists are actively engaged in training the next generation of ecologists; many have adjunct appointments at colleges and universities, including Yale, Cornell, Princeton, Columbia, and Bard. On-site offerings include a public lecture series, weekend ecology field programs, undergraduate research opportunities, science and management forums, teacher training workshops, and an ecology-themed summer camp.





FRESHWATER ECOSYSTEMS

The nation's freshwater ecosystems, large and small, are under siege from human-induced impacts. These include runoff from fertilizers and agricultural products, hydropower facilities, and the spread of invasive non-native species. Since arriving at the Cary Institute in 2009, aquatic ecologist Emma Rosi-Marshall has added to the Institute's portfolio of contributions to freshwater conservation and resource management. Rosi-Marshall is untangling threats to the ecological health of freshwaters, from tiny headwater streams in northeastern mountains to the big rivers of the American West.

By altering water flow and temperature, large dams change rivers. To date, there has been little research on food web consequences. Working with a team that includes scientists from the U.S. Geological Survey and universities in Montana, Wyoming, and Idaho, Rosi-Marshall is revealing how dams transform river food webs through experiments conducted below the Glen Canyon Dam in the Grand Canyon section of the Colorado River. This insight is instrumental for resource management in a nationally beloved ecosystem and will help scientists' efforts to stabilize humpback chub, an endangered fish.

Rosi-Marshall is also exploring another gap in freshwater ecology—the role that large rivers play in nutrient uptake, a quality typically attributed to smaller streams. This research is significant because, until now, large rivers were assumed to act like pipes that delivered nitrogen received from tributaries straight to saltwater gulfs.

Recently, Rosi-Marshall and her colleagues developed a new method to assess nutrient uptake in large rivers. After establishing a river's flow path, the team releases trace amounts of nutrients and then measures the removal of these nutrients by the river. Calculating the decreasing levels of nutrients in each successive station led the team to discover that, in addition to some uptake occurring at the river bottom, reactions in the deeper water column also remove nutrients as they flow downstream.

Rosi-Marshall and her colleagues have used this method on rivers in Wyoming and Idaho and will be applying it to more turbid rivers in Colorado and Utah as well as to warmer rivers in Michigan and Indiana to provide a better understanding of nutrient load and processing in the continent's major waterways.



Rosi-Marshall is untangling threats to the ecological health of our nation's freshwaters. 🐟

Little is known about how pharmaceuticals and personal care products affect stream ecosystems. With colleagues in Illinois and Indiana, Rosi-Marshall is tackling this question on several fronts. A series of pioneering studies looks at how medical and personal care products—drugs, antibiotics, soaps, perfumes, antimicrobials—influence the way that freshwater ecosystems function. “While U.S. waste-water treatment systems are excellent by many standards, they don’t filter all the substances that could compromise freshwater ecosystems and resources,” notes Rosi-Marshall. Findings will illuminate the consequences of such substances reaching our waterways.

Many of us know that our medicine cabinets contain substances that could degrade freshwaters, but what about our pantries? Rosi-Marshall has published a series of articles raising concerns about the unintended ecological costs of genetically-modified crops. With Midwestern colleagues, she’s studied waterways and irrigation ditches nearby and downstream of fields planted with Bt-corn, which has been engineered to carry a protein that destroys corn borers. Bt-corn currently supplies 63% of the U.S. corn crop, and it enters streams via summer pollen and post-harvest plant remains.

In laboratory studies, Rosi-Marshall has documented that caddisflies, which are closely related to corn borers, experienced slower growth as a result of Bt-corn exposure. This result raises concern because caddisflies link the bottom and top tiers of the stream food webs; in their larval stage, they eat algae and are eaten by fish, and when they emerge and fly in their adult stage, they are a key food source for birds, bats, spiders, and lizards.

“Streams and rivers are tightly linked to their watersheds,” comments Rosi-Marshall. “What we do on land has effects on streams, and understanding the consequences of new technologies will allow us to better manage and conserve these ecosystems.”





CONSERVATION

Zebra mussels initially appeared in North America in 1986 and were found in the Hudson River by 1991; that same year, freshwater ecologist David Strayer correctly predicted that the invasive species would spread across the continent. Because Cary Institute scientists were studying the Hudson River's food web prior to the arrival of zebra mussels, they have been able to document the resulting effects on the Hudson River ecosystem, building one of the most complete snapshots of pre- and post-invasion conditions.

“Nearly everything about the Hudson River ecosystem changed when zebra mussels arrived,” notes Strayer. “They took off quickly, outweighing all other animals in the river just 18 months after they first appeared in the river. Because the mussels are filter-feeders, they caused a 50 to 90 percent drop in the plankton, which is the base of the aquatic food web that supports other native species, including fish. Water clarity and water chemistry were also affected.”

Recently, however, survival rates for zebra mussels in the Hudson River have plummeted: only one percent currently lives longer than a year, which means that while plenty of zebra mussels remain, their smaller body size lessens the

ecological impact. Strayer and his colleagues are working to understand the cause behind the change in zebra mussels' mortality. One factor is increased predation by blue crabs; when species enter an ecosystem, it can take existing predators a while to learn to eat new prey. But other mechanisms such as pathogens or parasites may also be involved.

In the wake of high zebra mussel mortality, Strayer and his colleagues are also assessing the status of many native organisms. They have found that zooplankton have returned to pre-invasion levels; many types of crustaceans, worms, and other small invertebrates are nearly fully recovered; and populations of native mussels, which had fallen by 20 to 60 percent, are stabilizing.

While the Hudson River appears to be recovering from some of the effects of the zebra mussel invasion, scientists have much more to learn, such as why the microscopic phytoplankton that zebra mussels eat have not recovered at all.

In the 1990s, collaborations with fisheries biologists at the New York State Department of Environmental Conservation revealed population changes among fish species that lived in the Hudson River estuary. Strayer plans to analyze the fish



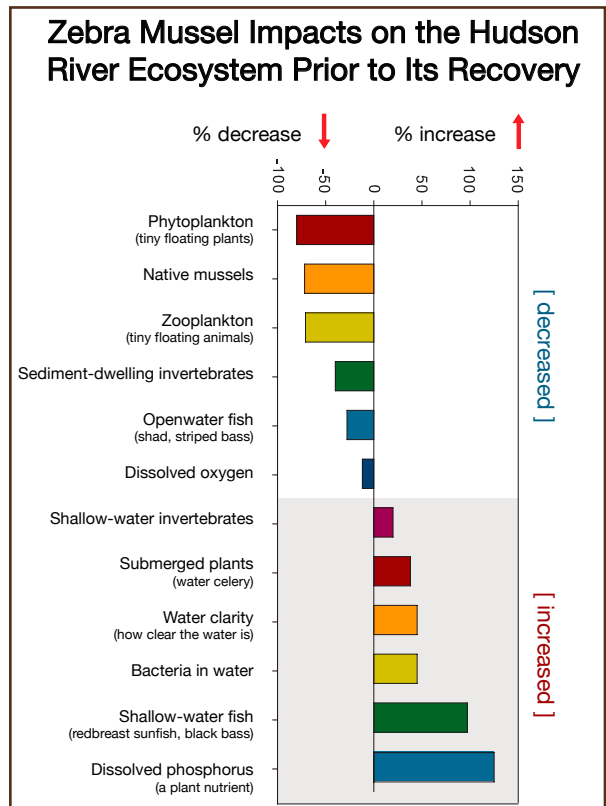
Freshwater ecosystems are richer in species than either land or marine habitats and are under great stress. 🦋

populations in the river again over the next few years. “Fish such as shad or striped bass, which live in the open water habitats and rely on the plankton and sediment-dwelling animals as a major food source, may now have a chance to recover. We will also assess fish such as largemouth bass or sunfish that live in the shallows.”

The recovery of native pearly mussels in the Hudson River is also of particular note. “The Nature Conservancy has identified pearly mussels as the most imperiled group of plants or animals in North America,” remarks Strayer. “Of the 300 species of pearly mussels unique to this continent, nearly 40 are extinct, and 150-200 other species are under threat of extinction.” Pearly mussels are very sensitive to human impacts, and the Hudson River population has been under extraordinary stress, given both the zebra mussel invasion and the long history of pollution and habitat destruction.

Strayer’s monitoring shows that pearly mussels in the Hudson are currently reproducing at a higher rate than at any other time since the zebra mussel invasion. His future work on these animals will explore how multiple factors—such as habitat, predators, and oxygen levels—jointly regulate pearly mussels’ chances of survival or extirpation.

Freshwater species have not been well represented in conservation biology, despite the reality that freshwater ecosystems are richer in species than either land or marine habitats and are under great stress. As more freshwater ecologists move toward conservation research, however, the Cary Institute’s long-term data provide principles for adaptive management, so that stakeholders might agree upon interim strategies to address accelerating biodiversity losses.





AIR POLLUTION

Scientists at the Cary Institute have long been at the forefront of air pollution research. Their findings have been essential to the creation and success of policy initiatives such as the Clean Air Act (CAA), which has reduced the ecological and human health damages resulting from atmospheric deposition generally and acid rain in particular.

Acid rain refers to rain, snow, or fog that contains unnaturally high levels of both sulfur and nitrogen—byproducts of human activities, with fossil fuel combustion being the main contributor. Sulfur emissions in the United States have dropped significantly in the past 40 years, largely due to regulatory programs that took effect after the 1990 Amendments to the CAA, which benefited directly from research conducted by Cary Institute scientists, notably Founding Director and President Emeritus Gene Likens.

Nitrogen emissions have not been closely regulated as part of the CAA, but research shows nitrogen deposition causes far greater environmental problems than was previously assumed. Furthermore, nitrogen emissions are rising rapidly due to global industrial development and agricultural expansion. Work by biogeochemist Kathleen Weathers is shedding new light on the full spectrum of acid deposition,

revising estimates of known impacts and drawing attention to previously unrecognized dangers.

Weathers has been investigating the ecological importance of fog for more than two decades. As a component of acid rain, fog delivers nutrients and pollutants to coastal and mountain ecosystems worldwide. With Cary Institute colleagues Likens, Gary Lovett, and Nina Caraco, Weathers revealed how fog plays a positive role in nitrogen-limited ecosystems of southern Chile. And with her students and colleagues, Weathers continues to discover how fog water and its chemistry maintain quintessential fog forests in northern Chile, Mexico, and coastal California.

Building on her fog work, Weathers' models of ocean-to-air-to-land chemical cycling is spurring new and exciting findings, especially along urban coastlines. Eli Dueker, a Columbia University/Cary Institute graduate student whom Weathers advises, is identifying the microbiology of fog and air with research conducted in and around New York City. "This is not only groundbreaking research—understanding the microbiology of air—but has real implications for human health, since pathogens can be kicked up from urban waters and transported to land via air and fog," Weathers comments.



Weathers' research has been instrumental in identifying mountain ranges as pollution hotspots. ☞

Weathers' research has also been instrumental in identifying mountain ranges as pollution hotspots. "We tend to think of mountains as pristine environments, but they receive a large amount of deposition in all three forms—wet, dry, and fog," she notes. Conducting research along the Appalachian Trail as well as in the Acadia and Great Smoky Mountain National Parks, Weathers and colleagues have developed a model to predict total atmospheric deposition over large areas that also provides spatially explicit measurements. Their findings indicate that high elevation hotspots of deposition receive four to eight times more pollution than was previously estimated.

Their model not only better measures actual rates of sulfur and nitrogen pollution across complex terrain, but it also helps scientists estimate the delivery of other chemicals that are of growing concern, such as mercury, to sensitive ecosystems. Assessing how mercury cycles from emissions and deposition through terrestrial and aquatic food webs is on Weathers' most recent research agenda.

Weathers remarks, "It's easy to forget that air pollution is not just acid rain—and that there's much more to acid rain than simply acid and rain." Her path-breaking work is essential to understanding complex biogeochemical processes on land, in the air, and in lakes and streams.





URBAN ECOLOGY

Cities—one of the most intense human disruptions to the environment—remain poorly recognized, much less understood, as ecosystems. As the pace of urbanization accelerates around the globe, plant ecologist Steward Pickett has positioned the Cary Institute as a world leader in urban ecology. Through his directorship of the Baltimore Ecosystem Study (BES), a long-term ecological research project, Pickett and colleagues are illuminating how urban, suburban, and exurban areas function as an integrated ecosystem.

Launched in 1997 with continued support from the National Science Foundation, BES research investigates soil, water, and air quality as well as animal and plant life from the city center to surrounding rural areas, taking into account the effects of the built environment and human activities. Through championing the integrative element—going beyond the study of separate ecological processes to model cities as large biophysical-social complexes—BES has pushed the field of urban ecology to develop both new research methods and best management practices for public policy.

To advance urban ecology, Pickett has assembled an interdisciplinary team of researchers, educators, and policymakers—including Cary Institute scientists Alan

Berkowitz, Peter Groffman, Shannon LaDeau, and Emma Rosi-Marshall—and more than 70 partner organizations. Understanding the relationships between natural and human processes in cities will expand options for planning, design, and restoration, with the goal of improving urban quality of life and minimizing negative environmental impacts. The methods developed in Baltimore will be applicable to cities worldwide.

Recently, Pickett has worked with Mary Cadenasso, who is associate professor of plant sciences at University of California-Davis and a former Cary Institute post-doctoral fellow, to develop a new land cover classification system. Called the High Ecological Resolution Classification for Urban Landscapes and Environmental Systems (HERCULES), it accounts for the variations in building type, vegetation, and impervious surfaces that mark metropolitan spaces. HERCULES has already been useful in assessing the distribution of lead in urban soils, bird diversity in urban tree canopy, and land surface temperature patterns.

“This system,” Pickett says, “is also much more effective than existing methods for assessing how the structure and management of residential lands, especially lawns in urban watersheds, affect the export of nitrate, a form of nitrogen



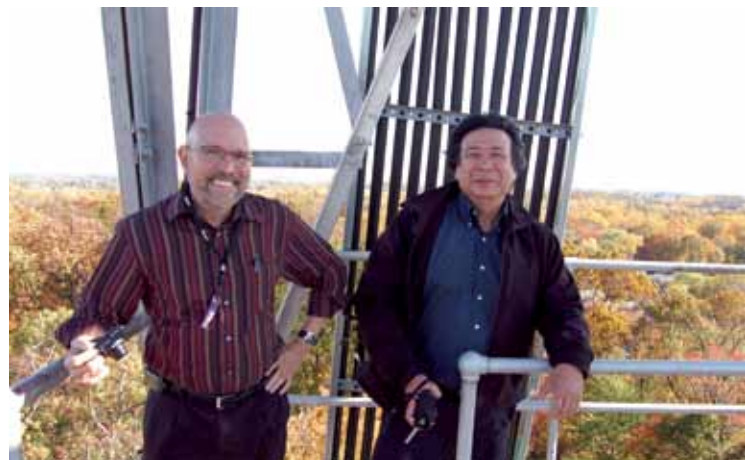
Pickett and colleagues are illuminating how urban, suburban, and exurban areas function as an integrated ecosystem. ❧

that is a serious pollutant of drinking water and coastal bays such as the Chesapeake.” HERCULES is scalable from individual city row houses to entire exurban neighborhoods. It can be directly applied to the design of metropolitan stormwater management systems as a potential control of nitrate pollution.

BES researchers have also installed the first permanent eddy flux tower in an urban environment. Located beyond the Baltimore city center, the tower measures carbon dioxide concentrations, temperature, and other atmospheric variables. “By monitoring these elements in an urban site,” Pickett notes, “we not only gain annual estimates of carbon sequestration in suburban ecosystems, but we also learn about daily and seasonal variations in carbon load that could be applied to practices that reduce the carbon footprint of cities.” Furthermore, the elevated levels of greenhouse gases in urban ecosystems may foreshadow future conditions that forests may face, and such data can help scientists estimate long-term growth response to these stresses.

As BES begins its third six-year funding phase, Pickett and his colleagues are exploring scientific solutions to the challenges of sustainability that confront urban ecology. “We face a transitional moment for American cities—indeed, cities worldwide,” states Pickett. “Sustainability in urban ecology attempts to recognize and reconcile differing demands in economic, social, and environmental spheres that allow the whole system to grow and adapt as changes occur.”

BES research findings have already contributed to Baltimore’s Sustainability Plan, adopted in 2009 as formal policy. By challenging the professional field with new thinking and working with many educational and outreach partners, BES researchers are providing the science that will help make urban areas more adaptive and resilient to future change.





GLOBAL CHANGE

When microbial ecologist Peter Groffman looks at snowpack in forests, he sees an insulating layer that protects soil microbes and fine plant and tree roots from freezing. In a long-term project at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire, Groffman and his colleagues are studying the effects of climate change on winter forest biogeochemistry. Their findings reveal that a warmer world will create colder soils in winter, with negative effects on nutrient cycling and forest growth.

“When people think about climate change,” Groffman observes, “blazing hot days or severe droughts typically come to mind. In the Northeast, our research has revealed that climate change is more marked in winter than in summer.” U.S. Forest Service researchers have been monitoring climate conditions at Hubbard Brook since 1955. Their winter measurements show that air temperatures are rising, extreme cold days (-25 degrees or lower) are becoming rare, and rain is increasing.

While data from Hubbard Brook indicate that the amount of snowfall has remained steady since the 1950s, the thickness

of the snowpack and the number of days with snow cover has dropped considerably, because snow is melting faster due to warmer temperatures and increased winter rains. When soil loses its snow blanket, it is more susceptible to freezing.

To understand the ecological importance of snow, Groffman and colleagues have conducted experiments by removing snow from small forest plots and comparing data from naturally occurring variations in snow cover at different elevations. The results of these studies make clear the consequences of colder soils in a warming world.

Winter may seem to be a dormant period for forest ecosystems, but a great deal of biological activity occurs in unfrozen, snow-covered soil; microbes still decompose organic matter, and plant roots continue a slow uptake of nutrients. Soil freezing increases over-winter root mortality, which decreases root uptake of nutrients during the following growing season.

“What we find with soil freezing,” Groffman explains, “is that root damage allows plant nutrients such as nitrate and phosphate to wash out of the forest ecosystem. This is an



Losing intense cold means that forest ecosystems are more susceptible to destructive pests. ❄️

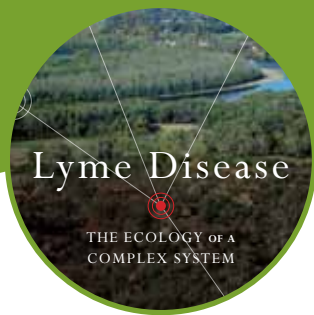
important loss to forest ecosystems, and it creates water problems downstream, where these nutrients cause eutrophication in lakes and estuaries. The change in nutrient dynamics also leads to increases in the production of nitrous oxide, an important greenhouse gas.”

Groffman notes that while changes in winter climate might be most dramatic in northern places such as New Hampshire, they are also important in transition zones such as the Hudson Valley. “Here in Millbrook, long-term data collected at the Cary Institute’s Environmental Monitoring Station shows significant changes in winter climate,” he points out. “Our long-term data indicate that Millbrook has not experienced temperatures at or below -25 degrees since 1994.”

In addition to biogeochemical shifts, a warming world will usher in a host of more visible changes in our local woodlands. For instance, extreme cold spells hinder invasive insect species such as the hemlock woody adelgid and the emerald ash borer from becoming established in northern forests. Losing that intense cold means forest ecosystems are more susceptible to these and other destructive pests.

“Less snow results in measurable changes to water quality, greenhouse gases, wood resources, biodiversity, and woodland aesthetics and recreation—tangible things that people care about,” Groffman comments. By making the connections between snow depth, soil freezing, and nitrogen losses in the northern hardwood forest, Groffman and his colleagues have fit another piece into the puzzle of climate change.





SELECTED BOOKS AND PAPERS

July 1, 2010—June 30, 2011

In the past year, Cary Institute scientists have published more than 96 papers or chapters in the primary literature of science. Among these papers are contributions to *Biogeochemistry*, *Ecology*, *Ecological Applications*, *Ecosphere*, *Frontiers in Ecology and the Environment*, *Journal of Environmental Management*, *Nature*, and *Science*. Below is a selection; to view a full listing, please visit www.caryinstitute.org.

Books published

Ostfeld, R. S. 2011. *Lyme Disease: The Ecology of a Complex System*. New York: Oxford University Press.

Papers published

Butler, T. J., F. M. Vermeylen, M. Rury, **G. E. Likens**, B. Lee, G. E. Bowker, and L. McCluney. 2011. Response of ozone and nitrate to stationary source NO_x emission reductions in the eastern USA. *Atmospheric Environment* 45:1084-1094.

Carpenter, S. R., **J. J. Cole**, M. L. Pace, R. Batt, W. A. Brock, T. Cline, J. Coloso, J. R. Hodgson, J. F. Kitchell, D. A. Seekell, L. Smith, and B. Weidel. 2011. Early warnings of regime shifts: A whole-ecosystem experiment. *Science* 332(6033):1079-1082.

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on stable isotopes of carbon, nitrogen, and hydrogen. *Proceedings of the National Academy of Sciences* 108(5):1975-1980.

Findlay, S. E. G. and V. R. Kelly. 2011. Emerging indirect and long-term road salt effects on ecosystems. *Annals of the New York Academy of Sciences: The Year in Ecology and Conservation Biology* 1223:58-68.

Foley, J. E., D. Clifford, K. Castle, P. Cryan, and **R. S. Ostfeld**. 2011. White Nose Syndrome: A roadmap for investigating and managing the ultra-rapid emergence of a novel, fatal infectious disease of hibernating bats. *Conservation Biology* 25:223-231.

Harrison, M. D., **P. M. Groffman**, P. M. Mayer, S. S. Kaushal, and T. A. Newcomer. 2011. Denitrification in alluvial wetlands in an urban landscape. *Journal of Environmental Quality* 40:634-646.

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LaDeau, S. L. 2010. Advances in modeling highlight a tension between analytical accuracy and accessibility. *Ecology* 91(12):3488-3492.

LaDeau, S. L., C. A. Calder, P. J. Doran, and P. P. Marra. 2010. West Nile virus impacts in American

crow populations are associated with human land use and climate. *Ecological Research*. DOI: 10.1007/s11284-010-0725-z.

Lindenmayer, D. B., **G. E. Likens**, C. J. Krebs, and R. J. Hobbs. 2010. Improved probability of detection of ecological "surprises." *Proceedings of the National Academy of Sciences* 107(51):21957-21962.

Lovett, G. M. and C. L. Goodale. 2011. A new conceptual model of nitrogen saturation based on experimental nitrogen addition to an oak forest. *Ecosystems* 14:615-631.

Lovett, G. M., M. A. Arthur, **K. C. Weathers**, and J. M. Griffin. 2010. Long-term changes in forest carbon and nitrogen cycling caused by an introduced pest/pathogen complex. *Ecosystems* 13:1188-1200.

Miranda, M. L., D. Hastings, J. Aldy, and **W. H. Schlesinger**. 2011. The environmental justice dimensions of climate change. *Environmental Justice* 4:17-25.

Mitchell, M. J. and **G. E. Likens**. 2011. Watershed sulfur biogeochemistry: Shift from atmospheric deposition dominance to climatic regulation. *Environmental Science and Technology* DOI: 10.1021/es200844n.

Pickett, S. T. A., G. L. Buckley, S. S. Kaushal, and Y. Williams. 2011. Social-ecological science in the humane metropolis. *Urban Ecosystems* DOI:10.1007/s11252-011-0166-7.

Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, C. G. Boone, **P. M. Groffman**, E. Irwin, S. S. Kaushal, V. Marshall, B. P. McGrath, C. H. Nilon, R. V. Pouyat, K. Szlavecz, A. Troy, and P. Warren.

2011. Urban ecological systems: Scientific foundations and a decade of progress. *Journal of Environmental Management* 92:331-362.

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Winchcombe, R. J. 2010. Hunting for balance. *The Wildlife Professional* 4(3):Fall 2010.

MAJOR SCIENTIFIC STAFF DISTINCTIONS

AWARDS, DISTINCTIONS, AND OFFICES HELD

Charles D. Canham

Board of Governors and Secretary, Ecological Society of America

Jonathan J. Cole

American Academy of Arts and Sciences
Fellow, American Association for the Advancement of Science
Fellow, American Geophysical Union

Clive G. Jones

Fellow, American Association for the Advancement of Science

Gene E. Likens

National Medal of Science
National Academy of Sciences
American Academy of Arts and Sciences
American Philosophical Society

Steward T. A. Pickett

American Academy of Arts and Sciences
President, Ecological Society of America (2011–2012)
Fellow, American Association for the Advancement of Science

William H. Schlesinger

National Academy of Sciences
American Academy of Arts and Sciences
Fellow, American Association for the Advancement of Science
Fellow, American Geophysical Union
Fellow, Soil Science Society of America

David L. Strayer

Fellow, American Association for the Advancement of Science

Kathleen C. Weathers

Fellow, American Association for the Advancement of Science

SERVICE TO NONPROFIT ORGANIZATIONS

Charles D. Canham

Adirondack Council, Board of Directors
Adirondack Land Trust, Board of Directors
Nature Conservancy, Adirondack Chapter, Board of Trustees
Great Mountain Forest, Board of Directors

Stuart E. G. Findlay

Nature Conservancy, Eastern New York Chapter, Board of Trustees

Peter M. Groffman

Dutchess Land Conservancy, Board of Directors

Gene E. Likens

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Additionally, our Ph.D. scientists serve as editors or editorial board members of the most important journals in our fields of strength, including *Ecology*, *Ecological Monographs*, *Journal of Ecology*, *Aquatic Biology*, *Aquatic Sciences*, *Biogeochemistry*, *Ecosystems*, *Freshwater Biology*, and *Tree Physiology*.



September 2010

Dr. Mark A. Bradford

Yale University
“Soil microbial community effects on ecosystem carbon dynamics”

Dr. Byron Crump

University of Maryland
“Can temporal patterns in planktonic microbial communities serve as indicators of ecosystem change?”

Dr. Martin Berggren

UQAM-Montreal
“Transfer of organic carbon from terrestrial sources to aquatic secondary producers: Pathways and time scales”

October 2010

Dr. Joe Arvai

Michigan State University
“Engineered environments and structured processes: Two strategies for improving decision making in risk management”

Dr. Thomas Philbrick

Western Connecticut State University
“Flowering plants in tropical river-rapids and waterfalls: Ecology, endemism, and impacts”

Dr. Jennifer Tank

University of Notre Dame
“The influence of agricultural land use on stream ecosystem function”

Dr. Jill Mikucki

Dartmouth College
“Cold, dark isolation: Life is good for subglacial microbes”

November 2010

Dr. Kiona Ogle

University of Wyoming
“Living in the past: Quantifying the ecological memory of plant and ecosystem processes”

Dr. Ilana Brito

Columbia University
“Estimating the true distribution of emerging infectious diseases: Accounting for systematic biases in surveillance”

Dr. Sara Baer

Southern Illinois University
“Restoration remains an acid test: Constraints to ecosystem and community recovery during grassland restoration”

December 2010

Dr. Matthew Wallenstein

Colorado State University
“Microbial adaptations to global change: Linking microbial physiology to ecosystem functioning using the molecular toolbox”

Dr. Colin Beier

SUNY-ESF
“Sustainability science in forest landscapes”

Dr. Katherine McNeill

Boston College
“Supporting meaning making in science: The role of scientific inquiry, argumentation, and the use of evidence in science learning”

January 2011

Dr. Jennifer Morse

Cary Institute of Ecosystem Studies
“Farm fields to wetlands: Biogeochemical consequences of re-flooding in coastal agricultural lands”

Dr. Charles Mitchell

University of North Carolina
“Host traits and biogeography: Controls on pathogen species richness and reservoir potential”

February 2011

Dr. Cathy Collins

Bard College
“Tracking species declines and restoring species diversity on a rapidly changing planet”

Dr. Craig Tobias

University of Connecticut
“Biological and geochemical controls on Diel DIC cycling in a mid-western USA stream”

Dr. Dina Fonseca

Rutgers University
“Fine-scale population genetics of disease vectors”

March 2011

Dr. Ann Hajek

Cornell University
“Entomopathogens on the move: Transmission, spread, and dynamics”

Dr. Neil Bettez

Cary Institute of Ecosystem Studies
“Nitrogen deposition at the Baltimore LTER”

Dr. Philip Camill

Bowdoin College
“Impacts of climate warming and aridity on high latitude ecosystems in north central North America: Modern and paleo perspectives”

Dr. Robert Hall

University of Wyoming
“Treating the Colorado River like a small stream”

Dr. Stephen Porder

Brown University
“Phosphorus inputs to managed and unmanaged ecosystems”

April 2011

Dr. Kurt J. Vandegrift

Pennsylvania State University
“A potential role for Pterygodermatites peromysci in the population dynamics of Peromyscus leucopus”

Dr. Patrick Megonigal

Smithsonian Environmental Research Center
“Will wetland responses to elevated CO₂ amplify or attenuate climate change?”

Dr. Janneke HilleRisLambers

University of Washington
“Life on the edge: The impacts of global warming on range limits”



The Cary Institute's educational offerings strive to convey an understanding of the critical links and complexities of ecosystems. This insight is crucial to assessing and protecting the environment that we all depend on. Under the guidance of Alan Berkowitz, the Cary Institute's Education Program translates cutting-edge science into offerings for a broad range of learners, from K-12 students and their teachers to undergraduates honing their emerging research skills and graduate students enriching their understanding of advanced scientific concepts.

These programs are guided by the Cary Institute's Ecosystem Literacy Initiative (ELI), which works to advance an understanding of how people learn about ecological concepts, with the goal of innovating best practices.

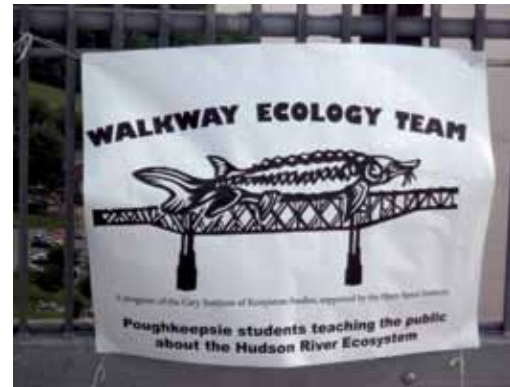
K-12 Students

Educational outreach to secondary school students ranges from after-school programs and classroom experiments to an ecology day camp. This past year, Institute educators taught more than 2,100 students in New York public schools during both on- and off-site field trips, and 101 students and 16 junior counselors participated in the summer camp held annually on the Cary Institute grounds.

Two new stewardship initiatives gave students a chance to deepen their understanding of regional issues. Educator Cornelia Harris developed the Hudson Stewards program at Poughkeepsie's Krieger Elementary School. Fourteen fifth-graders who had participated in a Cary-led water cycle curriculum extended their learning with hands-on projects such as building rain barrels and marking storm drains. This summer, Harris also launched the Walkway Ecology Team, in which 17 Poughkeepsie students in grades 5-12 volunteered as docents at the Walkway Over the Hudson in collaboration with the Hudson River Environmental Conditions Observing System.

Secondary School Teachers

Guided by Berkowitz's research in ecological learning theory, Cary Institute educators continue to develop innovative curricula for use by science teachers. A pilot module on Lyme disease was tested this spring in Beacon and Hyde Park schools. Additionally, the Institute debuted a publicly-available curriculum database, which offers teachers increased access to lesson plans on topics such as calculating carbon footprints and assessing climate change impacts.



This year's annual Summer Institute for Teachers brought 27 educators from across the nation to Millbrook to focus on understanding climate change. Cary Institute also has three education research grants, which allow staff to develop small working groups with selected teacher fellows both on campus and in Baltimore.

Undergraduates

The Cary Institute boasts one of the nation's longest running Research Experiences for Undergraduates (REU) programs. Now in its 24th year, the NSF-funded program pairs 11 college students with mentor scientists to develop and carry out independent summer research projects. REU students also translate their data to a class of Poughkeepsie High School students. Topics this year included the effects of drought on an invasive forest pest, alternatives to road salt, and ways of reducing nitrate runoff from urban lawns.

Graduate Students

Our scientists currently advise 72 graduate students (54 Ph.D. candidates and 18 M.S. candidates) from 34 different universities, including several abroad. Arrangements between the Institute and these universities range from individual appointments and membership on graduate committees to externally-funded joint education programs, such as the series of NSF Graduate Training Grants involving Cary Institute and Cornell University.

Each year, the Cary Institute hosts the Fundamentals of Ecosystem Ecology (FEE), a graduate-level ecology course held on campus that attracts students from the United States and overseas. The 2011 course was led by forest ecologist Gary Lovett, and 16 scientists and staff served as instructors. The class accepted 18 students from 8 countries, including one compliance officer from Shell Oil. Topics included biogeochemistry, geo-engineering, communicating science, and the global carbon cycle.





The Cary Institute remains committed to making its research findings and scientific expertise available to public audiences. Methods of engagement include news releases, staff-authored newspaper articles, regular public lectures, weekend education programs, and a series of science and management forums.

From July 1, 2010, to June 30, 2011, staff experts from the Cary Institute were featured more than 300 times in print, television, and radio media. Outlets included the *New York Times*, *USA Today*, *Scientific American*, *Discover*, and BBC News, as well as the internet.

Ecofocus, the Cary Institute's bimonthly column in the *Poughkeepsie Journal*, continued to connect our science research with current environmental concerns. This year, 26 columns appeared and dealt with such topics as hydraulic fracturing, West Nile virus, stormwater management, environmental collapse forecasting, and forest conservation.

This year, the Cary Institute continued its writer/artist-in-residence fellowship; by inviting established writers and artists to our campus, we seek to build interdisciplinary connections between science and the arts that expand ecological literacy. Akiko Busch, who is author of four published books and a prolific writer for a variety of media, was a spring fellow. Living on campus for several weeks, she immersed herself in lectures, conversation with staff, and the natural surroundings while writing a book on citizen science.

The monthly Friday Night Lecture series brought national speakers to overflow audiences at the Cary Institute auditorium. Presenters included environmentalist and 350.org founder Bill McKibben (*The Building Movement to Tackle Climate Change*), bird song expert Donald Kroodsmma (*The Singing Life of Birds*), author and botanist Douglas Tallamy (*Bringing Nature Home*), Climate Central climatologist Heidi Cullen (*The Weather of the Future*), and Natural Resources Defense Council President Frances Beinecke (*One Year after the Gulf of Mexico Oil Spill*). Institute scientists Emma Rosi-Marshall (*Genetically Modified Crops and the Environment: An Evolving Story*) and Peter Groffman (*Snow is Good*) also contributed to the series.

Screenings of several movies were also offered; they included *Carbon Nation* (with commentary from director Peter Byck), *Food Inc.* (with a post-screening panel discussion), and *The Last Mountain* (with commentary from producer Clara Bingham).

Last spring the Cary Institute hosted a Science and Management Forum on regional freshwater issues. This well-attended event drew a diverse audience—from town officials and state agency staff to concerned citizens—to focus on potential solutions for issues of regional concern. We also continued our program of weekend educational offerings. Highlights included a hike that focused on the trees used to make stringed instruments (culminating in a bluegrass jam), a moonlight ecology walk, and a winter ecology hike.

The Cary Institute continues to grow its presence in social media and will be embarking on a new collaboration with WAMC, a northeast affiliate of NPR, to launch a radio segment called Earthwise Radio. Airing daily, the segments will feature environmental content of national concern, with the goal of creating environmentally literate citizens.





While the Cary Institute's grounds are primarily a laboratory for field research, they also serve as an outdoor classroom for our public and education programs. Hands-on learning from active research sites and nature stands at the core of the Cary Institute's educational outreach. Study ponds orient young day campers to aquatic ecology, meadows provide habitat for butterfly forays, and hiking trails serve as the backdrop for forest ecology walks.

Portions of our 2,000-acre campus are set aside for public use and enjoyment. These include roadways and trails as well as the Fern Glen, which features naturalized groupings of native plant species. Kiosks distributed throughout the grounds contain maps, interpretive brochures, and information about upcoming public programs to help orient

and educate visitors. Our fields and forests are popular sites for birding, fall foliage explorations, and GIS scavenger hunts.

We continue to plan and develop improvements in both access and interpretation. New signage and materials draw from the surroundings to teach visitors what an ecosystem is, why ecosystems are important, what we do as ecosystem scientists, and how Cary Institute research relates to current environmental issues.

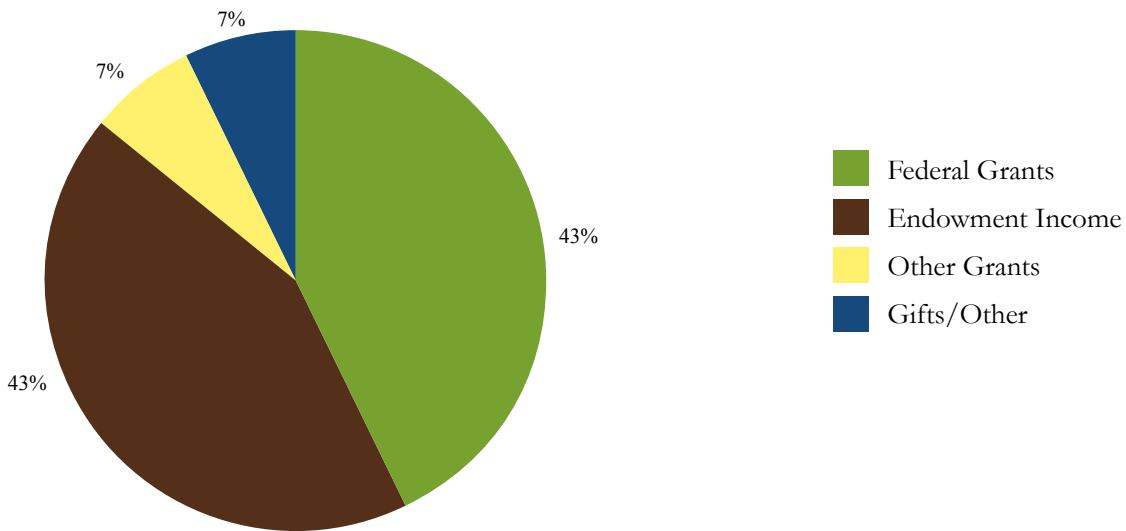
Our trails and roadways are open to the public from dawn to dusk from April 1 to October 31. Internal roadway gates open at 8:30 a.m. and are locked at 7 p.m.



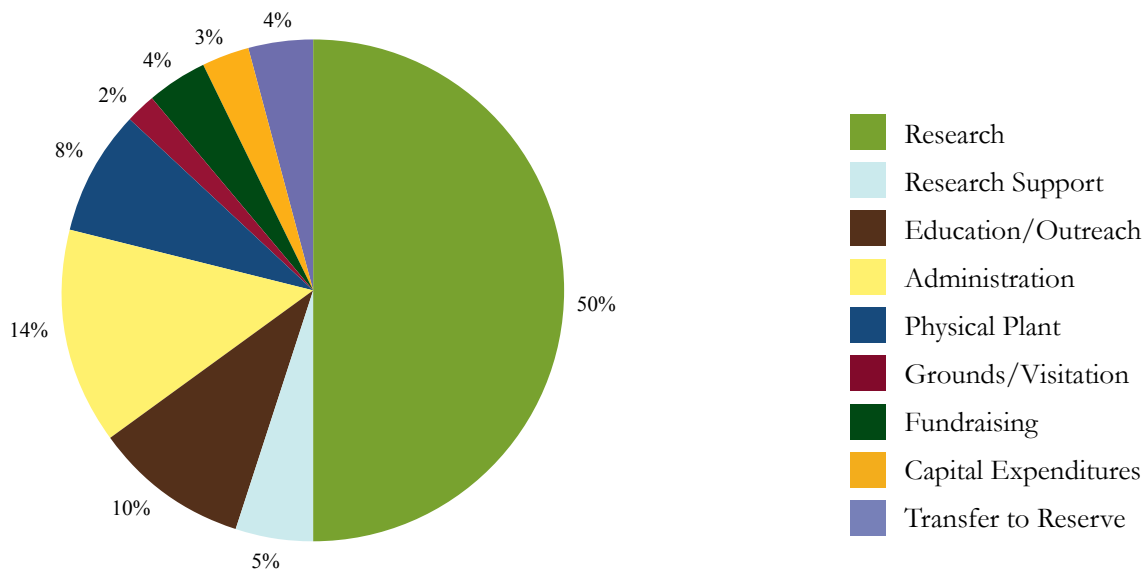
FISCAL YEAR 2011 OPERATING RESULTS

July 1, 2010—June 30, 2011

Sources of \$10.7 Million in Operating Support



Uses of \$10.7 Million in Operating Expenses



As of June 30, 2011

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Denise A. Schmidt, *Director of Laboratory Research Facilities and
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Milada Vomela, *Lab Technician II*

Safety

Lau-Réné A. Manuel, *Safety Officer*



The combined expertise of the Cary Institute's scientific staff make the organization one of the world's leading centers for ecological research. Areas of expertise include freshwater ecosystems, the ecology of infectious disease, forest response to environmental change, invasive species, conservation biology, and alternative energy sources. By improving our ability to understand the natural environment, Cary Institute research plays a role in shaping effective management and policy decisions.

Alan R. Berkowitz, Ph.D.

Plant Ecologist, Head of Education

Ecosystem literacy; urban and schoolyard ecosystems; education research; undergraduate and teacher education; fostering a diverse ecological profession

Charles D. Canham, Ph.D.

Forest Ecologist

Dynamics of forest ecosystems; effects of climate change on tree population dynamics; invasion of northeastern forests by exotic tree species; watershed-scale analyses of nutrient loading to lakes

Jonathan J. Cole, Ph.D.

Limnologist

Carbon cycling in inland waters; regulation of aquatic bacteria; gas flux; biogeochemistry

Stuart E. G. Findlay, Ph.D.

Aquatic Ecologist

Detritus dynamics; microbial ecology; interactions between stream water and shallow groundwater; dissolved organic carbon; ecology of the Hudson River and tidal wetlands

Peter M. Groffman, Ph.D.

Microbial Ecologist

Terrestrial microbial ecology; ecosystem and landscape biogeochemistry; transformation of environmental pollutants

Clive G. Jones, D. Phil.

Terrestrial Ecologist

Ecosystem engineering: environmental modification by organisms; ecological engineering: ecological processes for sustainable environmental management; acorn connections: complex interactions in oak forests; ecological synthesis, integration, and theory

Michael W. Klemens, Ph.D.

Research and Policy Conservationist

Interface of land-use planning and ecosystem protection; biodiversity conservation; turtle ecology; genetics of polyploid Ambystomid salamanders; vernal pool ecology and fragmentation response

Shannon L. LaDeau, Ph.D.

Community Ecologist

Climatic and anthropogenic influences on pest and pathogen dynamics; ecology of disease transmission in forest and urban ecosystems; avian community response to multiple stressors

Gene E. Likens, Ph.D.

Ecologist, Founding Director and President (1983-2007), President Emeritus (2007-present)

Ecosystem analysis; biogeochemistry; limnology; effects of air pollution on ecosystems

Gary M. Lovett, Ph.D.

Forest Ecologist

Forest nutrient cycling; responses of forest ecosystems to stress; impacts of air pollution and exotic species on forests; atmosphere-canopy interactions

Richard S. Ostfeld, Ph.D.

Disease Ecologist

Ecology of infectious disease; links among biodiversity, habitat destruction, and disease transmission; community responses to pulsed acorn production; climate change and human health

Steward T. A. Pickett, Ph.D.

Plant Ecologist

The function of spatial heterogeneity in ecosystems; ecological studies of urban systems

Emma J. Rosi-Marshall, Ph.D.

Aquatic Ecologist

Ecosystem function in human-dominated systems; agricultural stream dynamics; pharmaceuticals and ecosystem function; influence of dams on food web dynamics; large river ecology

William H. Schlesinger, Ph.D.

Biogeochemist, President

Global element cycling, with an emphasis on the role of forests and soils in climate change; desert ecology and desertification

David L. Strayer, Ph.D.

Freshwater Ecologist

Freshwater ecology; distribution and roles of freshwater invertebrates, especially bivalves and meiofauna; ecology of nonnative species; conservation ecology

Kathleen C. Weathers, Ph.D.

Biogeochemist

Biogeochemical linkages across atmosphere-terrestrial-aquatic systems; importance of fog in ecosystem function; effect of biology on geochemical cycling; ecosystem function in heterogenous landscapes

Raymond J. Winchcombe, B.S.

Wildlife Biologist, Manager of Field Research Facilities and Grounds
White-tailed deer population management

POST-DOCTORAL RESEARCHERS

Heather A. Bechtold, Ph.D.

Aquatic Ecologist

Stream nutrient cycling and metabolism in response to changing forest structure in the northeast

Neil D. Bettez, Ph.D.

Terrestrial Ecologist

The impact of local nitrogen emissions in watershed nitrogen budgets along an urban to rural gradient in Baltimore, MD

Katherine F. Crowley, Ph.D.

Community Ecologist

Regional effects of nitrogen deposition on nutrient limitation and the influence of tree species composition on carbon and nitrogen cycling in northeastern forests

Michelle H. Hersh, Ph.D.

Community Ecologist

The ecology of babesiosis, an emerging tickborne disease; effects of tick parasitism on mouse populations

Jorge Duran Humia, Ph.D.

Forest Ecologist

The effect of climate change on carbon and nitrogen biogeochemical cycles in forest ecosystems

Robert C. Johnson, Ph.D.

Aquatic Ecologist

The effects of urbanization on insect emergence from wetland habitats with an emphasis on mosquitoes

Eric G. Keeling, Ph.D.

Forest Ecologist

Assessing student thinking and learning, designing innovative teaching strategies and professional development programs for improving student and teacher literacy about the global carbon cycle and climate change

Jennifer L. Morse, Ph.D.

Biogeochemist

Investigating nitrogen gas losses from soils in relation to oxygen dynamics in northern hardwood forests

M. Andrea Previtali, Ph.D.

Animal Ecologist

The role of climatic factors, human disturbance, and pathogens on the dynamics and life-history parameters of small mammals

Alexandra Rodriguez Pereiras, Ph.D.

Forest Ecologist

The role of atmospheric nitrogen deposition and tree species composition in stabilizing carbon in northern hardwood forests soils

Andrea Swei, Ph.D.

Disease Ecologist

Impact of habitat disturbance and species composition on the prevalence and transmission of Lyme disease in California

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Grupo de Investigación y Educación en Temas Ambientales (GrIETA), Mar del Plata, Argentina

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Department of Environmental Sciences, University of Virginia

Michael J. Papaik, Ph.D.

Ecologist

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Department of Biology, SUNY New Paltz

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Cooperative Wildlife Research Laboratory and Department of Zoology, Southern Illinois University

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Department of Biological Sciences, Texas Tech University

Radka Wildova, Ph.D.

Plant Ecologist

Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor

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