

City-Grown Ozone Leads to Smaller Country Trees

A tree is planted in Astoria, Queens, at a Con Edison fuel depot. An identical tree is planted on the rural campus of the Institute of Ecosystem Studies in Millbrook, NY. A year later, despite living in an urban environment, the city tree is twice the size of its country cousin. Ecologists attribute this counter-intuitive finding, recently published in *Nature* (July 10, 2003), to elevated levels of rural ozone generated by urban pollution.

Research on the effects of urban systems is timely and critical; urbanization is occurring globally at an accelerated pace. With that in mind, Dr. Jillian W. Gregg (Cornell University and the Institute of Ecosystem Studies), Dr. Clive G. Jones (Institute of Ecosystem Studies) and Dr. Todd E. Dawson (formerly of Cornell University and now at the University of California at Berkeley) set out to quantify the impact that the New York metropolitan area had on vegetation grown in urban and outlying rural areas.

Dr. Gregg explains, "Urbanization involves altering many environmental variables. Does it matter to plants whether they grow in a rural or urban setting? Our study shows a way to deal with the complexity of environmental change and quantify the impacts of urbanization." Gregg began the project when she was a Cornell graduate student collaborating with Dr. Jones, and dedicated over five years to the study. The results were surprising; city-grown pollution – and ozone in particular – is harder on country trees.

One aim of the research was to see how the tough city life – where gaseous, particulate and photochemical pollutants bombard plants as they struggle to grow in heavily metal-laden soils – impacts growth. To investigate the overall effects of urbanization, Gregg and her colleagues grew genetically identical cottonwood trees (also known as poplars or by the scientific name *Populus deltoides*) at test sites in and around New York City. The fast-growing trees are sensitive to environmental conditions, allowing the researchers to assess the cumulative effect of

multiple human-driven environmental changes.

Air quality was the primary factor of concern, and researchers controlled for differences in light, precipitation, season length, and soil factors. For three consecutive growing seasons, trees were planted at the sites and then harvested and weighed at the end of the growing season. Many environmental factors are known to affect plant growth and Dr. Jones notes, "This type of forensic approach to ecology allows you to identify the most important factors amidst all that environmental complexity."

Unexpectedly, the city trees thrived. As reported in *Nature*, "...urban plant biomass was double that of rural sites." Ecologists have long known that some urban conditions, such as increased nitrogen, carbon dioxide and temperature, can actually enhance plant growth. However, experiments, calculations and correlations showed that these factors could not account for the increased urban tree growth.

The difference, the researchers discovered, lies in ozone exposure. Depending on the height in the atmosphere at which it is found, ozone either protects or harms organisms. In the high stratosphere, the three-oxygen molecule shields earthly life from harmful solar ultraviolet radiation. At the ground level, however, ozone

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Dr. Jillian W. Gregg gathering data on cottonwood trees grown at a New York City test site.

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Editors's Note

Long-term studies are critical to understanding how ecosystems function. This year marks the 40th anniversary of the Hubbard Brook Ecosystem Study, an experimental forest program co-founded by IES Director Dr. Gene E. Likens in 1963. He and his colleague and co-founder, Dr. F. Herbert Bormann of Yale University, recently received the international Blue Planet Prize for their pioneering work.

Many research programs start when students are pursuing their doctoral degrees. While a graduate student at Cornell University, Dr. Jillian W. Gregg sought to understand how pollutants impacted trees. Dr. Gregg's surprising findings about the role of ground-level ozone culminated in a front page *Nature* article. Co-authored by IES ecologist Dr. Clive G. Jones and Dr. Todd E. Dawson of UC Berkeley, the paper contributes to our understanding of how pollution affects plant growth.

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Hubbard Brook: Pioneering Ecological Understanding

Tucked away in the White Mountains of New Hampshire lies one of the most intensely studied landscapes on Earth. Since 1955, when it was established by the US Department of Agriculture Forest Service, scientists have been monitoring the ecosystem effects of human modifications on the 3,160-hectare Hubbard Brook Experimental Forest.

To the casual eye, the site is an oasis of stately mountains covered with northern hardwood forest. Behind the picturesque beauty, rain or shine, data are being collected. Scientists analyze water samples, data-loggers chronicle precipitation, and weirs monitor water flow out of watersheds. To date, long-term studies on the forest and associated aquatic ecosystems in these watersheds have made significant contributions to our understanding of resource management, environmental policy and climate change.

IES Director Dr. Gene E. Likens and his longtime colleague Dr. F. Herbert Bormann (Yale University) have been a driving force for the evolution of the research program at Hubbard Brook. "The Hubbard Brook Ecosystem Study (HBES) was a synthesis of forest ecology and aquatic ecology. It began when I met Gene Likens," Dr. Bormann remarks. Both men, then faculty colleagues at Dartmouth College, were interested in how ecosystem stresses, such as logging or extreme climate events, affected ecosystem function. More importantly, they wanted to discover how stressed systems recovered.

In 1963, along with Dr. Robert S. Pierce (USDA Forest Service) and Dr. Noye M. Johnson (Dartmouth College), they proposed using their newly developed small watershed approach to understand the ecosystem ecology of these systems and explore the link between forest disturbance and ecosystem function. By monitoring the amount and chemistry of precipitation and stream water, the small watershed approach allows researchers to assess forest "health" through water chemistry analysis. Once a baseline is established, researchers are able to reveal how ecosystem health is impacted by natural and human-created disturbance.

With mature 80-year old forest stands, and several similar-sized adjacent watersheds, the Hubbard Brook Experimental Forest proved to be an ideal site for watershed manipulation experiments. By cutting select forest areas, to simulate logging or natural disturbance, HBES studies have shed light on how watershed ecosystems respond to disturbance. What began forty years ago, as a project between a small



(L-R) Dr. Gene E. Likens and Dr. F. Herbert Bormann, co-recipients of the 2003 Blue Planet Prize for their collaborative research at the Hubbard Brook Experimental Forest in New Hampshire.

group of scientists, has grown into a model for the study of whole, intact or experimentally manipulated ecosystems worldwide.

The global importance of Hubbard Brook was underscored again this June, when Tokyo's Asahi Glass Foundation awarded Drs. Likens and Bormann the Blue Planet Prize. The prize honors those whose outstanding scientific research is put to use to solve global environmental problems. The distinction acknowledges the role that Drs. Likens and Bormann's research on acid deposition and forest disturbance has played in informing national policy. A HBES study, led by



Concrete structures called "weirs" are used to measure water outflow from experimental watersheds. Stream height measurements, taken at the v-notch, accurately determine streamflow volume even when flow levels are very low.

Dr. Likens, revealed the relationship between fossil fuel use in North America and acid rain- contributing critical data to the 1990 Clean Air Act Amendments.

Drs. Likens and Bormann are the first to point out that the Hubbard Brook community is responsible for the lasting success of the study they initiated. Likens stresses that, "A strong, dedicated, and competent support staff has been vital to the long-term functioning of the Hubbard Brook Ecosystem Study."

They emphasize that numerous scientific colleagues, postdocs, students, and state and federal agencies have made significant contributions to the study. Since 1963, HBES research has generated an estimated 1,881 publications, including 84 Ph.D. dissertations, 6 books, and 1,200 professional journal articles. Over 100 senior scientists have collaborated at the site and cooperative agreements exist between the USDA Forest Service, Cornell University, Dartmouth College, Syracuse University, Yale University, the Institute of Ecosystem Studies and the US Geological Survey. Much of the work is collaborative, with data sharing at the heart of the systems-level research. Major long-term funding has been provided by the National Science Foundation and The A.W. Mellon Foundation.

At an alumni meeting this past July, celebrating the 40th anniversary of HBES, the importance of community and interpersonal relationships was a reoccurring theme. When reflecting on the success of his collaboration with Dr. Likens, Dr. Bormann was quick to note, "We had a wonderful relationship where we openly shared each other's knowledge." He also stressed the importance of teamwork, and tapping into the unique strengths of colleagues, noting, "Gene always had the ability to take on a complex problem and keep it focused, keep it going."

The community nature of HBES encourages fruitful social and intellectual interactions. Long-term residents reside on site, typically in the Pleasant View Farm House. Ecologists, geologists, and limnologists share their meals and research findings with one another. The on-site housing, remarks Dr. Likens, "is a melting pot that has produced ideas, papers, cooking skills, and at least one marriage." Conversations among researchers from different disciplines have resulted in the multidisciplinary studies that epitomize the Hubbard Brook Ecosystem Study. It is a place where, in the words of alum Dr. Jeff Hughes

Asahi Glass Foundation

Lori M. Quillen

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(University of Vermont), "everything is interconnected."

Another reoccurring theme amongst the gathered HBES alumni was enthusiasm for research. Alumni presentations were peppered with words like "exciting," "neat," and "fun." Dr. Bormann believes the success of the HBES depends, "not just on solid sustained science but on an esprit de corp among participants." When reflecting on his contributions to the site, alum Dr. Jim Hornbeck (USDA Forest Service) expressed, "It is fun to see our data used by HBES and it is fun to collect data in such a way that it is usable." Dr. Lars Hedin (Princeton University), an alum and former doctoral student of Dr. Likens, recalled the excitement he felt working at the site, describing its cofounders' views on human alterations as "visionary." "The fundamental statement guiding research at Hubbard Brook today was put forth by Likens and Bormann in 1967," Dr. Hedin noted.

Like many remote field sites, Hubbard Brook's laboratories went through some early growing pains. Prior to the creation of the Henrietta Kendall Towers Laboratory, lab analysis was often done in a borrowed trailer. Ingenuity led one researcher to convert the dirt-floored basement in the Pleasant View Farm House into a lab; its controlled environment proved to be ideal for laboratory incubations. Research performed in the basement facility led to several Ph.D. dissertations. During his tenure, alum Dr. Bill McDowell (University of New Hampshire), another doctoral student with Dr. Likens, quickly learned that, "Good ideas trump good facilities."

Over the past four decades, HBES has helped lay the foundation for modern ecosystem science. Studies performed at the site have yielded a range of findings, from management protocols for timber harvesting to insight into the ecological factors that regulate migratory neo-tropical bird populations. The site, and its accomplishments, is testimony to the fruits of intellectual exploration and long-term commitment to collaborative science.

Amidst present accomplishments, HBES also keeps an eye on the future. Dr. Richard Holmes (Dartmouth College) stressed the importance of further collaboration between avian ecology and ecosystem science. "Organisms unify everything we do. Studies on how bird population fluctuations influence nutrient cycles could be very telling." With over 100 papers on avian life at Hubbard Brook since 1969, HBES is in an excellent position to advance this idea. Dr. Charles Driscoll (Syracuse University) also stressed strengthening HBES's ability to disseminate research findings to both the public and policy makers. □

The Gazebo Gets a Facelift!



(Clockwise) Andrew Bush, Paul DeBonis, and John Oles hard at work renovating the gazebo. Nearly two decades ago a generous and timely gift from Mr. Elliot Dann helped create the Gifford Garden. Continuing the Dann family legacy of giving, his son Mr. Geoffery Dann recently donated funds to renovate the Gifford Garden gazebo. When completed, the Gardening Staff will use the building as an information center. This is a gift that will keep on giving, helping to educate the thousands of visitors that pass through the garden each year.

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is a pollutant that interferes with plant metabolism. Severe ozone exposure can result in necrosis, or cell death, evidenced by plants with brown spots marring their leaves. At lower doses, as was the situation in this study, ozone causes cellular injury to plants that is invisible to the naked eye, but nevertheless reduces plant growth.

A secondary pollutant, ozone's precursors are emitted in cities. The situation is compounded in New York City because this urban center is downwind from another densely populated and industrialized area – New Jersey. "A lot of the ozone moving into New York City was formed in the so-called Garden State," remarks Gregg. Explaining, "The reactions of ozone formation are cyclical. In urban areas, the presence of one of the primary precursors, nitric-oxide (NO), destroys ozone once it has formed. As new nitric-oxide compounds develop, ozone (O₃) is reduced to the more benign, two-atom oxygen (O₂)."

Urban plants benefit from NO scavenging reactions that reduce the ozone-exposure

period; trees growing in the purportedly clean rural areas aren't so lucky. In less developed areas NO concentrations are low, and ozone remains in the atmosphere longer. Although one-hour peak ozone exposures can be high in urban centers, longer exposure periods in rural environments result in higher cumulative exposures.

The findings do not negate the known detrimental effects of many urban pollutants, but show the importance of understanding the secondary reactions that create increased ozone beyond the urban core. As urbanization causes urban air sheds to begin merging throughout the globe, the study underscores the need to reconsider how cities affect outlying rural environments.

Jones remarks, "In recent years, researchers have tended to overlook ozone effects on plants as they examine impacts of human-induced increases in CO₂, temperature and nitrogen deposition. However, our paper shows that ozone is a major factor determining how urbanization affects plant growth." □



Gardeners- Mark Your Calendars!

The IES Fall Plant Sale will take place on Saturday September 6th (10am-4pm) and Sunday September 7th (11am-4pm) in a tent outside the Gifford House Visitor and Education Center. For a plant list, or additional information, contact Diane Fagregren at (845) 677-7600 x 300, or send an e-mail to FagregrenD@ecostudies.org.



Newsletter

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Calendar

CONTINUING EDUCATION

The Continuing Education Program is now accepting fall registrations. For information, or to request a brochure, call 845-677-9643 or visit www.ecostudies.org/education/continuing.html. Remaining summer and fall semester programs include:

Gardening

Aug. 9 (1 Sat.) Gardener's Clinic
Aug. 10 (1 Sun.) Gardening in the Shade

Biology and Ecology

Sept. 21 (1 Sun.) Fall Wild Plant Identification with Judy Sullivan

Workshops

Sept. 20 (1 Sat.) Alan The Mushroom Man, In Search of the Wild Mushroom

Excursion

Sept. 13 (1 Sat.) River Ecology Cruise
Sept. 20 (1 Sat.) Weed Walk with Ursula Bosch

SATURDAY ECOLOGY PROGRAMS

Come to free public programs on the first Saturday of each month. Children age 6 and up are welcome with an accompanying adult. Pre-registration isn't necessary. If you have questions, call 845-677-7600 ext. 317 for information on upcoming programs:

October 4: Exploring the Institute Grounds: Join IES Ecologist Dr. Rick Ostfeld on an informative tour of the Institute property. Learn more about the natural history of the area and the animals that inhabit the site. [Dress according to the weather for the outdoor programs.]

GROUP TOURS

Garden clubs, community groups, student organizations and others can request guided tours of the Gifford Garden, Greenhouse, or Plant Science Building. For information on fees, or to make reservations, call Luanne Panarotti at 845-677-7600 ext. 317.

IES SEMINARS

Free scientific seminars are held on Fridays in the auditorium from September until early May. The fall schedule will be available in late August. For more information, contact Matt Gillespie at (845) 877-766 x 140 or GillespieM@ecostudies.org

GREENHOUSE

The greenhouse is a year-round tropical plant paradise and a site for controlled environmental research. Stop in to view the staghorn ferns and scented herb collection! Open daily until 3:30 p.m., please get your free visitor's permit at the Gifford House (see hours below)

VOLUNTEER OPPORTUNITIES

Call Ms. Susan Eberth at 845-677-7600 ext. 316 or visit www.ecostudies.org/volunteer.html.

THE ECOLOGY SHOP

Looking for a more meaningful gift? Stop by The Ecology Shop and find products made from recycled materials and merchandise that encourages sound forest management techniques and fair trade practices. It's a win-win shopping experience!
Senior Citizens Days: 10% off on Wednesdays

HOURS

Summer Hours: April 1 - September 30

Public attractions: Mon.-Sat., 9-6, Sun. 1-6: closed public holidays. The greenhouse closes at 3:30 daily.

The Ecology Shop: Mon.-Fri., 11-5, Sat. 9-5, Sun. 1-5. (Please note: The shop is closed Mon.-Sat. from 1-1:30.)

Free permits are required and are available at the Gifford House Visitor and Education Center until one hour before closing time.

MEMBERSHIP

Join the Institute of Ecosystem Studies. Benefits include subscription to the IES Newsletter, member's rate for courses and excursions, a 10% discount on IES Ecology Shop purchases, and participation in a reciprocal admissions program. Individual membership: \$40; family membership: \$50. Call the Development Office at 845-677-7600 ext. 120.

The Institute's Aldo Leopold Society
In addition to receiving the benefits listed above, members of The Aldo Leopold Society are invited guests at spring and fall IES science updates. Call the Development Office at 845-677-7600 ext. 120.

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Box R, Millbrook NY 12545-0178
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The Ecology Shop: 845-677-7600 ext. 309

Street address: Gifford House Visitor and Education
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... IES website:

www.ecostudies.org

For information on current IES public events and attractions, visit: www.ecostudies.org/ThisWeek.html.

For garden tips, visit: www.ecostudies.org/gardens.html.

