IES Newsletter

Volume 9, Number 6
November-December 1992

Director's Note

When the Institute of Ecosystem Studies was created in 1983, one of its principal goals was "to establish and maintain long-term, experimental and reference studies of ecosystems". The worth of long-term ecological research already was recognized from a number of investigations, including the Hubbard Brook Ecosystem Study that had been gathering data on air-land-water interactions since 1963 (and continues to do so). With the formation of the Institute of Ecosystem Studies, sites in forests, fields and streams across the Mary Flagler Cary Arboretum were established as long-term research plots.

Now, almost a decade later, data continue to be collected, baseline information against which scientists and educators will be able to measure change for years to come. Some of these data now are being incorporated into a new long-term project, Forest Responses to Stress and Damage, described in the cover story of this issue of the IES Newsletter.

The IES Newsletter is published by the Institute of Ecosystem Studies at the Mary Flagler Cary Arboretum. Located in Millbrook, New York, the Institute is a division of The New York Botanical Garden. All newsletter correspondence should be addressed to the Editor.

Gene E. Likens, Director
Joseph S. Warner, Administrator
Alan R. Berkowitz, Head of Education

Editor: Jill Cadwallader
Printing: Central Press

INSTITUTE OF ECOSYSTEM STUDIES
The New York Botanical Garden
Mary Flagler Cary Arboretum
Education Program
Box R
Millbrook, NY 12545
(914) 677-5359

Stresses and Change in Hudson Valley Forests

The composition of our forests is changing. Flowering dogwood trees in wooded areas have experienced a 96% decline over the past decade because of a fungal infection. The wooly adelgid, a tiny sucking insect, is slowly killing hemlocks. Chestnut oaks are dying, probably from repeated attacks by the gypsy moth, while data from long-term research plots at the Arboretum show that the densities of some species, for example the chestnut, are increasing.

Natural changes occur constantly in ecosystems. In these times of increasing human impact on the environment, however, changes may be accelerated, and they are not always natural. In order to know when changes are occurring, to try to understand the reasons for these changes and to make predictions regarding the future status of ecosystems, routine monitoring is essential.

Recognizing the need for an integrated approach to monitoring Hudson Valley forests, Institute ecologists Drs. Gary M. Lovett, Charles C. Canham, Clive G. Jones and Richard S. Ostfeld developed FORSTAD — Forest Responses to Stress and Damage. This long-term monitoring program was in the planning stage for several years before field sampling began in March 1991. With a number of potential agents of environmental stress to consider, the ecologists chose to focus their attention on the forest's responses to insect outbreaks, air pollution and climate change. The FORSTAD team is interested especially in linking ecosystem components to the whole system, to learn what stress or damage to individual trees might do to the entire forest. For example, when an oak tree is damaged by gypsy moths, are forest functions such as nutrient cycling affected? Then, if that oak dies, does the same species take its place or do new species move in, and how does the forest change as a consequence?

While the goal of FORSTAD scientists is to establish forest monitoring sites throughout the Hudson Valley, the early focus of the project is the development and refining of sampling methods and the establishment of research plots at the Arboretum. Monitoring sites are located primarily along the sides of the Cannoo Hills, in typical upland forest dominated by oak, hickory and maple trees. Some of the plots are part of previously established long-term research projects, so more than 10 years of vegetation and gypsy moth population data are already available for integration with new FORSTAD measurements. In the vegetation plots, data on species of trees, their size, which individuals have died and what new ones are growing will continue to be recorded at regular intervals. Against this background, other measurements also will be made.


TOM TAFT

FORSTAD research assistants Christopher Borg (left) and Michael Miller measure and permanently mark trees in the long-term vegetation plots on the Arboretum. (The white coveralls help Institute staff find any deer ticks that they might pick up.)

Understanding Forest Stress

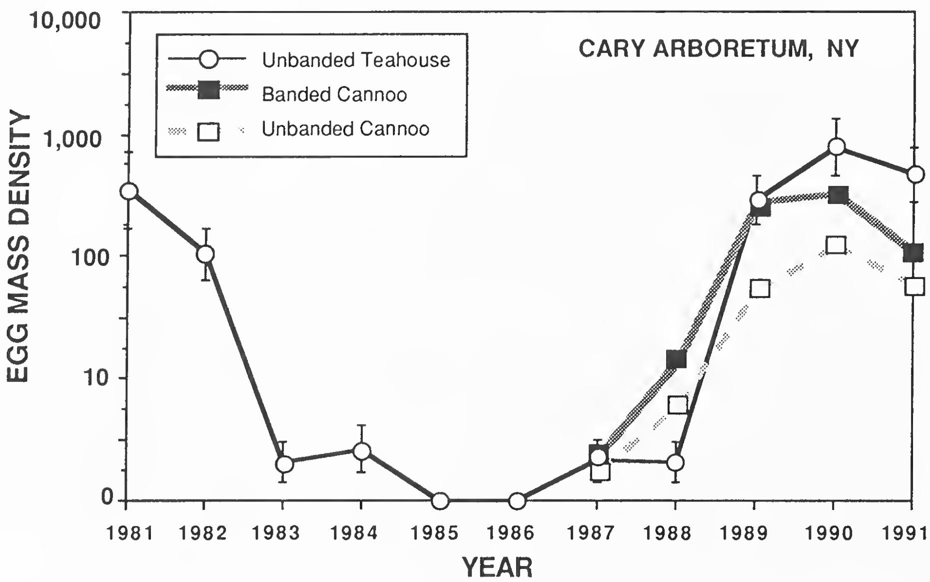
The gypsy moth is an introduced pest that has become a major cause of forest stress and damage in the Northeast. To date, there is neither a clear understanding of what causes gypsy moth outbreaks nor a reliable means of predicting defoliation. Data on egg mass densities and episodes of defoliation have been collected at 20 Arboretum sites since 1981. Observations will continue at the existing long-term sites, and data also will be collected across all other FORSTAD plots, on numbers of egg masses, larval instars (stages of development between molts) and pupae, as well as on degrees of defoliation.

In the course of the Institute's long-term gypsy moth studies, it was found that increases in the population density of these insects coincided with declines in small mammal populations, suggesting that animals such as the white-footed mouse may be important predators of moth larvae and pupae. As part of FORSTAD's

continued on page 2

FORSTAD, *from page 1*

monitoring program, live-traps are set out for short periods during spring, summer and fall to estimate population sizes of white-footed mice, chipmunks and other small forest mammals. Data will be used to confirm the correlation between small mammal and gypsy moth populations as well as for other studies. Small mammals have an impact on tree reproduction, for example — their diet is primarily seeds, so an increase in their numbers can lead to a decrease in seed survival and eventually to a reduction in numbers of new trees.



One example of long-term cycling in a forest ecosystem is illustrated by this graph of numbers of gypsy moth egg masses. Data collected from forested sites on the Arboretum's Cannoo Hill and Teahouse Hill show peak levels in 1981 and in 1990. The downward part of the cycle now has begun again. ('Banded" and 'Unbanded' refer to a sampling method in which burlap bands are tied around some trees.) *Graph prepared by research assistant Michele P. Richard*

Data gathered on small mammals also will contribute to IES studies on the ecology of the deer tick, the carrier of Lyme disease. Numbers of white-footed mice are of particular relevance because these animals are reservoirs for the disease-causing bacterium. The ticks themselves will be identified and counted before host mammals are tagged and released. To complement these data, FORSTAD scientists are using a technique known as "tick dragging": questing ticks will be collected on a square of white cloth dragged along transects in the research plots. Taken to the IES laboratory, the tiny arthropods then can be examined microscopically for the presence of the Lyme disease bacterium.

There are also climatic and air pollution stresses to the forest, and one way in which these stresses may affect the ecosystem is by altering the nitrogen cycle. Nitrogen (N) is a nutrient, an element that is essential for the growth and development of all living organisms. Like other nutrients, nitrogen recycles constantly through the biosphere

Gaseous nitrogen, N_2, is converted to usable compounds by natural processes occurring in the atmosphere or soil. Ths "fixed" nitrogen may be used over and over again by plants, animals and microbes in cycles of growth, death and decomposition. Combustion of fossil fuels (for instance, in automobiles or power plants) increases the rate at which nitrogen gas is converted to usable forms and deposited to the biosphere. The nitrogen occurs as nitrogen dioxide (NO_2) or nitric acid gases, as particles, or dissolved in raindrops (as one of the acids in "acid rain"). Deposition of nitrogen in our area has increased approximately tenfold since pre-industrial times. This has increased the amount of nitrogen cycling in forest ecosystems, but the effect of this increase on forest health is still a matter of research and debate.

To learn how increases in nitrogen deposition have changed nitrogen cycling and the health of our forests, the FORSTAD team has established two nitrogen cycling plots to monitor levels of nitrogen in water, soil and trees. The chemistry of throughfall, or the water dripping from the trees, and of water in the soil (collected by a suction device) as well as of leaves is being analyzed. The rate of cycling of nitrogen from the plants to the soil is measured by collecting and analyzing the annual leaf fall. The rate of nitrogen mineralization, or how fast the element becomes available for uptake and use by plants, is determined by incubating a sample of the forest floor in the laboratory and measuring the change in available nitrogen over a two-week interval.

In addition, FORSTAD ecologists have access to a long-term database from the Institute's Meteorology and Air Quality Station, a facility that provides continuous measurements of precipitation chemistry (e.g., acid rain) and amount, air temperature, wind speed, wind direction, relative humidity, solar radiation, and atmospheric concentrations of ozone, sulfur dioxide, nitric acid vapor and fine aerosols. The scientists currently are developing and testing methods for nitrogen dioxide measurement as well.

Some might expect that with increased nitrogen deposition from the atmosphere there would be a corresponding increase in plant growth, due to a "fertilizer effect". This generally has not been observed in Hudson Valley forests, for reasons that are not yet clear. Normally almost all the nitrogen deposited in a forest is used up in normal plant or microbial growth processes, or is tied up in non-decomposing compounds in the soil. It is possible that trees that have evolved over the millennia in an environment where nitrogen is a scarce resource cannot deal with sudden nitrogen excesses. The consequences for the trees may be nutritional imbalances for individuals or shifts in competition between species. If the trees or microbes cannot use all the nitrogen being deposited, the excess may leach out into streams, lakes and groundwater. By monitoring nitrogen levels and observing forest health over time, FORSTAD ecologists hope to learn what might be happening. (It has been discovered recently that nitrate — another nitrogenous compound — is leaching out of forest watersheds in the Catskill and Adirondack Mountains. Since nitrates in drinking water pose a potential health threat [see story on page 3] this is a question that Dr. Lovett is pursuing in another ongoing IES project.)

By correlating their observations of atmospheric deposition, forest chemistry, tree populations and insect and mammal species, Drs. Lovett, Canham, Jones and Ostfeld will develop ecosystem "models" — mathematical formulations of essential relationships between components of the forest ecosystem. These computer simulations will help the ecologists understand how the ecosystem works and make predictions about the effects of continued stresses to forests.

* * * * *

This research is funded through a grant to the Institute of Ecosystem Studies from the General Reinsurance Corporation.

Dr. Boyer Studies Path of Groundwater Pollutant

A casual observer might guess that Dr. Joseph Boyer is a geologist rather than the microbial ecologist that he is. Soil maps of the Arboretum and surrounding areas are spread out on his desk in the post-doctoral scientists' laboratory, and when he identifies likely sites he packs his soil auger and sets out to take core samples. The information he is looking for with these geologist's tools, however, will help to answer important ecological questions about why nitrate (NO_3^-) collects in soil and how it can be prevented from contaminating groundwater.

As described in this issue's cover story, nitrogen is an important part of the global ecosystem. Nitrogen gas makes up nearly 80% of the Earth's atmosphere and combines naturally with oxygen or hydrogen to make other chemical compounds. While these compounds are used by living organisms in the growth process, at high levels they can have detrimental effects. Nitrate, for example, becomes a potential problem when present in high concentrations in drinking water — upon entering the gastrointestinal tract, it is converted to nitrite, which enters the bloodstream and competes with oxygen for binding sites in hemoglobin molecules. This condition, called methemoglobinemia, can lead eventually to suffocation; infants who suffer from it are called "blue babies".

Major sources of nitrate in agricultural areas are commercial fertilizers and animal wastes. Dr. Boyer and another microbial ecologist at the Institute, Dr. Peter Groffman, are particularly interested in the nitrate that rain washes down through the soil into aquifers ... underground water in rock, sand or gravel. Dr. Boyer hopes to develop ways to keep nitrate out of the groundwater, thereby not only assuring better quality drinking water but also minimizing the loss of valuable nitrogen from agricultural fields.

Once nitrate is in groundwater, engineering options for clean-up are limited and costly. Dr. Boyer is investigating another approach, denitrification — a naturally occurring process in which nitrogenous compounds are converted to harmless nitrogen gas — as a solution to the problem of nitrate build-up in groundwater.

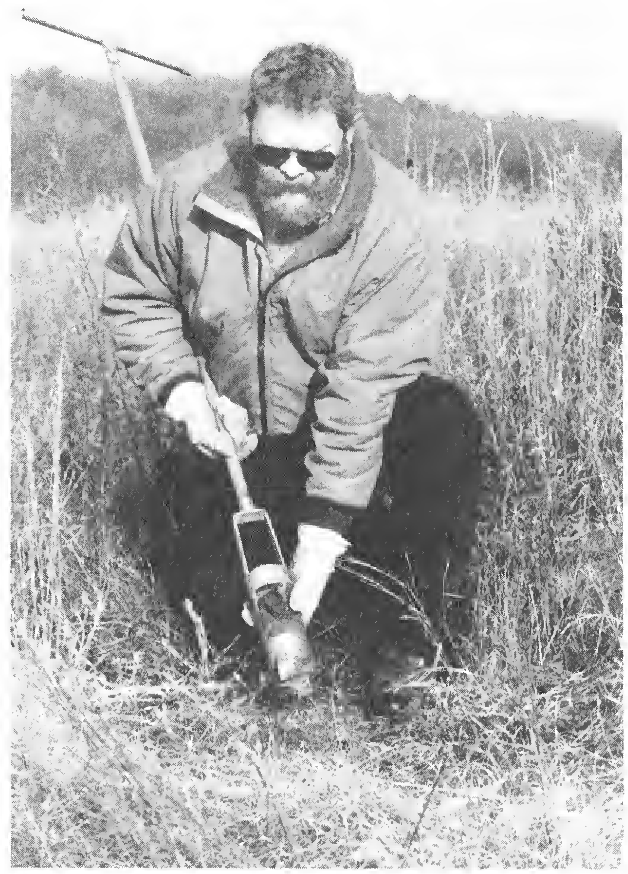
$$5C + 4NO_3^- + 2H_2O = 2N_2 + CO_2 + 4HCO_3^-$$

carbon + nitrate + water =
nitrogen gas + carbon dioxide gas + bicarbonate

Denitrification (represented chemically above) is the work of bacteria living in the soil, and because it is an anaerobic process — one that occurs in the absence of oxygen — it can occur deep underground. Under normal conditions, almost all excess soil nitrate is converted by this process. However, when nitrate levels are high due to the effects of agriculture or other causes, denitrification does not happen fast enough and some nitrate escapes from the soil into the groundwater.

What factors control denitrification? As stated, the process requires low oxygen levels and thus cannot occur near the soil surface. The pH, or the level of acidity or alkalinity, must be neutral — approximately 7 or 8*. Soil temperature is a factor too, with the rate of denitrification doubling for every increase of 10°C (just less than 20° F). Nutrients and trace metals are required for the bacteria to grow, while the presence of some chemical compounds — sulfide, for example — may inhibit denitrification. Finally, and of particular interest to Dr. Boyer, is the source of the carbon required for the chemical reaction to occur.

While some forms of carbon are easy to use (like the sugar, glucose) others are not. During the degradation of plant litter, the easy-to-use forms are used first, and the remaining humic acids end up in soils and are broken down at an as-yet-unknown rate. Dr. Boyer will be investigating carbon sources in the soil to learn how they affect the denitrification process. *Where does the carbon used by denitrifying bacteria come from?* Is it material that has been in the ground for years? Or is it from recently decomposed organic matter, washed down through the soil by the rains? *How is it distributed through the soil column?* Is it concentrated at the surface and therefore not available at the groundwater level? This is of potential relevance because nitrate dissolves easily in water and therefore is carried rapidly to deeper soils. *How does the amount of carbon in the soil relate to current and historical land use?* Whereas forest soils receive nutrients from decomposing plant material, agricultural soils often do not because much of the plant material is removed during harvest. Is there a difference in available carbon levels between forest and agricultural soils?



TOM TAFT

Dr. Joseph Boyer uses a soil auger to collect soil samples in different land use areas. He is comparing forested and agricultural sites to learn what factors affect denitrification.

Dr. Boyer is consulting soil maps, studying historical land use and taking samples to identify similar soil types in different land use areas; by selecting present and former forest and farm sites with the same geological origins, he will eliminate soil as a variable in his investigations. The soil type that he seeks is glacial outwash, whose well-sorted material provides good drainage with water percolating in a relatively straight path to the groundwater. He will analyze soil cores taken from surface to water table to determine the carbon source for the groundwater denitrification process.

Fortunately for Dr. Boyer, certain plant materials have distinctive carbon isotope

continued on page 4

** On the logarithmic pH scale of 0 - 14, very acidic materials have a value at the low end of the scale — the pH of lemon juice is approximately 2 — while very basic ones are at the high end of the scale — ammonia has a pH of 11.)*

Groundwater, *from page 3*

ratios (isotopes are atoms of the same element with different weights). Most forest plants in this area — deciduous trees, shrubs and pines — have one ratio, while certain agricultural plants such as corn have another. Since "you are what you eat", by analyzing the carbon isotope ratios of denitrifying bacteria and the CO_2 produced by their respiration, Dr. Boyer will be able to determine which sort of plant was the major food source for the bacteria. In sites where the source of new soil carbon differs from historical sources (e.g., forests growing on old corn fields), the carbon isotope ratio will help him distinguish whether the bacteria are using new or old carbon. This, in turn, will help him understand how carbon availability might limit microbial activity in soil, knowledge that is key for developing strategies to increase pollutant removal from groundwater.

* * * * *

Dr. Joseph N. Boyer joined the Institute's scientific staff in October. With a doctorate in marine science from the Virginia Institute of Marine Science, College of William and Mary, he has taught at East Carolina University in North Carolina, has been involved in the design and implementation of water reuse systems for aquaculture, and has been an environmental consultant. Dr. Boyer is at the Institute on a two-year postdoctoral appointment funded by a U.S. Department of Agriculture grant awarded to Dr. Peter M. Groffman.

Winter Calendar

CONTINUING EDUCATION PROGRAM
Winter and Spring Semesters

The winter semester begins in mid-January. Free catalogues describing **classes, workshops and ecological excursions** offered during winter and spring are available from the Gifford House. Call the number below for information.

SUNDAY ECOLOGY PROGRAMS

Free public programs are held on the first and third Sunday of each month, except over holiday weekends. Programs begin at 2 p.m. at the Gifford House on Route 44A unless otherwise noted. Call (914) 677-5359 to confirm the day's topic.

Jan. 17: **Earthworm Investigations**, an indoor program for young people, ages 6-12, and their parents, led by Kass Hogan

Feb. 7: **Diatoms: Microscopic Jewels in Aquatic Food Webs**, a walk and demonstration led by Dr. R. Jan Stevenson

Feb. 21: **Update on Zebra Mussels in the Hudson River**, a slide presentation by Dr. David Strayer

Mar. 7: **Gaia Theory: Wake-up Call for Humanity!**, a slide presentation by Dr. William Shaw

• *In case of inclement weather, call (914) 677-5358 after 1 p.m. to learn the status of the day's program. For outdoor programs, dress for the weather conditions, with sturdy waterproof shoes.*

IES SEMINARS

The Institute's program of **scientific seminars** features presentations by visiting scientists. Free seminars are held at the Plant Science Building on Fridays at 3:30 p.m.

Jan. 15: **Remote Sensing of Ecosystem Processes in Grasslands**, by Dr. Clarence Turner, Kentucky State Univ.

Jan. 22: **The Application of a Geographic Information System to Watershed Modeling**, by Dr. Paul Barten, Yale Univ. School of Forestry

Jan. 29: **Elevated Atmospheric CO_2 and Feedbacks Between Carbon and Nitrogen Cycling in Terrestrial Ecosystems**, by Dr. Don Zak, Univ. of Michigan

Feb. 5: **The Socioecology of Density-Dependent Competition, Infanticide and Dispersal in a Fluctuating Environment**, by Dr. Jerry Wulff, U.S. Environmental Protection Agency, Corvallis, Ore.

Feb. 12: **Intra- and Inter-ecosystem Comparisons of Nitrogen Cycling Using Network Analysis**, by Dr. Robert Christian, East Carolina Univ.

GREENHOUSE

The IES greenhouse is a year-round tropical plant paradise as well as a site for controlled environmental research. The greenhouse is open during Arboretum hours. Admission is by free permit from the Gifford House.

GIFT SHOP

Senior Citizens Days: On Wednesdays, senior citizens receive a 10% discount (except sale items).
January Sale: Most holiday items and calendars half price; 20% off most gifts, 10% off most books.

ARBORETUM HOURS
(Winter hours: October 1 - April 30; closed on public holidays)

Arboretum grounds are open Mon. - Sat., 9 a.m. - 4 p.m.; Sun. 1 - 4 p.m. (Trails and internal roads may be closed when snow-covered or icy.)
The **Gift and Plant Shop** is open Tues. - Sat., 11 a.m. - 4 p.m. and Sun. 1 - 4 p.m.
(Closed weekdays from 1 - 1:30 p.m.)

• *All visitors must obtain a free permit at the Gifford House Visitor and Education Center on Route 44A for access to the Arboretum. Permits are available until 3:00 p.m. daily.*

MEMBERSHIP

Become a member of the Mary Flagler Cary Arboretum. Benefits include a member's rate for IES courses and excursions, a 10% discount on purchases from the Gift Shop and a free subscription to the IES NEWSLETTER. Individual membership is $30; family membership is $40. For information on memberships, contact Janice Claiborne at (914) 677-5343.

For more information, call (914) 677-5359 weekdays from 8:30 - 4:30.

INSTITUTE OF ECOSYSTEM STUDIES
The New York Botanical Garden
Mary Flagler Cary Arboretum
Education Program
Box R
Millbrook, New York 12545-0178

IES

Newsletter

Volume 9, Number 6
November-December 1992