

# HARVARD FOREST

*Harvard University*



**2013** Biennial Report



**T**HE HARVARD FOREST, founded in 1907 and located in Petersham, Massachusetts, is Harvard University's 3,500-acre center for ecological research and education, engaging thousands of students and hundreds of scientists each year. Interdisciplinary scholars are drawn from Harvard and an international array of colleges, universities, and research centers, as well as regional conservation organizations, forestry groups, and K-12 classrooms. The Forest has served as the Northeast regional center for the Department of Energy's National Institute for Global Environmental Change (NIGEC; 1988), the National Science Foundation's Long-Term Ecological Research program (LTER; 1988) and National Ecological Observatory Network (NEON; 2011), and the Smithsonian Institution's Global Earth Observatory (SIGEO; 2010). Thousands of Harvard Forest research publications and datasets, some dating back to the Forest's founding, are publicly available online.

The Harvard Forest landscape, comprised of varied forests, fields, wetlands, and streams, is one of the oldest and most intensively studied research landscapes in North America. Open to the public year-round, the site includes educational and research facilities, the Fisher Museum, and miles of recreational trails.

### Support

The Harvard Forest is a department of the Faculty of Arts and Sciences (FAS) of Harvard University. In the 2012 fiscal year, a total operating budget of \$5.5 million was funded nearly evenly by research grants and restricted endowments and gifts.

Research and education at the Forest are supported by many sources, public and private. Wherever possible, those funding sources have been noted throughout this report.

### Contact

#### **HARVARD FOREST**

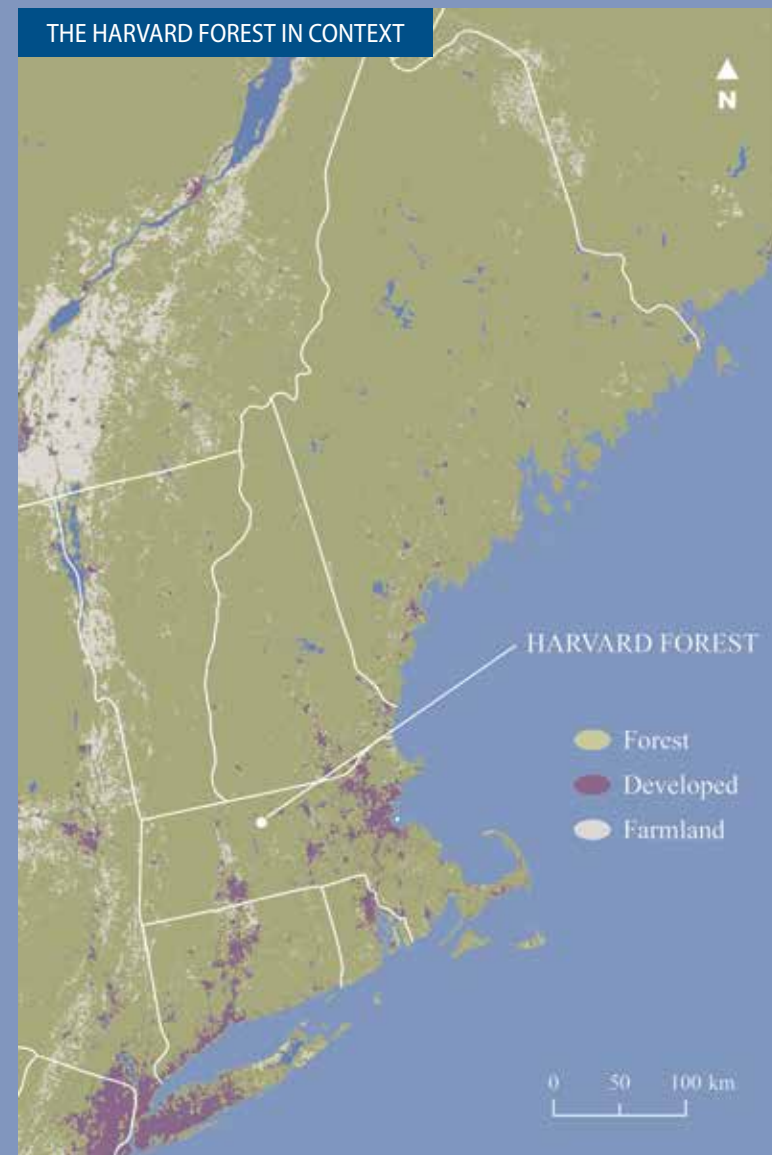
*Harvard University*  
324 North Main Street  
Petersham, MA 01366

(978) 724-3302

<http://harvardforest.fas.harvard.edu>

<http://www.twitter.com/harvardforest>

<http://www.facebook.com/theharvardforest>





Friends and colleagues:

Harvard Forest is a unique institution. At our core, we are a vibrant research and educational department of Harvard University and a tightly knit community of scholars based in rural New England. Our success in these roles has fueled our growth as an international hub for ecological research; a pioneering center for innovation in conservation, science policy, and forest management; and an unparalleled resource for hands-on ecological learning.

Our dual mission of research and education remains unchanged since our founding in 1907, but the tools, approaches, and collaborative effort needed to accomplish these well in the 21st century have grown.

Harvard Forest research programs are well known for incorporating the human and historical elements of long-term ecosystem change here in Petersham, across New England, and beyond. Today, we draw that focus forward, to examine the natural and human elements of *future* change. In a regional landscape that is mostly privately owned, decision-making by individuals and society at large—choices such as land protection, forest harvest, and development—joins climate change as a fundamental driver of what our landscape will look like, how well our ecosystems will function, and what kinds of services those ecosystems will deliver back to society in the coming century.

As scientists, historians, policy experts, and educators, we have a duty to address these changes, to make a case for our forests, watersheds, and the communities that depend on them, and to work with policy makers and other stakeholders in addressing major challenges for the future.

In this report, we've outlined some of our efforts to understand our changing ecosystems; to educate science learners from "K to gray" using ecology, communications, and the arts; to bring good science to bear on forward-looking environmental policy; and to advance land conservation across New England and in our own backyard. We welcome your ideas and participation in this work.

With gratitude for your continued interest and support,

David R. Foster  
*Director*

Banner photo: 2012 summer students Yvan Delgado de la Flor, Andrew Moe, and Elizabeth Kennett head out to the field with mentor Aaron Ellison. See page 14.

Top right photo: Eastern hemlock cones. See page 8.

Center photo: The Fisher Museum dioramas help us understand the past and make informed choices for the future.

Bottom photo: The ant *Aphaenogaster rudis* carrying a plant seed. See page 5.

**“As scientists, historians, policy experts, and educators, we have a duty to address these changes to make a case for our forests, watersheds, and the communities that depend on them.”**



# RESEARCH



## Funding Sources





## Wildlife in a Transformed Landscape

The return of forests over the past two centuries has welcomed a host of familiar species back to southern New England. Black bear, beaver, deer, fisher and most recently, moose—once locally extirpated—are more abundant today than they have been in over 250 years. The influence of these animals on our landscape is great but largely unquantified.

Browsing by large herbivores like moose and deer can heavily impact forest ecosystems at both local and landscape scales. A single moose eats more than 50 pounds of woody material—buds, bark, stems, and leaves—every day. Sites heavily disturbed by storms, timber management, or destructive insects—including the Forest's recently harvested pine plantations (see Box 1) and the long-term Hemlock Removal Experiment—promote the kind of dense, vigorous sapling growth that attracts large herbivores to feed.

To evaluate the impacts of moose and deer browsing on forest ecosystems, in 2008, Highstead ecologist Ed Faison and Steve DeStefano of the USGS Cooperative Fish and Wildlife Unit, both Harvard Forest LTER collaborators, began constructing a series of fenced exclosures on 15 sites at the Forest, at the Quabbin Reservoir, and elsewhere in southern New England. The exclosure fences prevent moose and deer from entering and browsing in these 400m<sup>2</sup> patches of forest. Over time, the types and quantities of plants growing inside the fences, beyond the reach of deer and moose, can reveal how much, and which varieties, these herbivores are eating when they are allowed to browse freely.

Faison and DeStefano's data illuminate the powerful role of moose and deer as ecosystem engineers. Inside the fences, where moose and deer cannot browse, woody stems grow twice as thickly. Outside the fences, heavily browsed tree species include the early successional pin cherry, paper birch, and aspen, as well as oak and red maple. White pine saplings, on the other hand, are largely left uneaten. Over time, herbivore food preferences may become visible at the landscape scale, with reduced overall regeneration of hardwood trees and increased growth of white pines.

The research team has also begun to consider indirect effects of herbivore browsing on other wildlife species. For example, data from bird nest searches revealed several nests built inside fenced-off areas but none in the areas freely browsed by moose and deer, suggesting that browsing may influence early successional bird nesting habitat.

As disturbance by humans, invasive insects, and major storms continues to clear large patches of forest in our region, and as large herbivore populations continue to shift, studies like these will continue to provide information vital to effective land management.



*Deer-browsed maple stump  
with sprouts*



### BOX 1. RESTORING NATIVE FOREST

Between 2008 and 2010, a local timber crew harvested approximately 80 acres of mature plantation forests, largely non-native red pine and Norway spruce that had been established by Harvard Forest scientists in the 1920s and 30s. The clearing concluded several long term experiments, regenerated a diversity of native tree species on these sites, initiated a new

suite of long-term experiments, and was accompanied by the control of invasive plant species.

Approximately 45 acres of remaining plantations were left standing to protect existing study sites and to provide for scientific comparisons with the harvested stands.

**Illustration:** Some species, like pin cherry, paper birch, and black birch, suffer major declines in the browsed areas. Species like red maple, black cherry, and white pine are more resilient.

**Photos top and middle:** Motion-sensitive cameras mounted on the exclosure fences reveal visiting wildlife.

**Bottom photo:** Harvard Forest scientists tour a fenced exclosure site.





## Vanishing Acts

In 2007, the majestic oaks that define the wooded landscape of Martha’s Vineyard were overrun by a sudden outbreak of caterpillars of the native winter moth. The next year, more caterpillars defoliated the same trees. And the third year, as the caterpillars began munching leaves again, a drought finished off the weakened trees, leaving oak skeletons across the landscape.

According to Harvard Forest paleoecologists David Foster and Wyatt Oswald, an analogous event happened before: about 5,000 years ago. Pollen grains buried deep in the mud beneath the many ponds they have studied reveal a sudden and widespread oak die-off across the Vineyard and on adjacent islands and Cape Cod, followed by 1,000 years of beech forest dominance, and the slow re-emergence of oak.

Based on studies funded by two grants from the National Science Foundation, Foster, Oswald, and their colleagues David Orwig, Jonathan Thompson, and Brian Hall point to modern lessons we can take from this historical parallel. A period of rapid climate changes and extreme weather preceded the ancient oak die-off—conditions analogous to ones we face today. While increasing temperatures alone may not kill trees, unusual weather can trigger novel behavior among formerly benign insect species. And trees weakened by pests are much more susceptible to climate factors such as drought.

Oak forests aren’t the only ecosystems shifting on the Vineyard. Foster and his students also study the disappearing cliffs at Wasque, an expansive coastal landscape on the island of Chappaquiddick owned by The Trustees of Reservations. Shifting currents and intense storms are fast eroding the beach there, sometimes at a rate of many feet per day, cutting over 200 feet of shore in the past two years. The Harvard Forest research group has been sampling Wasque’s forests and their history for years—capturing the particulars of a unique coastal ecosystem before it vanishes into the sea.



*Winter moth caterpillar*

**A period of rapid climate changes and extreme weather preceded the ancient oak die-off — conditions analogous to ones we face today.**



- Top photo: Summer student Lindsay Day and her mentors Wyatt Oswald and Elaine Doughty prepare to core Squibnocket Ridge Pond on Martha’s Vineyard.
- Center photo: Rapidly eroding cliffs at Wasque on the Vineyard.
- Bottom photo: Scattered standing dead oaks in the hills of West Tisbury, Martha’s Vineyard.
- Right photo: Lindsay Day and Wyatt Oswald extrude a 5000-year-old core of sediment from a Vineyard pond.



## A Closer Look at a Warming World

► **IN THE SOIL** In every layer of forest soil, diverse communities of microscopic organisms help facilitate the movement, breakdown, and storage of key nutrients that benefit countless plants, animals, and ecosystem functions. Several long-term experiments at the Forest investigate how human-induced ecosystem change alters the way microbial communities move and store these nutrients—particularly carbon and nitrogen.

To represent the accumulation of certain airborne pollutants, researchers from the University of New Hampshire and the MBL Ecosystems Center have been adding extra nitrogen to eight plots covering 1.5 acres of Harvard Forest soil for more than 20 years. Over time, the extra nitrogen has suppressed microbial decomposition activity, leading to an increase in the amount of carbon in the soil—creating a stronger carbon “sink.” In a second experiment, warming the soil over time to mimic projected future climate has the opposite effect. Warming stimulates microbial activity, releasing more soil-based carbon to the atmosphere as carbon dioxide.

A new grant from the Department of Energy will help researchers determine which microbes are contributing to these changes. Over the next several years, researchers will sequence three terabases of DNA and RNA from soil microbe communities collected in the Forest’s experimentally warmed plots. Sequencing three terabases is roughly equivalent to sequencing 1,000 human and plant genomes, 10,000 ant genomes or 500,000 bacterial genomes.

► **IN THE AIR** A recent Harvard Forest study on butterfly population dynamics employed data from an unusual source—the trip accounts of the Massachusetts Butterfly Club. Over the past 19 years, the amateur naturalist group has logged species counts on nearly 20,000 expeditions throughout Massachusetts. Their records fill a crucial gap in the scientific record, which Harvard Forest post-doctoral fellow Greg Breed and senior ecologist Elizabeth Crone reported in a paper published in *Nature Climate Change* in 2012.

The data show that Massachusetts butterfly populations are already responding to a warming climate. Subtropical and warm-climate species such as the giant swallowtail and zabulon skipper—many of which were rare or absent in Massachusetts as recently as the late 1980s—show the sharpest increases in abundance over the 19-year period. At the same time, more than three quarters of northerly species—species with a range centered north of Boston—are now declining in Massachusetts, many of them rapidly.

► **ON THE FOREST FLOOR** Ants are everywhere in our forests, from the soil to the branches of trees. Besides making up a large proportion of animal biomass, they provide essential ecosystem services including soil turnover, decomposition, and dispersal of seeds. Aaron Ellison, Harvard Forest senior ecologist and lead author of the newly published *Field Guide to the Ants of New England*, designed the long-term “Warm Ants” experiment to test how increased air temperatures—aligned with climate predictions for the next 50 to 100 years—will impact ant biodiversity and its effects on ecosystem services. The experiment, initially funded by the Department of Energy (2008-2012), and now supported by the National Science Foundation (2012-2015) is replicated at the Duke Forest in North Carolina.

In the first several years of the experiment, North Carolina ants—many of which are already living at or near their thermal maximum—have shown more vulnerability to warming. Warming temperatures there reduce the abundance of many ant species while strongly favoring ants in the group *Crematogaster* (so-called “acrobat ants”). In contrast, warming tends to increase ant abundance across the board in Massachusetts, but has not yet changed overall species diversity.

A grant from the National Science Foundation will fund Ellison’s team to use genomics and proteomics to explore evolution of thermal tolerance in ants and to clarify species boundaries and identities of a widespread group of ants (the *Aphaenogaster rudis* complex) responsible for seed dispersal of many native spring-flowering plants, including trillium and bloodroot.

- Top photo: A soil sample is collected from the Harvard Forest soil warming experiment.
- Center photo: The giant swallowtail butterfly, a southern species, is now seen in high numbers in Massachusetts.
- Bottom photo: Post-doctoral fellow Shannon Pelini checks on an ant nestbox in the Warm Ants experiment.







## Hayfever and Climate Change: Putting the *where* and *when* on wheezing

For allergy sufferers in North America, the amount of pollen flying during allergy season is an important public health concern. The pollen of the common ragweed plant (*Ambrosia artemisiifolia*) is the leading cause of hayfever in autumn. Because the plant is associated with warm conditions, it's likely to become more prevalent in future landscapes. But where, exactly, and to what extent? To answer these questions, lead scientists Kristina Stinson and Christine Rogers from the University of Massachusetts are studying how ragweed responds to a changing climate.

Past studies show that ragweed plants grown in atmospheres with elevated carbon dioxide increase their overall growth, reproductive capacity, and pollen production by up to 60 percent. However, because the ragweed plant is broadly distributed across North America, not all populations, or genetic ecotypes, are alike. Determining how ragweed allergy hotspots may shift over time in the Northeast requires a closer look at our local ecotypes.

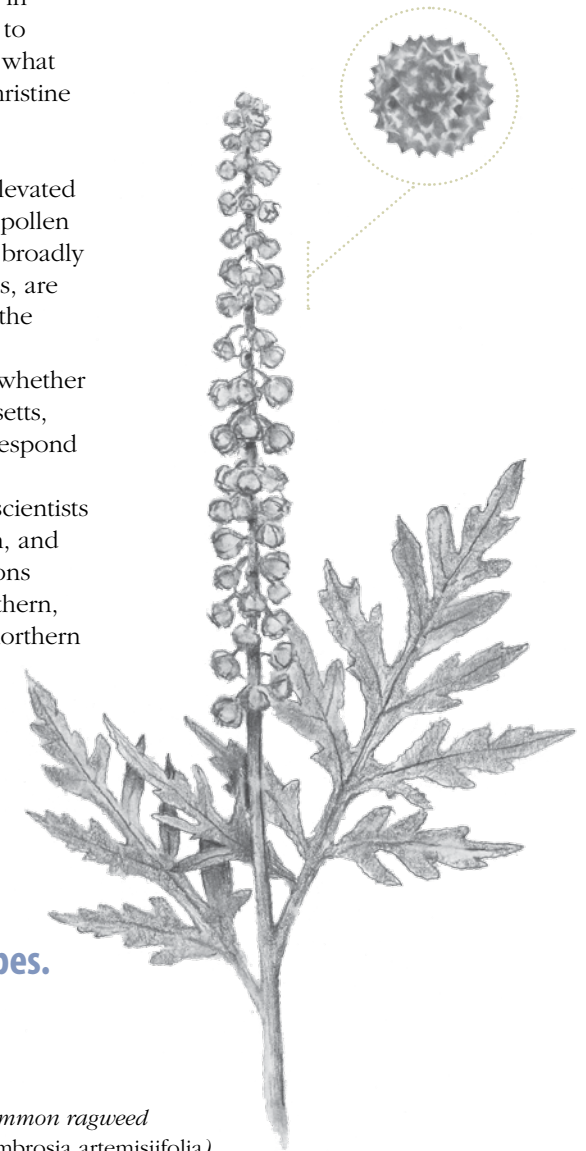
A 3-year, EPA-funded experiment at the Harvard Forest investigates whether ecotypes from different environmental conditions in Vermont, Massachusetts, and New York will respond differently to carbon dioxide levels that correspond to 20 and 50-year climate projections.

In 12 hoophouses in the Lyford experimental garden, students and scientists measured over 1,000 ragweed plants' growth, flower timing and duration, and pollen production and potency. Preliminary data show that the populations most responsive to the elevated carbon dioxide conditions were the northern, rural ecotypes from Vermont. In high carbon dioxide conditions, those northern ecotypes flowered sooner and grew better than ecotypes from the south (Massachusetts and New York).

Other aspects of the research include field surveys of wild ragweed populations, rooftop pollen traps spread across Massachusetts, and the honing of computer models that, in the end, will help to create regional maps of allergy hotspots over the next 50 years.

**Because ragweed is associated with warm conditions,  
it's likely to become more prevalent in future landscapes.**

- Top photo: 2011 Summer Research Program students build hoophouses in the experimental garden to house the experiment's ragweed plants.
- Center photo: 2012 Summer Research Program students Courtney Maloney and Tiffany Carey work with mentor Kristina Stinson to prep pollen samples.
- Bottom photo: Kristina Stinson demonstrates one of her rooftop pollen traps for journalists from NBC Learn.



*Common ragweed  
(Ambrosia artemisiifolia)  
and its pollen*



## Balancing the Budget

► **CARBON** Two eddy-flux towers at the Forest—each more than 70 feet tall—provide a unique vantage to track long-term carbon dynamics across different forest types in the Prospect Hill Tract.

The Environmental Measurement Station (EMS) tower, maintained by Harvard University scientists Bill Munger and Steve Wofsy, supports the world's longest record of carbon exchange between a forest and the atmosphere. More than twenty years of data from the tower reveals a remarkable trend: the rate of carbon storage in the EMS oak-maple forest has mostly increased over time, rather than leveling off as had been expected.

Tree growth accounts for only part of the observed carbon storage. Roots and carbon accumulation in the soil, which have not been measured, are also important. The tendency for carbon uptake to increase over time may be partly explained by longer growing seasons. In early spring, the forest around the EMS tower begins to take up more carbon than it respire. Today this occurs about 28 days earlier than it did 20 years ago. And that uptake continues about 19 days later in the fall. Annual temperatures recorded at the Harvard Forest since 1964 have been increasing by about 0.3 degrees Celsius per decade, while the amount of precipitation has also increased.

► **WATER** Harvard Forest's 3,500 acre property spans two watersheds—the Swift River, which flows into the Quabbin Reservoir, the water source for more than 2 million residents of metro Boston, and the Miller's River, which flows into the Connecticut River. Four headwater stream gages and two wetland gages measure water level, flow discharge rate, and water temperature on Prospect Hill, providing critical insights for our understanding of forest ecosystem function and the hydrologic cycle.

Water is measured at the Forest in all its forms. The Harvard Forest snow pillow, installed in 2009, provides continuous measurements of the water content of the snow pack. Such data can be hard to come by: snow measured by depth does not account for the air between the water crystals. Snow pillow data, which measures the water in the snow by weight, are collected every two weeks in winter.



- Left photo: Spring snowmelt flows through a stream gage on Prospect Hill.
- Top right photo: Students from the Harvard Forest Freshman Seminar climb the 71' hemlock canopy access tower to learn more about forest carbon exchange.
- Bottom right photo: Harvard Forest ecologist Emery Boose explains the snow pillow to a group of high school students from the Kohler Environmental Center at Choate Rosemary Hall.

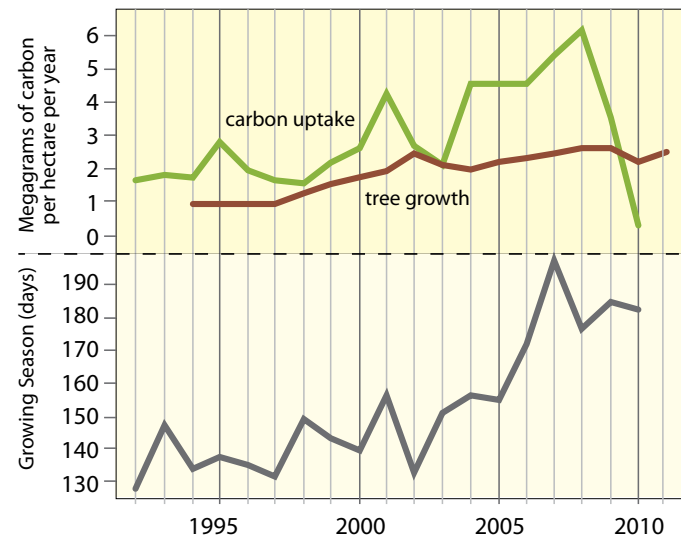


Figure 1. Length of growing season (increasing on the lower graph) plotted with carbon uptake (green line) and the growth of trees (red line) in the EMS plot over a 20-year period. The variation over time points to the need for long-term data collection.







## Tracking Invaders

The hemlock woolly adelgid (HWA), an invasive insect that has killed millions of eastern hemlock trees across the East Coast, is now advancing across the Harvard Forest. Although the insect is limited by cold temperatures, a warm winter in 2011-2012 has made the white woolly casings visible even to a casual observer walking our trails.

Hemlock is a key tree species on many areas of Harvard Forest land. Within the 85-acre “mega-plot” on Prospect Hill (see Box 2), 78 acres contain hemlock trees. In a summer 2012 survey led by Harvard Forest ecologist David Orwig, the adelgid was confirmed in over 90% of small plots (comprising 71 acres) where hemlock occurs; was likely present on upper branches in plots across 6 acres; and fully absent in less than one acre. One spot of good news: adelgid density was low on most branches. However, the insect’s widespread occurrence suggests a significant ongoing threat.

In 2009, HWA invaded the Forest’s long-term Hemlock Removal Experiment, which was designed in 2005 to help forecast the impacts of future invasions by the insect. Because the study involves logged and experimentally girdled hemlock stands, over the coming years, researchers will be able to separate the effects of physical death of hemlock from the impacts that HWA may have on forest structure, species composition, and ecosystem dynamics.

Research into New England’s post-glacial history reveals a similar, rapid collapse of eastern hemlock populations about 5,000 years ago. According to the pollen record, the trees made a slow recovery over the three millennia that followed. Harvard Forest paleoecologists Wyatt Oswald and David Foster have attributed the historical hemlock decline to climate change in conjunction with at least localized insect outbreaks (see “Vanishing Acts,” page 4).

A forthcoming book, *Hemlock: A Forest Giant’s Life in the Shade and on the Edge*, currently being drafted by nearly a dozen Harvard Forest scientists, will document the cultural and historical importance of eastern hemlock and the challenges it faces in the future. The book will be published in 2014 by Yale University Press.



*Hemlock woolly adelgid under a scanning electron microscope*

- **Top photo:** David Orwig and students inspect woolly adelgid casings on a hemlock branch.
- **Center photo:** Hemlock branch infested with woolly adelgid.
- **Bottom photo:** Tree damage from another invasive pest being studied by Harvard Forest scientists in Worcester, MA: the Asian Longhorned Beetle.

### BOX 2. “MEGA-PLOT” KEEPS CLOSE WATCH ON FOREST CHANGE

In 2010, in partnership with the Center for Tropical Forest Science (CTFS) at the Arnold Arboretum, forest ecologist Dave Orwig accepted a daunting challenge: map, identify, and measure every tree wider than one centimeter in a 35-hectare (85-acre) area of the Harvard Forest. In 2013, after three years of effort by summer and winter field crews, measurements of the more than 90,000 trees will be complete. Forthcoming digital maps will provide details on each tree and

its position within several major long-term experiments and a range of ecosystem types. Future remeasurements of the “mega-plot” will allow robust analysis of forest change over time, including the decline of a more-than-200-year-old stand of eastern hemlock trees. The mega-plot places the Forest within the Smithsonian Institution’s expanding Global Earth Observatory (SIGEO), which contributes funding to this effort and promotes international comparisons of forest dynamics over time.

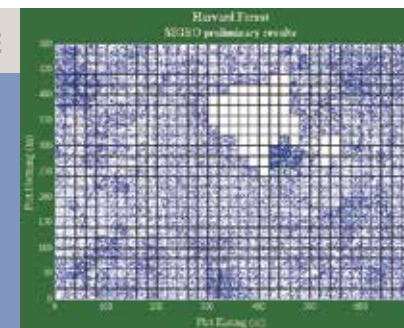


Figure 2. In this map of the Harvard Forest SIGEO plot, individual trees and other woody plants are represented by tiny blue dots. The white area of the map will be filled in by 2013.



# Conservation & Policy



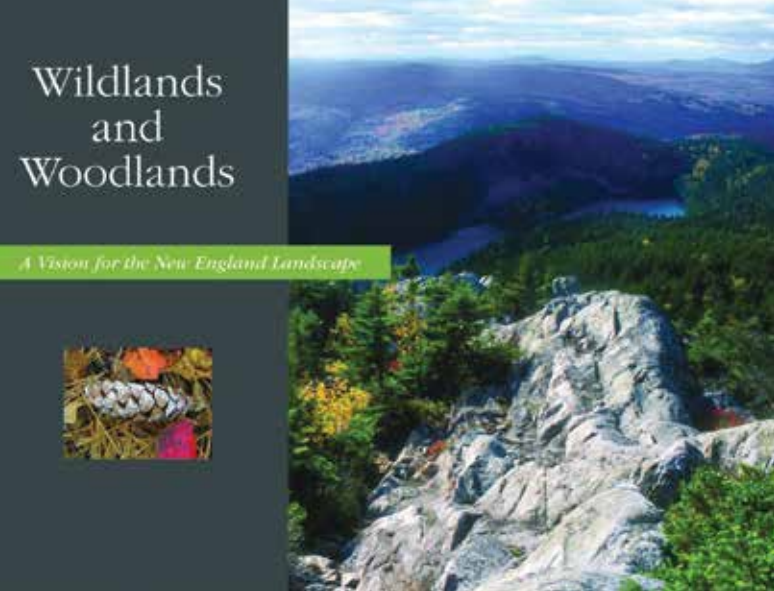
## Funding Sources



The Jessie B. Cox Trust  
Conservation & Research  
Foundation  
The Fine Fund

Fields Pond Foundation  
The Orchard Foundation  
Massachusetts Water Resources  
Research Center





Harvard Forest policy and conservation initiatives draw on ecological research to inform and inspire earth stewardship. Our programs bring specialized expertise in conservation networking, scenario planning, science-policy synthesis, and science communication to bear on pressing environmental challenges in the region and around the world.

- Top photo: Cover for the Harvard Forest “Wildlands and Woodlands” report.
- Center photo: Scenarios project scientists meet with stakeholders in Boston.
- Bottom photo: 2012 Summer Research Program students Laura Bartock and Emma Schnur survey Massachusetts landowners at their home.

## » LOCAL to STATE: Learning from Landowners

### EXPLORING HOW LANDOWNERS SHAPE OUR FORESTS

Two-thirds of forest acres in Massachusetts are privately owned. As a result, our forests’ ability to provide a range of environmental benefits, such as clean water and air, to the region depends largely on the thousands of families and organizations who own and manage the land. A new collaborative project by social scientists and ecologists at Boston University, UMass Amherst, and the Harvard Forest will survey landowners and explore municipal and ecological data in communities along an urban-to-rural gradient from Boston to Central Massachusetts. Their research will identify how social, political, and economic factors interact with ecological processes to change forests and the ecosystem services they provide.

## » REGIONAL to NATIONAL: Linking Science, Policy, and Conservation

### BUILDING A SCIENCE POLICY EXCHANGE

Rigorous science strengthens environmental policy and conservation—and scientific research becomes more valuable when informed by the questions that decision-makers pose. Unfortunately, the exchange between these groups is often haphazard: scientific knowledge on any topic springs from a host of institutions and spans decades, making the information difficult to synthesize into decision-ready forms. To address this challenge, senior directors from six major Northeastern research institutions (the Harvard Forest, Cary Institute for Ecosystem Studies, Hubbard Brook Research Foundation, the MBL Ecosystems Center, Syracuse University, and University of New Hampshire) have joined together to form the Science Policy Exchange, a collaborative dedicated to harnessing science to solve environmental challenges. The consortium is led by Kathy Fallon Lambert, director of the Harvard Forest Science & Policy Integration Project. Exchange members collaborate to engage stakeholders to define critical environmental challenges, synthesize complex science around the issues, and communicate the management implications for people and the environment. The Exchange focuses on challenges at the intersection of land use, climate, energy, and water, and its efforts will be modeled on the success of regional projects such as Harvard Forest’s Wildlands and Woodlands initiative.

### EXPANDING WILDLANDS AND WOODLANDS

In 2010, the Harvard Forest report *Wildlands and Woodlands: A Vision for the New England Landscape* (W&W) entered the public eye with a bang: newspapers in every New England state carried headlines about declining forest cover, outlining the shift needed to protect our landscapes and bolster local economies. Since then, dozens of organizations from Rhode Island to Maine have joined the Harvard Forest to contribute to the vision of permanently protecting 70% of the landscape by 2050. Within the network, hubs of leadership have emerged, expanding the capacity of the project well beyond the Harvard Forest. The Highstead Foundation, a regional nonprofit based in Connecticut, has devoted its mission and growing staff to achieving

- INSTITUTIONAL PARTNERS:**
- Cary Institute of Ecosystem Studies
  - Highstead
  - Hubbard Brook Research Foundation
  - Lincoln Institute of Land Policy
  - Marine Biological Lab
  - New England Forestry Foundation
  - Smithsonian Institution
  - Syracuse University
  - University of New Hampshire



the W&W vision throughout the region (learn more at [highstead.net](http://highstead.net) and [wildlandsandwoodlands.org](http://wildlandsandwoodlands.org)). The New England Forestry Foundation has launched a “Heart of New England” campaign to support W&W-related outreach to landowners, land trusts, and foresters and to expand landscape-level conservation in every New England state. The Harvard Forest continues to provide ecological data that strengthens the regional conservation imperative and leadership that propels the vision forward.

- Top photo: Logging in a suburban landscape.
- Center figure: Modeling future forest conversion in Massachusetts.
- Bottom photo: A perforated forest on Martha’s Vineyard.

## MAPPING THE FUTURE: SCENARIOS OF LANDSCAPE CHANGE

How might the New England landscape change in 50 years, and what consequences might follow for people and the environment? The Scenarios project addresses these questions by bringing a diverse team of stakeholders and scientists together, first to identify potential scenarios that would differ from our current path: 1) environmental regulations roll back and sprawling development increases by 125%, 2) important resources become scarce and agriculture increases along with demand for wood biomass energy, or 3) smart growth, permanent land protection, carbon caps, and sustainable forest harvest become widespread.

Computer simulations of landscape change based on these three scenarios for Massachusetts illuminate the potential consequences of today’s choices on the landscapes of tomorrow—information that can then inform policy, landscape planning, and conservation decisions. A series of workshops at the Forest and in Washington DC have brought together state and federal stakeholders to discuss the scenarios and to help adjust computer models being developed by Jonathan Thompson at the Smithsonian Conservation Biology Institute. By summer 2013, Thompson’s models will have produced a map for each scenario in Massachusetts, forecasting changes in forest carbon, tree species, landscape structure, and wildlife habitat. A follow-on set of workshops has laid the groundwork for expanding this work into northern New England.

## » NATIONAL to INTERNATIONAL: Uniting Institutions to Catalyze Conservation

### THE CONSERVATION CATALYSTS NETWORK

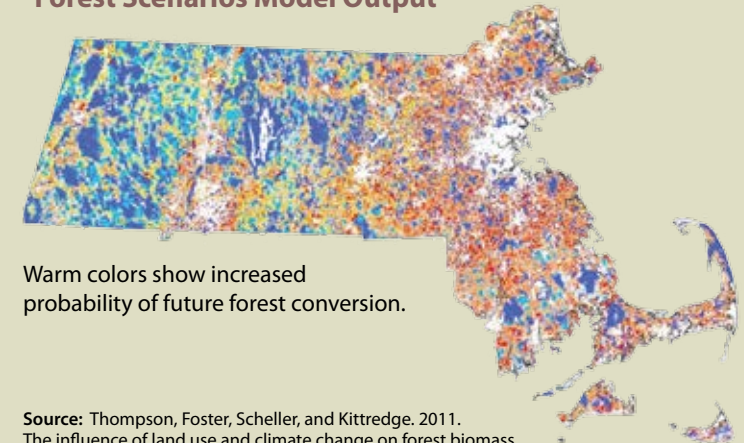
Jim Levitt, director of the Harvard Forest’s Program on Conservation Innovation and a fellow at the Lincoln Institute of Land Policy, is organizing a new network focused on the role played by universities, colleges, and independent research organizations in catalyzing large landscape, oceanscape, and biodiversity conservation initiatives. The new group, known as the Conservation Catalysts Network ([ConservationCatalysts.org](http://ConservationCatalysts.org)), includes among its members pairings of academic and research organizations with conservation goals, such the pairing of the Harvard Forest with the Wildlands and Woodlands initiative. The group met in Boulder, Colorado, in May 2012 to launch their work.

Attendees at the Boulder meeting included conservationists from a broad geographic and disciplinary spectrum, including David Foster from the Harvard Forest, Karl Flessa from the University of Arizona, Gary Tabor and Perry Brown from the University of Montana, Geoff Wescott from Deakin University in Australia, Robin Reid from Colorado State University (recently returned from the University of Nairobi), and Wei Dongying from Beijing Normal University.

The 25 disciplinary backgrounds represented in the attendees was a reflection of the range of talents required to succeed at cross-parcel, cross-sectoral, multi-national conservation projects. Working papers from the meeting, and those from a similar meeting to be held in 2013, will be compiled into a book on the topic of Conservation Catalysts to be edited by Levitt and published in 2014. The aim of the group is to build a new cross-disciplinary community of interest, and to inspire other colleges, universities, and research institutions to follow the example set by the Conservation Catalysts.



### Forest Scenarios Model Output



Warm colors show increased probability of future forest conversion.

Source: Thompson, Foster, Scheller, and Kittredge. 2011. The influence of land use and climate change on forest biomass and composition in Massachusetts, USA. *Ecological Applications* 21(7): 2425-44.

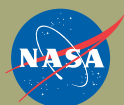




# Education



Funding Sources



G. Peabody Gardner Memorial Fund  
Mount Holyoke College Miller Worley Center  
for the Environment



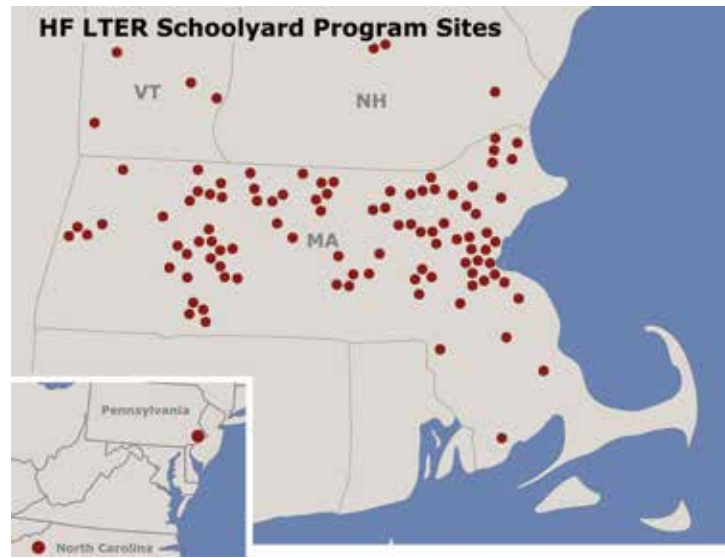
Since the Forest's founding as a university training ground for forestry, our educational mission has expanded to include thousands of schoolchildren and a range of public and professional learners. Our programs for university students have expanded as well; we believe the next generation of scientists and environmental leaders should be grounded not only in science, but in history, public policy, communications, and the arts.

## REAL-WORLD ECOLOGY FOR K-12 CLASSROOMS



The Harvard Forest Schoolyard Ecology program, led for eight years by coordinator Pamela Snow, trains elementary, middle, and high school teachers to conduct ecological

research projects with their students in their own schoolyards. Each year, more than 3,500 students collect data for long-term projects on tree phenology, vernal pools, and the invasive hemlock woolly adelgid. Professional development workshops led by Harvard Forest ecologists throughout the year help teachers build skills in field methods and data analysis.



Far left photo: Schoolyard Ecology students collect leaf data in the field.

Right top photo: Middle school students measure the depth of a vernal pool in winter.

Center photo: Elementary school students analyze leaf-fall at the start of autumn.

Bottom photo: Ecologist John O'Keefe explores phases of bud emergence with Schoolyard teachers in a Harvard Forest field workshop.

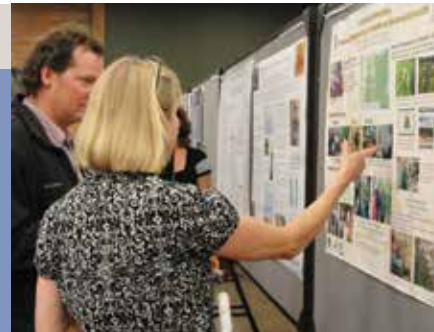


### BOX 3. TRAINING A TEACHER-SCIENTIST

Fifth-grade teacher Kate Bennett never thought of herself as a scientist. Her formal training was mainly in the language arts. Eight years ago, to improve her science curriculum, she joined the Harvard Forest Schoolyard Ecology program and began collecting data with her students. Her confidence growing, she spent two summers doing pitcher plant research at Harvard Forest with ecologist Aaron Ellison. In 2009, Kate and Aaron published their study results in *Biology Letters*. Back in the classroom, Kate's fifth graders

began to outperform other district schools in standardized tests of math and science.

In 2011 and 2012, Kate worked on a new summer project at the Forest, with support from NASA and mentorship by Harvard professor Andrew Richardson. She builds new lesson plans based on her research and also presents her work at national scientific conferences. She explains: "Our students deserve a science curriculum that is current and authentic. And I can't help but bring my enthusiasm back to the classroom."



Kate Bennett presents at the 2012 LTER All Scientists' Meeting in Colorado.





**“The Forest showed me an entirely different, unexpected and amazing side of Harvard. I can’t wait to come back in future courses.”** ~ Sara Vazquez, Harvard Freshman Seminar Student

## INNOVATIVE LEARNING FOR UNIVERSITY STUDENTS

- ▶ **SUMMER RESEARCH PROGRAM** Each year, thirty students from Harvard and many other colleges across the US spend 11 weeks conducting cutting-edge research as part of the Harvard Forest Summer Research Program. With guidance from a research mentor, students tackle real-world, complex environmental questions, often working in interdisciplinary groups to combine engineering and computer science solutions with research in ecology and conservation.
- ▶ **HARVARD’S OUTDOOR LABORATORY & CLASSROOM** Harvard students at all levels participate in year-round programs at the Forest, including the university’s longest-running Freshman Seminar, “Global Change Ecology: Forests, Ecosystem Function, and the Future”; an interdisciplinary Winter Break Week, “Reading and Conserving New England”; and the Summer Research Program. Hundreds more Harvard students, faculty, staff, and alumni visit the Forest each year for course field trips and weekend retreats.



• Above: Nga Nguy '15 analyzes a sediment core. Middle: Harvard students snowshoe out to a field site. Right: Pastel sketch by Meng Chen '13, Winter Break student.

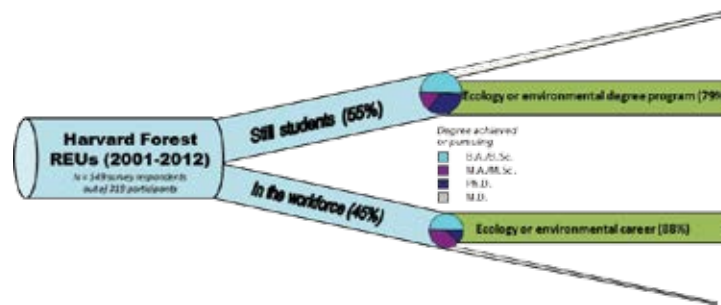


Figure 3. Surveys of Summer Research Program alumni reveal that a vast majority of participants go on to pursue advanced degrees and careers in environmental fields.

- Top left photo: 2012 Summer Research Program students on a service and career day field trip to a local Trustees of Reservations preserve.
- Bottom photo: Summer Research Program student Ben Mew, from Oberlin College, in the field.



## ENGAGING PROFESSIONALS AND THE PUBLIC

- ▶ **JOURNALIST TRAINING** As part of a hands-on short-course, six science journalists from the Logan Science Journalism Program spent 3 days at the Harvard Forest in 2012, working alongside ecologists to count hemlock woolly adelgid, measure tree seedlings in herbivore exclosures, calculate carbon dioxide fluxes, and core down to ice-aged sediments in the Black Gum Swamp. Chris Neill, former Bullard Fellow (see inside back cover) and now director of MBL's Ecosystems Center, designed the program to highlight LTER global change research and give journalists a hands-on window into the scientific process.
- ▶ **LANDOWNER OUTREACH** Every April since 1988, twenty-five forest landowners and community leaders have arrived at the Harvard Forest for a 3-day conservation training as part of the Massachusetts Keystone Project. The training, led by Harvard Forest collaborators Dave Kittredge and Paul Catanzaro from the University of Massachusetts, covers topics such as forest ecology, wildlife management, land protection, and community outreach. In exchange for the training, graduates of the program agree to return to their communities and volunteer at least 30 hours of service towards projects that promote conservation. To date, the Keystone Project has trained more than 450 Cooperators, who have collectively volunteered 37,125 hours to conservation-related activities (the equivalent of 18 full-time positions), reached 12,669 people, and made 1,419 landowner referrals to foresters, land trusts, and other resources.
- ▶ **MUSEUM EXHIBITS** An exciting collaboration with the Harvard Museum of Natural History (HMNH) culminated in 2011 with the unveiling of a new permanent exhibit: "New England Forests." The exhibit is visited by tens of thousands of people each year and features many elements of Harvard Forest long-term research. An ongoing public lecture series at the HMNH regularly includes standing-room-only presentations by Harvard Forest ecologists, and organized field walks bring HMNH members out to the Forest each fall.
- ▶ **ARTIST RESIDENCIES** In 2010, Harvard Forest began an exciting new era in ecological inquiry by supporting its first artist-in-residence. Several art collaborations since then have generated a range of public exhibitions, both locally at the Fisher Museum and in traveling exhibits starting at National Science Foundation headquarters in 2012.

Top photo: Logan Science Journalism Fellows collect data at the Harvard Forest in 2012.

Center photo: Landowners and community leaders participate in the Massachusetts Keystone Project at Harvard Forest, led by Paul Catanzaro from UMass-Amherst.

Bottom photo: "New England Forests" exhibit at the Harvard Museum of Natural History.

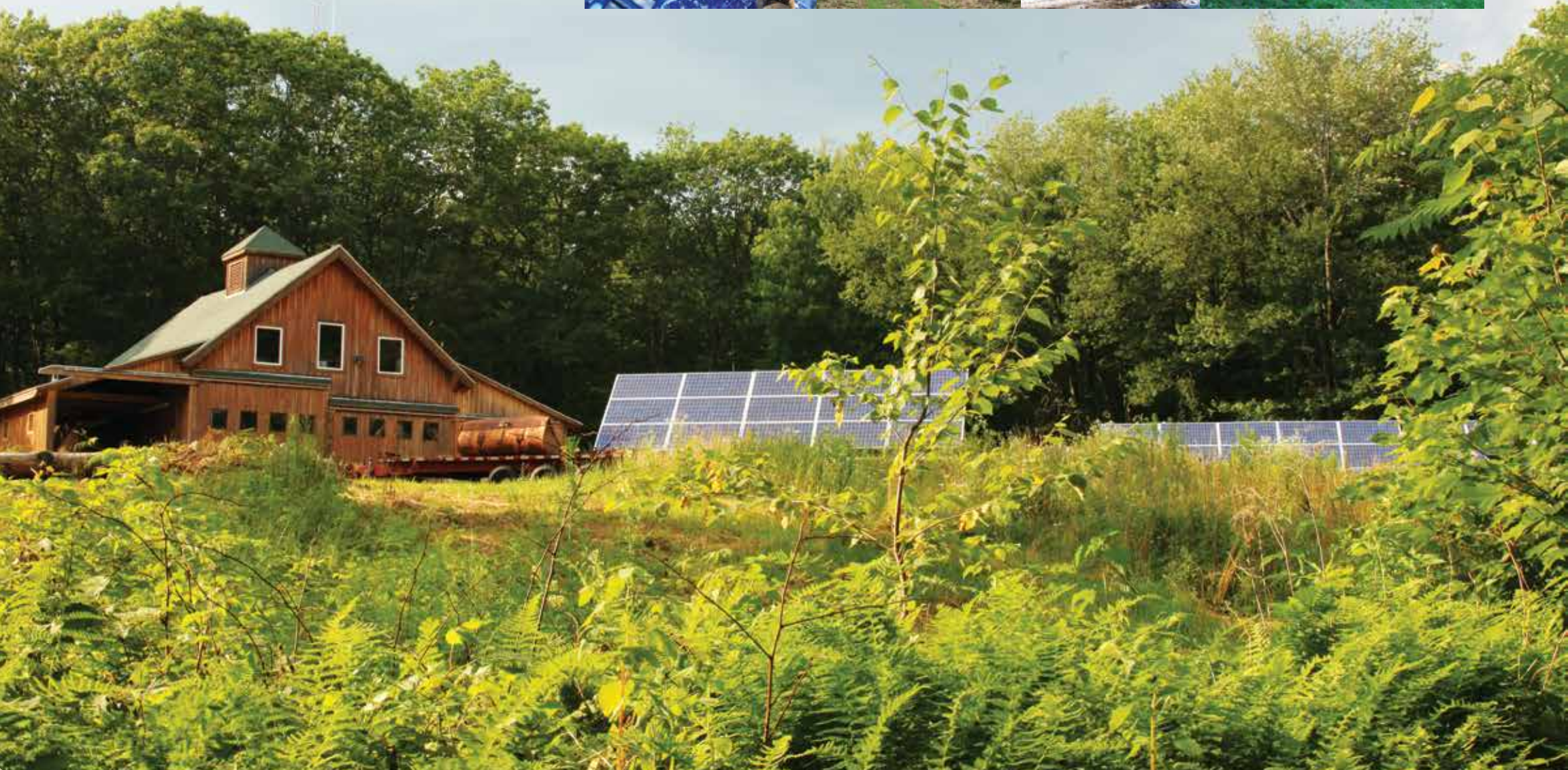


Above: "Aura Triptych: A View of Nipmuc Country from Phillipston" by Roberto Mighty, 2012 artist-in-residence—part of the multimedia "First Contact" exhibit in the Fisher Museum.

Left photo: 2011 Bullard Fellow and artist-in-residence Debby Kaspari draws in the field.



# New Resources



Funding Sources



neon



Faculty of Arts and Sciences

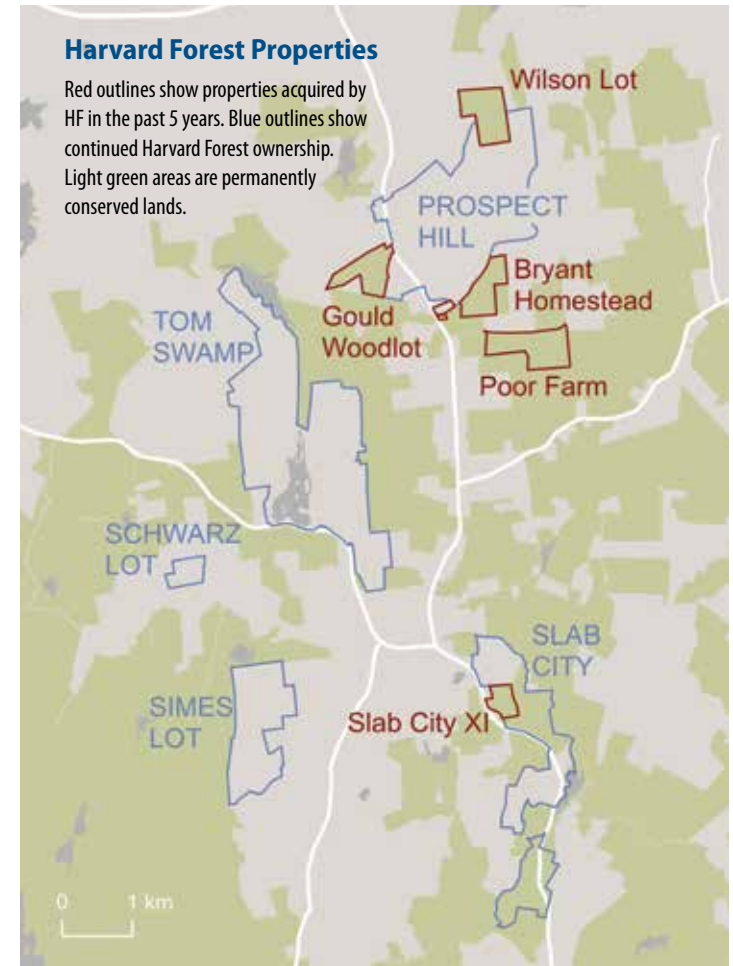
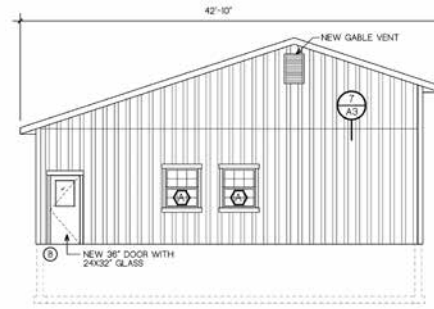


## MODELING SUSTAINABLE MANAGEMENT

It's no small feat to manage 3,500 acres of forest, fields, and wetlands. A **Land-Use Master Plan** developed in 2008 designates sizeable areas of Harvard Forest for long-term research, sustainable harvest, and wildland reserves (see land-use zone map, lower right).

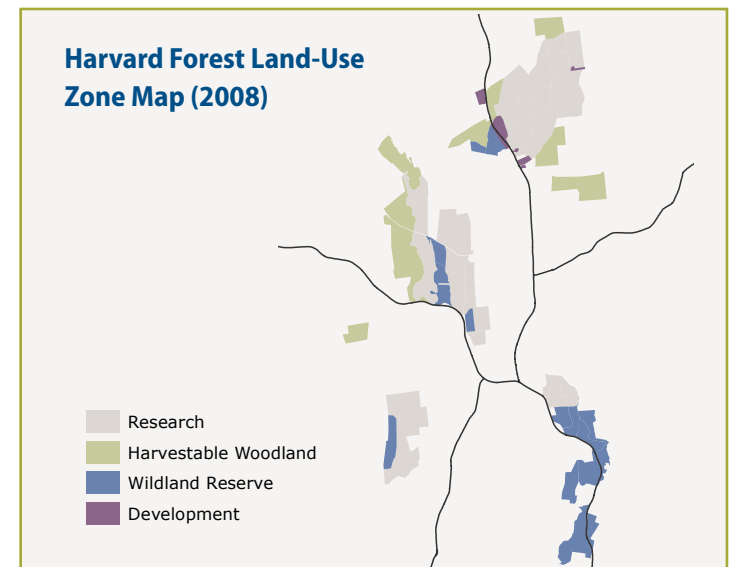
By fall 2013, harvested wood will be the primary source of heat for buildings in the Shaler Hall complex, thanks to a new, highly efficient **small-scale thermal biomass facility** (see schematic detail, right) being built behind the Archive. Core funding from the Harvard University Faculty of Arts and Sciences, with a crucial grant from the USDA, helped design and build the project. Several new pieces of forestry equipment will help to ensure efficient production of cordwood. Creating a closed system from harvest to heating, the Harvard Forest biomass facility will serve as a basis for much-needed research in the ecological dimensions of biomass fuel use and production.

The biomass facility is a new but not exclusive chapter in the Forest's portfolio of ongoing **sustainability efforts**, which include a solar array, which powers research on Prospect Hill; a recycled water network in the John Torrey Lab; and a "green" garage built of our own wood (pictured, left). Stewardship practices on several new land acquisitions include pasture revitalization of the Bryant Farmstead and the permanent conservation of critical watershed land on the east branch of the Swift River in the Slab City tract (see recent land acquisitions map, top right).



## NEW TECHNOLOGY

- A **field wireless network** now provides high-speed internet access to major research sites on Prospect Hill. Where unconnected equipment used to require manual download of data, results are now being transmitted to the internet in real-time. This all requires electricity: an electrical line, replaced in a major undertaking in collaboration with NEON (see Box 4), runs two miles into the Prospect Hill tract, powering equipment and data access 24 hours a day.
- Want to check in on the Forest from afar? Now on our website:
  - A series of 5 **web-cameras** offers above- and below-canopy footage of Prospect Hill in real-time. The cameras are part of a growing network of webcams devoted to phenological research across the US and Canada.
  - **Real-time weather data** from the Fisher Meteorological Station offers an inside look at major weather events as they pass through the Forest.
  - Our weekly **Seminar Series** is not just for locals anymore: the presentations stream online in real-time. Log in on Friday mornings during the academic year to hear speakers present their cutting-edge research in ecology and conservation.
  - A new digital catalog makes the thousands of resources in our **Historical Archive**—photos, maps, stand records, samples, and much more—searchable online.



## BOX 4. NEON BREAKS GROUND

In June 2012, leaders from the National Science Foundation (NSF), the Massachusetts Office of Energy and Environmental Affairs (EEA), and the National Ecological Observatory Network (NEON) joined scientists and students at the Harvard Forest to celebrate the groundbreaking for the core site of NEON's Northeastern domain.

NEON infrastructure at the Forest will include an eddy-flux tower, aquatic and soil arrays, and an airborne remote sensing platform, which began test flights in August 2012. In a major endeavor by the National Science Foundation, the Forest will be the first of 20 NEON sites developed around the country by 2016.





# Harvard Forest TIMELINE

1900



**1903** – Harvard Forestry School founded in Cambridge with R.T. Fisher as first director



**1907** – Harvard Forest established in Petersham as center of Forestry at Harvard University



**1909** – First resident class of graduate students

1920

**1920s** – R.T. Fisher appointed professor at Harvard Business School, conducts the Forest's first studies on forest policy



**1924** – First large experiment established on harvesting white pine and hemlock • Bob Marshall (left) undertakes first HF project in forest reconstruction



**1927** – Pisgah old-growth forest area in NH purchased and permanently conserved



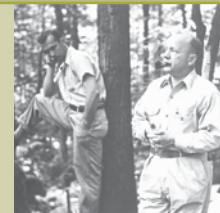
1940

**1940s** – Hugh Raup, Ernie Gould, and others initiate HF Production Symposia with support from the Maria Moors Cabot Foundation

**1941** – Shaler Hall and the Fisher Museum dedicated, funded by Ernest G. Stillman



**1944** – Camouflage studies conducted by Steve Spurr in Petersham during WWII



**1946** – Hugh Raup becomes fourth director of the Forest

**1949** – Stillman Endowment and Black Rock Forest donated to Harvard

1960

**1960s** – Rhizotrons built for below-ground studies by Walter Lyford

**1962** – Charles Bullard Fellowship in Forest Research established

**1967** – Hugh Raup publishes seminal essay, "The View from John Sanderson's Farm"



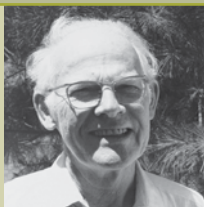
**1969** – Martin Zimmermann becomes fifth director of the Forest

**1969** – Walter Lyford meticulously maps all trees, rocks, and streams in a 2.9 hectare plot, the Lyford grid, that is still resampled today



1980

**1984** – John Torrey becomes sixth director of the Forest



**1986** – Summer Research Program begins



**1988** – HF selected to be an NSF-funded Long-Term Ecological Research (LTER) site



**1988** – HF named the field site for the DOE-funded Northeast Center of NIGEC (National Institute for Global Environmental Change)

2000

**2004** – HF Schoolyard Ecology students collect their first data



**2005** – *Wildlands & Woodlands* vision for Massachusetts published • Simes Hemlock Removal LTER experiment established



**2008** – HF plantations harvested; moose & deer browse experiments begin



**2009** – Warm Ants, Hot Plants LTER experiment established • *Harvard Forest Flora* published





1910

**1910** – Harvard Forestry Club and Bulletin formed. First publication: *Trees and Other Woody Plants Found in the Harvard Forest* by James Jack



**1910** – Chestnut blight detected in Petersham



**1913** – Joseph Kittredge publishes “Notes on chestnut bark disease in Petersham”

**1916** – Richard Fisher’s “Unwritten records in the Harvard Forest” lays the groundwork for the school’s emphasis on historical ecology

1930



**1935** – Historical dioramas completed for display at Harvard Tercentenary

**1936** – Ward Shepard becomes second director of the Forest

**1938** – The Great Hurricane, followed by the New England Timber Salvage Administration



**1939** – Albert Cline becomes third director of the Forest

1950



**1953** – Worcester Tornado touches down in HF’s Slab City tract



**1955** – Steve Spurr, Earl Stephens (right), and Margaret Davis (left) conduct PhD fieldwork at HF in forest ecology, history, and paleoecology



**1957** – Forest fire sweeps across 200 acres of Prospect Hill

1970

**1970s** – Barry Tomlinson brings HF research in plant morphology to the cutting edge



**1970s** – Assistant Director Ernie Gould introduces his famous Management Game to HF students (right)



**1971** – The Controlled Environment Facility (now known as the John G. Torrey Laboratory) is constructed with funds from the Cabot Foundation



**1976** – Ground-breaking Tropical Trees Symposium held at the Harvard Forest • First Harvard students attend a Freshman Seminar at the Forest

1990

**1990s** – HF begins modern era of land conservation, adding 600 acres to its holdings over the next 20 years



**1990** – David Foster becomes seventh director of the Forest • Key LTER experiments initiated: EMS tower, Chronic N, Hurricane Pulldown, DIRT, Soil Warming



**1990 to 2005** – A. W. Mellon Foundation’s program in ecology funds joint Harvard Forest-Yale program in microbiology

**1996** – Alisa Golodetz undergraduate thesis spurs formation of North Quabbin Regional Landscape Partnership

2010



**2010** – *Wildlands and Woodlands* vision for New England published • SIGEO “mega-plot” census begins



**2011** – ‘New England Forests’ exhibit opens at HMNH in partnership with HF • The Forest supports first full-time artist-in-residence, Debby Kaspari • First Winter Break Week at HF

**2012** – NEON breaks ground for a research tower • Restoration of the Bryant Farmhouse completed

**2013** – HF’s highly efficient thermal biomass facility goes online to heat the Shaler complex



## STAFF & COLLABORATORS

### » Staff

David Foster - Director

#### Research & Policy

Audrey Barker Plotkin - *Research Assistant*

Emery Boose - *Information Manager*

Betsy Colburn - *Aquatic Ecologist*

Elizabeth Crone - *Senior Ecologist*

Brian Donahue - *Environmental Historian*

Elaine Doughty - *Research Assistant*

Aaron Ellison - *Senior Ecologist*

Brian Hall - *Research Assistant*

David Kittredge - *Forest Policy Analyst*

Kathy Fallon Lambert - *Director of the Science & Policy Integration Project*

James Levitt - *Director of the Program on Conservation Innovation*

Liza Nicoll - *Research Assistant*

David Orwig - *Forest Ecologist*

Manisha Patel - *Lab Manager & Summer Program Coordinator*

Tristram Seidler - *Research Associate*

Kristina Stinson - *Community Ecologist*

Mark VanScoy - *Research Assistant*

#### Post-Doctoral Fellows

Benjamin Baiser

Greg Breed

Leone Brown

Joshua Rapp

Norah Warchola

Rui Zhang

#### Administration

Jeannette Bowlen - *Accounts Payable*

Laurie Chiasson - *Administrative Assistant*

Edythe Ellin - *Director of Administration*

Linda Hampson - *Administrative Assistant*

Julie Pallant - *System and Web Administrator*

Lisa Richardson - *Accounting Assistant*

#### Education

Clarisse Hart - *Outreach and Education Manager*

John O'Keefe - *Museum Coordinator (emeritus)*

Pamela Snow - *Schoolyard Program Coordinator*

Greta VanScoy - *Museum Assistant*

#### Woods Crew

Lucas Griffith

Oscar Lacwasan

Ronald May

Scot Wiinikka

John Wisnewski - *Woods Crew Supervisor*



Harvard Forest staff in front of Shaler Hall.

### » Affiliates

#### Harvard University

Stacey Combes - *Organismal & Evolutionary Biology*

Richard Forman - *Graduate School of Design*

Michele Holbrook - *Organismal & Evolutionary Biology*

Paul Moorcroft - *Organismal & Evolutionary Biology*

J. William Munger - *School of Engineering & Applied Sciences*

Anne Pringle - *Organismal & Evolutionary Biology*

Andrew Richardson - *Organismal & Evolutionary Biology*

Steven Wofsy - *School of Engineering & Applied Sciences*

#### Boston University

Adrien Finzi

Mark Friedl

Lucy Hutyra

Nathan Phillips

Anne Short

Pamela Templer

#### Marine Biological Lab

Jerry Melillo

Jim Tang

#### University of Massachusetts at Amherst

Jeffrey Blanchard

Elizabeth Chilton

David Kittredge

Lee Osterweil

Christine Rogers

#### University of New Hampshire

Serita Frey

Scott Ollinger



### » Affiliates, continued

Eric Davidson - *Woods Hole Research Center*

Stephen DeStefano - *USGS Massachusetts*

*Cooperative Fish and Wildlife Research Unit*

Brian Donahue - *Brandeis University*

Dianna Doucette - *Public Archaeology Laboratory*

Edward Faison - *Highstead*

David Fitzjarrald - *Atmospheric Sciences Research Center*

Danielle Ignace - *Smith College*

Bill Labich - *Highstead*

Barbara Lerner - *Mount Holyoke College*

Nsalambi Nkongolo - *Lincoln University of Missouri*

Wyatt Oswald - *Emerson College*

Shannon Pelini - *Bowling Green State University*

Evan Preisser - *University of Rhode Island*

Peter Raymond - *Yale University*

Sydne Record - *Smith College*

Cory Ritz - *NEON*

William Sobczak - *College of the Holy Cross*

Jonathan Thompson - *Smithsonian Conservation*

*Biology Institute*

Christopher Williams - *Clark University*

#### Post-Doctoral Fellows and Graduate Students

Rose Abramoff - *Boston University*

Grace Barber - *UMass Amherst*

Elizabeth Burakowski - *U. of New Hampshire*

Allyson Lenora Degrassi - *U. of Vermont*

Israel del Toro - *UMass Amherst*

Josh Gray - *Boston University*

Danielle Haddad - *U. of New Hampshire*

Ahmed Hassabelkreem - *UMass Amherst*

Myroslava Khomik - *Clark University*

Steve Klosterman - *Harvard University*

Richard MacLean - *Clark University*

Eli Melaas - *Harvard University*

Laura Meredith - *MIT*

Eric Morrison - *U. of New Hampshire*

Grace Pold - *UMass Amherst*

Andrew Reinmann - *Boston University*

Jesse Sadowsky - *U. of New Hampshire*

Patrick Sorensen - *Boston University*

Michael Toomey - *Harvard University*

Melanie Vanderhoof - *Clark University*

James Wheeler - *Harvard University*



Harvard University President Drew Faust tours the Forest with HF faculty and staff in 2012.





## BULLARD FELLOWS

Since 1962, the Charles Bullard Fellowship program has supported advanced research and study by individuals who show promise of making an important contribution, either as scholars or administrators, to forestry and forest-related subjects from biology to earth sciences, economics, politics, administration or law. Bullard Fellows spend between 6 months and a year collaborating with Harvard researchers, and for the most part, working in residence at the Harvard Forest, to investigate topics ranging from seed dispersal and biophysical modeling to sustainable forestry.



Recent Bullard Fellows, L to R: Paul Siqueira, Duncan Stone, Andrew Bennett, Michael Steele, Martha Hoopes

### 2011-2012 BULLARD FELLOWS

#### Dawn Bazely

*Biology Department, York University*

Deer herbivory, forest conservation, invasive species, habitat restoration

#### Andrew Bennett

*Landscape Ecology, Deakin University*

Resilience in regional landscapes, woodland birds

#### Erik Hobbie

*Institute for the Study of Earth, Oceans, and Space; University of New Hampshire*

Ectomycorrhizal fungi, organic nitrogen use, mammalian fungivory

#### Alan Knapp

*Department of Biology, Colorado State University*

Climate change and ecosystems

#### Stephen Long

*Northern Woodlands Magazine*

1938 Hurricane impact on forests, woodland landowner outreach

#### George Perry

*School of Environment, University of Auckland*

Spatial dynamics of forest ecosystems

### 2012-2013 BULLARD FELLOWS

#### Mark Friedl

*Earth and Environment, Boston University*

Remote sensing, biophysical modeling, forest phenology and climate change

#### Martha Hoopes

*Biological Sciences, Mount Holyoke College*

Invasion ecology, biodiversity and community structure

#### John Roe

*Conservation Consultant, Vermont*

Regional conservation planning, sustainable forestry

#### Paul Siqueira

*Electrical and Computer Engineering, University of Massachusetts-Amherst*

Remote sensing of vegetation structure, dynamic models for tree growth and structure

#### Michael Steele

*Department of Biology, Wilkes University*

Plant-animal interactions, oak dispersal and seed predation

#### Duncan Stone

*Land Use and Forests Policy, Scottish Natural Heritage*

Forest conservation policy and climate change

#### Varun Swamy

*Center for Tropical Conservation, Duke University*

Plant-animal interactions, tree diversity and community organization

### 2013-2014 BULLARD FELLOWS

#### Nigel Asquith

*Fundacion Natura Bolivia*

Incentive-based forest management policy

#### Franco Biondi

*Department of Geography, University of Nevada, Reno*

Dendrochronology, stand and disturbance dynamics, geospatial analysis

#### Laura Johnson

*Massachusetts Audubon Society*

U.S. private land conservation as an international model

#### Michael Knoblauch

*School of Biological Sciences, Washington State University*

Phloem transport in large trees

#### Barbara Lerner

*Computer Science Department, Mount Holyoke College*

Scientific data provenance

#### Pamela Templer

*Department of Biology, Boston University*

Winter climate change and northeastern U.S. forests

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For research publications and datasets that cover the material in this report, and the full history of research at the Harvard Forest, visit <http://harvardforest.fas.harvard.edu>.





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*Harvard University*

**2013** Biennial Report