Baltimore Ecosystem Study

Annual Report

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Covering

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Urban LTER: Human Settlements as Ecosystems: Metropolitan Baltimore from 1797 – 2100

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Preface to the Annual Report

On the following pages is the Annual Report of the Baltimore Ecosystem Study (BES) for the period 2007-2008. The Baltimore Ecosystem Study, a Long-Term Ecological Research (LTER) project, was initiated in 1997. The BES is one of 26 LTER projects, representing diverse ecosystems and research emphases. It is funded by the National Science Foundation to learn how an urban area works as an ecological system. Over the last nine years we have learned new, and sometimes surprising, things about Baltimore's urban ecosystem. This report summarizes the most recent scientific and educational contributions BES has made.

As one of only two Long-Term Ecological Research sites focused on an urban environment, we want to know the ecological interactions in the whole range of habitats—from the center city of Baltimore, to the surrounding rural areas. We are conducting research on the soil, the plants and animals on land and in the streams, the water quality, and condition of the air in and around Baltimore. For that information to make sense, we are also studying how families, associations, organizations and political bodies make decisions that affect ecological processes. In other words, we are treating the whole collection of city, suburban and rural areas as a complex urban ecological system that includes people and their activities.

This is a really unusual approach to ecology because it combines with social sciences, physical sciences, and education to understand a big metropolitan area as an ecological system. Saying that an urban area is a system just means that we are concerned with the interactions between wild and domestic organisms, people and their organizations, the natural and built environment, and how they all affect one another. It is these relationships that determine the quality of the environment we experience.

The program brings together researchers from many disciplines and organizations to collect new data and synthesize existing information on both the ecological and engineered systems of Baltimore. Our interest is not only with the present environment, but with the historical changes that have led to the conditions that exist today, and with the environmental trends into the future. The ecological knowledge BES creates helps support educational and community-based activities. Indeed, the interactions between our researchers and the Baltimore community are important components of our project. We hope that the information produced by our work, which integrates many disciplines and the efforts of many research and educational institutions in Baltimore and beyond, is of interest and use to you.

You may contact the researchers, educators, and professional members of the Baltimore Ecosystem Study through the Project Facilitator, Holly Beyar (BeyarH@ecostudies.org), and locate updated information and additional information on the project through its website (http://www.beslter.org).

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Acknowledgement of Support

The Baltimore Ecosystem Study project is supported by the National Science Foundation Long-Term Ecological Research program, grant number DEB 0423476. The USDA Forest Service Northern Research Station contributes research staff time, equipment, funds and in kind services to BES. In addition we thank the University of Maryland, Baltimore County for their contribution to office, laboratory and field space at the Center for Urban Environmental Research and Education. The US Geological Survey, the City of Baltimore Department of Recreation and Parks, the Baltimore City Department of Public Works, the Baltimore County Department of Parks, the Baltimore County Department of Environmental Protection and Resource Management, the Maryland Department of Natural Resources, and the McDonogh School all kindly provide access or management of land and equipment used by the Baltimore Ecosystem Study for ecological, hydrological, and meteorological field studies. The USDA ARS Environmental Microbial Safety Lab contributes resources for water pathogen analysis. Additional support and assistance has been provided by many agencies, communities and individuals who are listed in the report.

Acknowledgment and Disclaimer

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"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."

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Baltimore City Green School Task Force
Baltimore City Public School System
Baltimore City Sustainability Commission
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Activities

How cities and suburban areas function as integrated, ecological systems remains an open frontier. This gap in knowledge means that our basic understanding of ecology does not yet fully embrace one of the most widespread and extreme human interventions in the biosphere. It also means that people's ability to assess options for ecological management, design, and restoration in and around cities and suburbs is limited. The ecological knowledge gap in urban areas is a crucial lapse because urbanization in all its forms is a growing component of global change.

The Baltimore Ecosystem Study LTER (BES) has three components: 1) Research, 2) Education, and 3) Community Engagement or Outreach. The research component employs two complementary approaches needed to build ecological knowledge of urban systems. First, social and economic processes are combined with physical dynamics and ecological processes. Second, because cities and suburbs are characterized by rapid change, both retrospective and long-term perspectives are critical. The community engagement component of BES recognizes the responsibilities and opportunities of conducting research where people live. Developing and making the most of a broad range of educational opportunities satisfies the responsibility to share ecological knowledge with the widest audience. Applying ecological knowledge to management, environmental quality, and environmental equity acknowledges society's needs. Finally, the use of new ecological knowledge of urban systems in planning, design, and restoration provides important opportunities both to test ecological theory and to improve urban quality of life.

The scientific knowledge gap, new scientific opportunities, and our responsibility to the public have prompted us to pose three questions to guide our scientific research and our interactions with citizens in metropolitan Baltimore:

1. How do the spatial structure of socio-economic, ecological, and physical factors in an urban area relate to one another, and how do they change through time?

2. What are the fluxes of energy, matter, capital, and population in urban systems, and how do they change over the long term?

3. How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air- and watersheds?

In our tenth year we have continued and enhanced core long-term activities, and initiated new work that promotes the goals of the Long-Term Ecological Research Network. Field studies continue to emphasize the 17,150 ha Gwynns Falls watershed, a forested reference watershed at Oregon Ridge County Park, an urban atmospheric flux tower at Cub Hill, and a highly urbanized storm drainage – Watershed 263 (WS 263) – in west Baltimore. Gwynns Falls includes stable agricultural land, farms that are currently being converted from agricultural to suburban uses, as well as areas that have been intensively urbanized for centuries. The Cub Hill site is on the edge of the city and represents extensive suburban landscapes. In addition to these intensively studied sites, our research also includes 200 sample points for soils, vegetation, and surfaces, spread throughout the city. We list key activities under each of our three guiding questions.

Ongoing Major Activities Addressing Question 1: How do the spatial structure of socio-economic, ecological, and physical factors in an urban area relate to one another, and how do they change through time?

To answer Question 1, we are conducting the following major research activities:

- Quantify the biological, built, and social patch structure of Baltimore.
- Document patch change.
- Discover biotic changes.
- Survey soil heterogeneity and quantify heavy metals.
- Operate a meteorological network.
- Conduct modeling at various scales.
- Compare gradients within metropolitan Baltimore, and with other cities.
- Model and empirically test ecological-social relationships.

The activities answering Question 1 address the spatial structure, the temporal dynamics, and the integration of the social, ecological, and physical components of the Baltimore ecosystem. Additional detail appears in the research section of the BES web page at http://beslter.org

New Activities Addressing Question 1:

1. ***Relationship of Tree Species Distribution and Urban Environmental Factors in Baltimore, MD.***

Urban landscapes are diverse spatial mosaics that represent a variety of ecological conditions. Natural sources of spatial heterogeneity in ecosystems underlie the effects of land-use and land-cover change; however, humans introduce an additional source of heterogeneity by altering landforms and drainage patterns, constructing structures, introducing nonnative plant and animal species, and modifying natural disturbance regimes. In this study we investigate the relationship between urban environmental factors and tree species distribution at multiple scales in Baltimore City.

2. ***Effects of Urban Parks on Property Values.***

We completed research on the effect of urban parks on property values in Baltimore City. Anecdotal evidence suggested that proximity to some parks was capitalized positively into housing values, and other parks affected property values negatively. We researched whether crime was the mediating factor in this difference, using a technique called hedonic analysis, which disaggregates the selling price of a home into its constituent components, and published the results.

3. ***Vegetation Survey of Private Properties in the Gwynns Falls Watershed.***

In the summer of 2007, we conducted survey of over 1000 private properties in the Gwynns Falls watershed, collecting information on tree, grass and shrub cover and health, and level of garden and lawn management. This survey included vacant and occupied parcels. Using this information Ashley Lidman, a master's student on the project, conducted an analysis to look at the relationship between private yard management and crime, as well as neighborhood satisfaction. The results were published as a master's thesis.

4. ***Automation of High-resolution Remote Sensing.***

We worked on developing new methods for automating the classification of high resolution remotely sensed imagery into "object types" using Object Oriented classification methods. This involved creating "knowledge bases" of rules used to help segment and classify imagery based on spectral characteristics, shape and overlay properties. Using this approach, we classified land cover for the Gwynns Falls watershed using high resolution imagery from 2004. We were then able to do a change detection analysis by comparing this layer to land cover from 1999. Results of the methods for classification and change detection were published.

5. ***A Longitudinal Analysis of the Social Dynamics of Environmental Equity in Baltimore.***

Post doc, C. Sister and Co-PI, C.G. Boone have employed a method for park service areas (PSAs) to measure park congestion, or the per capita amount of park land accessible by residents, for the Baltimore metropolitan region. This was made possible by the considerable effort of Sister to validate the 3,122 polygons for spatial and categorical validity. This comprehensive, validated, GIS park layer across the five counties and the City of Baltimore will be of great value to this

research and to other BES researchers. In the PSA analysis of park equity, such a park layer is indispensable.

Sister digitized a 1965 parks layer for the city of Baltimore, working backwards from the present day parks layer. Boone and Sister will conduct a PSA for the 1965 layer using 1960 and 1970 census data and examine if relationships between accessible park acreage and social characteristics have shifted over the last 40 years.

Co-PI's G. Buckley and C. Boone have made several visits to archives and libraries in Baltimore to collect data on neighborhood improvement zones, the civic bodies that were very influential in land use decisions and residential restriction before the major zoning ordinance of 1931, and the fair housing act of 1964. These include minutes of the improvement associations, which are held at the Maryland Historical Society and the Baltimore Municipal Archives. Boone and Buckley have also collected historical planning documentation on parks and recreation areas at the Baltimore Legislative Library. They have also made copies of historical maps showing park distribution, as well as park needs assessments. These data will be critical for the historical reconstruction of environmental equity patterns and processes, in particular access to amenities. Buckley and Boone have also collected documents at the University of Maryland's archive. One particularly important find is 1930s assessment of Baltimore by the Urban League, a document that includes data and commentary on park access, residential segregation, and occupational restrictions for the city's black population.

Boone and Sister have begun compiling a historical database of heavy industries in the Baltimore metropolitan region for 1960, 1970, and 1980. They are drawing on the Dun & Bradstreet directories which list establishments by name, Standard Industrial Classification (SIC) code, and address. They will map the distribution of facilities that fall into the same SIC categories as the EPA's Toxic Releases Inventory (TRI). The TRI database is available from 1986 to the present. Boone and Sister will work backwards from the TRI database to generate point maps of facilities that were likely polluters. These data will then be matched to the census data of 1960, 1970, and 1980 to explore the longitudinal relationships between heavy industry and TRI sites with social characteristics of neighborhoods.

Co-PI's O'Neil-Dunne and Troy have supervised the georeferencing of 81 Sanborn fire insurance maps from 1928-1935 so that they can be fused with other geospatial datasets to map trends in the environmental inequality patterns in the city. They have integrated large amounts of geospatial datasets in an object-oriented classification framework to provide a new mechanism to characterize the urban landscape beyond tradition land cover and land use systems. Along with their students, they are in the process of collecting and 'geo-enabling' environmental inequality related incidents from media sources (using data mining techniques), such as the closing of Swann Park after the detection of unsafe levels of arsenic in the soils. The text and documents of this story have been geocoded to the location of Swann Park.

Boone, Buckley, Grove, and Sister analyzed the distribution of parks in Baltimore using three metrics – walkable access, parks service areas, and a needs-based assessment. The distributional analysis was complemented with a historical analysis of procedural equity, especially the role of institutions in shaping present day park distributions.

6. ***Forest Successional Sequence.***

Co-PI's Grace Brush and Dan Bain have been studying forest successional sequence on the uplands of the Gwynns Falls Watershed and comparing this with pioneer forests in the riparian areas.

7. ***Urban Forest Change.***

The main project activity for this past year has been analysis of the 2004 permanent plots within the city of Baltimore, MD and Syracuse NY. The goal of this project is to assess urban forest change (1999-2004) for both cities to quantify rates of change and how change varies by such factors as land use, species and tree size.

8. ***Historical Activities of Neighborhood Improvement Associations regarding Urban Parks and Trees.***

Graduate and undergraduate students Andrew Giguere, Andrew Kenney, and Jennifer Guthrie indexed twenty years of newspaper microfilm. They searched for and tagged articles in the *Baltimore News* dealing with parks, urban trees, and the activities of neighborhood improvement associations, among other things. The period covered was 1897–1917. In the upcoming year, another undergraduate student will commence indexing the *Baltimore Afro-American.*

9. ***High Ecological Resolution Classification for Urban Land and Ecological Systems (HERCULES).***

Co-PI Mary Cadenasso is developing and testing the HERCULES land cover model, maintaining the sampling and data of the permanent vegetation plots, collaborating on linking ecological theory and urban design, assisting in the conceptual development of the program. Grad Student James McConaghie is analyzing the relationship between land cover and water quality in small subcatchments of the Gwynns Falls Watershed using the new HERCULES model.

This team also located suitable small watersheds for comparison studies in the Sacramento, CA metropolitan region.

Also investigated was the level of agreement between human classified land cover elements and results from an automation of the classification using object-oriented classification approaches.

Using the HERCULES model, Grad student Kirsten Schwarz is testing the link between lead levels in residential soil and characteristics of land cover.

Post doc Weiqi Zhou is developing and testing the HERCULES land cover model to determine its performance relative to other LU/LC models, linking land cover and

urban heat island. Remote sensing and GIS integrating biogeophysical and social datasets in the Baltimore metropolitan region

10. ***Landscape Fragmentation.***
REU student Scott Sener has been working with Co-PI Erle Ellis this summer on a groundbreaking effort to measure, model and map landscape fragmentation globally, as part of a collaborative project with David Potere at Princeton University, and Mutlu Ozdogan at the University of Wisconsin-Madison. The project is based on high resolution land cover mapping of a stratified random sample of high resolution imagery that is linked to global datasets for population density and land use. Scott has been involved from the beginning of the project and has made significant contributions to its design and execution, including the production of a global sample using GIS, obtaining and processing satellite image samples, and developing the project's database and fragmentation analysis. However, his greatest contribution has been in obtaining high-resolution image samples and mapping land cover across these using manual photointerpretation in a GIS. His painstaking efforts to map these samples form the basis for the project's global analysis, which we anticipate submitting for publication later this year.

11. ***Environmental Justice.***
As part of our long term environmental justice research, we examined the spatial distribution of households in relation to a) flood plain areas, b) streams (historic and current) and c) shorelines (historic and current). We characterized households in terms of racial characteristics and social class.

To conduct this research, we developed novel spatial methodologies by using dasymmetric mapping at the parcel level by landuse, within Census block groups. This builds upon previous approaches that used only landuse within Census block groups. The development of this novel method was necessary because of a) the high spatial resolution necessary for comparing social and ecological phenomenon and b) the need for historic comparisons and the absence of historic landuse data.

12. ***Gwynns Falls Watershed.***
In 2007, the US Geological Survey (USGS) began collaborating on a project with the Center for Urban Environmental Research and Education (CUERE) and the National Oceanic and Atmospheric Administration *(*NOAA) to expand the Gwynns Falls monitoring network for purposes of investigating, evaluating, and quantifying watershed response to storm events in urban environments. As part of this expansion, USGS is collaborating with CUERE staff on the design and installation of groundwater monitoring stations in the Gwynns Falls watershed. Currently, thirty potential sites within the Gwynns Falls Watershed have been identified. Thus far, the study has resulted in nine new stream-gaging stations that have been built in the Gwynns Falls watershed between November 2007 and May 2008. USGS is collaborating with CUERE staff on the operation and maintenance of these new stations. The study has also resulted in equipment upgrades at five existing BES stream-gaging stations, four of which were added to the realtime data network. BES precipitation stations are to be upgraded as part of this work. NSF has also provided separate funding to allow USGS to conduct field investigations and evaluate the magnitude of storm flows at five of the nine new stream-gaging

stations. Thus far, USGS personnel have measured storm flows during four to five storm events during the first half of 2008. Land owner permissions and permits to use the additional sites are being secured. Sites include a number of Baltimore County schools and parks. A design for monitoring groundwater levels at each site has been developed—consisting of two monitoring wells, one in bedrock, and one in the overlying saprolite (weathered in place unconsolidated bedrock). Borehole drilling and construction of the monitoring wells is slated for the Fall of 2009. This monitoring will provide a continuous data stream which will be published annually with station data available in continuous near real-time.

Given the nature of the sites chosen, USGS staff have been collaborating with the Parks and People Foundation to develop outreach activities in the schools, parks, and local communities before, during, and following drilling and monitoring well construction. It is anticipated that drilling and well construction will provide opportunities for observation and possible participation of students interested in groundwater hydrology and surficial geology. Additionally, K-12 curriculum on groundwater and its role in the hydrologic cycle in this urban setting is being planned.

13. ***Ecological Economic Indicators.***
Since March, 2008, Gund Institute for Ecological Economics (GIEE) PhD student Stephen Posner has completed background research on the Genuine Progress Indicator (GPI). He began computation of a GPI estimate for Baltimore City and Baltimore County, developed potential for further GPI calculations in surrounding counties (Carroll, Harford, Anne Arundel, and Howard Counties), and will communicate the results through targeted written and spoken education. Prospective partnerships with institutions of higher education could provide meaningful outreach to citizens about indicators of flux through the Baltimore ecological-economic system, quantifying the environmental impacts of their lifestyles, and understanding those aspects of their lifestyles that have the greatest impact on natural systems (including land use decisions and sprawl, community planning, and urban/suburban agriculture and biodiversity).

Ongoing Major Activities Addressing Question 2: What are the fluxes of energy, matter, capital, and population in urban systems, and how do they change over the long term?

To answer Question 2, we are conducting the following major research activities:

- Document human demographic and social processes.
- Quantify stream flow, chemistry, and key biota.
- Measure extreme storm water flows and flooding.
- Measure vegetation processes and nitrogen flux in riparian zones.
- Measure biogeochemical pools and fluxes in contrasting upland patch types.
- Quantify meteorological exchanges between surface and atmosphere using flux tower technology.
- Model atmospheric, hydrological and socio-economic fluxes in and across contrasting watersheds.

The research aimed at answering Question 2 takes into account the spatial structure of the Baltimore ecosystem, seeks feedbacks between socio-economic and biogeophysical processes, and has established sites in which long-term status and changes in fluxes are being measured. Integrated models, which incorporate ecological, hydrological, built, human and social capital, are key tools for understanding processes of flux and projecting changes into the future.

New Activities Addressing Question 2:

1. ***Stream Chemistry.***

Co-PI Dan Bain, along with REU student Amar Mehta, measured the major cation concentrations in a wide variety of archived BES stream water samples. Ongoing work includes measurement of trace metals in these samples and measurement of major cations in additional archived water samples.

2. ***Fluvial Geomorphology***.

Growing out of Co-PI Dan Bain's presentation at the 2007 annual meeting, he performed a meta-analysis of urban fluvial geomorphology for the Eastern US Piedmont. This analysis was used to critique the urban stream syndrome, an emerging paradigm of urban streams form and function.

3. ***Historical Hydrology*.**

In conjunction with Mark Green (UNH/CCNY), we received funding from the LTER Network office to convene a workshop leading toward cross-site synthetic work with Plum Island, Hubbard Brook, Harvard Forest, and Coweeta LTERs. This workshop will address several fundamental questions:

- Are the degradations we currently attribute to hydrologic response to urbanization (e.g., stream incision, etc.) actually a response to urbanization or more dependent on the accumulation of landscape change occurring before urbanization begins?
- How do urbanization and glaciation independently and synergistically impact nutrient efflux from eastern US hydrologic systems?

This workshop, tentatively scheduled for Feb 2009, should spark an exciting body of work and highlight ongoing work in the BES. The work on fluvial geomorphology cited in item 2 is a key precedent.

4. ***Organic Matter.***

Sampled in Baltimore Ecosystem Study-Forest Service (BES-FS) streams during baseflow and stormwater runoff, for dissolved and particulate organic matter, utilizing existing BES stream sampling program. Constructed four stormwater monitoring stations to enable the drawing of water samples during storm hydrographs. Constructed eight-foot (2.4m) nets for capturing CPOM during storm events. Most of this data, along with previously collected urban stream litter breakdown data, is being analyzed and used for a number of publications.

5. ***E. Coli*.**

- Sampling in BES-FS streams for *E. coli* continued until May 2008 (when Forest Service budget constraints forced cessation). These data are currently being reviewed and will be analyzed in the context of the temperature data collected

by US Forest Service, the flow data collected by US Geological Survey and ancillary nutrient and cation data produced by the Cary Institute of Ecosystem Studies.
- Work is under way for an *E. coli* survival paper which will describe the long periods *E. coli* 0157 can survive in urban stream waters (Co-PI Jim Higgins primary author). The bench / field work was sponsored in part by the USDA-ARS and the BES, and conducted in 2005-2007.
- Plans are under way to produce a proposal (with Co-PI's Charlie Nilon and Laura Hungerford) that addresses the role storm drains and urban stream corridors play in animal movement and the dispersal of pathogens in urban landscapes.

6. ***Stream Temperature.***
- These continuous measurements of stream temperature in ca 20 BES-FS streams have continued (but with about half the stations being dropped in May 2008 due to Forest Service budgetary reasons). These data are currently being reviewed and will be analyzed in the context of the flow data collected by US Geological Survey and ancillary nutrient and cation data produced by Cary.
- A subset of this stream temperature data was used by a University of Maryland, Baltimore County (UMBC) graduate student, Hyun Jin Kim, for her masters research (advisor C. Welty).
- A subset of this data was used in a paper on climate change and urbanization by Co-PI, S. Kaushal et al.

7. ***Watershed 263.***
- This work, done in partnership with Baltimore City Department of Public Works, continues. Monitoring at the two small urban headwater catchments continues (albeit with equipment problems) and data are being analyzed to produce a paper which discusses the water quality characteristics of these two ultra urban sites and how they are being used to place into context old, highly impervious sites such as these in terms of other urban and suburban sites and in terms of management issues.
- CWP Street and Inlet Cleaning Study & Masters Thesis: Participated as part of group doing a street sweeping and inlet cleaning study in Watershed 263; which was coordinated by the Center for Watershed Protection.
- A US Forest Service general technical report is being planned that will serve as a summary of research in this catchment.
- Storm Water Management Model (SWMM): Co-PI Ken Belt has been working with a student from Cornell who is using a SWMM model to assess the impacts of best management practices on water quality in stormwater runoff.

8. ***Gwynns Falls Watershed.***

USGS operates six stream-gaging stations using full or partial NSF funding that provide part of the base infrastructure for physical investigations by BES. In addition, USGS operates five additional stations in the Gwynns Falls watershed and thirty other stations in the Baltimore region using USGS and cooperator funding.

USGS, in cooperation with U.S. Environmental Protection Agency (USEPA), has continued an investigation of the relationship of stream restoration and riparian zones and their impact on water quality, with an emphasis on nutrients. Work was

conducted in Minebank Run, which is just east of Gwynns Falls and close to the U.S. Forest Service air monitoring tower. One additional stream-gaging station and a precipitation station are in operation as part of this study.

USGS is also continuing to collaborate with the USEPA and Montgomery County, MD to investigate impacts of urbanization on stream ecology in the Clarksburg Special Protection Area. A unique element of this work includes partial operation of stream-gaging stations by County staff using USGS protocols, and the refinement of standard operating procedures to ensure data quality to meet USGS standards.

9. ***Cross System Comparisons of Urban Environmental Effects on Soils.***
We investigated the effects of urban environments on the chemical properties of forest soils in the metropolitan areas of Baltimore, New York, and Budapest. We hypothesized that soils in forest patches in each city will exhibit changes in chemistry corresponding to urbanization gradients, but more strongly with various urban metrics than distance to the urban core. Moreover, differences in parent material and development patterns would differentially affect the soil chemical response in each metropolitan area.

10. ***Hydroclimatic Variability on Nitrate Export from Urban, Suburban and Agricultural Watersheds.***
Our long-term stream and watershed monitoring program provided a platform for examining the effects of extreme hydroclimatic variability on nitrate export from urban, suburban and agricultural watersheds. During 2002, approximately 48% of the contiguous U.S. was placed in the moderate and severe drought categories (National Climate Data Center Annual Review, http://www.ncdc.noaa.gov/oa/climate/research/2002/ann/paleo-drought.html) with the mid-Atlantic U.S. experiencing historic record drought levels. In the year from October 2001 through September 2002, Baltimore-Washington International Airport recorded 60.6 cm of precipitation, less than 57% of the 100-year record average, and a deficit of more than 46 cm. During this time, the city of Baltimore experienced its driest February since recordkeeping began in 1871 and its fourth-driest winter. In July, August, and September 2002, freshwater flow into Chesapeake Bay averaged 45%, 64%, and 61% below respective long-term (1937-2001) averages for these months. In 2002, total annual freshwater flow input from tributaries was estimated at 24% below the long-term average from 1937-2001 (U.S. Geological Survey Water Resources Division MD-DE-DC, 2002, http://md.water.usgs.gov/publications/press_release/current#archive).

Greater precipitation than normal in October, November, and December of 2002 contributed to the end of the state drought emergency in Maryland. In 2003, almost all monthly rainfall amounts were greater than the 100-year average. Freshwater flow into the Chesapeake Bay was 83% above the long-term average (1937-2001) in July and 125% above the long-term average in August 2003. In September 2003, Hurricane Isabel provided large amounts of rainfall to the Chesapeake Bay region, and freshwater flow into Chesapeake Bay was 400% above the long-term monthly average (*5*, U.S. Geological Survey Water Resources Division MD-DE-DC, 2002, http://md.water.usgs.gov/publications/press_release/current/#archive). The

combination of the historic record drought conditions followed by the very wet year coincided with one of the most severe zones of eutrophication and hypoxia reported in Chesapeake Bay in 2003.

Our eight long-term monitoring sites in and around the city of Baltimore allowed us to evaluate the interactive effects of urban land use and the extreme climatic variability from 2002–2004 on nitrate-N export. Nitrate-N and total N exports for the Baltimore LTER watersheds were estimated using both a flow bin-averaging approach that accounts for relationships between nitrate and total N concentrations and discharge and the Fluxmaster program developed by the USGS. Input–output N budgets were computed for three of the Baltimore LTER watersheds; Glyndon (GFGL) the 81-ha suburban headwater subwatershed of the Gwynns Falls watershed; McDonogh (MCDN), the 8-ha agricultural small watershed; and Pond Branch (POBR), the 32-ha forested reference watershed, for the years 2002-2004 and compared to previously published values from 1999–2001. Inputs of N from atmospheric deposition were taken from the U.S. Environmental Protection Agency's Clean Air Status and Trends Network (CASTNET) site at Beltsville, MD, approximately 50 km south of the Gwynns Falls watershed. Both wet and dry N deposition are measured at this site and showed very little variation from 2002 to 2004, ranging from 7.0 to 9.0 kg N ha/y. Fertilizer input to lawns in the Glyndon watershed (14.4 kg N/ha/y over the whole watershed area) was calculated from measurements of lawn area and a detailed survey of residential lawn-care practices in the Glyndon watershed conducted in 2001. Fertilizer inputs to the agricultural watershed were from Maryland Cooperative Extension Service recommended application rates for maize production (120 kg N/ha/y) and estimates of N fixation by soybeans (30 kg N ha/y) for a mean annual input of 60 kg N ha/y.

11. ***Land Cover Influences on Air Temperature.***
From measurements of temperature at a few representative locations in an urban area along with standard observations of weather from a first class weather station, regression models may be developed to predict air temperature differences as a function of land cover, elevation, and atmospheric stability. The regression equations may then be used to map the pattern of air temperature across the urban area.

12. ***Urban Soil Fauna Biodiversity.***
Using our own data and published records we compared the soil invertebrate fauna in several European and North American cities. We calculated the similarities using various indices and examined the degree of similarity as a function of distance. This synthesis has been reported in the Urban Biodiversity Conference in Erfurt, Germany. This year also the ant collection of the BES permanent plots has been identified.

13. ***Ecology of Invasive Species.***
The focus of this research is earthworm-soil fungi-tree three-way interactions. We are testing several hypotheses about how nonnative earthworms might alter soil microbial communities and thus plant growth. This summer we established earthworm manipulation plots in forests of two successional stages: relatively

young 70-yr forests and mature 150-yr forests. We are also investigating the effects of earthworms on soil organic matter transformation.

14. *Ecotoxicology: Investigating the Extent of Earthworm Trace Metal Accumulation, Physical Distribution and Alteration of Roadway-derived Dust in Urban Soils.*

In collaboration with Towson University we set up mesocosm experiments using conditions observed in urban bioretention cells receiving direct storm water input from a heavily used parking lot in College Park, MD. *Lumbricus friendi,* a non-native earthworm was exposed to Zn bearing roadway dust amended to a field soil at 6 target concentrations ranging from background levels (45 mg/kg Zn) to highly contaminated levels (460 mg/kg Zn) meant to bracket the observed concentration range in storm water retention basin soils but below the LD_{50} for Zn.

15. *Wireless Sensor Networks for Soil Monitoring.*

We have deployed two new sets of sensors in Baltimore: One set of twenty motes (each having two soil moisture and two soil temperature sensors) was deployed on the Johns Hopkins University campus forested site. In addition we have equipped our Vaisala weather station with a solar panel, and thus it has been continuously operating on Olin Hall. The other sets of motes (fifteen) have been also deployed in Cub Hill. Ten of the motes are in the forest along a transect, the other five have been deployed in various land cover types, including lawn and a patch covered with ivy. In August 2008 we also deployed a set of three Vaisala CO_2 sensors at the Cub Hill flux tower.

16. *Carbon Storage in Residential Lands.*

People manage their residential landscapes to meet a variety of physical and social needs. Virtually all across the United States and with few exceptions, residential landscapes are maintained as predictable sets of tree, turfgrass, shrub, and garden combinations. This land base is large and growing, and it contains substantial amounts of natural vegetation. Diurnal, seasonal, and annual patterns of net ecosystem exchange (NEE) in residential areas are driven strongly by vegetation carbon (C) uptake, and substantial C sequestration undoubtedly occurs in these human-dominated systems. Still, very little is known about the magnitudes and drivers of C cycling in residential landscapes.

In this project we are quantifying the magnitudes of carbon (C) stocks and fluxes in the vegetated component of residential landscapes in Baltimore, MD. By choosing a cross-section of sites in the region with particular characteristics, we will also identify the relative importance of urban ecosystem structure, soil functional properties, historical land use, and land management practices as drivers of these C stocks and fluxes. The work is taking place in conjunction with the Baltimore Ecosystem Study (BES), and is therefore taking advantage of the infrastructure already in place for this Long-Term Ecological Research (LTER) project.

There are four distinct phases in the project: 1) land classification (applying and groundtruthing the HERCULES classification system for the Baisman's Run neighborhood); 2) site selection (gathering appropriate datasets, identifying suitable parcels for sampling, contacting landowners and soliciting citizen

participation in the project); 3) field sampling (including initial plot characterization and sampling to assess C stocks as well as ongoing C flux monitoring); and 4) data analysis and writeup. Phase 1 was completed in 2006. In the past year we have continued progress on phases 2-4 as described below.

1) Land classification. The HERCULES land classification system has been applied to the Baisman Run neighborhood, using EMERGE color infrared imagery and is available for the remaining analyses.
2) Site selection. A geodatabase including soil type, parcel boundaries and housing age, land use history (using information from a variety of sources and time periods), and HERCULES class was developed for the three study neighborhoods. Using this information a set of ten "neighborhood clusters" containing households with identical characteristics (according to our sampling criteria) was identified for sampling. (See "Findings" for a table with the site types selected for analysis.) We recruited thirty-three participating households out of our original target of forty (four households per cluster).
3) Field sampling.
   a. Initial site characterization visits to the thirty-three participating households were completed in 2007.
   b. Monitoring of C flux components (including grass productivity, soil respiration, and thatch and stubble accumulation) and stocks (thatch, stubble) has been ongoing continuously at all plots. As of February 2008, we have one full year of data at roughly half of the sites, and two full years at the other half.
   c. Soil sampling has been completed at all thirty-three sites. Cores have been analyzed for microbial biomass C and N content, potential net N mineralization and nitrification, microbial respiration and total C and N content, and are currently being analyzed for soil texture. Chemical analysis is complete, and data analysis is ongoing.
4) Data analysis and writeup. Clipping, productivity, soil respiration and thatch and stubble production data to date have been analyzed (see "Findings" section).

Additional efforts underway include:
Vegetation survey. Our work seeks to quantify the relationship between HERCULES land cover classes and carbon cycle dynamics. Since individual parcels tend to be consistently managed by the homeowner, these dynamics are most clearly expressed at the parcel level. In addition to our work on the turfgrass component of each parcel, we are quantifying the percent cover and C cycling rates of other vegetation (gardens, trees, impervious) in order to assess the parcel-level carbon dynamics for each HERCULES land cover type. The surveys are being conducted using methods developed for the UFORE (Urban FORest Effects) model (see http://www.fs.fed.us/ne/syracuse/Tools/UFORE.htm). Seventeen of the thirty-three residential carbon lots have been surveyed thus far; sampling points for eight of the remaining sixteen lots have been selected, and technical issues are being addressed for the other eight.

Household survey. Lawn management practices are likely an important predictor of turfgrass C cycling rates, but it was not possible to control for this possible effect during the site selection phase of the work. Thus we have conducted a lawn

management survey of participating households, in order to assess their lawn management practices. Results from this survey will be used to interpret the results from the turfgrass productivity study.

We also worked with Co-PI's Mary Washington and Morgan Grove, to facilitate their efforts to understand landowner motivations for lawn management as part of this survey. Their work sampled the landowners identified as part of our Residential Carbon study, and was funded via a Supplement to the LTER Program.

Controlled experiment: Effects of turfgrass management on C cycling. Together with Mark Carroll, the director of the University of Maryland's turfgrass management program, we have installed an experimental manipulation at the University of Maryland's Paint Branch Turfgrass Research Facility. This experiment uses a controlled environment to examine the effects of various intensities of common management activities (mowing, watering, and fertilizing) on pools and fluxes of C and N in a turfgrass system. The experiment consists of three split blocks of twelve 5'x5' squares. It was established and instrumented during the spring of 2007; treatments and data collection began in July 2007.

17. ***Salt Runoff.***

Graduate student Pete Bogush is working on his Master's thesis, focusing on the effect of salt runoff on N and C removal in stream sediments.

Graduate student Robin Van Meter is working on her PhD and is an IGERT trainee at UMBC. She is performing experiments to learn the consequences that road salt loading to stormwater ponds has for amphibians and pond food webs in general.

18. ***BES Host Partnership.***

The University of Maryland, Baltimore County (UMBC), Center for Urban Environmental Research and Education (CUERE) serves as host to the field operations of the Baltimore Ecosystem Study, providing lab, office, and meeting space to BES PIs and students as a subcontractor to the Cary Institute. CUERE's GIS Laboratory provides spatial data analysis services to BES researchers as needed. In addition, CUERE provides BES with an academic link to UMBC, whereby several of the BES PIs serve as adjunct faculty at UMBC, and UMBC faculty and students work on BES-related projects.

CUERE has continued to be instrumental in leveraging the presence of the BES on campus to increase related research activities. In the past year CUERE received an award from NOAA entitled, "Integrating Real-Time Sensor Networks, Data Assimilation, and Predictive Modeling to Assess the Effects of Climate Variability on Water Resources in an Urbanizing Landscape" ($3M, 9/1/07–8/31/10, C. Welty, PI) that will likely make the Gwynns Falls one of the most heavily instrumented watersheds in the world for real-time hydrologic data collection.

An additional contribution of CUERE to the mission of the BES is the Biocomplexity award, "Collaborative Research: Dynamic Coupling of the Water Cycle and Patterns of Urban Growth" (BCS-BE 0709659, $1.4 M, 9/1/07–8/31/10, C. Welty, lead PI; collaborative with Princeton University, Shippensburg University, Lawrence

Livermore National Lab, and USGS) to explore how urban growth and limits on water availability are predicted to interact, using the Baltimore region as a case study.

Ongoing Major Activities Addressing Question 3: How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air- and watersheds?

To answer Question 3, we conduct the following major education, interaction, and research activities:

- Develop or participate in educational partnerships.
- Analyze the ecological knowledge base and its use in different social contexts.
- Interact with governmental agencies at various levels to exchange ecological knowledge and information.
- Interact with communities, community groups, and non-governmental organizations to enhance ecological understanding.
- Design social and educational assessments to determine the changing role of ecological knowledge in Baltimore.
- Manage information to enhance flow of data and knowledge within BES, and between BES and agencies, communities, and individuals.
- Participate in assessment of storm drain Watershed 263 restoration activities and evaluation.
- Provide internships for secondary, college, and graduate students, and fellowships for teacher involvement in ecological research.
- Focus studies in the Minebank Run stream restoration project.

In addressing Question 3, partnerships are crucial. Because this question deals with the flow of information and its use, our activities recognize the diversity of sources and users of ecological and other relevant information, and the need to maintain two way flows of information and joint understanding of ecological issues. Of the three areas of activity in BES, this one is the most fluid and developmental, since it depends on evolving and expanding relationships in the Baltimore region as well as evolving and expanding ecological understanding.

New Activities Addressing Question 3:

1. ***Research and Education—University Courses.***

- Co-PI Larry Band taught ecohydrology in the Fall of 2007 and hydrology, nutrient cycling, and watershed GIS in Spring 2008.
- Co-PI Mary Cadenasso taught an upper division course entitled "Urban Ecology" at the University of California (UC) Davis, Winter 2008. Graduate and undergraduates enrolled. Lecture and discussion of primary literature. Covered topics such as 1) unifying concepts, 2) ecosystem approach, 3) nutrient cycling – nitrogen, carbon, and phosphorus, 4) meteorology and atmospheric processes, 5) soils, 6) vegetation, 7) wildlife, 8) hydrology and habitats, 9) urban design,

and 10) integrating frameworks. Drew heavily from the Baltimore and Phoenix LTER research for examples and literature.

- Dr. Cadenasso developed and taught a new graduate seminar course entitled "Environmental Justice and Ecosystem Services" that was informed by collaborations among BES PIs. She also used concepts, data, and insights from BES in guest lectures for two courses at UC Davis: 1) Ecology (Graduate core course), 2) Sustainable development theory and practice (Landscape Architecture undergraduate class).
- From Yardstick to Gyroscope: Interdisciplinary Methods for the Long-Term Study of Social-Ecological Systems. This course was co-taught by Morgan Grove (BES), Ted Gragson (UGA-Coweeta) and Laura Ogden (FIU-FCE).
- Advanced Spatial Methods (NR245). This course was co-taught by Co-PI's Morgan Grove and Austin Troy at the University of Vermont (UVM).
- GIS Analysis of New York City's Ecology: using spatial analysis tools to help with New York City's million tree campaign (NR378 / NR 285). This course was co-taught by Co-PI's Morgan Grove and Austin Troy at UVM.
- The Urban Ecology Institute has an NSF Instructional Materials Development (IMD) grant to develop an urban environmental studies capstone course and the data will be incorporate into the environmental justice chapter of these materials.

2. ***IGERT Interactions***.

There are ongoing interactions with UMBC IGERT and other UMBC graduate students, helping with formulation of research ideas and design.

Co-PI Ken Belt gave a number of class lectures, e.g., in urban research design class (primarily for UMBC IGERT Urban Water program students).

Co-PI Ken Belt also attended the graduate program kick-off celebration and get-acquainted session at UMBC GES labs as a BES representative. And, attended the annual UMBC IGERT reception for new, existing, and prospective graduate students.

Belt also loaned ca 10 stream temperature loggers and provided advice to Gwen Stanko and to facilitate her field research on the effects of stream restoration on water quality.

3. ***Interaction with Baltimore City Community College (BCCC).***

Parks and People Foundation partners strengthened our relationship with Baltimore City Community College to provided field experiences and professional development for their newly formed Environmental Sciences major. Co-PI Ken Belt continued helping with various aspects of the new environmental science program. This included field trips, hiring students, providing contacts, advice and information, etc., working through Hydrology instructor R. Danforth. Ken Belt was invited to give a presentation on environmental jobs and skills in BES research context at the Environmental Program Career Day at the Liberty Heights campus in Baltimore. Belt was appointed to serve on the BCCC Environmental Science Program Board.

4. ***KidsGrow.***

We have continued to develop and provide curriculum and teacher professional development to the Parks and People Foundation KidsGrow After-School Program. In the 2007-2008 school year, KidsGrow expanded to five sites; Sinclair Lane Elementary School, Franklin Square Elementary School, William Paca Elementary School, Harford Heights Intermediate School, and Commodore John Rodgers Elementary School. Approximately 250 students participated in the program at these five highly urbanized Baltimore City Public Schools. Three complete modules from the *My City's An Ecosystem!* curriculum were taught during the school year, plus the students were engaged in field trips and with classroom visitors including Dr. Gregory Jenkins and BES scientists Dr. Steward Pickett and Dr. Quin Holifield. The students took field trips to Port Discovery Children's Museum, Irvine Nature Center, the National Aquarium in Baltimore, the Frederick Douglass Isaac Myers Maritime Park, and the Maryland Science Center. Students also participated in the Baltimore Harbor Boat Program and in an overnight experience at Patapsco State Park and Echo Hill Outdoor Science Center. The fall semester was spent on a rich exploration of urban ecosystems and decomposition. Students developed an understanding of urban ecosystems by studying their schoolyard and neighborhood ecosystems. This module culminated with students setting up ecology centers in their classrooms. During the second half of the fall semester, students studied decomposition. They learned about the process of decomposition and the important ecological role decomposers play in the environment. During the spring semester, students were engaged in the Ecology of Food, Agriculture and Nutrition module. Students began to understand where our food comes from before it gets to the grocery or corner store. Students at three schools planted their own schoolyard vegetable gardens and held a Salad Extravaganza at the end of the school year. During Black History month, several schools visited the Reginald F. Lewis Museum of Maryland African American History and Culture and invited prominent African American scientists into the classroom.

5. ***Research Experience for Teachers (RET).***

- **Rennie Watson,** Doris M. Johnson High School.

Karen (Rennie) Watson completed her Research Experiences for Teachers work this past year. Ms. Watson, a science teacher at Doris M. Johnson High School, piloted lessons she developed as part of her RET, conducted with mentor scientist, Dr. Richard Pouyat (BES & USDA Forest Service). Her research took place during summer 2006 at Clifton Park, a 263 acre Baltimore City Park. Ms. Watson's school, Doris M. Johnson, an Expeditionary Learning High School, is physically located in the park. Sixty-four percent of the students at Ms. Watson's school meet eligibility requirements for the free or reduced price lunch program and 99% are African-American. Ms. Watson and Dr. Pouyat implemented an Entitation survey in Clifton Park in conjunction with the Baltimore City Department of Recreation and Parks. Watson also redesigned the entitation survey form during her research summer. She is currently assessing her lessons and editing and updating them in a "teacher friendly format" for other educators. Excerpts from her final report provide strong evidence for the highly valuable nature of the RET program for Ms. Watson

> "Throughout the following school year, I applied many of the things I learned to my instruction. In a key student project, I used my new understanding of

the park's history, techniques for mapping plant communities, and plant identification—together with aerial photographs of the park, research into plants' ecological roles, and student field work—to guide students in evaluating the park's ecological health and impact on the surrounding neighborhoods. They used their research to support recommended changes for the future. Their reports—presented as posters, reports and PowerPoints—were displayed for the public and city officials as the city gathered public opinions for creating a park master plan. Several students discussed their work during this display.

"Other RET-related activities I developed and implemented in my classroom included an assessment of soil characteristics and their possible impacts on tree health (prior to the selection of tree species for a student tree planting in the park), a tree identification survey, and a biodiversity study.

"In addition to helping shape my instructional design, the RET experience greatly strengthened my confidence in developing and guiding field projects for students. Being in the field with experts and watching them at work proved invaluable in helping me understand how to develop and model field work for my own students."

- **Terry Grant,** St. Paul School for Girls

Mr. Terry Grant began work as a Research Experiences for Teachers (RET) Fellow in June 2007. Mentored by Peter Groffman (BES Co-Investigator and Microbial Ecologist, Cary Institute of Ecosystem Studies), Mr. Grant sought to better understand stream ecology in the urban ecosystem including the interaction between a stream and its riparian zone. He collected samples for several months from several sites along the Jones Falls. During his Fellowship, he also developed an urban-suburban-rural gradient research and education project for his and other schools in the region. Grant has used his research experience to develop a project focus for the Advanced Placement Environmental Science class he in the fall 2007.

- **Bradley Harrison**, Western High School of Technology and Environmental Science

Brad Harrison began a Research Experiences for Teachers Fellowship in spring 2008, working with BES scientists Charlie Nilon (University of Missouri) and Paige Warren (University of Massachusetts). His focus is on the ecology of bird communities in the metropolitan area through the BES Birdscape project. He is investigating whether there is a relationship between the number of vacant lots in a neighborhood and bird diversity. He also is asking whether the abundance of exotic tree species (especially tree of heaven) has any influence on diversity. The protocols and findings will be integrated into his teaching in the upcoming school year.

6. ***School-based Urban Rural Gradient Ecosystem Studies (SURGES).***

Three teachers from the 2007 Teaching Urban Ecology in Baltimore workshop, under the leadership of Terry Grant (BES RET Fellow), formed a working group to develop and pilot test SURGES in the 2007-8 school year. In addition to Grant from the St. Paul School for Girls were Deb Kinder from Friends School and Shan Rajendran from Paul Laurence Dunbar High School. The teachers worked to develop a protocol for surface water sampling and earthworm investigations which

they then conducted with their students. All three schools are located within the Jones Falls Watershed and they arrayed their sampling to cover the full urban-rural gradient: one sampled near the outfall at the inner harbor, one in Greenspring Valley at the northern end of the watershed and one school between the two. In addition to sharing among teachers, the students themselves shared with each other when Paul Laurence Dunbar students visited Friends School to conduct joint sampling and exchange information. Plans for the 2008-9 school year will build on these initial efforts, with the goal of establishing long-term relationships with targeted schools in urban, suburban and rural settings for sustained professional development, direct BES support, student exchange and comparative research, education and stewardship projects.

7. ***Education Research: Describing Baltimore's Ecology Education System.***

Urban Ecosystems in the Maryland State Curriculum Framework – In this reporting period, Alan Berkowitz worked with Heather Langford from the Urban Ecology Collaborative (UEC) Education Committee to refine our framework and protocol, first developed for in analyzing the Maryland State Voluntary Curriculum, for use in analyzing curriculum frameworks from other states. The scheme will provide a common framework to allow all cities participating in the Urban Ecology Collaborative (comprising partners in Boston, New Haven, New York, Pittsburgh, Baltimore and Washington, DC) to compare their curriculum frameworks with each other and provide us with the first multi-city indication of ecology education curriculum expectations in urban school systems.

8. ***Education Research: Investigations in Ecology Teaching.***

Investigations in Student Thinking and Learning – BES is a partner in the Environmental Literacy Project based at Michigan State University (MSU) and headed by Andy Anderson. The project is associated with the MSU-led Kellogg Biological Station LTER site, along with the Santa Barbara Coastal Ecosystem LTER site (Allison Whitmer, UC Santa Barbara) and the Short Grass Steppe LTER Site (John Moore, Colorado State University). During this period, significant effort was given to developing a proposal to the National Science Foundation's Math Science Partnership Program (MSP). If funded, this will allow us to conduct significant, long-term and large scale (across sites) research about how students think and learn along key strands of an environmental literacy learning progression.

9. ***Storm Drain Restoration and Management.***

Worked with federal, state, and local government and community-based organizations to develop and implement restoration plan for 900-acre storm drain watershed (Watershed 263) incorporating eleven neighborhoods in southwest Baltimore to demonstrate impact of greening strategies on quality and quantity of storm water runoff and quality of life; collaborated with the US Forest Service and Baltimore City Department of Public Works to collect baseline data for assessing impact of restoration activities.

Formed a relationship with the Housing Authority of Baltimore City to green and implement storm drain management practices on public housing property.

10. ***Building Resources and Nurturing Community Health & Environmental Stewardship (BRANCHES)***.

Implemented BRANCHES youth forestry training and summer employment program with Department of Recreation and Parks in four public parks in Baltimore. BRANCHES provided economically disadvantaged youth with training and employment experience to develop useful job skills that lead to long-term opportunities in tree care related professions. Coordinated with BES scientists and the Department of Recreation and Parks staff to develop training for youth team supervisors. Secured funding to extend the BRANCHES youth training forestry program into the fall semester of 2008 as an after-school program.

11. ***Watershed 263 Stakeholder Council.***

Continued to work with Watershed 263 Stakeholder Council to develop indicators to monitor and evaluate outcomes of large-scale watershed restoration project. Submitted proposal to Chesapeake Bay Trust on behalf of the Watershed 263 Stakeholder Council to fund restoration and environmental education projects.

12. ***SuperKids Camp.***

Provided environmental education enrichment for 1,100 Baltimore City 2nd and 3rd graders participating in the Parks and People Foundation SuperKids Camp, six week reading enrichment summer program.

13. ***Educational and Technical Support.***

Parks and People Foundation partners organized and provided technical support for formation of Watershed 263 Coordination Working Group. Secured NSF Lawn Study and KidsGrow Longitudinal Database Study. Employed fifteen summer interns to conduct project related to watershed education, restoration and natural resource career development.

14. ***Teacher Decision Making.***

BES has partnered with researchers at the University of Maryland, College Park on an NSF-funded effort that sought to better understand teacher decision making in the high school science classrooms (*What influences teachers' modification of curriculum?*, NSF 0455711). As part of a larger project, researchers worked with seven Baltimore county and city teachers who incorporated BES' *Investigating Urban Ecosystems* materials, fieldwork-based biology/ecology units for biology or environmental science classes.

15. ***Planting and Follow Up of Native Trees and Riparian Invasive Species.***

Planting and follow-up maintenance of 250 native trees and riparian invasive species removal projects in Chinquapin, Herring Run and Leakin Park. The program will include a variety hands-on site visits for students to learn more about careers in natural resources research.

Outreach

Outreach is fundamental to the mission and success of the Baltimore Ecosystem Study. As a research question, we are concerned to know how people develop and use knowledge of the metropolitan area as an ecological system. In addition, we have learned from the literature and from a ten year social science and community restoration research program in Baltimore predating the LTER effort, that informing and working with communities and constituencies is required to conduct ecological research in the city and suburbs. Hence, we conduct a wide variety of community and educational activities.

1. ***BES Annual Meeting and Community Open House/Greening Celebration***.

Formal public outreach was accomplished through the BES Annual Meeting, attended by scientists, educators, community members, and decision leaders from the Baltimore region as well as by BES researchers and educators. Attendance at the Annual Meeting and Open House has been approximately 100-150 people in the last several years. The evening Open House is held annually in conjunction with the Parks and People's Annual Greening Celebration. Over time, the number of attendees at these functions has grown. At the 2007 Open House, a Certificate of Recognition from Mayor Sheila Dixon was presented to the Parks and People Foundation and the Baltimore Ecosystem Study in recognition of our "dedication to making the City of Baltimore cleaner, greener, and healthier… ." Three additional Research Meetings were held at roughly three month intervals focused on research and education. The topics were: "Altered Community Structure and Trophic Interactions in Urban Ecosystems," "Organic Matter," and "K-12 and Graduate Education and Research."

2. ***Interaction and Sharing with Other Agencies.***

Advisory activity for the Chesapeake Bay Foundation on the Chesapeake Bay watershed model.

At the BES Quarterly Research Meeting on April 9, 2008, on the topic of Organic Matter Dynamics, the US Geological Survey (USGS), in collaboration with BES, supported the attendance and related presentations by Brian Pellerin and Brian Bergamaschi, Supervisory Hydrologists at USGS, Sacramento, CA. Their presentations on the effects of land use on organic matter trends, and on DOC dynamics and trihalomethane formation in California reservoirs, and small streams to major river systems in CA provided insight, parallels, and contrasts, to DOC trends and dynamics in the BES. They also provided BES scientists with an array of *in situ* stream and reservoir continuous near-real time monitoring designs for dissolved organic matter and related parameters.

BES hosted the 2008 LTER Science Council Meeting and conducted field trip of the BES research sites for approximately 75 participants. The LTER Executive Board meeting was held at the new USGS on-campus office.

Contributed to Baltimore Neighborhood Indicators Alliance report on Vital Signs for Baltimore's Neighborhoods.

Participated in the making of "Return to the Forest Where We Live," a documentary about urban restoration projects; aired in September 2008. See www.lpb.org/forest.

Participated in Urban Ecology Collaborative Second Annual Meeting. Transferred Watershed 263 restoration, greening and tree survey models to partner organizations in Washington, DC and Boston. Parks & People Foundation partners had leadership roles in the Environmental Education Working Group, Restoration Tools and Green Jobs Network Working Group.

Participated in the Working Group and Community Outreach portions of the development of the Baltimore City Sustainability Plan. Co-PI Mary Washington serves on the Baltimore Sustainability Commission.

Developed and carried out a community organizing plan for storm drain watershed restoration project in southwest Baltimore, working with community-based organizations in eleven neighborhoods to engage community residents to improve water quality and ecosystem function in Watershed 263 and recruit members for Watershed 263 Stakeholder Council.

Provided technology transfer and community outreach and education support to Baltimore Harbor Watershed Association to create Harris Creek (Watershed 246) project in east Baltimore. We continue to work with business leaders, city agencies and community-based organizations. Relationships have been developed with local public agencies, non-profits, community groups and residents.

Co-PI's, K. Belt, K. Szlavecz and I. Yesilonis conducted a tour of BES LTER plots in Leakin Park, and the Rognel Heights stream monitoring site for Diana Wall of the University of Colorado when she visited Baltimore for a seminar at Johns Hopkins University.

Co-PI's K. Belt and other Forest Service staff participated in a field trip to Senator B. Cardin's office in Washington DC organized by Dr. R. Pouyat. Grad students and research technicians were able to explain their research and interact with the senator's staff. The group also visited the new soils exhibit at the Natural History Museum where Co-PI Dr. Holifield explained the various components of the exhibit ("Dig It! The Secrets of Soil").

Co-PI's K. Belt and R. Pouyat participated in a Parks and People Foundation meeting with National Fish and Wildlife, Baltimore City officials, and the WS263 Community Stakeholder Council representative. This meeting included a field visit to the Lanvale storm drain monitoring site as well as discussion of how urban runoff research can be integrated into environmental improvements in an ultra urban community in Baltimore, MD.

Co-PI K. Szlavecz invited to serve as Advisory Committee Member: Smithsonian Institution Soils Exhibit ("Dig it: The Secrets of Soils"); "Matter of Life and Death"

short movie on decomposition. She was also invited to serve as Advisory Committee Member: "Savage Yard" planned PBS series on backyard biodiversity.

3. ***Education Outreach.***

Many of the educational items listed in "Activities" above can also be considered outreach, as they brought urban ecology perspectives to important and often underserved audiences. Beyond our formal work with participating teachers and their students, and the KidsGrow after school program we engage in informal outreach on a regular basis, often in conjunction with Parks and People Foundation programs. During the current reporting period, the Education Coordinator participated in many Parks and People events, sometimes wearing a combined volunteer/BES education hat.

USGS has established collaborative planning effort with Parks and People Foundation to develop outreach and education activities for interns and educators in Baltimore County schools and parks. USGS, along with Parks and People Foundation interns, is engaging schools selected for future monitoring sites to observe the drilling and well construction operations.

On May 19, 2008, personnel from USGS provided a tour and technical discussion for BES interns from the Friends School at the Minebank Run study site in Cromwell Valley Park, Baltimore County. The tour was geared toward showing the interns a local stream restoration project in an urban environment and discussing the work that USGS is involved in at the study site, including stream gaging, precipitation monitoring, measurement of ground water levels in wells, physical measurements of stream geometry, and water quality sampling.

Five Hundred 2nd and 3rd graders planted trees as part of the SuperKids Camps during Summer 2008 at locations across Baltimore City. Students learned about the Chesapeake Bay Watershed water quality and the importance of tree canopy to a healthy environment.

Organized outdoor experiential activities for the Barclay Elementary School at Winans Meadow, a trailhead of the Gwynns Fall Trail in Leakin Park.

Developed content for "Linking Science and Decision-making" section of BES website, highlighting role of URI and Green Career Ladder in coordinating research on and restoration of Baltimore's urban ecosystem.

Co-PI Gordon Heisler, along with the BES Education Coordinator, provided consultation on a teaching module for meteorology for the KidsGrow program at the Franklin School in Baltimore. We also installed a weather station at the school with a display of current weather data in the KidsGrow classroom.

4. ***Conferences.***

Contributed to the organization of a Regionalism conference sponsored by the Center for the Study of Regional Change at the University of California, Davis. This two-day conference brought together academics, members of environmental non-profits, regulators at all levels of government, policy makers, educators, etc. to

discuss integrated understanding of regionalism in CA, especially the central valley. Co-PI Mary Cadenasso provided a synthesis talk highlighting and integrating themes from the two days together and suggesting a way forward. This activity benefited from years of cross disciplinary collaborations within BES.

Contributed to the organization of a conference focused on climate change and homeowner management sponsored by the California Center for Urban Horticulture at UC Davis. This two day conference was attended by research academics, master gardeners, nursery industry leaders, landscape architects and non-profit organizations to focus on the opportunities for change at the scale of the individual homeowner management decisions.

5. ***Urban Tree Canopy.***
Based upon our research in Baltimore and development of Urban Tree Canopy (UTC) analyses, we have developed numerous outreach strategies including training webinars, videos, websites, and conference calls. These outreach activities have contributed to UTC assessments and adoption of UTC goals in a number of cities throughout the U.S.

Presentations, Posters and Websites Considered Outreach Activities

Presentations

Bain, D.J. 2007. Baltimore floodplains: source or sink or both? Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Bain, D.J. 2007. Mining waste sediment tracers: the Piedmont chromite case. Invited presentation. Franklin & Marshall College, Geology Department, Lancaster, PA. November 1.

Bain, D.J. 2007. Constraining the floodplain: land use change, sediment dynamics, and Baltimore's riparian ecology. Friday Seminar Series. University of Maryland, Baltimore County, Baltimore, MD. November 2.

Bain, D.J. 2007. Constraining the floodplain: land use change, sediment dynamics, and stream restoration. Thursday Colloquium. University of Pittsburgh, Department of Geology and Planetary Science, Pittsburgh, PA. November 15.

Band, L.E., M. Lipscomb, C.L. Tague, C. Shields, P. Groffman, and D.E. Tenenbaum. 2008. Hydroclimate variability impacts on urban and suburban water quality. Annual Meeting of the Association of American Geographers, Boston, MA. April 18.

Brush, G.S. 2008. Presentation at workshop: Understanding human signals in the hydrologic cycle during the colonial period in the Northeast U.S. The Northeast Consortium for Hydrologic Synthesis, Massachusetts Institute of Technology, Cambridge, MA. June 23.

Brush, G.S. and D.J. Bain. 2007. Land use and forest succession in the Gwynns Falls uplands. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Belt, K.T. 2008. Presentation on jobs and skills utilized in ecological research at the Baltimore Ecosystem Study LTER. Environmental Career Day, Baltimore City Community College (BCCC), Liberty Heights Campus, Baltimore, MD. January 23.

Belt, K.T. 2008. Urban streams: altered states. Class lecture to Dr. P. Wilcock's 575.730 Geomorphic and Ecologic Foundations of Stream Restoration course, Johns Hopkins University, Geography and Environmental Engineering Department, Baltimore, MD. March 3.

Belt, K.T., S.S. Kaushal, C. Swan, R.V. Pouyat, and P. M. Groffman. 2008. Organic matter fluxes in urban catchments: the gutter subsidy and schmutz transport and fate. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. April 9.

Belt, K.T. 2007. Development of the organic matter research questions and approaches. Invited presentation to Urban Experimental Design graduate class (GES 622 Research Design for the Urban Environment), University of Maryland, Baltimore County, Baltimore, MD. October 4.

Belt, K. 2007. Organic matter research methods and project goals. Informal presentation for student interns and technicians, Baltimore Ecosystem Study Lab at University of Maryland, Baltimore County, Baltimore, MD. December 14.

Belt, K., S. Kaushal, C. Swan, R. Pouyat, P. Groffman. 2007. Particulate and dissolved organic matter in urban streams: fluxes, spatial patterns and the effects of urban hydrology along the urban stream continuum. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD, October 17.

Buckley, G.L. 2007. Baltimore's urban forest: a century of change. Mid-Atlantic Chapter of the International Society of Arboriculturists, Hagerstown, MD. October.

Burgess, J., K. Szlavecz, C. Swan, L. Xia, A. Poudel. 2007. Resource quality and diversity: implications for detritivore inter- and intraspecific interactions. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 17.

Cadenasso, M.L. 2008 Exploding the urban riparian zone: opportunities up-catchment to prevent nitrate movement across land-water interfaces. Department of Civil and Environmental Engineering, University of California, Los Angeles, CA. May 13.

Carroll, W., S.M. Lev, K. Szlavecz, E.R. Landa, R. Casey, and J. Snodgrass. 2007. Investigating the extent of earthworm trace metal accumulation, physical distribution and alteration of roadway-derived dust in urban soils. 28th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Milwaukee, WI. November 11-15.

Costanza, R. 2007. Modeling ecosystem services and sustainability across scales. Invited speaker. AAAS Annual Meeting Symposium, Advances in modeling coupled human-natural systems for sustainability, San Francisco, CA. February 15-19.

Costanza, R. 2007. Toward an integrated, transdisciplinary science of humans-in-nature. Peking University, College of Environmental Sciences, Bejing, China. May 26.

Costanza, R. 2007. Modeling integrated human and natural systems dynamics over multiple time and space scales. Invited plenary speaker. United States Society for Ecological Economics Biannual Conference, Pace University, New York, NY. June 23-27.

Costanza, R. 2007. Use of ecosystem service valuations to inform local and regional land use decisions. Invited workshop speaker. United States Society for Ecological Economics Biannual Conference, Pace University, New York, NY. June 23-27.

Costanza, R. 2007. Protecting the commons. Eighth Annual Edward & Nancy Dodge Lecture. Center for a Livable Future, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD. November 29.

Costanza, R. 2008. Payment for ecosystem services. Invited speaker. National Conference on Science, Policy and the Environment. Washington, DC. January 16-18.

Costanza, R. 2008. Understanding, modeling and valuing ecosystem services. Invited keynote plenary speaker. 24th Conference of the Association of SIMULA Users (ASU). Salzau Castle, Germany. May 13-15.

Filley, T. and Szlavecz, K. 2008. Macroinvertebrate (earthworm) controls on the transformation of plant derived organic matter in soils. 235th National Meeting of the American Chemical Society, New Orleans. May.

Fisher, G.T., W.P. Stack, K.T. Belt. 2007. Reflections on the Baltimore NURP results, 25 years later. (Presentation by K.T. Belt.) Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18.

Grove, J.M. 2008. From pixels to parcels: the anatomy of household and parcel based methods for urban social ecological analyses and characterization of place. French Embassy, Fontainebleau, France. January 10-13.

Grove, J.M. 2008. From pixels to parcels: the anatomy of household and parcel based methods for urban social ecological analyses and characterization of place. Clark University, Wooster, MA. January 29-30.

Grove, J.M. 2008. From pixels to parcels: the anatomy of household and parcel based methods for urban social ecological analyses and characterization of place. Harvard Forest, Petersham, MA. April 11.

Grove, J.M. 2008. From pixels to parcels: the anatomy of household and parcel based methods for urban social ecological analyses and characterization of place. Pennsylvania State University, State College, PA. April 30.

Heisler, G.M. 2008. Mapping Baltimore-area air temperatures. Seminar at the Center for Urban Environmental Research and Education, Baltimore, MD. March 14.

Lilly, P., and J.C. Jenkins. 2007. Why I watch the grass grow: attaching ecological significance to lawn management in residential areas. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18.

Logan, M., K. Smith, and M.L. Washington. 2008. Parks & People Foundation's green career ladder: a case study in environmental education. Greater Baltimore Children and Nature Conference, Baltimore, MD. February 20.

Logan, M., and M. Washington. 2008. Pathways to partnerships: building effective programs for middle and high school youth. After School Institute and Maryland After School Partnership, Baltimore, MD. August 5, 2008.

Lord, C. 2008. Environmental justice and zoning. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18.

McCormick, M.K., K. Szlavecz, K. Parker, T.R. Filley, D.F. Whigham 2007. Effects of abundant non-native earthworms on plants and soil dynamics. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 17.

Nowak, D.J., J. Wang, T. Endreny, and A. Lee. 2007. Urban forest effects on stream flow and water quality. 83rd International Society of Arboriculture Conference and Trade Show, Honolulu, HI. July 30.

Pouyat, R.V., P.M. Groffman, K. Szlavecz, I.D. Yesilonis, and Q. Holifield 2007. Spatial and temporal variation of soil properties and processes in urban landscapes. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18.

Pouyat, R.V. 2007. Biogeochemical cycles of urban and urbanizing landscapes: Baltimore a case study. Colloquium on Emerging Environmental Issues in New York City, City University of New York-Graduate Center, New York, NY. November 8.

Pouyat, R.V. 2008. The urban mosaic: implications for ecological restoration. Mid-Atlantic Chapter Conference, Society of Ecological Restoration International, Philadelphia, PA. January 9.

Pouyat, R.V. 2008. Nutrient cycling in urban ecosystems. City University of New York-Queens College, New York, NY. February.

Pouyat, R.V. 2008. Urban ecology: The changing face of ecology. EvoS Seminar Series, Evolutionary Study Program, State University of New York-Binghamton, Binghamton, NY. April 25.

Pouyat, R.V. 2008. Anthro-soils. State University of New York-Binghamton, Binghamton, NY. April.

Pouyat, R.V. 2008. Long-term studies of urban ecosystems: the Baltimore Ecosystem Study. Wildflower Week Festival, Torrey Botanical Club, New York, NY. May 5.

Pouyat, R.V., K. Meade, M. Neel, D. Nowak, and I. Yesilonis. 2008. Relationship of tree species distribution and urban environmental factors in Baltimore, MD, USA. State University of New York, Binghamton, Erfurt, Germany. 21-24 May.

Pouyat, R.V. 2008. Biogeochemistry of urban ecosystems. Department of Environmental Science, Towson University, Towson, MD. June.

Pouyat, R.V. 2008. Communicating science: a case for interpersonal relationships. ESA Workshop on Communicating Science to the Public, Milwaukee, WI. August 1.

Sister, C., and C.G. Boone. 2007. Measuring park equity in Baltimore using a park service areas approach. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18.

Smith, K. 2008. Tree surveying. Parks and People Foundation, Baltimore, MD. April 18.

Smith, K. 2008. Community greening in Baltimore. Maryland Dietetics Association, Baltimore, MD. April 30.

Smith, K. 2008. Street trees: 101. Parks and People Foundation and Baltimore City Department of Recreation and Parks, Baltimore, MD. June 18.

Stack, W.P., K.T. Belt, S.S. Kaushal, and G.T. Fisher. 2008. Urban runoff: not as dirty as it once was but dirtier than you think. 12th Annual Tributary Team Meeting, Maryland Department of Environment, Montgomery Center, Baltimore, MD. February 9.

Swan, C.M. 2008. Emerging questions in community and food web ecology: an opportunity for new directions in urban systems. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. January 23.

Szlavecz, K. 2008. The decomposer food web in urban environments. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. January 23.

Szlavecz, K. 2008. Environmental sensor networks. Invited. PRISM (Princeton Institute for the Science and Technology of Materials) University–Industry Research Symposium, Princeton University. March 17-18.

Szlavecz, K., E. Hornung, C. Csuzdi, Z. Korsos, F. Vilisics, P. Solymos. 2008. Earthworms, isopods and millipedes on the urban landscape: patterns in European and American cities. URBIO: Conference on Urban Biodiversity and Design. Erfurt, Germany. May 22-26.

Tenenbaum, D.E., L.E. Band, A. Moody, and J. Xiao. 2008. MODIS surface moisture in urbanizing landscapes. Annual meeting of the Association of American Geographers., Boston, MA. April 18.

Twery, M., and K. Gottschalk. 2008. Field tour for IUFRO invasive species working group. IUFRO Working Party 7.03.12—Alien invasive species and international trade, Baltimore, MD, Shepherdstown, WV, Catoctin, MD. May 28.

Van Meter, R., and C.M. Swan. 2008. Road deicers impact anuran food web dynamics: a preliminary study. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. January 23.

Washington, M. 2007. Race and culture in natural resources. Rubenstein School of Environment and Natural Resources University of Vermont, Burlington, VT. October 30.

Washington, M.L. 2008. Careers in ecology and natural resources management. Baltimore City Community College, Environmental Science Program, Baltimore, MD. January 23.

Washington , M.L. 2008. Baltimore sustainability: Chesapeake Bay watershed and Baltimore city water supply. New Light Leadership, Youth Development Program, Baltimore, MD. August 1.

Washington, M.L., and R. Patterson. 2008. Chesapeake Bay Watershed demonstration. New Song Community Learning Center and Parks and People Foundation, Baltimore, MD. April 4.

Posters

Belt, K., S. Kaushal, C. Swan, R. Pouyat, and P. Groffman. 2007. Particulate and dissolved organic matter in urban streams: fluxes, spatial patterns and the effects of urban hydrology along the urban stream continuum. Annual MEES (Marine, Estuarine and Environmental Sciences) Graduate School Colloquium, University of Maryland, College Park, MD. October 5-6.

Belt, K.T., S. Kaushal, C. Swan, P. Groffman. 2007. Particulate and dissolved organic matter in urban streams: fluxes, spatial patterns and the effects of urban hydrology along the urban stream continuum. Maryland Water Monitoring Council 13th Annual Conference: Closing the Knowledge Gap Connecting Maryland’s Streams to the Bay. December 6.

DiBlasi, C., U. Ghosh, N. Law, K. Belt. 2007. Effectiveness of street sweeping as a stormwater best management practice. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Klofas J., J. Cogan, K. Szlavecz, G. Heisler. 2007. A new weather station for the Baltimore Ecosystem Study. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 17.

Mehta, A.S., D.J. Bain, K.T. Belt, P.M. Groffman, S.S. Kaushal, R.V. Pouyat. 2007. Cation chemistry in Baltimore streams. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Mehta, A., D. Bain, K. Belt, P. Groffman, S Kaushal, R. Pouyat. 2007. Cation chemistry in Baltimore streams: another syndrome symptom? American Geophysical Union Fall Annual Meeting, San Francisco. December 11-15.

Runyan, C., K.T. Belt, W. Greenwood, and I. Turcsanyi. 2007. Particulate organic matter in urban streams: TSS and FPOM concentrations and transport. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Sikora, M.T., D.J. Bain, and E.M. Elliott. 2007. Water quality in a restored urban stream, Pittsburgh, PA. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Stanko, G.M., K.T. Belt, E.C. Ellis, R.V. Pouyat, and P.M. Groffman. 2007. Efficiency of a constructed wetland in proving water quality in an urban stream. Annual MEES (Marine, Estuarine and Environmental Sciences) Graduate School Colloquium, University of Maryland, College Park, MD. October 5-6

Stanko, G.M., K.T. Belt, E.C. Ellis, R.V. Pouyat, P.M. Groffman. 2007. Efficiency of a constructed wetland in improving water quality in an urban stream. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Watts, T., Belt, K.T., D. Jones, C. Swan, S. Kaushal, and R. Pouyat. 2008. Organic matter concentrations in urban streams. Mid Atlantic Chapter of the Ecological Society of America Annual Meeting, Wilkes-Barre, PA. April 19.

Watts, T., K.T.Belt, C. Runyan, W. Greenwood and I. Turcsanyi. 2007. Suspended solids and particulate organic matter in urban streams: hydrologic drivers. Baltimore Ecosystem Annual Meeting, Baltimore, MD. October 17.

Welty, C., A. Miller, M. McGuire, J. Smith, R. Maxwell, R. Shedlock, E. Doheny, K. Belt, T. Kerchkof, and P. Larson. 2007. Maryland Water Monitoring Council 13th Annual Conference: Closing the Knowledge Knowledge Gap Connecting Maryland's Streams to the Bay. December 6.

Xia, L., K. Szlavecz, J. Burgess, C. Swan. 2007. Effects of earthworm density and species on soil CO_2 flux. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 17.

Websites

www.beslter.org – Main website for the Baltimore Ecosystem Study.

http://beslter.org/perspective/perspective.aspx?action=all-pages&collection=Education – Repository of curricula and other instructional support materials, education-related report and other resources for educators.

http://beslter.org/biocomplexity-and-habitable-planet.html – This is the repository of curriculum and instructional support materials for the BioComplexity and the Habitable Planet project.

http://www.besdata.org – The ORS system provides partnering research groups and the broader environmental research community a mechanism to share research and data products on the web.

www.umbc.edu/cuere – Website for BES contributing organization—Center for Urban Environmental Research and Education.

http://his09.umbc.edu/dash/ – In cooperation with the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), CUERE has also utilized some of the long-term BES data to demonstrate the capabilities of the CUAHSI Hydrologic Information System.

http://cuereims.umbc.edu/website/bes – This is a clickable Arc-GIS map which includes BES data collection points. A number of features have been added to the map such as the capability to link directly to monitoring site information and directly download stream chemistry data.

www.lifeunderyourfeet.org – This website is dedicated to various aspects of soil research, primarily to developing sensor networks for soil monitoring. We have been collecting data from several sites, among them from urban forests in the Baltimore Ecosystem Study. The data are downloadable from the web. We are currently working on a section usable for high school science projects.

http://www.as.phy.ohiou.edu/Departments/Geography/lter.html – Ohio University webpage describing faculty, students, publications and theses related to BES.

www.fsl.orst.edu/climdb/ – Meteorological data supplied to the ClimDB, an interest-available dataset for public access to LTER climate and hydrological data. The CLIMDB/HYDRODB, is a centralized server to provide open access to long-term meteorological and streamflow records from a collection of research sites. Weather data is collected from the primary BES weather station and submitted daily—means, minimums, maximums, or total as appropriate for nine variables including air temperature, dew-points temperature, relative humidity, solar radiation, precipitation, and wind speed and direction.

http://ecovalue.uvm.edu/ – Based at the University of Vermont, the EcoValue project provides an interactive decision support system for assessing and reporting the economic value of ecosystem goods and services in geographic context.

http://md.water.usgs.gov/BES – USGS webpage describing BES and USGS related activity.

http://waterdata.usgs.gov/nwis – Historical data for six stream gaging stations supported by BES and many other stations in or near the study area.

http://waterdata.usgs.gov/md/nwis/current?type=flow – Near real-time streamflow data for five stream-gaging stations supported by BES and many other stations in or near the study.

http://ida.water.usgs.gov/ida/ – Instantaneous discharge data for six stream-gaging stations supported by BES and many other stations in or near the study reach are available for downloading at this site.

http://wdr.water.usgs.gov/ – Annual summary of data for six stream-gaging stations supported by BES and many other stations in or near the study area.

http://www.residentialcarbon.org – The site supports community outreach for the Residential Carbon Project, educates landowners about the project, and describes the work to interested parties. Note: Website was mentioned on NPR in a radio interview.

http://www.unb.ca/enviro/research_baltimore.html – Describes the analysis work on Organizational Partnerships and Natural Resource Management in the Gwynns Falls Watershed.

http://nrs.fs.fed.us/urban/utc/ – Description: Urban Tree Canopy (UTC). First UTC prototype was developed for Baltimore and has now been applied to numerous cities in the U.S. Many of the associated publications focus on Baltimore. The website 1) describes the UTC, 2) addresses frequently asked questions; 3) identifies current UTC cities; 4) lists data requirements; and 5) includes relevant publications and products.

ftp://bcftp:bacounty@towson4.co.ba.md.us/deprm – The Oregon Ridge Park Forest Health Assessment and Forest Management Plan. User name=bcftp, PW=bacounty. The Oregon Ridge Park Forest Health Assessment and Forest Management Plan prepared by Mar-Len Environmental Consultants, with assistance from Co-PI Mark Twery. This report is the result of a DEPRM initiative, in collaboration with the Department of Recreation and Parks, to address forest sustainability of large forested County-owned lands, using the UDSA Forest Service NED method.

http://www.dnr.state.md.us/forests/programs/urban/urbantreecanopygoals.asp Description of needs and methods for assessing existing and potential Urban Tree Canopy; resources describing general and various specific assessments and UTC goals.

www.parksandpeople.org – Section of the website is devoted to the Baltimore Ecosystem Study and the Urban Resources Initiative.

www.beslter.org/biocomplexity – Used to disseminate curricula and study materials including GIS files and software for the BES Biocomplexity K-12 education program.

Findings

For each of the three overarching research questions for BES, we highlight new findings below.

Findings Addressing Question 1: Structure, Integration, and Dynamics of Ecological, Socio-economic, and Physical Factors in the Baltimore Ecosystem.

BES is founded on the hypothesis that urban ecosystem function is related to urban ecosystem structure. Therefore, findings concerning the structure of patchiness throughout the metropolitan ecosystem are crucial.

1. ***Relationship of Tree Species Distribution and Urban Environmental Factors in Baltimore, MD.***

We estimate that Baltimore has 2.6 million trees resulting in a canopy cover of approximately 21%. Thirteen genera make up 75% of the total number of stems at least 15 cm in DBH. Non-native species made up 23% of the total stems. Roughly half of the total number of stems was established through natural processes. Soil pH separated primarily native species (<5.5) from non-native species that have escaped (>6.4). At the neighborhood scale, invasive plant species and soil contamination by heavy metals were associated with disturbed areas. These results suggest that both natural and urban factors affect the spatial variation of vegetation structure and soil properties at the city scale, while at finer scales urban factors are the most important.

2. ***Effects of Urban Parks on Property Values.***

We found that urban parks negatively influence property values in areas with high crime and positively influence property values in areas with low crime. We further defined the exact thresholds at which this change occurs.

3. ***Survey of Private Properties in the Gwynns Falls Watershed.***

We found a slight relationship between grass cover and neighborhood satisfaction. The relationship was less clear for trees. We found a strong relationship between neighborhood level crime and indicators of yard management. Areas with well managed lawns and yards tended to be located in lower crime areas.

4. ***Automation of High-resolution Remote Sensing.***

We discovered new, more efficient ways to classify high resolution imagery accurately into land cover. We applied this to the Gwynns Falls, yielding a very high accuracy level (~92%). We then compared an object-based change detection approach to a pixel based approach, finding that the object-based approach performed better.

5. ***Historical Activities of Neighborhood Improvement Associations regarding Urban Parks and Trees.***

Research on improvement associations in Baltimore revealed the wide range of activities these organizations engaged in as they strived to "protect" the material space of their districts. While all groups sought to attract amenities (improved services, street trees, park expansions, and so on) while discouraging disamenities (unwanted land uses, roads, air pollution, etc.), some also attempted to protect the "cultural identity" of their neighborhoods via restrictive covenants and exclusionary housing practices. Their goal was to prevent African American settlement. Several of our publications reveal the extent to which such practices produced an inequitable distribution of amenities.

6. ***A Longitudinal Analysis of the Social Dynamics of Environmental Equity in Baltimore.***

We found that a higher proportion of African Americans have access to parks within walking distance, defined as 400 meters or less, than whites, but whites have access to more acreage of parks within walking distance than blacks. A needs-based assessment shows that areas with the highest need have the best access to parks but also have access to less acreage of parks compared to low-need areas. Park service areas that are predominantly black have higher park congestion than areas that are predominantly white, although differences are less apparent at the city level than the metropolitan level. We show that segregation ordinances, racial deed covenants, improvement associations, the Home Owners Loan Corporation, and the Parks and Recreation Board created separate black spaces in the city historically underserved with parks. These mechanisms ultimately fueled middle class flight and suburbanization and black inheritance of much of Baltimore's space, including its parks.

7. ***Forest Successional Sequence.***

Major findings are that the hydrologic structure of the riparian areas has been altered by stream incision caused primarily by increased impervious surfaces so that groundwater is not being recharged and this has affected the vegetation in that most new growth consists of tree species that generally grow in dry habitats. This is not the case in the uplands where land use has not resulted in a fundamental hydrologic/soils change and afforestation occurs along expected successional gradients.

8. ***Urban Forest Change.***

Urban forests in the coterminous United States are estimated to produce about 61 million metric tons (67 million tons) of oxygen annually, enough oxygen to offset the annual oxygen consumption of about 2/3 of the U.S. population. Although oxygen production is often cited as a significant benefit of trees, this benefit is relatively insignificant and of negligible value due to the large oxygen content of the atmosphere. Other benefits of the urban forest are more critical to environmental quality and human health than oxygen production by urban trees.

9. ***High Ecological Resolution Classification for Urban Land and Ecological Systems (HERCULES).***

User derived percent cover of land cover element is surprisingly in agreement with computer generated covers at about an 80% level. There are some patterns in the level of agreement in terms of which elements of land cover a human user routinely under or overestimates.

10. ***Environmental Justice.***

Our environmental justice research on long term trends of household location and floodplains, streams, and shorelines indicates that low-income whites disproportionately live in floodplain areas. The proportion of these households diminishes in the 1960s as formal segregation ends and black populations have more freedom to choose where they live.

Household location associated with current and historic streams is not different from general location proportions for the city.

In the case of current shorelines, high-income white households are disproportionately associated with these areas, particularly in recent decades.

These trends reflect larger processes associated with historic preferences to live close to work (manufacturing jobs located in floodplains), long term segregationist housing practices, and regional demographic changes with older, and lifestyle trends associated with more affluent white households moving back into the city to live close to the water and city amenities.

Variance data has now been overlaid with demographic data and with financial "redlining" data. This allows an analysis of the correlation between race, poverty and redlining and the location of environmental disamenities in Baltimore. This will be one of the only studies to present a causal analysis of the current distribution of environmental disamenities in a US city.

Findings Addressing Question 2: This question evaluates fluxes of energy, matter, capital, and population in the Baltimore ecosystem.

1. ***Fluvial Geomorphology***.

Several important findings have emerged from the meta-analysis of urban fluvial geomorphology for the Eastern US Piedmont.

- In every case where stream cross-sections were measured before and after urbanization, very little incision occurs post-urbanization. Rather, urban systems occupy fluvial systems that are entrenched. Doubtless stream widening occurs, however there is little evidence for incision in cases where both pre- and post- data are available.
- In addition, even in deeply entrenched stream systems, there is evidence that floodplain sediment accumulation continues in the Gwynns Falls. This corroborates recent findings by Allmendinger et al. (JAWRA, 2007) that floodplains continue to act as a sediment sink even in urban systems.

- These findings indicate that some symptoms assigned to the urban stream syndrome (e.g., lowered water tables in riparian zones) were likely established before urbanization and resulted from processes other than urbanization. As a consequence, caution is necessary in restoration of streams in urbanized eastern US Piedmont systems.

2. ***Stream Studies.***

- Our primary product is a continuous data stream, published annually, with some station data available in near real-time.
- Streamflow distribution of nutrient loading is dependent on upstream land use, which has important implications for restoration potential.
- Using standard stream spiraling equations for nutrient uptake, reaches with heavily urbanized catchments show little potential for significant nutrient reduction due to in channel restoration, and require watershed flow modification.
- Hysteresis effects in annual flow-N concentration in mixed land use catchments indicates the degree of system memory to drought, with important implications for receiving water body eutrophication due to interannual climate variability.
- DOC and FPOM concentrations were greater in more urbanized catchments and in elevated flows; urbanized streams likely export huge quantities of organic matter.
- Water temperatures in summer were higher in more urbanized streams; small catchments exhibited a large spike in temperature that did not immediately cease with the cessation of surface runoff, indicating that shallow groundwaters may also be higher in temperature. A significant portion of the summer stream temperature distribution fell outside the tolerance limits of a number of fish species.
- *E. coli* concentrations are higher in more urbanized streams, but *E. coli* 0157 also was detected in less urbanized catchments suggesting that sources other than leaky sewers may be important. Longer than expected in-situ survival rates of *E. coli* 0157 also suggest that these pathogens are able to survive outside their host bodies and do not die quickly after spending time in aquatic environments.
- Ultra urban small catchments may be hotspots for the export of urban runoff pollutants (metals, nutrients, BOD, etc), with concentrations exceeding background and regulatory levels in both baseflow and stormflows. With both high concentrations and flows (on a per hectare basis) these watersheds likely have extremely high export rates.

3. ***Stream Chemistry.***

Measurements of major cation concentrations in a wide variety of archived BES stream water samples has uncovered exciting initial results, including:

- Flow weighted average calcium (Ca) concentrations are strongly related ($r^2=0.84$) to road density in the basin contributing water to the station.
- This excess Ca does not seem to be related to road salting activities (e.g., Co-PI, Sujay Kaushal's work on sodium dynamics), as the largest flow weighted average sodium concentration occurs in Dead Run, which has lower road density and Ca concentrations relative to other basins. If road salt were the explanation for the higher Ca concentrations, we would expect stronger relationships between flow weighted sodium and calcium.

- At the storm sewer-dominated station (Rognel Heights), the Ca/Mg ratios suggest the source of Ca is dominated by weathered concrete.
- At most stations, the Ca/Mg ratios seem to follow those observed in the Cockeysville Marble, potentially indicating weathering of building or road materials.
- At several stations (Dead Run and Glyndon) Ca/Mg ratios suggest the input of additional Mg, potentially from the mafic bedrock underlying large proportions of these basins.

This work is being organized into a journal article, and has important implications for ecological processes in the BES watersheds.

4. ***Cross System Comparisons of Urban Environmental Effects on Soils.***

Results of the effects of urban environments on the chemical properties of forest soils in the metropolitan areas of Baltimore, New York, and Budapest showed that soil chemical properties varied with measures of urban land use in all three cities; including distance to the urban core, which was an unexpected result. Moreover, the results showed that the spatial extent and amount of change was greater in New York than in Baltimore and Budapest for those elements that showed a relationship to the urbanization gradient (Pb, Cu, and to a lesser extent Ca). The spatial relationship of the soil chemical properties to distance varied from city to city. In New York, concentrations of Pb, Cu and Ca decreased to approximately background concentrations at 75 km from the urban core. By contrast, concentrations of these elements decreased closer to the urban core in Baltimore and Budapest. Moreover, a threshold was reached at about 75% urban land use above which concentrations of Pb and Cu increased by more than twofold relative to concentrations below this threshold. Results of this study suggest that forest soils are responding to urbanization gradients in all three cities, though characteristics of each city (spatial pattern of development, parent material, and pollution sources) influenced the soil chemical response.

5. ***E. Coli*.**

E. coli ensconced in dialysis tubes (50 kD MW cutoff) at a concentration of 10(8) cfu / ml were capable of surviving periods of > 80 days of submergence in streams in the metro Baltimore, MD area.

6. ***Hydroclimatic Variability on Nitrate Export from Urban, Suburban and Agricultural Watersheds.***

There was considerable interannual variability in discharge in the Baltimore LTER watersheds during the drought and wet years, with prolonged low flows during the drought followed by peaks in discharge during 2003, including Hurricane Isabel in September. We observed a clockwise hysteresis in discharge-weighted mean annual nitrate-N concentrations. Nitrate-N concentrations declined as runoff declined during the severe drought and then rapidly increased when runoff increased during the wet years such that there were markedly different nitrate concentrations at similar runoff values depending on if runoff was in a decreasing or increasing phase, i.e. hysteresis.

Annual nitrate-N export from the Baltimore LTER watersheds showed significant interannual variability between 2000-2004, with declines during severe drought (2002) and increases during extreme wet years (2003, 2004) (See Figure 1). Nitrate-N exports were considerably higher in suburban, urban, and agricultural watersheds (1.4 to 39 kg N/ha/y) than in the forested reference watershed (0.03 to 0.2 kg N/ha/y).

Watershed retention of N also varied substantially from 2002 - 2004, with much higher retention during drought years than wet years. Retention ranged from 99% to 76% in the forested watershed, 94% to 41% in the agricultural watershed, and 85% to 35% in the suburban watershed. The retention estimate encompasses N stored in soils and vegetation, gaseous losses, and harvest and export of crops and residential grass clippings and leaves. The patterns in nitrate concentrations, export and retention that we observed were likely driven by differences in watershed processing of nitrogen during dry and wet conditions. High retention is commonly observed during dry years as the residence time of reactive nitrogen in the watershed is longer, facilitating retention by plant, soil and microbial processes. In-stream processing of nitrogen is also facilitated by low flows and longer residence times. While retention is expected to decline in all watersheds during wet years, we observed marked declines in retention in the suburban watershed (from 85% to 36% from 2002 to 2003) and the agricultural watershed (from 94% to 41%). Several studies have shown that N retention in suburban and urban watersheds can be considerable, i.e. > 65%. Our results here, however, suggest that suburban watersheds may also be prone to high nitrogen export during high flow conditions. This vulnerability can result from extensive hydrologic manipulation of suburban watersheds that facilitates rapid export of nitrogen that accumulates during dry periods when high flow conditions return. There may also be a limited ability for interaction with biological "hot spots" of denitrification in urban streams during pulses of runoff from impervious surfaces during

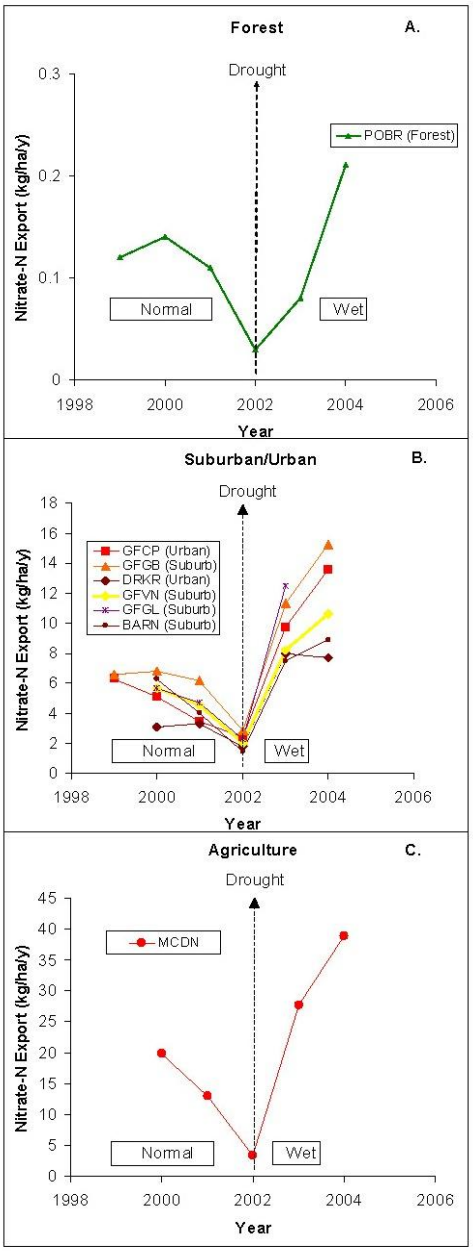

Figure 1. Annual nitrate-N exports from 8 Baltimore LTER watersheds during 2001-2004 (McDonogh-MCDN, Agricultural), (Pond Branch-POBR, forested), Baisman Run-BARN, suburban) and Dead Run-DRKR, urban) and longitudinal reaches of the Gwynns Falls (Glyndon-GFGL), Delight/ Gwynnbrook (GFGB), Villa Nova (GFVN), Carroll Park (GFCP).

storms. This may be particularly important in our suburban/urban watersheds, where most of the nitrate-N export occurs during high flow. Surprisingly however, the percentage increase in nitrate-N export from dry to wet conditions appeared to be no greater in the suburban/urban and agricultural watersheds than in the forested watersheds. The lack of change in percentage nitrate-N export was surprising given the extensive hydrologic modification of suburban and urban watersheds, but may be due to the large effect of climatic conditions during the study period.

These results suggest that urban land use can increase the vulnerability of ecosystem nitrogen retention functions to climatic variability. Further work is necessary to characterize patterns of nitrate-N export and retention in small urbanizing watersheds under varying climatic conditions to improve future forecasting and watershed scale restoration efforts aimed at improving nitrate-N retention.

7. ***Land Cover Influences on Air Temperature.***
In Baltimore, land cover decidedly influences air temperature, but the influence of land cover depends strongly on atmospheric stability. Elevation has a significant influence on air temperature in Baltimore.

8. ***Urban soil biodiversity.***
In only three forests a total of 35 ant species has been recorded. There was no difference in species richness between urban and rural forests. Ants are an arthropod group successfully colonizing urban environments. Our biotic homogenization analysis showed that the correlation between geographic distances and faunal dissimilarities were weak for homogenizing species, and those were higher and positive for native species. This indicates higher spatial turnover of species composition and a distance decay of similarity for native species but not for homogenizing ones.

9. ***Earthworms and Zn accumulation.***
After a 30-day exposure, there was no significant correlation between earthworm Zn body burden and Zn dose which was not unexpected. Zinc is an essential micro-nutrient for earthworms and is physiologically regulated. Zn storage in the intestine as a whole is positively correlated with dose as opposed to the total body burden. In addition, there is a change in the pattern of Zn storage with in the intestine with changing dose. This pattern suggests bioaccumulation via saturable uptake kinetics and potential "spillover" of Zn into a secondary storage pool within the chloragosomal cells associated with metal regulation and storage.

10. ***Wireless sensor networks for soil monitoring.***
The second generation mote design performs very well. The installation of the newly developed software, KOALA, allows us to access the data remotely in two sites (JHU campus and Cub Hill).

11. ***Carbon Storage in Residential Lands.***

Parcel-level sampling. The core of this work is the parcel-level sampling at thirty-three sites in ten "clusters," where we are testing hypotheses about biophysical vs. social science drivers of carbon cycling in residential systems.

As of February 2008, we have two full years of C flux measurements for the fifteen or so sites where measurements began in spring 2006 and one full year for all thirty-three sites (Table 1). These measurements include a) soil chemical analysis (one-time sampling), b) thatch, stubble, and clipping collection for grass productivity analysis, and c) soil respiration.

Carbon stocks and fluxes in residential landscapes
Baltimore Ecosystem Study
Key to sampling clusters
Jenkins, January 2007

			HERCULES 6.0				number of households recruited to date
cluster ID	**land use history**	**housing age**	**coarse veg density**	**structure density**	**soil group**	**neighborhood**	**(December 2006)**
1	agricultural	0-10	2	1	manor	Baisman	2
2	agricultural	10-30	2	1	manor	Baisman	3
3	forest	0-10	5	2	manor	Baisman	3
4	forest	10-30	5	2	manor	Baisman	4
5	forest	30-50	3	2	manor	Glyndon	4
6	agricultural	30-50	3	2	manor	Glyndon	4
7	forest	30-50	3	3	manor	Glyndon	4
8	forest	30-50	4	2	manor	Glyndon	4
9	unknown	50+	5	1	legore	Rognel	4
10	unknown	50+	5	1	manor	Glyndon	1
							33

comparisons summarized:

soils	9 vs. 10	(possible to find enough candidate sites given low household numbers?)
age	1 vs. 2; 3 vs. 4 vs. 10	(note structure density differs among these 3)
land use history	5 vs. 6	
veg density	5 vs. 8 vs. 10	(note structure density differs among these 3)
structure density	5 vs. 7	

Notes:
Each "cluster" refers to a set of sites with identical characteristics. *Within each of the 10 clusters, we need to identify 4 landowners willing to participate in the study.*
This should give us a total of 40 homes/ lawns for sampling.
This sheet contains the overall list of clusters and the comparisons in which each will be used.
Each sheet after this one is named according to its cluster number on this sheet, and contains the full list of candidate households falling in that cluster.
All landowner data come from Maryland PropertyView 2003.

Table 1. Key to Neighborhood Clusters in the Residential Carbon study. Note different categories of land use history, residential age, soil type, coarse vegetation density, and structure density. Comparisons among site types will be accomplished by varying one variable while holding all others constant, as indicated in the "comparisons summarized" section.

Results to date suggest that differences do exist between a) clusters and b) sampling months in thatch and stubble mass from sequential coring (Figure 2). The data shown here are from 2007, and show similar patterns to the data from 2006.

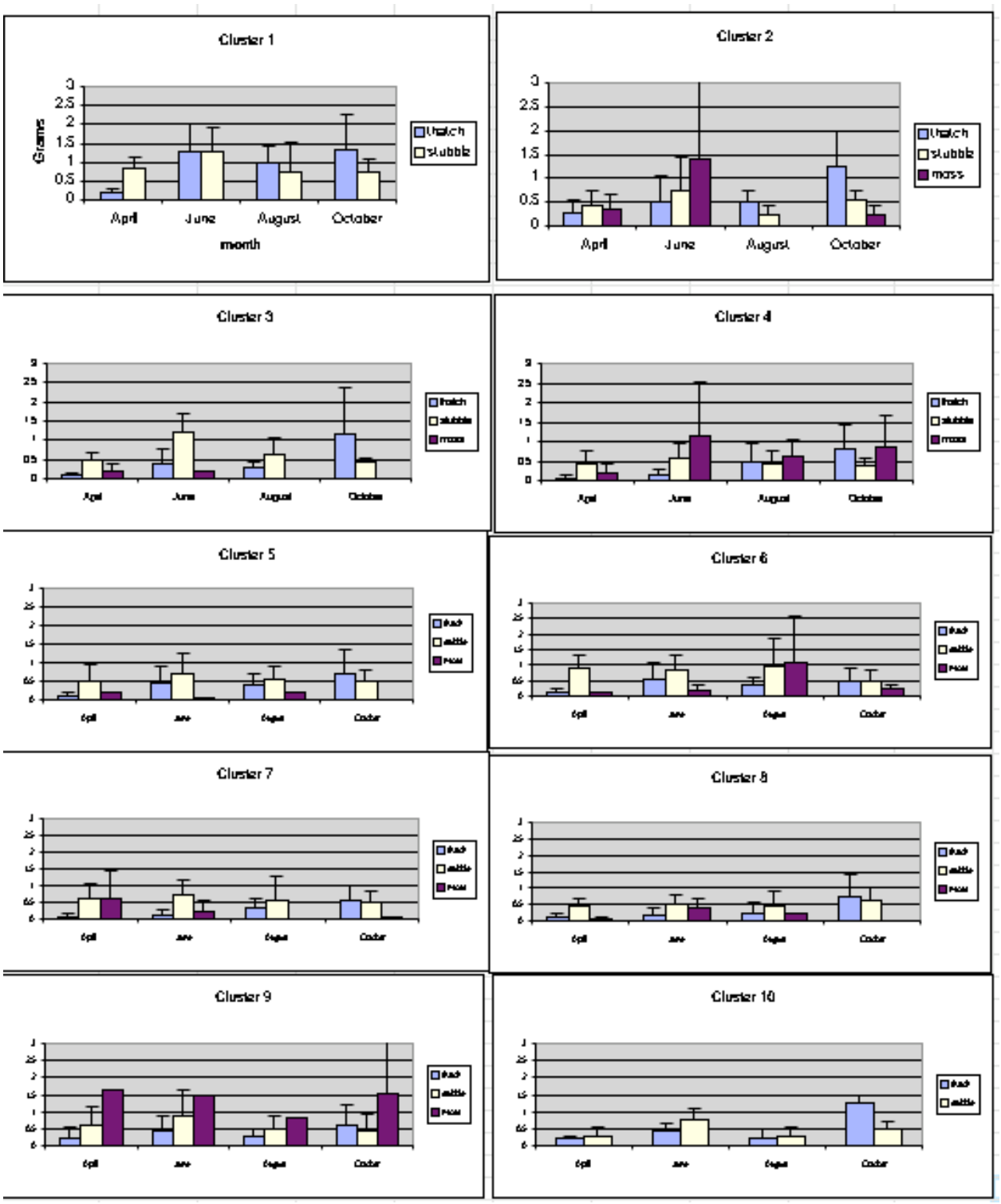

Figure 2. Thatch, stubble and moss data from all clusters for April, June, August and October 2007. Each panel shows a different cluster; each bar (with standard deviations based on three samples) shows a different sampling date.

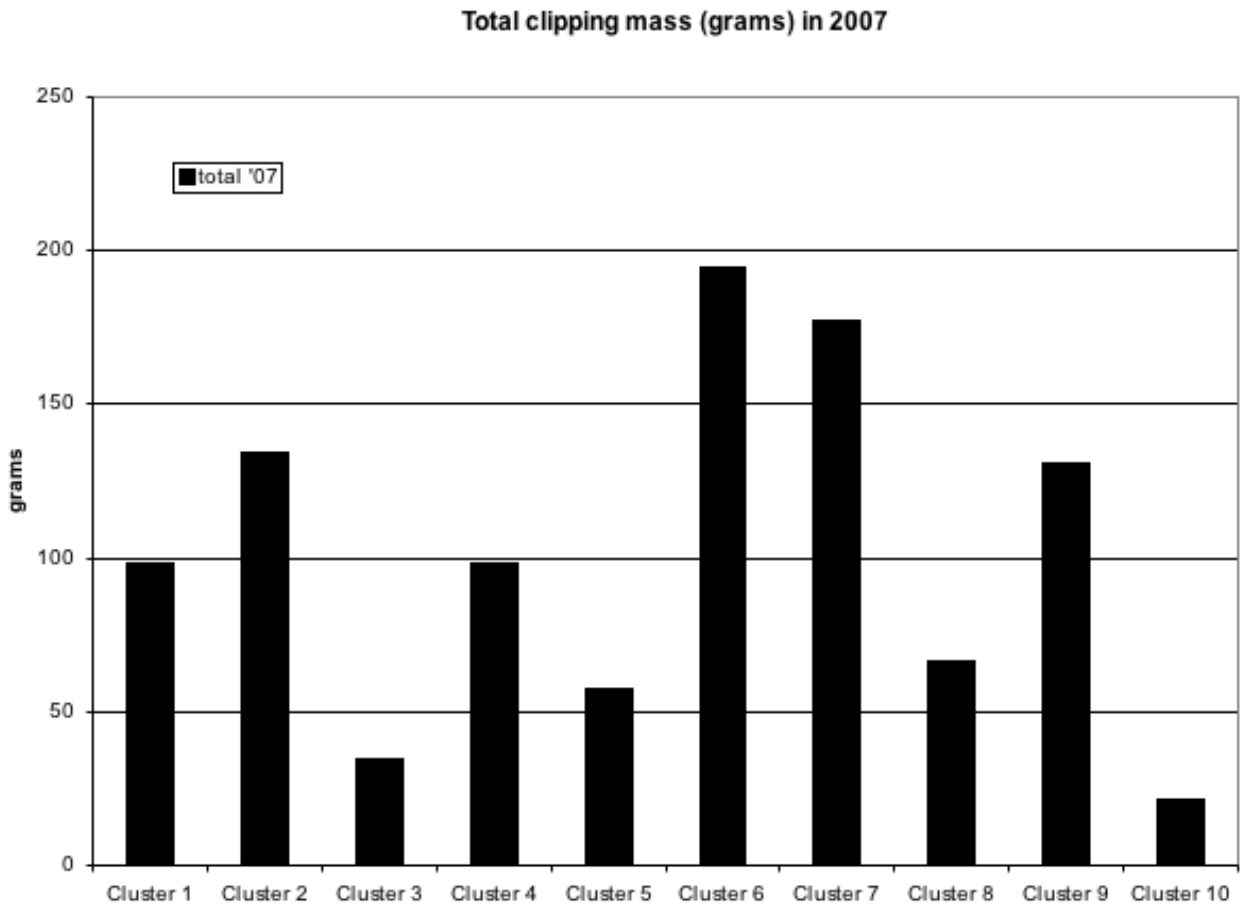

Figure 3. Total clipping production from clusters 1-10 from January to December 2007.

Even more compelling is our preliminary evidence that clipping production varies dramatically between clusters (Figure 3). We note that at the young, former agriculture clusters (1 and 2), clipping production seems to be higher than in the older, formerly forest clusters. We also note a potential effect of residential age on clipping production: all else equal, homes in the 10-30 year old range on former forest may be producing more clipping mass than lawns surrounding homes in the 0-10 year old range (clusters 3 and 4). Results from the chemical analysis of soils will help to clarify this effect.

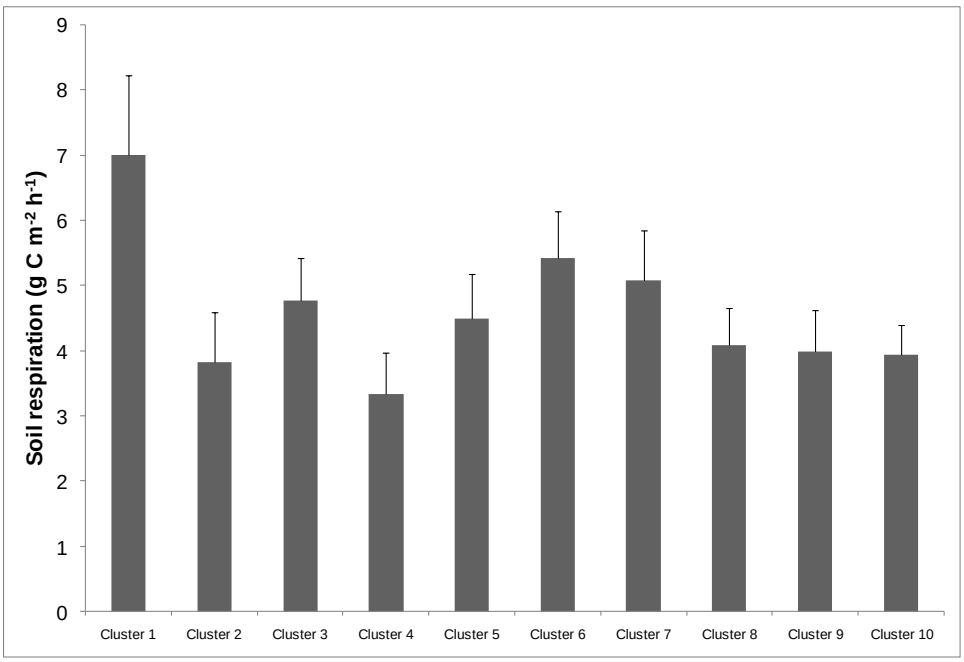

Figure 4.
Annual mean soil respiration in 10 clusters. Values are mean (standard error) of 10 monthly sampling dates from May – December 2007.

Soil respiration does not show strong patterns by cluster (Figure 4), but is strongly driven by temperature and moisture (Figure 5). Further analyses are underway to compare aboveground production versus soil carbon content as drivers of respiration and to determine how cluster characteristics influence the main drivers of respiration (temperature, moisture, soil carbon).

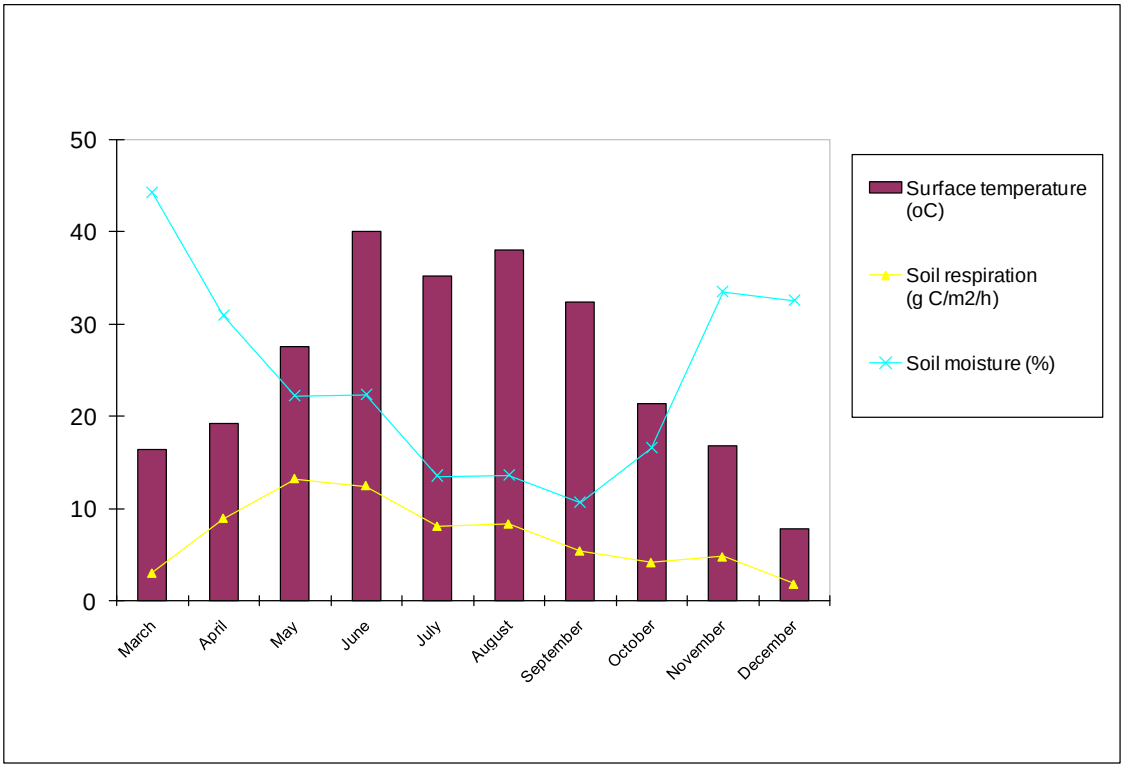

Figure 5.
Soil respiration, surface temperature and volumetric moisture content in soils of cluster 1 from March – December, 2007.

Household survey. Results from the household survey suggest a mixture of lawn management activities (Figure 6).

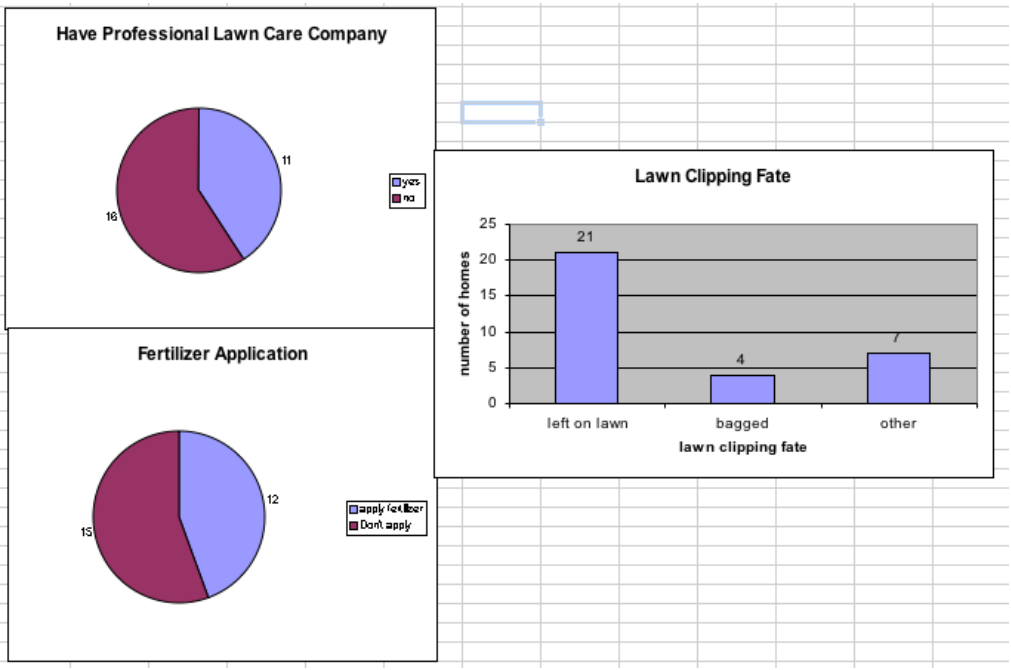

Figure 6. Preliminary results from household survey of lawn management practices.

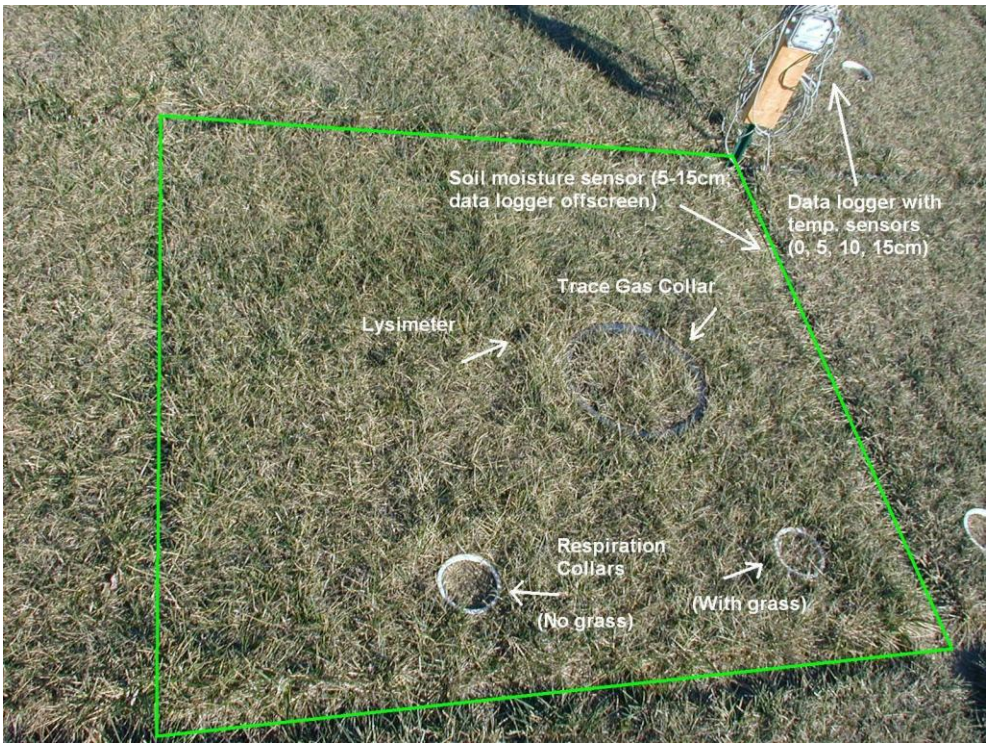

Figure 7. An instrumented sampling unit. Each unit has two respiration collars, one with vegetation and one with vegetation removed; one trace gas collar, and one tension lysimeters installed at 30cm. Each split also has data loggers collecting soil temperatures at the soil surface, 5, 10, and 15cm, and soil moisture at 5-15cm.

Controlled experiment: turfgrass management effects. Results from the controlled management experiment (Figure 7) suggest a variety of treatment effects.

The combination of irrigation + fertilization seems to have a much larger effect than irrigation alone on clipping production (Figure 8). Respiration seems to be influenced more strongly by irrigation than by fertilization (Figure 9).

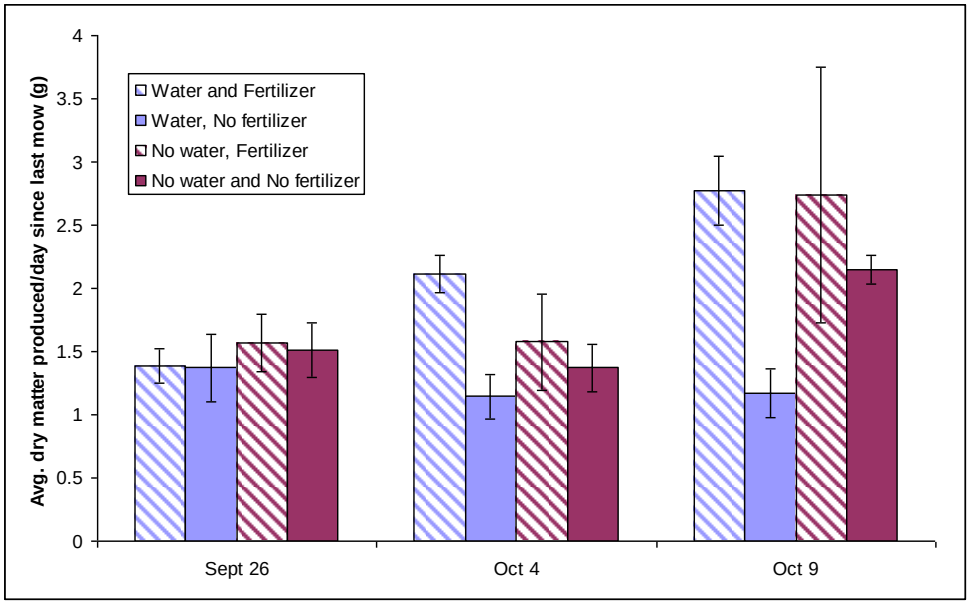

Figure 8.
Clipping production at several mowing dates after the first fertilization treatment, averaged by treatment over all blocks. A strong fertilizer effect is apparent with irrigation, but not without.

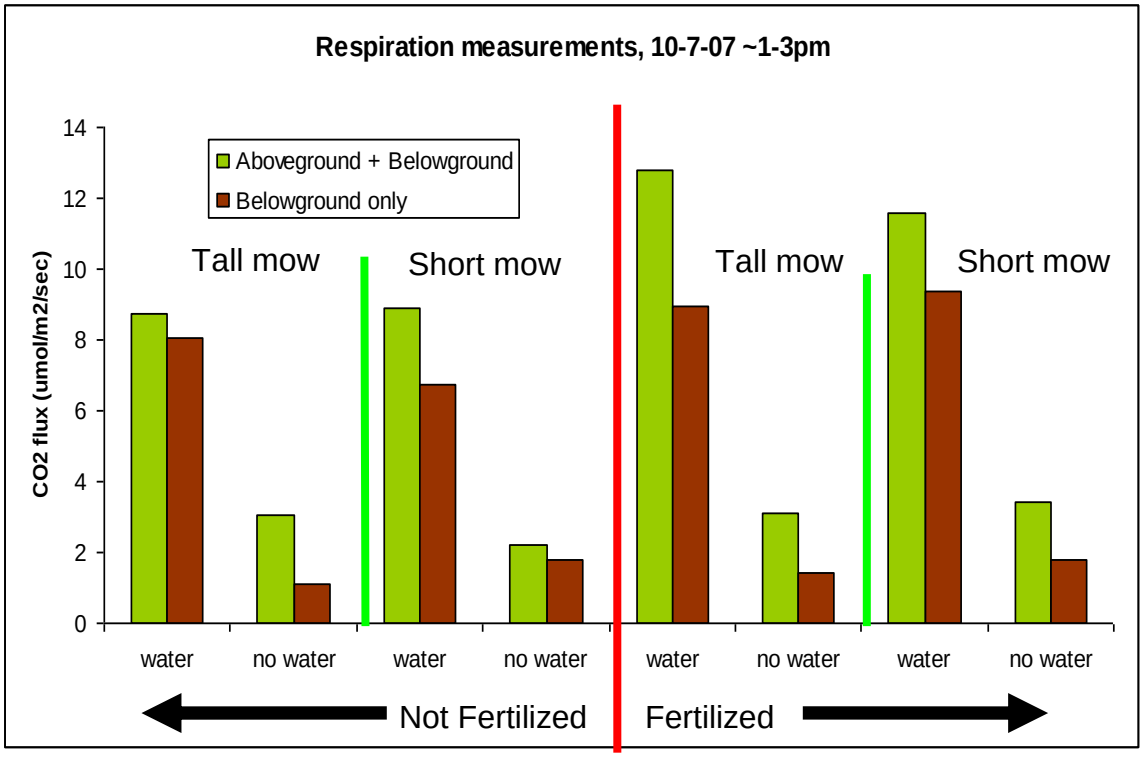

Figure 9. Representative sample of respiration data. Not surprisingly, there is an obvious irrigation effect. There may be a small fertilization effect as well, but that has not been confirmed as yet. Mowing height does not seem to have any effect.

12. ***Salt Runoff.***

Grad student Pete Bogush is finding that N and C removal in both stream sediments and benthic organic matter is changing under elevated salt concentrations.

Grad student Robin Van Meter is finding that road salt disrupts the interaction strength between food web components in ponds, with consequences for pond trophic state.

Findings Addressing Question 3: How can people develop and use an understanding of the metropolis as an ecological system to improve the quality of their environment, and to reduce pollution loadings to downstream air- and water-sheds?

The findings and outcomes reported here deal with the feedback between ecological, physical, and social knowledge, and the behaviors and actions of individuals and institutions. This section reviews accomplishments in transferring knowledge that can inform environmental actions and decision makings, including school, non-formal education, and interaction with managers and policy makers. This question also illustrates how BES is engaged with the communities and institutions in Baltimore.

1. ***Education Research: Describing Baltimore's Ecology Education System.***

Inventory of Urban Environmental Education Providers in Baltimore. Co-PI Alan Berkowitz continues to analyze the results of the Inventory. He presented a paper in the Research Symposium portion of the annual meeting of the North American Association for Environmental Education in fall 2007.

2. ***Education Research: Investigations in Ecology Teaching.***

- Responsive Teaching Study

We now are analyzing the results of two years of intensive professional development with teachers, and research with the teachers and their classrooms. Presentations based on this research were made at the annual meeting of the Ecological Society of America in August 2007, and at the BES Annual Meeting in October 2007. Papers based on this research are in preparation.

- The Ecology Teaching Study

Results of the Ecology Teaching Study, described in previous reports, were presented in a paper at the annual meeting of the Ecological Society of America in August 2007, and are being included in manuscripts now in preparation.

Additional Findings:

- Enhanced and better integrated the operations and activities of BES, with existing Parks and People Foundation projects and local partners.

- Increased the body of practical knowledge of how urban residents develop an understanding of the metropolis as an ecological system to improve the quality of their environment and daily lives.
- Increased understanding of participatory approaches to long-term integrated urban ecological research as it relates to public agencies and non profit organizations.
- Strengthened relationships in Watershed 263 between community leaders and BES scientists. Built Watershed 263 Stakeholder Council to serve as community voice in watershed restoration project.
- Strengthen existing relationships with Baltimore City government agencies and elected officials.
- Developed a 2008 Teacher and Staff More Kids in the Woods Workshop and Program Survey.

Contributions

1. ***Within Discipline.***

- Contributions to Hydrologic Community Model development through formal workshop and informal activity.
- Linkage of household and neighborhood community structure and activity within watershed ecosystem framework.
- Introduced and elaborated on 1) the idea of urban stormwater infrastructure drainage density providing a "gutter subsidy" in organic matter and other water quality constituents to urban streams, 2) the idea that older "ultra urban" watersheds contribute even greater pollutant loads than was thought, and that 3) urban hydrologic systems, with their alternate sources of water (potable, sanitary sewage and stormwater) may mimic the function of a "karst" landscape, with dry weather flows contributing to receiving stream impacts as well as stormwater.
- Showed that the transport of organic matter, both dissolved and particulate is highly driven by hydrologic variables and that urban areas may be huge exporters of dissolved and particulate organic matter.
- Showed that older urban catchments may be hotspots for the export of a variety of water pollutants (nutrients, metals, etc) and that many of these may be buried streams that can transport appreciable annual loads during dry weather flows that may exceed those exported during storms (at least in dry years.)
- Showed that *E. coli* ecology in urban streams is likely more complicated than previously thought, with these pathogens surviving long periods and possibly being part of a complicated system that not only includes leaky sewers and impervious surface sources as sources for short lived *E. coli* in streams, but likely aquatic refugia where these microorganisms can survive
- Streamflow data provided on a regular basis and on special request to individual investigators. USGS scientists have participated on a continuing basis in appropriate BES planning and scientific meetings, including the BES Steering Committee. USGS is providing leadership in general hydrologic investigations in cooperation with other BES Co-PI's and collaborators.

- Research on the long-term environmental equity patterns and processes in Baltimore amends current contributions within geography, sociology, and environmental studies that have tended to focus solely on distributional analyses. By incorporating an analysis of the historical development of institutions related to amenities and disamenities, this project demonstrates the value of incorporating procedural equity analysis into environmental equity studies. A long term understanding of these processes—part icularly the role of legal, political, and regulatory institutions—contributes to broader comprehension of urban and social dynamics.
- Papers are being prepared on the successional development of uplands and lowlands in the Gwynns Falls Watershed.
- Studies on riparian vegetation are leading to recommendations with respect to whether or not denitrification has been reduced in riparian areas—this would affect the water quality of the streams and ultimately the Chesapeake Bay.
- HERCULES has proven to be a better tool to test the structure function link in urban systems than traditional land use/land cover classifications. It is an effective tool to characterize and quantify spatial heterogeneity in urban landscapes. Development of HERCULES has questioned assumptions embodied in widely used land use classifications and demonstrated why they may be limited when used for understanding the ecological function of systems.
- Demographic and social research contributes to Geography, Sociology, and Regional Sciences by revealing a more nuanced understanding of the relationships among household locational patterns and choices in a spatial and temporal context associated with environmental amenities and disamenities and affected larger social forces.
- The project maintains the first permanent urban flux tower—technical, maintenance and management.
- The team developed a unique format for researching and mapping zoning decisions over time. This method will also be published for use in other cities. This provides raw data for a causal analysis of environmental justice, and constitutes a groundbreaking method for identifying and mapping zoning outcomes in a city.
- Our research on modeling air temperatures contributes to the discipline of meteorology.
- We are beginning to understand the consequences of road de-icer runoff on trophic interactions in adjacent waterways.
- Contributions to soil ecology are related to invasive species and toxic metals.
    - Species invasion is a global environmental problem, and cities are not only 'hotspots' for species introduction, the urban environment facilitate colonization and spread of non-native species. While there are several studies examining patterns of urban biodiversity in vertebrates and plants, to our knowledge this is the first attempt to synthesize urban soil invertebrate species distribution data. Understanding the ecology of non-native species and their behavior and population characteristics is essential for understanding the mechanisms of species invasion and management of invasive species. The results of this work highlight the complexity of the biotic interactions between and among species and trophic levels, and the implications for carbon transformations and long term carbon storage in soils.

- A major impact of urban development is an increase in the concentration of potentially toxic trace metals in soils and surface waters. A primary source of trace metals to near-surface environments in urban ecosystems is roadway runoff and dust. The study on the effect of earthworms in roadside zinc accumulation and transformation will lead to better understanding the fate of this important pollutant. This is significant because earthworms are important food sources for predators, and thus represent the entry point for the food web.
- Service on the Editorial Advisory Board for Springer's new series on "Future City."
- Service on the Editorial Board and the Editorial Advisory Board of Urban Ecosystems.
- Participation in the joint US-China workshop on Urban Ecology, June 2008, to explore and facilitate enhanced comparative urban research.

2. ***To Other Disciplines.***

- Education: Interdisciplinary collaboration is at the heart of BES education work. By integrating education with the BES scientists' work and science with our education work we strengthen all aspects of the project.
- USGS data and products are widely used in the geosciences and natural-resources management communities.
- HERCULES, our new land classification system serves as a tool for urban designers and planners. It operationalizes the concern for heterogeneity in designed systems and understanding the link between the structure of the systems they are designing and building and the function of those systems. The integration of biogeophysical heterogeneity captured by HERCULES and the social heterogeneity captured by census and consumer data has been useful for integrating social and biophysical ecology.
- Demographic and social research developed novel spatio-temporal methods for relating household locational patterns with high-resolution ecological phenomenon. These methods are crucial for long term spatial analysis of social ecological change in urban areas.
- Environmental law and environmental policy. The project provides powerful data on the outcomes of local environmental decisions over time. This should guide local environmental decision making in the future and provide guidance on local environmental policy development.
- As inexpensive computing devices become pervasive, scientific experiments increasingly use on-line data acquisition and monitoring. Multiple sensors collect densely sampled data streams, making data acquisition easy; but, it requires a substantial effort to turn the raw data into a scientifically meaningful, calibrated data set. To build an end-to-end system that collects real data, and to test the system in several domain sciences is an interest for computer scientists and engineers. Wireless sensor networks will revolutionize environmental monitoring. Our comparative measurements will allow giving more accurate estimates on soil CO_2 fluxes and the effects of land use and land cover on those fluxes.

3. ***To Education and Human Resources.***

- All of the BES education effort from the "My City's An Ecosystem" curriculum for KidsGrow, to ecology units for high school students, to work with IGERT graduate students, contribute to the development of an ecologically literate citizenry in Baltimore, and, potentially, to a new generation of urban ecologists.
- USGS moved its staff, field, library, conference, and laboratory facilities to UMBC on August 13, 2007 and its resources are now available to students, staff, and other researchers.
- Working on HERCULES has provided training in basic ecological concepts such as landscape ecology, urban ecology, and spatial heterogeneity and basic GIS skills for several graduate students and post-docs: (K. Schwarz, Ph.D. candidate, Rutgers University, James McConaghie, Ph.D. student, UC Davis; W. Zhou, Post-doctoral scholar, UC Davis).

4. ***To Research and Higher Education***

HERCULES:
- HERCULES provides a base layer of system heterogeneity that can be used to stratify investigations of other structural or functional variables. These can be ecological or be drawn from any number of other disciplines such as hydrology, soil science, social science, urban design, and economics.
- HERCULES exposes the constraints of widely used land cover/land use classifications that are derived from the Anderson et al. (1976) system.
- HERCULES provides an alternative tool to better describe the ecological structure of urban systems so that the link between system structure and ecological function can be tested
- HERCULES can be integrated with ancillary data either from ecology or other disciplines.
- HERCULES has been used in urban design studios at Columbia University.

Environmental justice data will be very useful in emerging curricula for urban high schools. Our team will work with the IMD curriculum developers at Boston College to include these data and the maps in the environmental justice section of a new urban environmental studies course being developed by the Lynch School of Education at Boston College.

The maintenance of weather stations in Baltimore is a contribution to both research and education.

Training/Development

Both graduate and undergraduate courses have been taught using material from BES—graduate and undergraduate student research has resulted.

In collaboration with BES Co-PI's graduate student Peter Bogus is completing his thesis by processing samples at BES Labs and working at BES field sites.

Paul Lilly, PhD student at the University of Vermont, advised by Co-PI Jennifer Jenkins, began work on the residential carbon studies in fall 2005 and has continued his work this year. Paul has spent the summers of 2006 and 2007 in Baltimore, helping with the fieldwork on this project and doing background research to support his dissertation. He has been the primary investigator responsible for the controlled turfgrass experiment at the University of Maryland Turfgrass Research Facility, and has been helping with the vegetation survey data collection and analysis as well.

Monica Smith, PhD student at the University of North Carolina, advised by Co-PI Larry Band, and Steve Raciti, PhD student at Cornell University, advised by Tim Fahey, are conducting infiltration studies on a subset of the thirty-three plots as separate components of their PhD dissertation projects. Raciti will also analyze and publish the soil core data.

USGS provides regular development opportunities to its scientists and technicians through its National Training Center, other training, and conference attendance. Cooperators, including BES investigators, are eligible to participate in USGS training programs on a space-available basis.

Many of our Co-PI's and collaborators are involved in the training and mentoring of high school, undergraduate and graduate students, including minority students. Examples include: Mentoring of two Ph.D. students and one post-doctoral associate at UC Davis, all conducting research linking urbanization and ecosystem processes. HERCULES occupies a central role in the doctoral research of K. Schwarz, Rutgers University. Work with graduate students and faculty in the community development program at UC Davis to encourage collaborative cross disciplinary research activities on regional change, urbanization of the CA landscape, and environmental justice issues.

Establishment of a SEEDS chapter on the UMBC campus. SEEDS is the acronym for Strategies for Ecology Education, Development and Sustainability. It is an education program of the Ecological Society of America. Its mission is to diversify and advance the profession of ecology through opportunities that stimulate and nurture the interest of underrepresented students. Focused at the undergraduate level, opportunities sponsored by the program include student field trips, undergraduate research fellowships, ESA Annual Meeting travel awards, and campus ecology chapters. The purpose of the UMBC SEEDS Chapter is to stimulate interest in urban ecosystem ecology. The chapter aims to provide educational, research and mentoring opportunities for SEEDS students.

Planned, coordinated and hosted the BES Annual Staff Field Safety and Community Awareness Training Workshop, held on June 5th & 9th, 2008 at UMBC-TRC. Attended by approximately thirty researchers and interns from the Cary Institute, US Forest Service, BES, and Parks & People.

Supervised and trained undergraduate and graduate student interns in the following projects:

- Developing and leading Watershed Ecology Education enrichment program with Parks & People's SuperKids Camp.
- Developing organizing and capacity-building strategies for Watershed 263 Stakeholders Council.
- Conducting Green Space Survey and Database construction.
- Developing Green Career Ladder enrichment activities for BRANCHES summer youth forestry training and employment program.
- Developing, implementing and analyzing Green Career Ladder program administration and evaluation tools for BRANCHES and Maryland Civil Justice Corps.
- Leading environmental and ecological sciences field studies for BRANCHES summer youth forestry program.

Conducted community training on:

- Community Grants program opportunities,
- Capacity building and leadership development in Watershed 263,
- Rainbarrel Construction,
- Community Greening training in planning and carrying out community restoration projects.

5. ***Beyond Science and Engineering.***

USGS has added real-time capabilities to ground-water stations to provide drought warning and a regular data stream for supply, education, and water-resources management applications.

BES Co-PI's and collaborators are involved on the committees of a number of local Baltimore organizations such as: Tree Baltimore, Revitalizing Baltimore Technical Committee, Baltimore County Sustainable Forestry Initiative, as well as many others. One serves on the Baltimore City Sustainability Committee.

Urban Tree Canopy (UTC). First UTC prototype was developed for Baltimore and has now been applied to numerous cities in the U.S. Many of the associated publications focus on Baltimore.

BES provided the keynote address and several specialists for the Baltimore Watershed Conference, (March 1, 2008), which included Baltimore City and Baltimore County officials and managers as well as citizens of both jurisdictions.

BES principals and Forest Service collaborators participated in a field trip to Chicago to help introduce Baltimore Mayor Sheila Dixon to successful urban sustainability programs and models.

Members of BES helped introduce leaders in Dongying City, China, to the benefits and insights of urban long-term research, and provided comments on their urban greening initiatives.

BES insights played a key role in introducing Midwestern landscapers and landscape architects to "Fifteen Principles for the New Urban Ecology" in October 2007 in Cleveland.

Publications and Products

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Other Publications Related to BES Work

Audiovisual Material - Documentary

Barnes, L. 2008. Return to the forest where we live. Louisiana Public Broadcasting Company. Laudun, T. Senior Producer/Project Director. (Watershed 263 project was a focus.)

Magazine Articles

The following are magazine articles that mention the Baltimore Ecosystem Study.

Mims, C. 2007. A city's living secrets. Zoogoer. 36(3):8-13.

Hanscom, G. 2008. Where the wild things are: scientists explore the urban ecosystem, and our edgy relationship with wild animals. Urbanite. 49:48-53.

Engelhaupt, E. 7-8-2008. In a changing climate, cities worsen water quality. Environmental Science & Technology.

Chesapeake Quarterly 7(2). 2008. Special feature articles in Chesapeake Quarterly, a Maryland Sea Grant Magazine, which focused on Watershed 263: *Renewing an Urban Watershed, What will it take to green Watershed 263, an ultra-urban watershed in West Baltimore, and clean up the stormwater that flows through a network of subterranean pipes?* The article by Jessica Smits (*Organic Overload*) discussed how urban infrastructure can create an overload of organic matter in streams and other receiving waters and the organic matter research being done by BES researchers. Articles by Erica Goldman (*Greening Gray Streets, Can it Clean Waters Below?*, and *The problem with Pavement*) also covered the results of the Watershed 263 storm drain monitoring work being done by the US Forest Service and Baltimore City Department of Public Works and featured on-line photographs of the Baltimore and Lanvale Street monitoring sites. Published as hard copy and as on-line content at http://www.mdsg.umd.edu/CQ/V07N2/index.html#TOC

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Brittain, A. 8-1-2007. How to bring shade to a city. The Christian Science Monitor. Online. Mentions US Forest Service Forest Opportunity Spectrum (FOS); interviewed Morgan Grove.

Cohen, C. 12-2007. Baltimore observed: development. Disputed ground. Urbanite. December 2007, #42. Interviewed Peter Groffman.

Associated Press. 2-20-2008. Cities step up tree plantings. The New York Times. Online. Interviewed Charlie Lord, Jarlath O'Neill-Dunne.

Kobell, R. 2-26-2008. Buried streams pose risk to bay: underground waterways rush pollution to Chesapeake Bay. Baltimore Sun. Highlights work of Sujay Kaushal in identifying buried streams. Bill Stack, Baltimore City water chief also interviewed.

Michael, S. 4-22-2008. Down by the river. The Examiner, Baltimore Edition. Sujay Kaushal interviewed. Photos of Sujay and Tammy Newcomer. Talks about Sujay's work at UMCES on tributary rivers and the runoff that reaches the Chesapeake Bay.

Costanza, R. 3-10-2008. Our three-decade recession: the American quality of life has been going downhill since 1975. Los Angeles Times.

Databases

HERCULES: Additional data layers were added to the Baltimore Ecosystem Study geodatabase housed on the University of Vermont's (UVM) Spatial Analysis Lab. Data layers were also quality checked and documented with metadata. One of the most important data layers created by the UVM lab was high resolution land cover for the Gwynns Falls watershed for 2004. Data are currently available to all BES researchers by request. UVM is in the process of developing a multi-user geodatabase that will allow users outside the UVM campus to access, and "check out" data through a database connection.

Vegetation data bases. The data base on exotic species is being used by Parks and People Foundation in developing a management strategy for invasive species in Baltimore.

Demographic and socioeconomic characteristics of households in floodplains, and adjacent to historic and current shorelines, and historic and current streams from 1950–2000.

Created a database of **zoning variances** in Baltimore from 1930 to the present. These have been integrated with demographic and other data in a GIS format for presentation. An article for submission to top law reviews is being prepared.

METADATA: The BES metadata relational database has been mapped to extensible markup language to facilitate inclusion in the Long Term Ecological Research networks Metacat system. The Metacat system allows data from all LTER sites to be searched and combined.

Educational Products

1. ***Video/Photos.***

Friends high school students, under supervision of Co-PI Ken Belt, went out with BES research personnel and produced a PowerPoint and a movie of numerous BES research activities conducted during the summer of 2008. It will be available on the BES and Forest Service websites.

2. ***Biocomplexity and the Habitable Planet: Curriculum for Teaching High School Environmental Science.***

Co-PI Alan Berkowitz and Project Director Steward Pickett are part of the Principal Investigator Team developing this innovative capstone course for High School with collaborators from TERC in Cambridge, MA. Upon completion, "Biocomplexity and the Habitable Planet" will be a set of instructional materials that engages students, teachers, and their parents in the science of coupled natural human (CNH) systems. It will include two semester-long modules, each with two units, comprising student guides, teachers guides, an ecology primer, research protocols, and data and other materials from the LTER and/or BioComplexity research communities. During the 2007-8 period covered by this report, full drafts of each of the four units have been completed and distributed for pilot testing. BES members took a lead role in developing the unit centered around a case study of a local land use decision in Baltimore.

3. ***My City's An Ecosystem: A Handbook for After-School Program Leaders.***

My City's An Ecosystem is an engaging set of modules that integrate good, hands-on science, an emersion in nature, and development of citizenship and thinking skills for elementary aged youth participating in after school enrichment programs. The modules have been used by several KidsGrow after school programs at five different school sites in inner-city Baltimore. While designed for school-based sites which serve their own students, the curriculum also is suited for other types of after-school programs. Modules are available at the BES Baltimore Education office through bess.caplan@parksandpeople.org . They include:

Creating an Urban Ecology Center in Our Neighborhood
Habitats
Microclimates and Mesoclimates
Hurricanes
What Happens to Stuff?
Ecology of Food, Agriculture & Nutrition
Phenology
Water in the City
Black History.