Baltimore Ecosystem Study

Annual Report

2007

Covering

August 2006—August 2007

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

August 2007

www.beslter.org

Preface to the Annual Report

On the following pages is the Annual Report of the Baltimore Ecosystem Study (BES) for the period 2006-2007. 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 eight 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 located in an urban environment, we want to know the ecological interactions in the whole range of habitats—from the center city of Baltimore, out into 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 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 Area Master Gardeners
Baltimore-Chesapeake Bay Outward Bound Program
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Watershed 263 Community Council
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Woodberry Urban Forest Initiative

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 third 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 ninth 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. ***Soil and Land Use Controls on Contemporary Urban Upland Forest Communities.***

We have been analyzing upland forest plot data collected in the early 2000's.

2. ***A Longitudinal Analysis of the Social Dynamics of Environmental Equity in Baltimore. NSF Human and Social Dynamics Competition.***

Although this project was only recently funded, several investigators have initiated research and activities outlined in the proposal. Co-PI's Buckley and 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 association, 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 justice 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 a 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, Buckley, and Grove completed a spatial analysis of parks in relation to social groups for the Baltimore Metropolitan Region.

3. ***Ecology and Environmental Justice Research Across the LTER Network: Long-term and Multi-scale Understandings of Past, Present, and Future.***

In September 2006, Co-PI's Grove and Boone organized a workshop on ecology and environmental justice at the LTER All Scientists Meeting. A proposal was submitted and funded by the LTER network office for a follow-up workshop to investigate linkages between ecological and environmental justice theory. A group of scientists met in February. These discussions explored data sets and methods for conducting integrated analyses of ecosystem structure and function with environmental justice.

4. ***Ecology of Environmental Justice in Metropolitan Areas. National Center for Ecological Analysis and Synthesis Working Group Proposal (2008-2010).***

This proposed working group will bring together experts in ecology and environmental justice to examine the socio-ecological dynamics of environmental justice in three LTER urban sites – Baltimore (BES), Phoenix (CAP), and Miami (FCE). The working group will assess how the distribution of environmental inequities, measured by the spatial unevenness of ecosystem services, affects the vulnerability and resilience of socio-ecological systems to regime shifts. In ecological and social systems, regime shifts are significant alterations, often rapid, in the function and structure of those systems. The working group will also evaluate how social and ecological regime shifts affect the distribution of ecosystems services and environmental justice patterns.

5. ***A Social and Environmental Analysis of the Origins and Effects of Asphalt Removal Programs in Baltimore, Maryland.***

A research agreement with the USDA Forest Service for $10,000 will allow an environmental studies graduate student, Steve Brown, to begin work on this project in the fall. Steve will study parcels of land in the city where asphalt has been removed, focusing on the social and environmental benefits of removal (lower albedo, etc.) as well as the driving forces behind the removal efforts.

6. ***Policies, Planning, and Investments in Open Space Preservation and Conservation in Urban Areas: A Cross-Site Comparison of Baltimore, Maryland and Edinburgh, Scotland.***

Supported by an $11,000 dollar research agreement from the USDA Forest Service, this research was conducted by Ohio University geography graduate student Erin G. McCarty. Erin traveled to Edinburgh, Scotland during the summer of 2006 to examine green belt development records housed at the National Archives of Scotland. She also reviewed records at the Edinburgh City Archives, including the meeting minutes of the Edinburgh Council and the Lothian Regional Council – groups which played instrumental roles in the creation of the green belt. In addition, the Cockburn Association (Edinburgh Civic Trust) granted her access to

their archival records. Erin's archival research was buttressed by interviews with key individuals involved with, or familiar with, the green belt's early development and management. Upon returning to Athens, Ohio, Erin made several trips to Baltimore where she carried out open space preservation research at the Maryland Historical Society and at municipal and county planning offices. Ms. McCarty completed her thesis in June 2007.

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

The HERCULES patch layer of the City of Baltimore and the Gwynns Falls watershed using 2004 images was completed. A comparative study drove completion of a HERCULES patch layer for the landscape surrounding three rivers in the Cincinnati metropolitan area. A 100 m wide buffer zone was established around each river to assess bird diversity. A HERCULES Atlas, a description of the high ecological resolution land cover classification system has been drafted to support use in urban design.

8. ***Urban Tree Canopy.***

The main project activity for this past year has been completion of the data entry and beginning of the analysis of the 2004 permanent plots within the cities 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.

9. ***Tree Influences on Exposure of Pedestrians to Ultraviolet Radiation.***

Ultraviolet radiation (UVB) is monitored in central Baltimore. The influence of tree cover on pedestrian exposure in different land use classes during summer months is determined by modeling trees and their influences on UV radiation transmission to ground level.

10. ***History of Trees.***

A manuscript has been completed which describes the successional history of trees in an urban environment.

11. ***Insect Pollination in Urban and Suburban Gardens.***

Sampling of bee richness in New York City community gardens and private gardens in Westchester County, NY continued. Factors that co-vary with bee richness in urban and suburban gardens were identified. Pollen limitation on cucumbers grown in urban community gardens was assessed. Pollen types deposited on cucumber stigmas in urban community gardens were identified. The Pollinator Project website was developed for the Lindbergh School District in St. Louis, MO.

12. ***Bird Populations and Diversity.***

A distinguishing feature of the bird monitoring at BES LTER, relative to other urban bird work, is the capacity for long-term monitoring of features at multiple scales through links to other parts of the project. Different processes influence habitat for birds at different scales, e.g. ongoing household level human decision-making at lot

scale vs. block or neighborhood scale abandonment/re-development. Some lot-level human actions can be consistent at the neighborhood scale.

13. ***Gray Squirrel Populations.***
Developed models using urban park habitat and squirrel data collected over the past three years at BES. Questions addressed were: (1) What is the relationship between gray squirrel abundance and habitat suitability? (2) What is the relationship between gray squirrel abundance and wariness of humans? (3) What is the relationship between gray squirrel abundance and intraspecific aggression? We hypothesized that squirrels in parks with higher abundances will have a greater reduction in wariness and increased intraspecific aggression.

14. ***Ecology of Invasive Species.***
This year the research focused on several types of invasive earthworm species interactions. In laboratory mesocosm experiments we examined the interactions between soil macrofauna (earthworms) and leaf litter decomposition. Specifically, we asked, how does resource quality affect interspecific and intraspecific interactions among soil fauna (earthworms), and what were the subsequent effects on organic matter decomposition (e.g., leaf decomposition, soil respiration)? Inter- and intraspecific interactions of two naturally coexisting earthworm species, *Lumbricus rubellus* and *Octolasion lacteum*, were examined in a factorial design, comprising twelve treatments: 0, 1, 2, 4, 8 earthworms in single and mixed species combinations. We combined a substitutive and additive design to specifically isolate the effects of inter- versus intraspecific between earthworm species. The experiment lasted six weeks, while *L. rubellus* and (or) *O. lacteum* fed on single or mixed leaf litter species of *Liriodendron tulipfera* and *Quercus rubra*.

15. ***Wireless Sensor Networks for Soil Monitoring.***
We have terminated the second deployment (six motes in Leakin Park), and we are currently analyzing data collected by this system for about a year. Most of our activities in fall and winter focused on designing and building the second generation mote, with new sensors, new antennae, and new motes. Our second generation system is based on the Telos SkyMote platform which has lower power consumption and better sleep mode properties. We have designed our own 4-channel analog interface board with its own stabilized reference voltage. The embedded software on the motes can now be upgraded remotely, without opening the box. The USB port of the mote is accessible from the outside, should a total code upgrade be necessary. In order to connect the dense patches of sensor deployments to one another across larger separations, we have started experiments with long range radio transmitters that use the 900MHz band, and have a range of several miles. We also started testing a new CO_2 sensor. The Vaisala GMP 343 can measure not only CO_2 efflux in chamber measurements, but using a soil insertion tool we can obtain continuous CO_2 concentrations at various soil depths. Graduate student Lijun Xia was testing the system in several vegetation types on the Johns Hopkins Campus, and forested areas at the Smithsonian Environmental Research Center. An addition to our sensor system is the Vaisala WXT500 Weather station. Research Experience for Undergraduate (REU) student, Julia Klofas, spent the summer putting the system together. The first field test took place July 21, at the BES

McDonogh site, where the weather station operated side-by-side to the BES-US Forest Service weather station for one day.

16. ***Avian Point Counts, a Long-term Monitoring Project.***
Co-PIs Charlie Nilon and Paige Warren have assisted with managing ongoing bird counts at UFORE and Watershed 263 sites. These point counts run in parallel with ongoing bird monitoring at CAP LTER. We have already conducted some comparisons of bird communities at CAP and BES (Shochat et al. paper in revision). Both bird monitoring projects consist of two components: First, there is a set of randomly located sites drawn as a subset of core LTER monitoring sites – UFORE sites in Baltimore and Survey200 sites in Phoenix. Second, we have a stratified sample of the same core LTER monitoring sites. In Baltimore, these were chosen using two sets of BES data: PRIZM and HERCULES. This second set of sites will allow us to measure associations of bird populations and communities with both human social groups and biophysical patch structure. Site selection aimed as much as possible for a blocked design with most HERCULES patch types falling into multiple PRIZM social groups. We expect, based on pilot data, that PRIZM classification will be a stronger predictor in sites with low housing density HERCULES patch types. At higher housing densities, we expect a fully expanded HERCULES classification to perform best at predicting bird community structure. The avian point count data are also providing the basic bird community data needed for Warren's research on human influences on cavity nesting birds in urban areas.

17. ***Land Cover Survey.***
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. This information will be used for a number of reasons. First is to help build a model that will allow remote sensing imagery and GIS data to differentiate between private land vegetation that is intentionally managed versus vacant lot or unmanaged successional vegetation. The next purpose is to develop a typology of yards for the Baltimore area using cluster or factor analysis. This categorization can be used as an important tool for future statistical analysis and for sampling. Third, is to understand the socio-economic and biophysical factors that predict the intensity of management of vegetation on private land.

18. ***Automating Classification of Remote Imagery.***
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 created "knowledge bases" of rules used to help segment and classify imagery based on spectral characteristics, shape and overlay properties.

19. ***Urban Vegetation Distribution.***
We conducted research on the predictors of urban private land vegetation distribution for Baltimore City. We mapped out the amount of plantable area in each parcel ("possible stewardship," or the amount of land not occupied by building

footprints), as well as the amount of the plantable area that actually had trees or grass on it ("realized stewardship"). We then analyzed the socio-economic predictors of these two metrics. We additionally looked at the predictors of lawn expenditures to see whether they were different.

20. ***Parks and Crime Study.***
We researched 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.

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. ***The Rate and Role of Overbank Deposition in Urban Fluvial Systems.***
Building on work on sediment accumulation in Red Run riparian areas, we have been investigating the role of flood plain sediment storage in the Gwynns Falls sediment budget. We continue to examine the riparian sediment data.

2. ***Gwynns Falls Water Sample Cation Chemistry.***
We have been examining the cation content of Gwynns Falls waters. REU student Amar Mehta conducted much of this analysis in Summer 2007.

3. ***Streamflow Distribution of Non-point Source Nitrogen Export from Urban-rural Catchments in the Chesapeake Bay Watershed.***

Nitrogen (N) export from urban and urbanizing watersheds is a major contributor to water quality degradation and eutrophication of receiving water bodies. Methods to reduce N exports using Best Management Practices (BMP) have targeted both source reduction and hydrologic flowpath retention. Stream restoration is a BMP targeted to multiple purposes, but includes increasing flowpath retention to improve water quality. As restorations are typically most effective at lower discharge rates with longer residence times, distribution of N load by stream discharge is a significant influence on catchment nitrogen retention. We explore impacts of urbanization on magnitude and export flow distribution of nitrogen along an urban-rural gradient in a set of catchments studied by the Baltimore Ecosystem Study. We test the hypotheses that N export magnitude increases and cumulative N export shifts to higher, less frequent discharge with catchment urbanization.

4. ***Evaluating the Potential of Stream Restoration as a Tool for Increased Nutrient Retention.***

Stream and river restoration is frequently presented as a useful tool for improving water quality in degraded areas. However, little monitoring of post-restoration water quality currently occurs in most regions and the level of reduction in nutrient export that can reasonably be achieved is not well-defined or understood.

5. ***Urban hydrology and Stream Ecology Research.***

Research in urban hydrology and stream ecology focuses on the interactions between small stream water quality, biogeochemistry, ecological structure and function, and the mosaic of forests and engineered infrastructure (impervious surfaces, drainage networks, water distribution systems, etc.) on and within urban landscapes. Urban streams are intimately connected to their landscapes through engineered drainage networks and the built environment, leading to stressed biotic communities and important water quality issues (pathogens, salt, metals, oxygen deficits, eutrophication, hydraulic scour, sediment). However urban residents are reliant on these streams for recreation, as they often occur in urban parks and recreational areas. It is therefore important to understand how they function to be able to minimize their degradation so that these resources are available to people, from public health, aesthetic, educational and recreational standpoints and so that urban environments can be properly and effectively managed. The interdisciplinary study of the modulation of terrestrial-aquatic ecological linkages by engineered drainage infrastructure will give managers and planners information that will facilitate the achievement of watershed and stream restoration goals.

This work includes the following areas of research:

- *The Urban Gutter Subsidy* - Studies on the influence of urban drainage networks and urban tree and other vegetation on the sources, transport, and processing of particulate and dissolved organic matter, nutrients, and sediment in urban catchments. (S. Kaushal, UMCES AL; C. Swan, UMBC GES; R. Pouyat, USFS NRS).

The US Forest service has been working with Baltimore City DPW and BES to sample baseflow and runoff in two highly impervious headwater catchments in west Baltimore within Watershed 263, where the goal is to characterize a baseline condition for storm drain runoff quantity and quality against which future changes due to a long-term reforestation and restoration efforts in the watershed can be measured. An emerging question is whether older urban headwater sites with high percentages of impervious cover are hotspots with respect to urban runoff pollution and therefore warrant special watershed restoration attention. In this preliminary analysis, we summarize water chemistry concentrations, seasonal patterns and variance at these sites for ca. one to five years of baseflow data collection for nitrate, chloride, sulfate, and *E. coli* concentration data.

- *Watershed 263 Urban Restoration* - Studies on improvements in runoff flows, chemistry, pathogens, and temperature over the course of a major ultra urban watershed restoration and greening-out effort (B. Stack, Baltimore City DPW, R. Pouyat USFS NRS.)

  The hydrology of two ultra-urban (70 % impervious cover) residential 15 ha headwater storm drain catchments in Watershed 263 (Baltimore City, MD) is being studied with continuous temperature recorders, stage and velocity gauges, and automated flow-paced samplers. The basic objectives of the study are to follow these two neighboring catchments over the long-term to evaluate changes due to the introduction of forest greening and various structural BMPs in terms of: 1) alterations in flow volume and rate, and 2) changes in water quality constituents, as well as to examine source areas and the utility of high resolution hydrologic and ecological models in evaluating BMP effectiveness over time. Water quality and quantity data collected here are also being used to measure the effectiveness of a street sweeping and inlet cleaning study being conducted by the Center for Watershed Protection, DPW, UMBC and others.

- *Pathogens in Urban Streams* - Studies on the survival, sources, and transport of pathogens in urban catchments, especially within the context of urban drainage networks, urban runoff dynamics, and sanitary sewerage networks. (J. Higgins & D. Shelton, USDA ARS EMSL, K. Readel, UMBC GES)

- *Thermal Fluxes in Urban Streams* - Studies on the role of impervious surfaces, urban drainage networks and the built environment with respect to the modulation of thermal fluxes to urban groundwater and stormwater, and to the thermal modification of aquatic and microbial habitats in receiving streams (C. Welty, UMBC CUERE, H. Kim, UMBC, G. Heisler, USFS NRS).

  Water and material fluxes from urban landscape patches to small streams are modulated by extensive “engineered” drainage networks. Small urban headwater catchments are different in character and function from their larger receiving streams because of their extensive, direct connections to impervious surface cover (ISC) and the fact that they are sometimes buried. They need to be studied as unique functional hydrologic units if impacts on biota are to be

fully understood. As part of the BES LTER project, continuous water temperature data are collected at 2-minute intervals at over twenty small catchments representing various mixtures of forest and ISC.

- *The Urban Water Budget* - Studies of the movement of water on and within the urban landscape with particular attention to the role of urban infrastructure (water supply, storm drainage, and sanitary sewers) in altering natural hydrologic cycle functions (C. Welty, UMBC CUERE, Andrew Miller, UMBC GES).

  This collaborative work is just beginning and should illuminate the connections in urban water pathways between urban stormwater drainages, groundwater and urban infrastructure. Data have already shown large fluoride concentrations in urban streams that most probably arise from leakage from pressurized aging potable water systems and high pathogen and microbial indicator concentrations suggesting leakage from sanitary sewer networks. Temperature data have similarly shown thermal spikes related to stormwater runoff in headwater urban catchments as well as influences of the urban landscape on water temperatures in underground streams flowing in storm drainage networks. Effects such as these, besides revealing impacts on receiving streams, also suggest that microbial processing in urban stream networks is potentially affected by the complete integration of anthropogenic and natural hydrologic drainage networks within the urban landscape, both above and below the surface.

6. ***Stream Gaging Stations.***

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 began a study in 2007 in cooperation with Baltimore City to evaluate and design a data network for monitoring the Baltimore reservoir system and its watersheds. Any understanding of the water supply system is essential to a comprehensive long-term study of human impacts on the urban ecosystem.

USGS also continued investigations of urban groundwater hydrology in the Gwynns Falls in cooperation with CUERE. An understanding of the urban subsurface environment is essential to determining an accurate urban water balance and to investigating urban water quality processes. The presence of water supply and sewerage infrastructure in urban ecosystems provides for unique and relatively unstudied problems, particularly in older urban settings such as BES.

USGS, in cooperation with 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 US Forest Service air monitoring tower. One additional stream gaging station was established.

USGS is also collaborating with the USEPA and Montgomery County (Maryland) 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.

7. ***Root Biomass, Organic Matter and Denitrification Potential in Degraded and Restored Urban Riparian Zones.***

A major theme of research in BES has been on how hydrologic changes associated with urbanization lead to lower water tables and drier, more aerobic soils in riparian zones. These changes reduce the potential for denitrification, an anaerobic microbial process that converts nitrate, a common water pollutant, into nitrogen gas. In addition to soil saturation, denitrification is also controlled by soil organic matter and nitrate levels. We have also investigated how geomorphic stream restorations, which are common in urban areas, affect riparian soil conditions and denitrification. In this study, which was led by REU student Danielle Gift, we measured root biomass, soil organic matter and denitrification potential at 0–10, 10–30, 30–70 and 70–100 cm depth in duplicate degraded, restored and reference riparian zones in the Baltimore metropolitan area.

Six riparian sites were sampled including Pond Branch (POBR) and Baisman Run (BARN), long-term BES study sites in predominately forested watersheds, Glyndon (GFGL) and Gwynnbrook (GFGB), long-term BES study sites in suburban subwatersheds of the Gwynns Falls, and Minebank Run (MBRN) and Spring Branch (SPBR), restored sites in suburban watersheds. Four 1-m long intact core soil samples were taken from each site within three meters of the stream bank. Cores were cut into 4 sections (0-10 cm, 10-30 cm, 30-70 cm, and 70-100 cm) roots were removed by hand. Soil moisture content was determined by drying, soil organic matter content was measured by loss on ignition. Denitrification enzyme activity (DEA) was measured using a short-term anaerobic assay.

8. ***Land Cover Influences on Air Temperature and Wind.***

Air temperature measurements at seven locations with varying land cover are compared to temperature at a central Baltimore location with high impervious cover. GIS analysis is used to derive average impervious, tree, and water cover over a range of distances in the upwind direction from each point, and to derive an index of topographic influences on cold air drainage. Regression analysis is used to develop prediction equations for temperature difference as a function of cover difference and forcing conditions such as atmospheric thermal stability. GIS is used to map predicted temperature patterns across the Baltimore urban area.

9. ***Soil and Stream Temperatures.***

Temperatures are continuously monitored with the goal of developing mathematical models to predict these values.

10. ***Bacteria in Baltimore Streams.***

USDA-Agricultural Research Service and the US Forest Service continued studies on the survival of *E. coli* in stream water during fall and winter seasons 2006–2007. In

another series of experiments, *E. coli* from Gwynns Run were assayed, using an in-vitro method, for toxicity by water pollutants commonly found in fresh waters in the US and Canada, such as MTBE, estrogens, caffeine, and herbicides.

11. ***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 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.

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 write-up. Phase 1 was completed in 2006, as described in the 2006 annual report. In the past year we have continued progress on phases 2-4 as described below.

Land classification. The HERCULES land classification system has been applied to the Baisman Run neighborhood, using EMERGE color infrared imagery. (Completed in 2006.)

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, in 2005 and 2006 a set of ten "neighborhood clusters" containing households with identical characteristics (according to our sampling criteria) was identified for sampling. (See "Findings" section for a table with the site types selected for analysis.) We continued to seek homeowner support through 2006 for our sampling effort, using this original list of candidate landowners.
- In August 2006, to draw from a larger list of candidate landowners we created a second geodatabase that included a larger geographic area, but still employed identical selection criteria from the original ten clusters. (This was possible because the HERCULES classification had since been completed for additional neighborhoods within the Gwynns Falls watershed.)

- As of January 2007, we have recruited thirty-three participating households out of our original target of forty (four households per cluster). An additional two or three households have agreed verbally to sign our participation agreement.

Field sampling. Initial site characterization visits have been made to nearly all of the thirty-three participating households.

- In order to test the field methods for this project, in the summer of 2005 a set of plots was established at a chronosequence of sites in South Burlington, VT. See the BES 2006 Annual Report for further details on this project.
- Monitoring of C flux components (including grass productivity, soil respiration, and thatch and stubble accumulation) has been ongoing continuously at all plots that were established in spring or summer of 2006. An additional set of plots was established in fall or winter of 2006; these plots will be monitored continuously through 2007.
- Methods for measuring C stock components have been developed and tested. Sampling of C stock components will take place during the 2007 field season.
- Soil sampling has been completed at all thirty-three sites. Cores are currently being analyzed for chemical and physical properties at the Institute of Ecosystem Studies.

Data analysis and write-up. While a full year of clipping and productivity data is not yet available, we do have some preliminary results for clipping, thatch and stubble production, and soil respiration (see "Findings" section). There are no data yet available for C stocks or soil profiles.

12. *Urban Streams as Transporters or "Transformers" of Organic Nutrients.*

Organic N and P represent a significant pool of nutrients capable of causing eutrophication and hypoxia in receiving waters, yet little is known about factors regulating their generation, transport, and uptake in running waters. Due to increased inputs of inorganic nutrients and alterations in temperature, stream habitat and biotic activity, many urban streams may now be shifting from "transporters" reflecting anthropogenic changes in the landscape to "transformers" actively changing the forms and ecological effects of nutrients. We are investigating the hypotheses that: (1) in-stream transformations can lead to increased generation of bioavailable organic N and P and, (2) the potential for in-stream transformations may be greatly accelerated in streams draining watersheds affected by increasing urbanization. This research is also supported by a grant from the National Science Foundation DBI 0640300 entitled "Collaborative Research: The effects of watershed urbanization on in-stream transformation of organic nutrients within running waters," Dr. Sujay Kaushal as lead PI, Drs. Peter Groffman and Stuart Findlay as collaborative PIs, and Dr. Mark Walbridge as a collaborative senior personnel.

13. *Stream Restoration as a Means of Reducing Nitrogen Pollution in Urban Streams.*

The Chesapeake Bay watershed contains one of the fastest growing populations in the US, and rapid expansion of its urban centers and suburban sprawl now poses a

serious problem for coastal water quality and eutrophication. While nitrogen pollution from non-point sources has increased, the capacity of many suburban and urban streams to remove nitrogen has been greatly reduced because of channel incision from increased runoff from impervious surfaces and decreased hydrological connectivity between running waters and denitrification "hot spots" in floodplains. We are investigating the potential role of stream restoration in reducing nitrogen transport using state-of-the-art ^{15}N stable isotope tracer experiments in the stream channel and riparian zone. This research is also supported by a grant from Maryland Sea Grant entitled, "Investigation of stream restoration as a means of reducing nitrogen pollution from rapidly urbanizing coastal watersheds of the Chesapeake Bay," Dr. Sujay Kaushal as lead PI and collaborators Drs. Peter Groffman, Paul Mayer, Margaret Palmer, Keith Eshleman, and Robert Hilderbrand.

14. ***Tracing Sources of Nitrogen Export from Watershed Urbanization.*** Quantification of the transport of anthropogenic N from non-point source pollution (septic systems, lawn fertilizer, atmospheric deposition, pet waste, etc.) has relied primarily on mass-balance estimates. This approach, however, does not allow sources to be discriminated along flow paths. We have analyzed the ^{15}N and ^{18}O of nitrate and ^{15}N and ^{13}C of particulate organic nitrogen in streams at BES draining watershed of differing land use in order to delineate seasonal changes in sources and forms of nitrogen.

15. ***Investigation of the Effects of Increased Salinization of Freshwater.*** Salinity is now increasing in many streams across Maryland toward thresholds beyond which significant changes in ecological communities and ecosystem functions may be expected. These increases in salinity are related to rapid suburban and urban expansion and increased deicer use on roadways with additional contributions from fertilizers, operation of water softeners, and discharges from septic systems and wastewater treatment plants. The concentrations of chloride, an important anion of many salts, observed in suburban and urban streams of the Baltimore metropolitan area have now exceeded the limit of 250 mg/L established by the USEPA for chronic toxicity to freshwater life. The observed ranges and extreme fluctuations in salinity have been shown to also inhibit denitrification, a microbial process that is critical for the removal of nitrate and maintenance of water quality in many streams. We studied effects of increased salinization on impairment of in-stream processing and removal of nitrogen via denitrification in streams, and subsequent implications for the increased downstream transport of nitrogen to coastal ecosystems. We investigated the effects of increased salinity on rates of nitrogen removal through denitrification in debris dams and characterized seasonal changes in levels and sources of salinity in streams by measuring concentrations and ratios of Na and Cl ions.

16. ***Interaction Between Climate Variability and Urbanization.*** Streamflow variability has increased significantly since the 1940's in the Chesapeake Bay region of the US and a major research challenge will be to understand how nitrate export in streams draining urbanizing watersheds responds to increasing precipitation variability. We have been investigating the effects of record drought/flood conditions during 2002-2003 on nitrate export in ten long-

term monitoring stream locations in Maryland (including the BES watersheds) and examining the potential for precipitation variability to influence nitrate export in other streams at a regional scale by analyzing land use and nitrate concentrations in over 1,000 small watersheds. The work is a synthesis effort comparing data from BES with other sites across the state of Maryland to forecast the interactive effects of climate variability and urbanization on nitrogen export.

17. ***Affect of Urban Land-use Change on Soil Carbon.***
To assess the effect of urban land-use change on soil organic carbon (SOC), we compared SOC stocks of turf grass and native cover types of two metropolitan areas (Baltimore, MD and Denver, CO) representing climatologically distinct regions in the United States. We hypothesized that the effect of introducing turf grass will lead to higher SOC densities in the arid Denver area, whereas in the mesic Baltimore area there should be a reduction in SOC densities relative to native cover types. Moreover, differences between residential turf grasses will be less than differences between the native soils of each metropolitan region.

18. ***Distribution of Heavy Metals in Urban Soils.***
We investigated the spatial distribution of heavy metal above-background (anthropic) contents of Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, Ti, V, and Zn in Baltimore City surface soils and related these levels to potential contaminating sources. In addition to the large scale survey of heavy metals in soils, Kirsten Schwarz, a doctoral student at Rutgers University is examining the distribution of lead in soil of residential areas to determine whether land cover or land use is a better predictor of soil lead levels. This research is important because exterior sources of lead are coming to be recognized as important contributors to lead burden in urban children. However, this source of lead, compared to interior sources derived from lead-based paint, is under investigated.

19. ***Effect of Salt Runoff on N and C.***
Graduate student Peter Bogush is working on his Master's thesis focused on the effect of salt runoff on N and C removal in stream sediments.

Other Activities.
The integration of different land use types as they impact the overall atmospheric C burden is an intriguing topic for continued analysis. In 2006 Dr. Jennifer Jenkins began working with Drs. Tim Fahey, Steve Hamburg, and colleagues on an effort called the "Carbon Sciencelinks" project, which will compare the net county-level C budgets of several different New England counties with different land-use profiles. Funding for this has been secured from the Hubbard Brook Research Foundation to support a Masters student whose project is to conduct a carbon budget for Chittenden County (VT).

Similarly, our work on the carbon-emission impacts of land use change has been integrated into a new three-year interdisciplinary, multi-investigator $1.6M Signature Project on "Modeling Transportation and Development Patterns," which has been selected for funding by the University of Vermont's new National

University Transportation Center and will begin in August 2007. That initiative will likely include a graduate student advised by Jenkins.

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 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. ***KidsGrow After School Program.***

We have continued to develop and provide curriculum and teacher professional development to the Parks and People Foundation KidsGrow After-School Program. In the 2006-2007 school year, KidsGrow expanded to three sites; based at three highly urban Baltimore City Public Schools. The fall semester was spent on a rich exploration of micro and meso climates. Students studied schoolyard temperatures and identified three microclimates in which to plant tulip bulbs. They also measured air temperatures and compared them with weather station temperature readings along an urban to rural gradient. The urban heat island effect was a topic of great interest. BES Co-PI and USDA Forest Service meteorologist Dr. Gordon

Heisler visited with students and discussed his studies and the students' studies. Students came back from winter break ready to embark on a watershed unit, a study of urban birds and habitat requirements. They spent time learning about the Ecology of Food, Agriculture and Nutrition. This comprehensive unit began with the students planting "winter garden crops" in cups to grow indoors under plant lights. They later planted their seedlings in a schoolyard garden. They tackled learning about inputs and outputs by focusing on the human body, something immediately familiar if somewhat embarrassing to the students when it came to outputs. They moved on to Food Production Ecosystems. Students began to understand where our food comes from before it gets to the grocery or corner store. They visited Cromwell Valley Organic Farm, and the Baltimore City Department of Recreation and Parks Howard Peters Rawlings Conservatory and Botanic Gardens of Baltimore. All three sites participated in a culminating Salad Extravaganza held in conjunction with the University of Maryland Cooperative Extension's Nutrition Education program.

2. ***Adopt a School.***

We worked closely with BES Co-PI and US Forest Service Soil Scientist Dr. Quin Holifield to develop a pilot educational program to promote and enhance both required science content and environmental literacy. The program was implemented at Franklin Square Elementary School in late fall 2006. We met with the 4th and 5th grade teachers and then completed schoolyard soil studies with the teachers and their students.

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

During the 2006-2007 school year, Ms. Karen (Rennie) 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 Co-PI and US 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. Of the 400 students enrolled at Doris M. Johnson High, School Year 2005-2006; 64% met eligibility requirements for the free or reduced price lunch program and 99% were African-American. Fifty-nine percent (59%) of 9th graders were promoted to the 10th grade in the 2004-2005 school year, the first year the school was operational.

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.

Mr. Terry Grant began work in June 2007 with mentor Dr. Peter Groffman (BES Co-PI and Microbial Ecologist, Institute of Ecosystem Studies) to better understand stream ecology in the urban ecosystem including the interaction between a stream and its riparian zone.

Grant is the recipient of two prior grant awards; (1) to work with students on a stream study of the Herring Run, and (2) to take students on a bicycle tour of Maryland which included stream sampling and talking with citizens about the impact of urban development on Maryland's communities and natural resources.

The summer research took place at regular BES sampling sites along the main stem of the Gwynns Falls and at smaller forested and agricultural sites. The areas of greatest interest to Grant are the interaction between a stream and its riparian zone. Potential research questions include: 1) How do changes in a stream affect plant life in the riparian zone? 2) What is the impact of erosion on stream water quality? 3) What role does the denitrification process in tributary streams play in the health of the Chesapeake Bay? 4) How is stream denitrification affected by runoff and road salt?

Grant hopes to use his research experience to develop a project focus for the Advanced Placement (AP) Environmental Science class he will be teaching in the fall 2007. He would like studies of the campus stream to be the centerpiece of the curriculum. Integration and comparison with BES research data would add another rich dimension to the course. His work during the summer is to design and answer a research question and use this experience to design field-based segments of his AP course.

4. ***School-based Urban Rural Gradient Ecosystem Studies (SURGES).***
We worked to identify teachers and high schools to participate in a new program that will facilitate unique learning experiences for students in Baltimore City and County. Because of the required commitment on the part of participating schools, recruitment has been a challenge. Our initial goal was to recruit teachers, from three schools along an urban to rural gradient, who would engage their students in data collection that would demonstrate environmental services provided by their local ecosystems. As a result of our July 17-20, 2007 teacher professional development workshop, "Teaching Urban Ecology in Baltimore: A Workshop for High School Environmental Science Teachers," we recruited three teachers interested in participating in SURGES. Their schools (Baltimore City public and Baltimore City and County private independent schools) are along an urban to rural gradient. These teachers will pilot SURGES and then engage other interested teacher workshop participants in the project.

5. ***Describing Baltimore's Ecology Education System.***
Urban Ecosystems in the Maryland State Curriculum Framework. In prior years, we developed a matrix for analyzing state curriculum frameworks as they relate to ecological concepts, with specific reference to teaching about urban ecosystems, the local environment and dimensions of ecological thinking. During this reporting period, Dr. Alan Berkowitz (BES Co-PI and Head of Education, Institute of Ecosystem Studies) worked closely with the Urban Ecology Collaborative (UEC) Education Committee in analyzing our application of the matrix to the Maryland State Voluntary Curriculum in order to refine the matrix. Ultimately the matrix 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.

Inventory of Urban Environmental Education Providers in Baltimore. BES has been an active partner in the Education Working Group of the Urban Ecology Collaborative. BES educators led all phases of the UEC's Urban Environmental Education Inventory (UEEI) project; survey development, implementation and during the current reporting period, data analysis.

6. ***Investigations in Ecology Teaching.***

Responsive Teaching Study. We have completed another year of participation in this project; continuing to support classroom teachers as they learn and practice the art of attending to student thinking. We are integrating our work on the Environmental Science Literacy project to provide the teachers with frameworks of "big ideas" in ecology to help focus their attention when listening for and responding to student thinking. Six Baltimore City and County teachers participated in biweekly meetings throughout the 2006-2007 school year. The BES team is led by Co-PI Dr. Janet Coffey with contributions by Alan Berkowitz. The BES Education Coordinator, Janie Gordon, facilitated teacher attendance at bi-weekly meetings, arranged professional development sessions on BES units at these sessions and provided supplies and direct support to teachers while they taught the units with their students.

The Ecology Teaching Study. We conducted a survey of high school biology and environmental science teachers in Baltimore City and County public and private schools in 2005. We studied how ecology is taught in Baltimore City and County schools, focusing on practices of interest; use of fieldwork, authentic data, community resources and action projects. We also looked at what was being taught and at supporting or constraining factors. We received responses from teachers from 82% of the Baltimore County public schools (105 teachers), 63% of the Baltimore City public schools (38 teachers), 24% of the Baltimore City private schools (five teachers) and 8% of the Baltimore County private schools (two teachers) for a total of 150 responses.

7. ***Investigations in Student Thinking and Learning.***

Environmental Science Literacy Project. BES is a partner in the Environmental Literacy Research Group based at Michigan State University and headed by Dr. Andy Anderson. The project is associated with the MSU-led Kellogg Biological Station LTER site, along with the Santa Barbara Coastal Ecosystem LTER site (Dr. Allison Whitmer, UC Santa Barbara) and the Short Grass Steppe LTER Site (Dr. John Moore, Colorado State University). The larger project is developing learning progressions for environmental literacy for water, carbon, and biodiversity/ evolution.

During the current reporting period, BES convened an interdisciplinary working group of scientists, graduate students and educators to focus on water. They reviewed the existing materials on water produced by the Michigan State working

groups and began work on Baltimore/urban specific additions or alternatives for the current learning progression.

During the next reporting period, we plan to develop and implement a plan for assessing Baltimore student thinking about water, collect teaching materials and carry out targeted teaching experiments focusing on water. We also hope to form a second working group focusing on carbon, another area for which BES has particular expertise.

8. ***Vocational Development of Ecologists and Green Career Interest.*** Interdisciplinary Student Training Outcomes through the UMBC/BES IGERT Program. With the recent advent of an IGERT program at UMBC, BES has a unique opportunity to learn more about the vocational development of ecologists and of interest in green careers. During the current reporting period, Alan Berkowitz provided input to the IGERT evaluation team on tools to assess interest/vocational development among participants.

9. ***Neighborhood Restoration and Greening in an Urban Storm Water Catchment.***
Continued working with federal, state, and local government and community-based organizations to develop and implement restoration plan for 900-acre storm drain watershed (Watershed 263). Eleven neighborhoods in southwest Baltimore are involved. Parks and People Foundation, the US Forest Service and the Baltimore City DPW have collaborated to collect baseline date for assessing impact of restoration activities. Three specific activities were conducted: 1) Worked with Watershed 263 Stakeholder Council to develop indicators to monitor and evaluate outcomes of large-scale watershed restoration project; 2) Submitted proposal to Chesapeake Bay Trust on behalf of the Watershed 263 Stakeholder Council to fund restoration and environmental education projects; and 3) Organized and provided technical support for formation of Watershed 263 Coordination Working Group.

10. ***Tree Baltimore.***
We worked with city agencies to implement Tree Baltimore's street tree sample survey, which was conducted throughout communities across the city. Nearly 100 volunteers used i-Tree—the new Inventory of Tree Resources, Environmental and Economics software—to gain critical information about Baltimore's trees. Using hand-held computers, volunteers are entering information about street trees on 500 randomly selected city blocks. The sampling includes recording the number, species, size and condition of trees, as well as the size of the tree pit or other areas where trees grow.

11. ***GIS Data.***
Collected data and created and analyzed GIS data layers on a variety of environmental indicators, including tree locations, size and species; location and condition of vacant lots; and location and condition of storm-water inlets. Numerous maps for analysis of environmental and social conditions in Watershed 263 were created.

12. ***Neighborhood Ecology Center.***

Implemented the Neighborhood Ecology Center at Harlem Park Elementary School and provided students and teachers with increased access to educational resources and scientific information on environmental issues that affect urban communities. Provided hands-on experiments performed at learning stations and teacher training workshops. Programs and concepts learned in the Ecology Center will be reinforced through field trips to local environmental venues and student directed outreach environmental projects including storm drain stenciling and installation and care of schoolyard habitats.

13. ***Urban Environment/Ecology Research.***

Conducted applied urban environment/ecology research and restoration on the Gwynns Falls Trail with funds secured from Congressional support for Urban Watershed Forestry Cooperative.

14. ***Watershed Forestry for Baltimore Youth.***

Co-PIs Dr. Mary Washington of the Parks and People Foundation and Dr. Mark Twery of the US Forest Service.

Objectives:

- To provide opportunities for neighborhood youths to develop public speaking and presentation skills through work on green infrastructure enhancement projects.
- To develop skills and habits of civic leadership character as the youths become WS 263/BES Ambassadors.
- To provide plant material and undertake two vacant lot restoration projects in Watershed 263 with the Environmental Justice Youth Advisory Board of Baltimore.
- To introduce youths to careers available at a variety of levels, and the educational, professional and/or technical skills needed to be successful.
- For seriously interested youth from the groups, arrange field trips to selected colleges and universities that have natural resource educational and professional development programs such as Morgan State, Frostburg State, UMBC, UMCP, UMES, and possibly University of Vermont.

Expected outcomes:

- Two vacant lots designed, restored and maintained by Environmental Justice Youth.
- Conduct at least ten presentations to neighborhood groups and schools, and possibly other venues such as to City Council and School Board.
- Participation by selected inner city youths in three career field trips.
- Participation by highly selected youths on three college/university field trips.

This project will reach and engage minority, inner city, low income population with natural resource management and careers with the Forest Service, while improving the environment in the city where they live.

15. ***BES Host Partnership.***

The 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 IES. 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.

In 2007, the CUERE Spatial Analysis Laboratory has continued to provide spatial analysis support to BES researchers by fulfilling numerous requests for spatial data and GIS expertise. CUERE also procured and installed five new Dell 690 Precision Workstations; funding was provided by NOAA. These workstations consist of two 2.6 GHZ Intel Dual Core processors, 4GB of RAM, 500GB of hard drive storage, and dual high resolution flat panel displays. CUERE has also procured a Dell 3190N Color Laser printer. The laboratory has been added to the UMBC Active Directory to provide secure authentication and centralized user management.

CUERE has continued to be instrumental in leveraging the presence of the BES on campus to increase related research activities. Following a NSF CLEANER planning grant in 2004-06, CUERE was successful in winning a NSF award for the BES to become a WATERs testbed for hydrologic and environmental engineering research. The title of the grant is "Quantifying Urban Groundwater in Environmental Field Observatories: A Missing Link in Understanding How the Built Environment Affects the Hydrologic Cycle" (EAR 0610009, $400,000, 11/1/06–10/30/08, C. Welty, PI). Building on this project, CUERE has recently received preliminary notification from NOAA of an award 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, 9/1/08–8/31/11, 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 a new Biocomplexity award "Collaborative Research: Dynamic Coupling of the Water Cycle and Patterns of Urban Growth" (BCS-BE 0709659, $1.4 M, 8/15/06–8/14/09, 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. Before this award had been made, one of the recommendations of the BES midterm review was to incorporate urban growth modeling as part of the BES research agenda; this new award directly addresses that comment.

In February 2007, CUERE submitted a proposal to the NSF CZO program entitled "Water, Sediment, and Salt: Stores, Fluxes, and Flowpaths Through the Critical Zone of an Urbanizing Landscape" that focused on the larger Gunpowder-Patapsco region in which the Gwynns is embedded ($4.25 M, Andrew Miller, PI). This was not selected for funding (three proposals were funded) but based on the high quality of the proposals, NSF has decided to set aside other funds for further CZO-related competitions.

In July 2007, a new building on UMBC's campus for the MD-DE-DC Water Science Center of the USGS was completed. They moved to campus in mid-August.

USGS's presence on campus will further strengthen the relationship between the USGS, BES, and CUERE.

In fall of 2006, UMBC's new IGERT program "Water in the Urban Environment" kicked off. As of August 2007, seven of the eight PhD trainees will be working with BES investigators as their mentors (Pickett, Groffman, Swan, Welty, Pouyat, Kaushal, Ghosh).

16. ***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 three public parks in Baltimore; 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 consultation between BES scientists and Department of Recreation and Parks staff to develop training for youth team supervisors. Secured funding to extend the BRANCHES youth training forestry program in the fall semester of 2007 as an after-school program.

17. ***Urban Resources Initiative (URI).***

Extended URI internships opportunities to mid-career working professionals.

18. ***Internships.***

Provided two internship opportunities for graduate students in public health and ecology to work with the Watershed 263 Stakeholders Council to build its capacity.

19. ***Baltimore City Community College.***

Developed a relationship with Baltimore City Community College to provided field experiences and professional development for their new formed Environmental Sciences major.

20. ***SuperKids Camp.***

Provided environmental education enrichment for 1,100 Baltimore City 2nd graders participating in the Parks and People Foundation SuperKids Camp 6-week reading enrichment summer program.

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***.
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 100-150 people in the last several years. The evening Open House is held annually, during the Annual Meeting, in conjunction with the Parks and People's Annual Greening Celebration. Over time, the number of attendees at these functions has grown. At the 2006 Open House, it was announced that Mayor Martin O'Malley had declared the day "Baltimore Greening Day" in recognition of the community improvements facilitated by the Parks and People Foundation, and related to BES research. We held three additional Research Meetings at roughly three month intervals focused on research planning.

2. ***Interaction and Sharing with other Agencies.***
Interaction and reports to EPA, Chesapeake Bay Program on tributary restoration potential, sharing of information with Baltimore City stream management group.

Participated in a Watershed 263 project strategy and planning meeting designed to coordinate activities of the various partners and to bring the community into the process.

Assisted Jana Davis, Associate Director for Programs, Chesapeake Bay Trust, with questions about approaches and equipment for sampling stormwater runoff for a LID monitoring project in Denton, MD.

Gave assistance to Zach Henderson, Stormwater Specialist at Edwards and Kelcey, Portland, ME, who was looking for information on trees and ISC temps in RO.

Conducted a BES field site tour for the Director and Deputy Director of the Beijing Urban Ecosystems Research Group of the Chinese Academy of Sciences (Xiaoke Wang, Zhiyun Ouang, State Key Laboratory of Urban and Regional Ecology Research Center for Eco-Environmental Sciences Chinese Academy of Sciences), who are leading the Beijing Urban Ecosystem Research Station, part of the China Ecosystem Research Network (CERN).

Co-PI Jane Wolfson is actively involved in the development of the Baltimore County Agriculture Resource Center planned for northern Baltimore County and is a member of the Board of Directors. The actual Center is being developed on land purchased by Baltimore County. Wolfson is also a member of their Steering Committee helping the county work through the process. To facilitate the successful development of this center Wolfson has participated in meetings of the Program/Education Committee which is responsible for outlining the future programs and functions of the Center. Wolfson continues to work to preserve agriculture as a viable land use within Baltimore County, develop educational/ programmatic initiatives that will ensure a future for farming in this region and provide opportunity for on-farm research for Towson University faculty once the site is established.

Co-PI Jane Wolfson was asked to join efforts to develop a Maryland Brownfield Chapter as an affiliate of the National Brownfield Association. She has been meeting and conferring with members of the local development community as a member of the Executive Committee. A successful kick-off event was held in early May. Wolfson continues to work with this organization to develop mechanisms to connect this group with the Towson University community.

3. ***Education Outreach.***

A number of presentations (listed below) and educational activities are also considered as 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 has participated in many Parks and People events, sometimes wearing a combined volunteer/BES education hat. In particular, Janie Gordon has participated in Flower Mart, talking about schoolyard greening and ecology education at Franklin Square Elementary, judging the Franklin Square Elementary School science fair, and recruiting Johns Hopkins University graduate students in the sciences to judge the science fair. She has engaged students from Goucher and Johns Hopkins to volunteer at KidsGrow and to plan special educational programs for the children. In addition, Ms. Gordon has spoken regularly with high school youth participating in the Parks and People summer BRANCHES program, discussing school/career pathways in ecology and engaging them in a pitfall trap investigation. Some of our Co-PIs have also spoken in the classroom and led field trips to local urban streams.

Presentations were made to 2nd grade students on pollinators at the Lindbergh School District and a curriculum development workshop was held with the 2nd grade teachers.

4. ***HERCULES.***

Talks and presentations about the important of integrating built and non-built components of the landscape to urban designers, city planners, and landscape architects in academia and the private sector.

5. ***Urban Design.***

The Baltimore Ecosystem Study has been a most rewarding experience for urban designers at Columbia University Graduate School of Architecture, Planning and Preservation, as it is the first time they have been able to work with scientists as well as political and community actors. The scientists brought important scientific models, metaphors and theories: patch dynamics, the human ecosystem framework—which allow designers to look at urban design problems in a totally fresh way. This has brought the Baltimore work a lot of attention (and a little jealousy) at Columbia—a major research university—which is searching for ways to connect design and science in its curriculum. What has expanded urban design practice is rethinking urban design practice through the Watershed framework, patch dynamics, and the forest opportunity spectrum. Examples of last year's student work illustrates how science and design can work together in academic framework, which provides professional designers a framework of urban ecosystem approaches and a spectrum of urban design opportunities.

6. ***Bird Monitoring.***

We have met with representatives of the WS 263 watershed partnership as a first step in linking our work more directly to the needs and concerns of local residents.

7. ***Community Relations.***

- Developed and carried out 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 the Watershed 263 Stakeholder Council.
- Provided technology transfer and community outreach and education support to the Baltimore Harbor Watershed Association to create Harris Creek (Watershed 246) project in east Baltimore. Will work with business leaders, city agencies and community-based organizations.
- Developed content for "Linking Science and Decisionmaking" section of BES website, highlighting role of URI and Green Career Ladder in coordinating research on and restoration of Baltimore's urban ecosystem.
- Aided BES scientists and staff in developing relationships with local public agencies, non-profits, community groups and residents.
- Contributed to Baltimore Neighborhood Indicators Alliance report on Vital Signs for Baltimore's Neighborhoods.
- Organized a Green Gathering on March 31, 2007 and invited local residents, gardeners, park stewards, and community activists to the Amazing Grace Lutheran Church for hands-on workshops, training sessions and networking. Attendees learned the basics about Baltimore's urban trees, constructed rain barrels, and participated in workshops on recruiting volunteers, green space and gardening.
- On April 27, 2007 KidsGrow students at Franklin Square Elementary School learned about the importance of trees in addition to caring for the existing trees at the school.

- Organized activities at four schools close to Farring Bay Brook Park and planted 100 trees in the park in honor of Maryland Arbor Day on April 4.
- Presented "Urban Forest," a participatory walk-through demonstration showcasing examples of an urban stream valley, school yard greening, vacant lot restoration, a recreational trail and much more at the 2007 Flowermart in Mt. Vernon. The exhibit was open Friday, May 4, 2007 and Saturday, May 5, 2007.
- Participated in Urban Ecology Collaborative First Annual Meeting. Information is being exchanged, joint funding proposals developed and joint projects implemented in the cities of: Boston, New Haven, New York, Baltimore, Pittsburgh, and Washington, DC. Transferred Watershed 263 restoration model to partner organizations in Washington, DC and Boston. Leadership roles in Environmental Education Working Group and Green Jobs Network Working Group.
- Participated in implementing Tree Baltimore the plan to increase Baltimore City's Tree Canopy.

8. ***Participation in:***

- Revitalizing Baltimore Technical Committee. This is a crucial mechanism for exchanging information with communities, government agencies and activist NGOs. It is a key element for BES technology transfer.
- Urban Natural Resources Institute (UNRI) webinar on UTC data and applications. 1-hour webinar, accessed by approximately seventy locations around the world.
- Urban Ecology Collaborative, which includes members from Washington, DC, Baltimore, NYC, Pittsburgh, and Boston.
- Baltimore County Sustainable Forestry Initiative.

9. ***Biodiversity and Conservation Values of Urban Habitat Fragments.*** Symposium organized by: Elisabeth Hornung, Szent Istvan University, Godollo, Hungary; Katalin Szlavecz, Johns Hopkins University, Baltimore; and Bela Tothmeresz, Kossuth Lajos University, Debrecen, Hungary. This symposium was held at the 1st European Congress on Conservation Biology, Eger, Hungary, August 22-26, 2006.

Presentations, Posters and Websites Considered Outreach Activities

Presentations

Bain, D.J. 2007. Buried floodplains and old mines: understanding legacy agricultural sediments in Maryland Valleys. Maryland Department of Natural Resources Marine and Non-Tidal Assessment (MANTA), Annapolis, MD. April 12.

Belt, K.T., W.P. Stack, R.V. Pouyat, G.T. Fisher, G. Heisler, and P.M. Groffman. 2006. Watershed 263 small headwater storm drain catchment hydrology: ultra urban hotspot? Invited presentation: Chesapeake Bay Program and Parks and People Foundation. Baltimore, MD. December 15.

Belt, K.T., W.P. Stack, R.V. Pouyat, G.T. Fisher, G. Heisler, and P.M. Groffman. 2007. Presentation and Field Trip, Cromwell Valley Park in Baltimore County. Presentation on reservoir water quality management to BES teacher workshop. Included a field trip to a restored urban stream. Handout materials: copy of presentation and DPW water quality annual report. Baltimore, MD. July 19.

Boone, C.G. and J.M. Grove. 2006. Environmental equity analysis of parks and open spaces in Baltimore, Maryland. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 18-19.

Boone, C.G. 2006. Importance of legacies for social sciences research in the LTER. First Workshop of the Joint ASU-Chinese Academy of Sciences Center for Urban Sustainability. Beijing, China. December.

Boone, C.G. 2007. Legacy effects on environmental equity in Baltimore and Phoenix: a cross-site analysis. CAP-LTER 9th Annual Symposium. Tempe, AZ. January.

Brush, G.S. 2006. The effect of history on native tree distributions in an urban environment. University of Maryland Appalachian Laboratory. Frostburg, MD. September 24.

Buckley, G.L. 2006 Reforesting Baltimore: challenges past and present. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 18-19.

Cadenasso, M.L. 2006. LTER network planning grant: status and activities. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Cadenasso, M.L., S.T.A. Pickett, K. Schwarz, W. Zhou, A. Troy, J.M. Grove, and C.G. Boone. 2006. Towards a theory of urban land cover classification and a multidimensional approach to spatial heterogeneity of cities integrating natural features and social artifacts. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Cadenasso, M.L. 2007. Ecological heterogeneity in urban ecosystems: reconceptualized land cover models as a bridge to urban design. Institute of Ecosystem Studies, Cary Conference, Millbrook, NY. May 1-3.

Carlson, C., M.L. Cadenasso, and G. Barrett. 2006. The effect of residential properties on breeding bird diversity in urban forest patches. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Carroll, W.S., M. Lev, K. Szlavecz, E.R. Landa, R. Casey, and J. Snodgrass. 2006. Investigating the extent of earthworm-driven physical and chemical alteration of roadway-derived dust in urban soils. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Cogan, J., J. Klofas, and K. Szlavecz. 2007. Transforming 13,000 components into a tested, and tracked wireless sensor network. MIRTHE Summer Workshop, Princeton, NJ. August 5-10.

Galvin, M.F. and H. Whitlow. 2007. Urban tree canopy project. American Planning Association 99th National Planning Conference, Philadelphia, PA. April 18.

Grove, J.M. and C.G. Boone. 2006. Environmental equity analysis of parks and open spaces in Baltimore, Maryland. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 18-19.

Grove, J.M. and C.G. Boone. 2007. Social science research in the Baltimore Ecosystem Study. Workshop: Developing and Evaluating Social Science Approaches for the Baltimore Ecosystem Study LTER: Local Focus, Global Thinking. Baltimore, MD. January 16-18.

Grove, J.M., C.G. Boone, and A. Troy. 2007. Overview of BES social pattern and process research. Baltimore Ecosystem Study Mid-term Review. Baltimore, MD. March 28.

Hager, G. 2006. Schoolyard greening Baltimore city public school system. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Heisler, G.M. 2006 Meteorology for Grades 2 to 5, KidsGrow after school program. Parks and People Foundation and Baltimore Ecosystem Study. November 1.

Hom, J., K. Clark, N. Skowronski, L.S. Grimmond, M. Patterson, B. Offerle, B. Crawford, and I. Yesilonis. 2006. Carbon flux associated with management and disturbance, along an urban to rural gradient from Baltimore, MD to the New Jersey Pine Barrens. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Hom, J., K. Clark, N. Skowronski, L. Ziska, S. Grimmond, B. Crawford, M. Patterson, B. Offerle, and I. Yesilonis. 2006. Carbon flux associated with management and disturbance along an urban to rural gradient: Baltimore, MD to the New Jersey Pine Barrens. Society of American Foresters, Pittsburgh, PA. October 25-29.

Hom, J. and R. Pouyat. 2006. Nitrogen, carbon, and water research: Baltimore Ecosystem Study-Long Term Ecological Research (LTER). Invited presentation. National Atmospheric Deposition Program Technical Meeting, Norfolk, VA. October 25.

Hom, J., K. Clark, and L. Ziska. 2007. Carbon flux associated with management and disturbance along an urban to rural gradient: from Baltimore, MD to the New Jersey Pine Barrens. Invited seminar. Smithsonian Environmental Research Center, Edgewater, MD. May 15.

Hom, J., Y. Pan, K. Clark, R. Birdsey, and M. Patterson. 2007. Scaling carbon dynamics with disturbance and management using urban to rural gradients and tiered hierarchical land surface measurements. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. June 21.

Hornung, E., K. Szlavecz, and I. Tuf. 2007. Variability of reproductive potential in terrestrial isopods at regional and ecosystem scales. Ninth Central European Workshop on Soil Zoology, Ceske Budejovice, Czech Republic. April 20.

Jenkins, J., P.M. Groffman, M.L. Cadenasso, M. Cox, J.M. Grove, S.T.A. Pickett, and R. Pouyat. 2006. Residential carbon: Stocks and fluxes in residential ecosystems. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Jenkins, J.C. and P.M. Groffman. 2007. Carbon biogeochemistry in suburban turfgrass. The Ecosystem Center, Woods Hole, MA. April 10.

Kaushal, S.S. 2006. Influence of land use on sources and transformations of nitrogen in streams. University of Maryland, Center for Environmental Science, Horn Point Laboratory, Cambridge, MD. October 4.

Kaushal, S.S. 2006. Influence of land use on sources and transformations of nitrogen in streams University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD. November 16.

Kaushal, S.S. 2006. Influence of land use on sources and transformations of nitrogen in streams. U.S. Geological Survey National Center, Reston, VA. December 8.

Kaushal, S.S. 2007. Influence of land use on sources and transformations of nitrogen in streams. University of Maryland, College Park, MD. February 12.

Kaushal, S.S. 2007. Overview of watershed research at the Baltimore Ecosystem Study Long-term Ecological Research Site. National Science Foundation BES LTER Mid-term Review. February 28.

Kaushal, S.S. 2007. Influence of land use on sources and transformations of nitrogen in streams. Department of Biological and Environmental Engineering, Maryland Sea Grant, College Park, MD. April 20.

Kaushal, S.S. 2007. Influence of land use on sources and transformations of nitrogen in streams. Department of Biological and Environmental Engineering. Cornell University, Ithaca, NY. April 23.

Kaushal, S.S. 2007. Successes and challenges in removing nitrogen from coastal streams of the Chesapeake Bay. Chesapeake Biological Laboratory, Research Seminar for Research Experience for Undergraduate (REU) Students. July 31.

Klofas, J., J. Cogan, K. Szlavecz. 2007. Comparability, reliability, and dependability: calibrating homemade thermistors and the Vaisala WXT510 weather station. MIRTHE Summer Workshop, Princeton, NJ. August 5-10.

Miller, A.J. 2007. Water in the urban environment. Keynote address, Vermont EBSCoR, University of Vermont. Burlington, VT. July 3.

Parker, T.S. 2007. Habitat and landscape characteristics correlated with density and behavior of gray squirrels in urban areas. University of Memphis, Memphis, TN. February 15.

Parker, T.S. 2007. Density and behavior of urban wildlife. Urban Ecology Center, Milwaukee, WI. June 12.

Pickett, S.T.A. 2006. Studying the human ecosystem in Baltimore: approaches and insights. Keynote address. Long Island University Symposium on Urban Ecology, Long Island City, New York. March 4.

Pickett, S.T.A. 2006. Urban Ecology and Conservation. University of Minnesota, Conservation Ecology Program, November 27-28.

Pickett, S.T.A. 2006. Structure and process in contrasting ecological systems: from the emergent to the designed. Invited seminar. Yale University School of Forestry and Environmental Studies, April.

Pickett, S.T.A. 2006. Workshop on ecological metaphors, analogies, and anecdotes. Keynote Speaker, Ecological Society of America Annual Meeting, Memphis, TN. August 8.

Pickett, S.T.A. 2006. Panel Speaker, Closing Lunch, Ecological Society of America Annual Meeting, Memphis, TN. August 11.

Pickett, S.T.A. 2006. Urban ecology and the evolution of ecology: examples from the Baltimore Ecosystem Study – LTER Project. Keynote address. Calder Summer Undergraduate Research-REU Symposium, Fordham University, Bronx, NY. August 16.

Pickett, S.T.A., M.L. Cadenasso, C.G. Boone. 2006. The ecology of environmental justice: relationships to ecological theory. Symposium of Linking Ecology and Environmental Justice, Ecological Society of America Annual Meeting, Memphis, TN. August 8.

Pickett, S.T.A. 2007. Ecological Society of America, Workshop on Sustainability. Providence, RI. March 5-7.

Pickett, S.T.A. 2007. LTER Mini Symposium, National Science Foundation, Washington, DC. March 8.

Pouyat, R.V. 2007. Integrating ecological science and policy. Florida A&M University, Department of Environmental Sciences, Tallahassee, FL. March.

Pouyat, R.V. 2007. Urban soils: the brown infrastructure of cities. Rutgers University, Department of Environmental Science, New Brunswick, NJ. April.

Pouyat, R.V. 2007. The use of metaphors, anecdotes, maxims, analogies, and similes in communicating ecological science. Annual Meeting of the Ecological Society of America, Workshop on Communicating Science, San Jose, CA. August 5.

Pouyat, R.V., I.D. Yesilonis, W.C. Zipperer, K. Schwarz, and D. Nowak. 2007. Spatial variation of soils and vegetation structure in urban landscapes of the USA. IALE World Congress, Symposium on Urban Landscapes, Ede, The Netherlands. July 8-12.

Pouyat, R.V., I.D. Yesilonis, and N.E. Golubiewski. 2007. A comparison of soil organic carbon stocks between residential turfgrass and native soil. Annual Meeting of the Ecological Society of America, San Jose, CA. August 4-10.

Schwarz, K., S.T.A. Pickett, M.L. Cadenasso, R.V. Pouyat, and I.D. Yesilonis. 2006. The spatial dynamics of lead levels in urban soil and correlations with land cover in Baltimore, Maryland. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Smith, J., K. Szlavecz, and C. Welty. 2006. MIRTHE and the BES: measurements of the coupled water, carbon and nitrogen cycles in urban environments. Baltimore Ecosystem Study Annual Meeting, Baltimore, MD. October 18-19.

Szlavecz, K., E. Hornung, F. Vilisics, Cs. Csuzdi, and Z. Korsos. 2006. The soil ecosystem in urban areas: soil biodiversity. 1st European Congress of Conservation Biology, Eger, Hungary. August 22-26.

Szlavecz, K. and Cs. Csuzdi. 2006. Land use change and earthworm communities is Eastern Maryland, USA. The 8th International Symposium on Earthworm Ecology, Krakow, Poland. September 4-9.

Szlavecz, K. 2006. Life under your feet at SERC: distribution and diversity of soil invertebrates. Smithsonian Environmental Research Center, Edgewater, MD. November 16.

Szlavecz, K. 2007. The soil biota in the urban landscape. Cleveland State University, Cleveland, OH. April 27.

Szlavecz, K. 2007. Soil moisture sensors and future opportunities with gas sensors. Baltimore Ecosystem Study Quarterly Research Meeting, Baltimore, MD. June 27.

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Welty, C., A. Miller, K.T. Belt, J. Smith, L.E. Band, P.M. Groffman, T. Scanlon, J. Warner, R. Ryan, D. Yeskis, and M. McGuire. 2006. Quantifying urban groundwater in environmental field observations. American Geophysical Union Fall Meeting. San Francisco. December 11-15.

Websites

www.beslter.org – Main website for the Baltimore Ecosystem Study. Re-designed 2006-2007.

http://www.orspublic.org/Ors/Search/Keywordsearch/search.cfm – 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://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 – Website dealing with soil invertebrates investigated in BES.

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/climhy/ – 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.

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 are publicly available at this site.

http://pubs.water.usgs.gov/wdr2006 – Annual summary of data for six stream gaging stations supported by BES and many other stations in or near the study area are publicly available on this site.

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://pages.lindberghschools.ws/education/dept/dept.php?sectionid=992
In cooperation with the Lindbergh School District in St. Louis, MO (which funded the Lindbergh grant that supported this project), this website houses a brief description of pollinators, gardening for pollinators, and the methods used in our research. The site is used primarily by elementary school teachers in the district, who include a section on pollinators in their second grade curriculum.

ftp://bcftp:bacounty@towson4.co.ba.md.us/deprm
The Oregon Ridge Park Forest Health Assessment and Forest Management Plan. User name=bcftp, Password=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.

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. ***Soil and Land Use Controls on Contemporary Urban Upland Forest Communities.***

Interesting results are emerging from analysis of upland forest plot data collected in the early 2000's:

- Community composition responds (i.e., becomes dominated by native, successional species) across a gradient defined by local slope and local soil erosion potential.
- This result implies that erodible soils on steeper slopes have had more time for community development, suggesting early abandonment.
- In addition, drier soils tend to support communities dominated by native, successional species, regardless of soil erosion potential or local slope.

2. ***A Longitudinal Analysis of the Social Dynamics of Environmental Equity in Baltimore. NSF Human and Social Dynamics Competition.***

Using an environmental justice framework, we examined the distribution of parks in the Baltimore Metropolitan region in relation to residential patterns of racial and income groups. 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. Similarly, more low income census block groups tend to be closer to parks, but have walking access to fewer acres per capita than high income census block

groups. 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. The greater accessibility to parks for blacks than whites is in spite of a long history of neglect of the recreational needs of black Baltimoreans. The dynamics of metropolitan growth, fueled in part by racism and fear, led to white flight from the city and black inheritance of much of Baltimore's space, including its parks. A combination of outcome and process analyses can improve understanding of environmental justice dynamics.

3. ***Ecology and Environmental Justice Research across the LTER Network: long-term and multi-scale understandings of past, present, and future.***

A network level analysis of environmental justice dynamics, one that is socio-ecological in approach, addresses the three grand challenges outlined in the LTER planning grant. Human behavior and action influence biotic structure, biogeochemical cycling, and climate change, which in turn impact human outcomes and behavior. But what is clear is that these environmental drivers do not affect all people equally, nor do social systems respond equally to environmental change, regardless of who is affected. The key is to move from anecdote to generalized understanding. The group agreed that future research on environmental justice would incorporate results from all questions of the planning grant, it is particularly salient to questions four and five, which address the feedback relationships between human and ecological dynamics.

4. ***A Social and Environmental Analysis of the Origins and Effects of Asphalt Removal Programs in Baltimore, Maryland.***

Although work is just beginning on this project, newspaper searches and a review of Women's Civic League records indicates that asphalt was commonly applied to derelict lots as a cost-effective "beautification" measure as early as the 1940s. By the 1960s, residents were complaining that the surface posed risks for children.

5. ***Policies, Planning, and Investments in Open Space Preservation and Conservation in Urban Areas: A Cross-Site Comparison of Baltimore, Maryland and Edinburgh, Scotland.***

Although Edinburgh's green belt is currently threatened with "wedge" development the total acreage it encompasses has expanded since its establishment in 1957. Meanwhile, Baltimore's attempts at preserving open space—including a 1960 initiative to create "separator belts" around the city—have fallen short by comparison. Among other things, lack of coordination among private and public entities, including multiple layers of government, have frustrated open space efforts in the Baltimore area, although Baltimore County's program is a notable exception. Cooperation among public and private entities and adherence to a regional plan has allowed Edinburgh to achieve its open space preservation goals to a much greater degree.

6. ***Insect Pollination in Urban and Suburban Garden.***

There are approximately fifty-four species of bees in New York City gardens, and over seventy species of bees in the private gardens of Westchester County, NY. Vegetables that require pollination to set fruit are pollen limited, when grown in NYC community gardens. The cause of pollen limitation appears to be a lack of visits to vegetable flowers in NYC gardens, and not to the deposition of heterospecific pollen on cucumber stigmas.

7. ***HERCULES.***

HERCULES provides urban designers with a useful tool in which to understand urban spatial and temporal patterns that could lead to more sustainable urban designs.

8. ***Bird Populations and Diversity.***

Cluster analyses of habitat-bird relationships revealed four distinct bird communities within Baltimore City, each associated with particular habitat features. Urban shoreline and inner city clusters are both associated with highly urbanized areas, but the urban shoreline birds are also associated with water. The Buildings & Shrubs and Mature Residential clusters differ in the kind of vegetation cover but are both associated with lower density residential areas.

9. ***Gray Squirrel Populations.***

Specific Findings:

- Gray squirrel population densities are not correlated with the habitat suitability of urban parks.
- Gray squirrel population density is negatively correlated with gray squirrel wariness in urban parks.
- Gray squirrel population density is positively correlated with intraspecific aggression in gray squirrels in urban parks.
- Gray squirrels in urban parks display the activity patterns of a species that has undergone synurbization.
- No differences were found between summer and fall activity of gray squirrels in urban parks.
- The number of buildings and trees in the area surrounding an urban park may be used to approximate squirrel abundance inside the park. Parks situated in a landscape with many buildings and few trees will have increased gray squirrel population densities.
- Park canopy cover and squirrel population density are the best predictors of gray squirrel wariness. Gray squirrels in urban parks with less canopy cover and low population densities will be more wary.
- The average basal area of park trees, the amount of tree cover in the area adjacent to the park, and gray squirrel population density are the best predictors of gray squirrel intraspecific aggression. Squirrels will be more aggressive in urban parks with larger trees, high population densities, and those that have a landscape with substantial tree cover.
- The best predictor of gray squirrel activity was population density. Gray squirrels in urban parks are more active with higher population densities.

10. ***Ecology of Invasive Species.***

In the laboratory mesocosm experiments we were able to demonstrate both intra- and interspecific competition between two invasive lumbricid earthworm species: *Lumbricus rubellus* and *Octolasion lacteum*. Increasing density resulted in a decline in weight gain as well as individual feeding rate. Intraspecific interaction was stronger than interspecific interaction. The strength of the effect depended on the food type, and whether single or mixed leaf litter was provided. In a subset of experiments we were also able to demonstrate how increasing density affects CO_2 efflux. This effect was the strongest in the first few weeks of the experiments with virtually no differences at the end of the sixth week. The results of this work highlight the complexity of the biotic interactions between and among species and trophic levels, and the implications for organic matter decomposition in soils.

11. ***Wireless Sensor Networks for Soil Monitoring.***

The first deployment of the new generation motes took place in June 2007 at the Jug Bay Wetlands Sanctuary. These motes are monitoring the soil conditions of box turtle nests for the duration of egg incubation (about two months). With CO_2 measurements we found great variations within and among sites, and big differences with the time of the day. These data are currently being analyzed more thoroughly.

12. ***Avian Point Counts, a Long-term Monitoring Project.***

Comparisons between BES and CAP: (Summary of results from Shochat et al. manuscript in revision.) Although declining biodiversity owing to urban and agricultural development is an established global pattern, its causes remain unclear. We propose competitive exclusion of native species by human-commensals as a theory for this phenomenon. Conversion of wildlands into agricultural and urban ecosystems often increases site productivity and resource abundance. As in many human societies, the increase in productivity does not result in "all boats rising," but closer to a "winner-take all" situation. Food is shared unequally among species, with a minority of invasive species dominating most of the resources. For example, CAP LTER bird communities changed from a relatively even desert community to uneven communities in agricultural and urban sites. The House Sparrow (*Passer domesticus*) moved from the fifteenth position in the desert, to fifth in agricultural, to the first position in the residential habitat, with mean abundance of 0.83, 4.78, and 10.77 birds/point count respectively. Bird communities in Baltimore wildland (forest) and urban habitats showed similar profiles to those in CAP. Here, the Chimney Swift (*Chaetura pelagica*) moved from the last position in the forest to the first in the urban habitat. We argue that to understand clearly the effects of habitat conversion on biodiversity and environmental sustainability, one needs to account for the interspecific interactions in the altered environment. Increasing inequality changes the community profile for birds at BES and CAP as well as for spiders at CAP. We suggest "taxing the maximum wage" of the "novo-rich" invasive species as a conservation strategy for increasing biodiversity in human-managed environments.

Cavity nesting bird habitat findings: Cavity nesting birds are among the bird species most strongly impacted by urbanization, due in part to reduced abundance of a key resource, snags or standing dead trees. However, many cavity nesters also nest in dead portions of live trees, and less is known about the distribution and management of this resource. A candidate mechanism affecting this resource is arboricultural tree care, a practice which typically removes hazardous deadwood from places that impact people or property. Using standardized hazard ratings by certified arborists, we assessed the degree of overlap between tree hazards and bird habitat in Baltimore and in two locations in Western Massachusetts. We conducted vegetation sampling, bird counts, and hazard ratings along 100m transects. We conducted nest monitoring in a wildland site, an area of abandoned town sites in western Massachusetts with relatively unmanaged, open-grown trees and an intact cavity nesting bird community. Trees used by cavity nesting birds exhibited higher hazard ratings than nearby randomly chosen trees of the same size and species, particularly in the category of "probability of failure" (probability of falling). In addition, the wildlands location had proportionally greater numbers of trees with both high hazard ratings and suitable nesting habitat than trees in suburban plots in Massachusetts and in the urban residential plots in Baltimore. The relationship between probability of failure and presence of suitable nesting habitat is nonlinear. Thus, while tree care practices likely constitute an important factor in loss of habitat for cavity nesting birds, it may be possible to reduce these impacts without increasing hazards to people and property.

13. ***Urban Vegetation Distribution.***

We found that social-stratification variables best predicted the variability in "possible stewardship," or plantable area on a parcel, including variables such as home value, vacancy, race, education, crime and housing age. For "realized stewardship," or amount of plantable area on a parcel covered with trees or grass, both social stratification and lifestyle variables predicted variation. Lifestyle variables included family size, marriage rates, and home type. There were differences in the predictors of yard expenditures from those of "realized stewardship." In particular the percentage of African American variables was positively related to realized stewardship but negatively related to yard expenditures, suggesting that in highly African American neighborhoods, vegetation was either the result of previous legacies, lot abandonment, or management that did not involve spending through traditional garden supply retailers.

14. ***Parks and Crime Study.***

We found park proximity was positively reflected in property values where neighborhood robbery rates were low but negatively valued where they were high.

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

1. ***The Rate and Role of Overbank Deposition in Urban Fluvial Systems.***

Work on investigating the role of flood plain sediment storage in the Gwynns Falls sediment budget has produced interesting results.

- While incised urban streams are often considered decoupled from their floodplain, sediment deposition continues on this floodplain.
- The rate of recent sediment deposition inferred from Bain's dissertation work is comparable to or larger than the rate of sediment remobilization from stream bank erosion calculated using Colosimo's dissertation data in collocated reaches of Red Run.
- This preliminary result raises some doubts about the effectiveness of stream restoration efforts that remove post-European "legacy" sediment accumulation from stream valleys.

2. ***Gwynns Falls Riparian Sediment Geochemistry.***

Continuing examination of the riparian sediment data includes the following findings:

- The change in physiographic provinces at the Fall Line has profound impacts on the physical and chemical characteristics of riparian sediments, leading to coarser sediments with less organic material and secondary minerals downstream.
- However, there are also increases in potentially toxic trace metal concentrations (e.g., Pb and Zn) as contributing areas become increasingly urbanized, including areas dominated by coarse sediments.
- Urban fill is an important determinant of this pattern of contamination in riparian zones.
- There is a pronounced increase in Ca concentrations with urbanization, as suspected by Pouyat. However, this increase does not seem to correspond with enhanced chemical weathering due to acidification or simple changes in atmospheric Ca inputs.

3. ***Streamflow Distribution of Non-point Source Nitrogen Export from Urban-rural Catchments in the Chesapeake Bay Watershed.***

We find increasing development in watersheds is associated with shifts in nitrogen export towards higher discharge while total magnitude of export does not show as strong a trend. Forested reference, low density suburban, and agricultural catchments export most of the total nitrogen (TN) and nitrate (NO_3^-) loads at relatively low flows. More urbanized sites export TN and NO_3^- at higher and less frequent flows. The greatest annual loads of nitrogen are from less developed agricultural and low density residential (suburban/exurban) areas; the latter is the most rapidly growing land use in expanding metropolitan areas. A simple statistical model relating export distribution metrics to impervious surface area is then used to extrapolate parameters of the N export distribution across the Gwynns Falls watershed in Baltimore County. This spatial extrapolation has potential applications as a tool for identifying variations in export distribution and targeting stream channel restoration efforts at the watershed scale.

4. ***Evaluating the Potential of Stream Restoration as a Tool for Increased Nutrient Retention.***

Estimates of nitrate (NO_3^-) export expected to result from restorations assuming specific increased uptake velocity (v_f) levels in a set of catchments along an urban-rural gradient in Baltimore, Maryland. Percent reductions in NO_3^- load were greatest in small headwater catchments with moderate to high rates of annual NO_3^- export. However, greatest absolute reductions in magnitude occurred in larger streams, where even small changes in v_f lead to large mass losses. Export flow distribution of NO_3^- also influenced restoration effectiveness such that sites where the majority of NO_3^- export occurs under low to moderate flow conditions have much higher potential for restoration. Results suggest that 1) decisions about restoring small versus large streams will need to focus on balancing costs, risks and local versus regional goals, 2) that restoration success depends on our ability to permanently increase v_f, which is currently unclear, and 3) that improving the nutrient performance of urban watersheds to meet specific goals may require alteration of hydrology (to increase baseflow) and/or reduction of inputs as well as stream restoration.

5. ***Urban hydrology and Stream Ecology Research.***

- *The Urban Gutter Subsidy.*
  This work is revealing large particulate and dissolved organic matter fluxes that are related to impervious surfaces and hydrologic state, suggesting that urban streams, with their greatly enlarged drainage networks, actually receive much larger inputs of organic matter than natural systems, which rely only on riparian input of leaves and their attendant dissolved organic matter.

  Although the three small catchments with buried streams (i.e., storm drains) had no visible point sources, they generally had the highest concentrations of all of the parameters, which are often found in aquatic environments influenced by inputs from sanitary sewage and urban runoff. Since the flows in the storm drains were from infiltrating groundwater, the results suggest that groundwater in these areas likely has been affected by both infiltrating stormwater runoff and leaking infrastructure. In fact, these buried streams had very high concentrations, suggesting that older storm drains, which are positioned within a three-dimensional matrix of aging water and sewage infrastructure, may be channeling groundwater contaminated by leaking sanitary sewers. The role of aging highly urbanized residential headwater catchments in supplying nutrients to receiving waters may be more important than heretofore realized.

- *Watershed 263 Urban Restoration.*
  Baseline dry weather and storm data collected at these sites (Baltimore and Lanvale Street gaging stations) reveal a dynamic thermal system with high bacterial concentrations and large nutrient and metal loads which suggest that older, ultra-urban residential catchments may be hotspots in terms of concentrations as well as runoff load exports.

  Copper, Lead and Zinc levels were high. Metal concentration (hardness-adjusted) water quality criteria were often exceeded; of the Cu, Pb and Zn

samples, only the Zinc dry weather flow samples were always below criteria levels. For dry weather, 57% (Cu) of the Baltimore Street samples exceeded criteria. Storm sample composites exceed Cu, Pb, and Zn criteria 89%, 79% and 26% of the time at Baltimore Street and 35%, 65% and 29% of the time at Lanvale Street, respectively. Metal loads at Baltimore Street were extremely large for both baseflow and storm runoff. Nutrient levels were also high; metal and nutrient concentrations were higher than typical values for residential areas. For example dissolved Cu and Zn (17 and 77 ug/l) and nitrate-nitrate N and total phosphorus (5.6 and 0.46 mg/l) storm EMC medians at Baltimore Street are much greater than medians for residential areas in the National Stormwater Quality Database (3.0 and 31.5 ug/l and 0.6 and 0.30 mg/l) and are orders of magnitude greater than what would be expected for forested small catchments. Moreover, at Baltimore Street nitrate N dry weather flow concentrations were extremely high (higher than storm runoff), suggesting that annual dry weather loads at this site may be greater than stormwater runoff. Fluoride concentrations (normally absent or at low concentrations in natural catchments) were very high at both sites, suggesting that leaking potable (or sewage) water is a significant part of the groundwater flow. Summertime water temperatures showed elevated levels for both dry weather flow (buried streams should be very cool), and for stormwater runoff, where spikes of great magnitudes were seen. These results suggest that thermal fluxes from these small catchments are influenced by thermal loads transferred by both surface runoff and groundwater flows. Both dry weather and storm runoff flows had high levels of bacterial contamination, also suggesting both surface and subsurface contributions.

- *Pathogens in Urban Streams.*
  Dry and Wet Weather *E. Coli* Concentrations in a small ultra urban headwater stream approach those of raw sewage. High levels of baseflow *E. coli* showed greatly increased concentrations during post storm periods in urbanized catchments, but not in more “natural” catchment streams or sewage impacted sites. Our data indicate that pathogenic *E. coli* are continually deposited into a variety of stream habitats and suggest that this organism may be a permanent member of the gastrointestinal microflora of humans and animals in the metropolitan Baltimore area.

- *Thermal Fluxes in Urban Streams.*
  Suburban stream sites with greater ISC generally had higher summer water temperatures. Suburban catchments with most of their channel drainage contained within storm drain pipes showed subdued diurnal variation and cool temperatures, but with very large spikes in summer runoff events. Conversely, high ISC urban piped streams had elevated “baseline” temperatures that stood well above all the other monitoring sites. There was a pronounced upstream-downstream effect; nested small headwater catchments experienced more frequent, larger temperature spikes related to runoff events than the downstream sites. Also, runoff-initiated temperature elevations at small stream sites unexpectedly lasted much longer than the storm runoff hydrographs. These observations suggest that for small headwater catchments, urban

landscapes not only induce an ambient, "heat island" effect on stream temperatures, but also introduce thermal disturbance regimes and fluxes that are not trivial to aquatic biota.

6. ***Stream Gaging Stations.***

Primary product is a continuous data stream, published annually, with some station data available in near real time.

7. ***Root Biomass, Organic Matter and Denitrification Potential in Degraded and Restored Urban Riparian Zones.***

There were three main findings in this study. First, while reference sites were wet and had high levels of organic matter, they had low levels of nitrate relative to degraded and restored sites and therefore there were few differences in denitrification among sites. These results suggest that evaluations of riparian restorations that have denitrification as a goal must consider the complex controls of this process and how they vary between sites.

Second, all variables declined markedly with depth in the soil profile. This decline is important because riparian denitrification functions depend on the interaction of nitrate-laden groundwater from uplands or the stream with soils with high denitrification potential. Root biomass declined much more sharply with depth in the degraded and restored sites than in the reference sites (Figure 1). These results suggest that recovery of root biomass, especially at depth, will be a slow process in restored riparian zones (our restored sites are 5–10 years old) and that restorations that increase riparian water tables will foster interaction of groundwater nitrate with near-surface soils with higher denitrification potential.

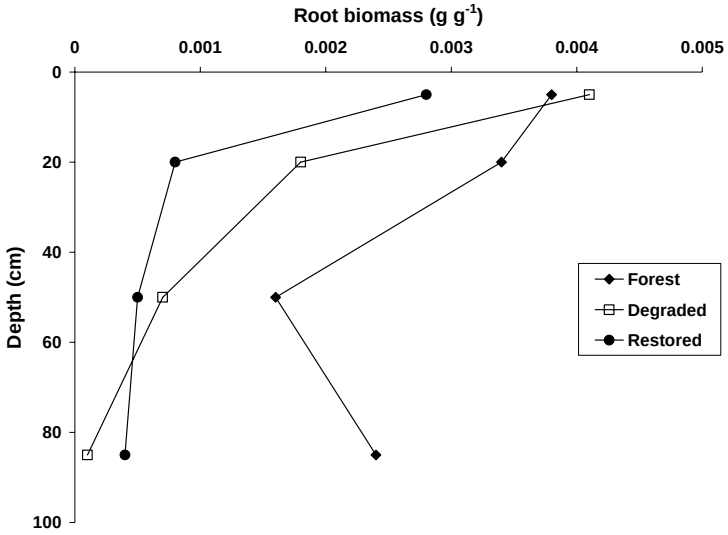

Figure 1. Root biomass versus depth for forested reference, suburban degraded and restored riparian zones. Values are the mean of two sites per riparian zone type.

Third, we observed strong relationships between root biomass and soil organic matter, and between soil organic matter and denitrification potential (Figure 2). These results suggest that establishment of deep rooted vegetation may be particularly important for increasing the depth of the active denitrification zone in restored riparian zone soils.

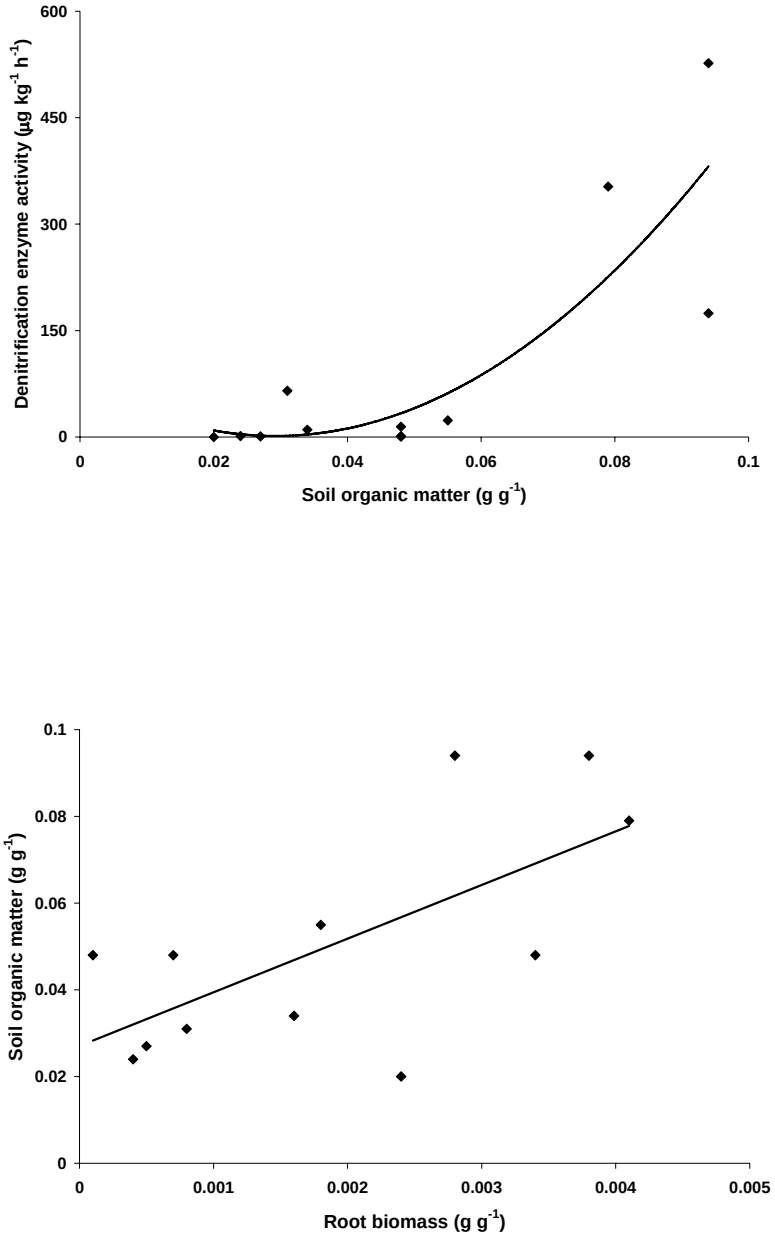

Figure 2. Denitrification enzyme activity versus soil organic matter (top) and soil organic matter versus root biomass (bottom) for forested reference, suburban degraded and restored riparian zones. Values are the mean of two sites per riparian zone type at four depths (n=12).

8. ***Land Cover Influences on Air Temperature.***
Where tree cover is higher, temperatures are generally lower. In downtown Baltimore, air temperatures at night are often 8ºC warmer than in a rural forested site. However, topography and proximity to large bodies of water, in Baltimore the Chesapeake Bay, as well as land cover is important in determining air temperature differences and the differences depend strongly on atmospheric stability. Prediction models can be developed that permit GIS mapping of hourly average temperature patterns across an urban region.

9. ***Bacteria in Baltimore Streams.***
E. coli (contained in dialysis tubes with a 50 kDA MW cutoff) were capable of surviving > 45 days submerged in stream water during these time periods. *E. coli* from Gwynns Run did not display inhibited growth when exposed to concentrations of water pollutants frequently observed in US streams and groundwaters.

10. ***Carbon Storage in Residential Lands.***
The process of residential development is obviously a substantial disturbance, and the topsoil on which new homes are built can be surprisingly infertile. To develop the methods for use in this project, we established a set of study sites on thirteen turfgrass sites (eleven lawns and two sites in a common area) in residential areas of South Burlington, VT. The lawns studied ranged in age from one to twenty-five years. Nine of the lawns and the two common area sites are in the same development (Dorset Farms) and range from one to eight years old. The remaining two lawns are in another development (Butler Farms) roughly 4-5 miles away, and are sixteen and eighteen years old.

Homes in Dorset Farms were built using identical site preparation methods, and filled using topsoil from the same source. The only factors that vary among these homes, therefore, are the age of the home and the management regime applied by the homeowner. The Butler Farms sites are useful as they provide additional older-home datapoints, but site preparation methods are unknown for these older homes. Findings related to the rate of soil C accumulation in lawns, clipping production, and foliar %N related to overall clipping production were reported in the 2006 annual report. In August 2006, data collection was completed for this project in Vermont, and data analysis is ongoing. There is a full year of measurement for soil C flux parameters for these thirteen sites; a manuscript is in preparation describing the complete C balance along this chronosequence.

In Baltimore, we have finalized the set of “clusters” that are being sampled and analyzed. We will be able to conduct comparisons of C flux parameters by comparing results among clusters (Table 1).

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

cluster ID	land use history	housing age	HERCULES 6.0 coarse veg density	HERCULES 6.0 structure density	soil group	neighborhood	number of households recruited to date (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.

We have nearly completed a full year of C flux measurements for the sites where measurements began in spring 2006. These measurements include thatch and stubble and clipping collection for grass productivity analysis. Results to date suggest that differences do exist between clusters in thatch and stubble mass from sequential coring (Figure 3).

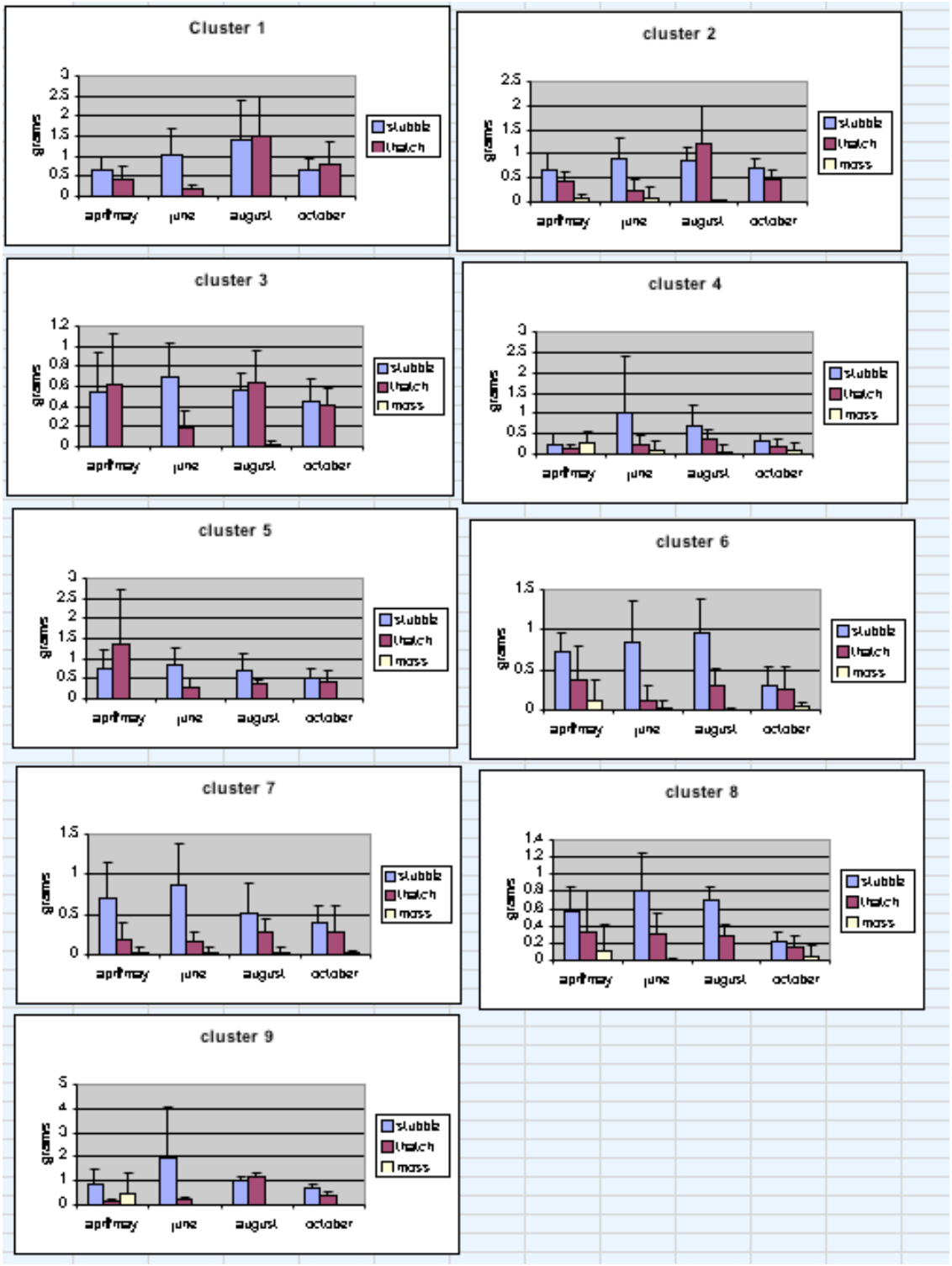

Figure 3. Thatch and stubble data from clusters 1-9 for April/May 2006 through October 2006. Each panel shows a different cluster; each bar (with standard deviations based on three samples) shows a different sampling date. Note differences in scale along the y axis for each of the clusters.

Even more compelling is our preliminary evidence that clipping production varies dramatically between clusters (Figure 4). While different start and end dates are incorporated into Figure 4, the differences in the period of time measured do not follow the same temporal pattern as the differences in clipping (in other words, sites with the longest records do not necessarily have the highest total clipping biomass). Soil respiration data have been collection but not yet analyzed. Information on C stocks, and soil physical and chemical properties, is not yet available.

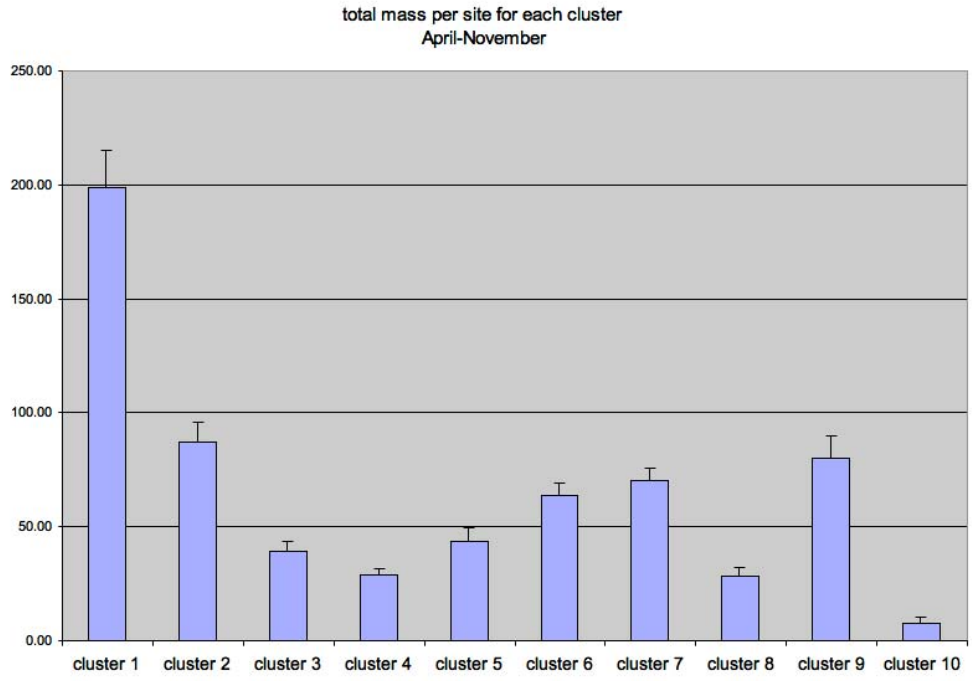

Figure 4. Total clipping production from clusters 1-9 for April through November 2006.

11. *Urban Streams as Transporters or "Transformers" of Organic Nutrients.*

Organic nutrients represent a substantial fraction of the total pool of bioavailable nitrogen and phosphorus in streams. Organic N and P appear to be generated by the stream during drought conditions. Changes in the quantity and chemical quality of organic N and P with land use can also stimulate changes in microbial communities.

12. *Stream Restoration as a Means of Reducing Nitrogen Pollution in Urban Streams.*

Denitrification in restored reaches of streams can be significantly higher than unrestored reaches (Kaushal et al. accepted pending revision). Designs incorporating hydrologic "connectivity" may be most effective in removing nitrogen. Whole stream reach denitrification in hydrologically "connected" areas can be substantial, particularly during baseflow conditions (Klocker et al. in preparation).

13. ***Tracing Sources of Nitrogen Export from Watershed Urbanization.***
Septic systems are a disproportionately major source of nitrate in suburban areas even though they contribute a smaller fraction of N loading from a mass balance perspective. Atmospheric sources of nitrogen are surprisingly important in urban watersheds due to runoff from impervious surfaces during rain events. There appears to be large seasonal transformations of nitrogen by microbial communities in forest and agricultural watersheds.

14. ***Investigation of the Effects of Increased Salinization of Freshwater.***
Salinization is widespread in streams across Maryland. Major sources of salinity appear to be road salt, but stoichiometric ratios suggest that groundwater contamination is a chronic source of stream salinization. Increased salinization appears to decrease potential denitrification activity in some streams.

15. ***Interaction Between Climate Variability and Urbanization.***
We observed large increases (700-2,000%) in annual nitrate export in small streams across Maryland between 2002-2004 as conditions ranged from record drought to extreme wet. Export of nitrate from a small agricultural stream in Baltimore, Maryland was forty times greater than the forest streams throughout Maryland and nitrate export from suburban/urban streams in Baltimore, Maryland was 10-15 times greater than the forest streams throughout Maryland. Our analysis in streams at the regional scale suggests that interactive effects of climate variability and urbanization greatly amplify nitrate export in small streams, management strategies focusing on small streams may be essential, and large variability in nitrate export in small streams can contribute to reduced water quality in downstream tributaries and N-sensitive coastal waters.

16. ***Effect of Urban Land-Use Change on Soil Carbon.***
Within Baltimore, turf grass had almost a two-fold higher SOC density at 0-1-m and 0-20-cm depths than in rural forest soils, whereas there were no differences with soils of urban forest remnants. Moreover, urban forest remnants had more than 70% higher SOC densities than rural forest soils. Within Denver, turf grass (> 25 years of age) had more than two-fold higher SOC densities than in shortgrass steppe soils, while having similar densities to Baltimore turf grass soils at a 0-1-m depth. The amount of SOC in 0-20-cm depth also was similar, though the percentage of SOC (relative to 1 m) at this depth was higher in Baltimore than in Denver. By contrast, the native soils of Baltimore were almost two-fold higher than the native steppe grass soils of Denver using SOC densities of remnant forest soils as representative of native soils in the Baltimore region. These results supported the hypothesis that differences in SOC densities between different climatic regions would be greater between native cover types than between residential turf grass soils.

17. ***Distribution of Heavy Metals in Urban Soils.***
Over half of the plots sampled exceeded the Netherlands guidelines for Cd or Pb, while 10.7% of the plots exceeded USEPA screening guidelines for Pb. In a principal component analysis, the first component corresponded to high contents of Co, Cr, and Fe, which are constituents of local mafic rock types. The second

component corresponded to high contents of Cu, Pb, and Zn. Lead and Zn contents were higher near major roads and in older residential developments. Our results suggest that contamination of Pb, Cu, and Zn occurs primarily in older sections of the city that have a high road density.

18. ***Effect of Salt Runoff on N and C.***
N and C removal in both stream sediments and benthic organic matter is changing under elevated salt concentrations.

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. ***Describing Baltimore's Ecology Education System.***
Inventory of Urban Environmental Education Providers in Baltimore.
The survey was conducted in the spring of 2005. Surveys were received from 147 organizations across the six cities. Response rates varied from 26% in New York City to 85% in Baltimore. An assessment of whether there was sampling bias—do the respondents and non-respondents differ in significant and important ways?—is beyond the scope of preliminary analysis.

Preliminary findings in the six northeast cities reveal a vibrant, diverse and powerful community of organizations. The collective capacity of the groups to serve broad audiences and offer a wide range of programs is impressive. The audiences served are quite diverse in race/ethnicity and age. While the expected emphasis of programs on elementary aged children was confirmed, there still was considerable attention to middle and high school students, and to adults.

Alan Berkowitz has been working with a statistician on a more in-depth data analysis plan during the current reporting period. Findings should be available during the next reporting period.

2. ***The Ecology Teaching Study.***
Preliminary findings revealed that teachers use traditional practices (lecture, reading, discussion) much more than any practices of interest (fieldwork, action projects, etc.), and focus on the Chesapeake Bay much more than on the urban ecosystem, with managed ecosystems receiving even less attention. Student investigations in labs are more frequent than in the schoolyard, with use of the

school's neighborhood being the least frequent. Other teachers and the internet are their most important sources of ecology knowledge, followed by college science classes. Their primary reasons for teaching ecology were to demonstrate relevance and encourage active protection of the environment. Support for ecology teaching from parents is perceived to be lower than from others.

These preliminary findings have important implications for how we craft curriculum materials, programs and professional development activities for teachers, and for our work with pre-service teachers while they are still in training programs. During the current reporting period Alan Berkowitz has worked closely with a statistician to conduct more in-depth data analysis. Findings should be available during the next reporting period.

3. ***Community Relations.***

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

Contributions

1. ***Within Discipline.***

- The environmental justice research extends beyond the traditional confines of social science disciplines, especially geography and sociology, by integrating environmental justice metrics and theory with ecological. This research will add to the growing field of urban ecology, on which this project is based. The research on parks equity will also add to environmental justice theory in the social sciences by turning attention to environmental amenities rather than solely disamenities. A combined analysis of outcome and process equity will also move social science theory forward.

- Timing and magnitude of biogeochemical loading by different land uses and catchment size, potential for stream restoration across the urban-rural stream network.

- HERCULES:
  - is a better tool to test the structure function link in urban systems than traditional land use and land cover metrics;
  - is a tool to characterize and quantify spatial heterogeneity in urban landscapes;
  - furthermore, it questions assumptions embodied in widely used land use classifications and demonstrated why they may be limited when used for understanding the ecological function of systems.

- Streamflow data provided on regular basis and on special request to individual investigators. USGS scientists have participated on a continuing basis in all appropriate BES planning and scientific meetings, including the BES Steering Committee. USGS is providing leadership in general hydrologic investigations in cooperation with other principal investigators and collaborators.

- Continuing studies on bacteria in streams contribute to stream ecology, public health and aquatic toxicology.

- Support from the USDA Forest Service continues for the Cub Hill flux tower. The flux tower provides continuous stream of meteorological data.

- Research on Ecology of Prestige, demonstrated the important role of ecological structure (trees, grass, and shrubs) as household and neighborhood symbols of status and identity (reference group behavior theory and symbolic interactions). The use of temporal attributes (age of housing) demonstrated the need to include a temporal component and that this component is non-linear. Further, our analyses distinguishing between Existing Canopy and Possible Canopy demonstrated the interaction between the Urban Filtering Model from urban

economic theory (Possible Canopy) and reference group/symbolic interaction theory (sociology) (Existing Canopy).

- Results on the streams and watersheds portion of the project have provided new information on: (1) the interactive effects of climate variability and urbanization on amplifying watershed nitrogen export, (2) tracing sources of nitrate to streams in watersheds undergoing rapid urbanization, (3) understanding the influence of land use change on rates of in-stream transformation of nutrients within streams, (4) understanding the effects of roadway chemicals on ecosystem functions/services in streams, and (5) assessing the potential for stream restoration to reduce and retain pollutants en route to coastal waters.

- We have generated one of the most extensive lists of bees found in urban and suburban areas, and one of the few lists of bees that are generally found in gardens. We have identified key, within garden factors that influence bee richness. We have identified bee behavior in florally diverse settings as a contributor to pollen limitation urban vegetable gardens.

- Collection of new information about hydrologic response of urban watersheds to intense rainfall events, magnitude and frequency of urban flooding in relation to rainfall inputs, and role of urban infrastructure as an influence on flood flow patterns; beginning collection of new information on spatial pattern and dynamics of urban groundwater as a contribution to streamflow at the small and intermediate watershed scale.

- Urban design analysis has helped scientists understand the role of the built environment and the design disciplines in shaping socio-natural systems.

- We are beginning to understand one of the consequences of the built environment, road de-icer runoff, on trophic interactions in adjacent waterways.

- 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. 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. Moreover, contrary to the general belief, we showed that soil invertebrates are suitable to test general ecological hypotheses about the effect of resource diversity on species interactions. The results of this work highlight the complexity of the biotic interactions between and among species and trophic levels, and the implications for organic matter decomposition in soils.

- BES has been intimately involved in the LTER Network Planning process, leading to the Integrated Science for Society and Environment report. Co-PI Cadenasso was the Site Representative for this process, and BES members Morgan Grove and Peter Groffman served on the writing team. BES social science knowledge and experience in integrating social and biophysical frameworks, models, and research proved quite valuable in the LTER planning process. BES provided

several compelling examples of operationalizing the feedback loop proposed by the Science Team for the Network Planning Grant (see Figure 5 for one of these examples).

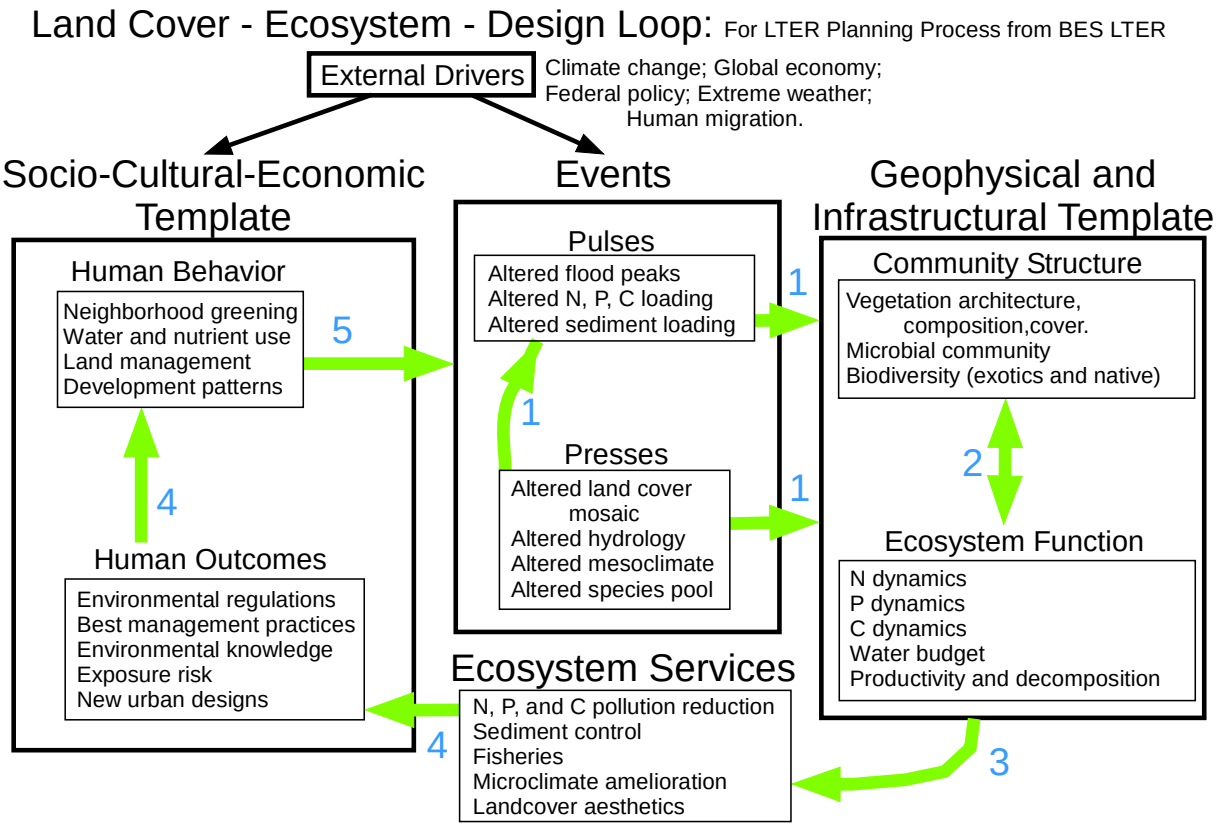

Figure 5. Feedback between ecological and social phenomena and events, exemplified by land cover change in Baltimore.

2. *To Other Disciplines.*

- 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.

- HERCULES is a proven 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.

- USGS data and products are widely used in the geosciences and natural-resources management communities.

- BES has opened up a deeper knowledge of ecological process to a large audience of urban designers and planners.

- 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. This topic was discussed in the April 2006 issue of Nature, where our experiment is also featured (http://www.nature.com/news/2006/060320/pdf/440402a.pdf).

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

- All of the BES education work; from KidsGrow, to ecology units for high school students, to work with IGERT graduate students; contributes to the development of an ecologically literate citizenry in Baltimore, and, potentially, to a new generation of urban ecologists.

- 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 post-baccalaureate technicians: (K. Schwarz, Ph.D. candidate, Rutgers University, E. Cook, Ph.D. student, Arizona State University, W. Zhou, Post-doctoral scholar, University of Vermont).

- Co-PI M. Cadenasso taught a new course entitled “Urban Ecology” at the University of California-Davis, winter 2007. 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.

- Used concepts, data, and insights from BES in guest lectures for four courses at UC Davis: 1) Urban Forestry, 2) Trees and Forests, 3) Restoration Ecology, and 4) Ecology (Graduate core course).

- Development, organization, and execution of the 12th Cary Conference at the Institute of Ecosystem Studies entitled "Resilience in Ecology and Urban Design: Synergies for theory and practice in the Urban Century," drew extensively on the research experience provided by BES.

- 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.

- Our work has developed extensive social-demographic databases in terms of temporal and spatial that are fine grain and extensive. The development and attribution of parcels with social and ecological data from a variety of sources, including government records and long term BES core data, is a unique and valuable resource.

- Two Research Experience for Teachers (RET), Keri Brandt and Sarah Ferraro, worked on a project regarding the effects of stream restoration on reducing watershed nitrogen export. They developed new lesson plans and experiments based on their experience.

- The Pollinator Project Website and associated materials developed during the teacher in-service training, are being used by 2nd grade teachers in the Lindbergh School District to teach their students about the importance of insect pollinators to ecology and agriculture.

- The principals of the Urban Design Working Group are all design teachers and practitioners. Working with BES has given them greater knowledge of ecology and urban ecosystem processes for both the classroom and built professional projects. This knowledge has been used in studios and courses at Columbia, The Parsons School of Design, the University of Toronto and the University of Pennsylvania.

4. *To Research and Higher Education*

HERCULES has been used in several research and educational contexts, where it:

- 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.
- exposes the constraints of widely used land cover/land use classifications that are derived from the Anderson et al. (1976) system.
- 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.
- can be integrated with ancillary data either from ecology or other disciplines.
- has been used in urban design studios at Columbia University.

The HERCULES Atlas is a great resource for teaching urban ecosystem processes but both describing the specifics of the Baltimore Region, and as a model of analysis in other places.

USGS moved its staff, field, library, conference, and laboratory facilities to the University of Maryland, Baltimore County campus on August 13, 2007 and its resources will be available to students, staff, and other researchers.

Training / Development

Two University of Pittsburgh undergraduate students, (1) Emily Broich learned GIS skills, historical map interpretation, etc. in her work on the historic stream course of Powdermill Run; and (2) REU student Amar Mehta has learned field sampling, laboratory analysis, and data analysis techniques. Helped a PhD graduate student with questions regarding the literature and experimental design for her paper and thesis addressing stream restoration and denitrification. Graduate student Hyunkee Bae gained experience in working with meteorological data, computer spreadsheets, and data quality assurance.

The project has contributed to the M.S. degree of Carolyn Klocker (University of Maryland, 2007). It has also contributed to ongoing graduate studies by other students Tamara Newcomer (M.S. University of Maryland), Peter Bogush (M.S. University of Maryland), Ken Belt (Ph.D. University of Maryland), Gwendolyn Stanko (Ph.D. University of Maryland), Katie Delaney (M.S. University of Maryland).

The REU supplement has offered the chance for Rebecca Reeves to work on research as a sophomore, which is quite early for an undergraduate. Collaboration with PI's within BES is allowing Peter Bogush to complete his thesis by processing samples at IES and working in the established field sites.

Paul Lilly, PhD student at the University of Vermont (advisor Jennifer Jenkins), began his work in fall 2005 and continued his work this year. Paul spent the summer in Baltimore, helping with the fieldwork on this project and doing background research to support his dissertation. The committee has been appointed and he plans to conduct a project in summer 2007 that defines the impact of management on turfgrass productivity and C sequestration.

Monica Smith, PhD student at the University of North Carolina (advisor Larry Band), and Steve Raciti (advisor Tim Fahey), PhD student at Cornell University, are conducting infiltration studies on a subset of the thirty-three plots as separate components of their PhD dissertation projects.

Yvette Williams, an IGERT Fellow at UMBC (advisors Pickett & Welty) is investigating the social/ecological effects of restoration on WS 263 neighborhoods.

Kirsten Schwarz, PhD student at Rutgers University (advisor Steward Pickett), plans to analyze soil cores collected from these thirty-three plots (or a subset of them) to understand the relationship between land use history and soil lead levels.

UMBC IGERT "Water in the Urban Environment" program involves several BES investigators, classes, and student internship opportunities.

Two undergraduate and three graduate students were trained in field techniques and statistical analyses in the pollinator studies.

Working with graduate student Whitney Carroll, Towson University; advising two graduates students, Lijun Xia and Jerry Burgess. Training and research opportunities for two undergraduate students, one female, who received REU awards. Working with a third REU student (Kenny Parker) at the Smithsonian Environmental Research Center.

Technicians Noonan and Quin received training in meteorological instrumentation, use of data loggers, use of computer spreadsheet programs, and quality control in research.

Participation (by invitation from Pat Bradley, USEPA) in the Towson University Environmental Science Graduate Student Practicum Paper Review Panel, providing guidance and feedback on student capstone projects and final papers related to urban runoff and stormwater and watershed management.

Professional development in attending to student thinking and then building upon it instructionally has been a key part of the Responsive Teaching Study's biweekly meetings held throughout the 2006-2007 school year. Regular 1-2 hour professional development sessions were held with the KidsGrow after school program leaders throughout the 2006-2007 school year. The BES Education Coordinator also regularly visited the program when in operation; either leading, observing or helping with sessions.

Professional development in ecology, research methods, and field work/ investigations was provided to the two teachers who participated in the Research Experience for Teachers (RET) program. Three specific activities were conducted:

1) Teaching Urban Ecology in Baltimore: A Workshop for High School Environmental Science Teachers - July 17-20, 2007: We recently completed a very ambitious professional development workshop, which included nine high school environmental science and biology teachers from city and county public and private schools; sited along an urban, suburban and rural gradient. We met at four different sites to facilitate completing investigations at an urban, suburban and rural school. The investigations explored questions regarding CO_2 concentrations, biodiversity and schoolyard water budgets. We visited an urban BES stream sampling site at Carroll Park, a USDA Forest Service carbon flux tower at Cub Hill in suburban Baltimore County, Loch Raven Reservoir (suburban/rural) and an organic farm at Cromwell Valley Farm (suburban/rural).

Noted experts spoke to the group including BES scientists Richard Pouyat and Kenneth Belt (USDA Forest Service), Katalin Szlavecz (Johns Hopkins University), Dan Dillon, (IES Research Assistant) and Matt Belmont (Cromwell Valley Farm Head Farmer). The workshop was led by Alan Berkowitz, Janet Coffey and Janie Gordon.

2) Three teachers who attended the "Teaching Urban Ecology in Baltimore" workshop are eager to participate in SURGES and later expand the program to include additional teachers and their students. We will be holding two half day Saturday sessions with the workshop participants; one in the fall and one in the spring. They will be providing us with an action plan for teaching some aspect of urban ecology with their students, using the IUE units as appropriate. In addition, each teacher will create a "focus on student thinking" section of the IUE unit of their choice. This assignment will include: (1) a clear statement of the key concepts and understandings the teacher chooses to focus on, (2) presentation of concepts in relation to national and state standards and their curriculum, (3) a description of effective techniques for looking at students' thinking, (4) a discussion of what the teacher learned about student thinking, and (5) effective teaching strategies for improving student thinking on the topic of interest.

3) A few of the "Teaching Urban Ecology in Baltimore" workshop participants will be joining the Responsive Teaching Study project for the 2007-2008 school year. This increasing integration of BES education work is very exciting and promises to provide new insights!

HERCULES occupies a central role in the doctoral research of K. Schwarz, Rutgers University. K. Schwarz has helped to develop HERCULES which has increased her skills in GIS and air photo interpretation. HERCULES also helped in getting a clear grasp of ecological concepts such as landscape ecology, spatial heterogeneity, and frameworks. HERCULES has provided fodder for W. Zhou (UVM) to develop skills using object oriented classification software and developing algorithms to automate HERCULES using his software. HERCULES has been incorporated as a data layer into the doctoral research of D. Pennington at the University of Minnesota.

Advanced Spatial Methods http://www.uvm.edu/envnr/gradgis/advanced/
This course at the University of Vermont teaches various statistical and spatial analysis methods through weekly lab exercises and a final project. Among the methods addressed are advanced overlay analysis with geoprocessing and cross-tabulation, Geographically Weighted Regression, spatial cluster analysis, analysis of variance, logistic regression, multi-model inference, spatially weighted regression, analysis of spatial residuals, and measures of spatial autocorrelation. Students will be introduced to S-Plus (including S-Plus spatial module) and GWR software, and will learn new methods in software they have already worked with, including ArcGIS and Microsoft Access. The course currently uses data from the Baltimore Ecosystem Study, an NSF-funded Long Term Ecological Research Project as the focus for all labs. These exercises build sequentially and thematically on a single question from the case study and methods are introduced in the context of

answering this question. For instance, the course currently analyzes the relationships between urban green space and socio-economic factors. In each lab, the instructor gives a short lecture on the analytic tools to be covered, giving the statistical, conceptual and mathematical background. Students then apply these concepts in the lab using instructions given on the website.

BES collaborations provide opportunities to combine resources on multidisciplinary studies of mutual interest, also provide data and case studies for education of graduate and undergraduate students in the Department of Geography and Environmental Systems at UMBC.

The urban design working group is a form of design research to work on problems beyond the limits, boundaries and restrictions of professional practice. Those professional limits, boundaries and restrictions we seek to go beyond are interpersonal: who you work with – who is your client – and spatial: how is the site you work on bounded by property lines, or other legal or political limits. In other words our working group enables urban design research at multiple nested scales and with a wider array of actors.

We train two undergraduate students in urban wildlife field techniques each year. We are exploring opportunities to partner with students and faculty from Baltimore City Community College. This partnership would increase the number of underrepresented students working with BES.

REU student Rebecca Reeves worked on a project asking how trophic interactions between amphibian larvae and their algal resources changes under salt loading from road de-icer runoff.

Planned, coordinated and hosted the BES Annual Staff Field Safety and Community Awareness Training Workshop. This annual workshop is held to familiarize new and summer researchers with information about the community, BES field research sites and safety awareness.

Graduate interns and undergraduate students were trained at Parks and People Foundation in the following projects:

- Developing and leading Watershed Ecology Education enrichment program with Parks and People's SuperKids Camp.
- Developing educational materials and resources for the Neighborhood Ecology Center.
- Developing organizing and capacity-building strategies for Watershed 263 Stakeholders Council.
- Providing technology transfer support to Watershed 263 Council.
- Developing outreach plan and interpretive materials for Gwynns Falls Trail and Watershed 263 Greenway.
- Developing and distributing social marketing tools for Urban Parks and Trails.
- Developing Green Career Ladder enrichment activities for BRANCHES summer youth forestry training and employment program.

- Leading environmental and ecological sciences field studies for BRANCHES summer youth forestry program.
- Create longitudinal database of KidsGrow participants 1998-2007. Will provide baseline for retrospective analysis of environmental education program and curriculum development.

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

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

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

The development of Urban Tree Canopy (UTC) tools has contributed significantly to the Chesapeake Bay Program's ability to describe, understand, and develop urban natural resource initiatives. The adoption of UTC tools figured prominently in PlaNYC and the adoption of a one million tree goal for NYC by 2030 by the Bloomberg Administration. Similarly, in Boston, the Menino administration has adopted a 100,000 tree initiative.

The pollen limitation work is being used to develop strategies that urban gardeners can utilize to maximize yield. This is especially important in the urban gardens we worked in (East Harlem and the Bronx, NY), where access to fresh produce is severely limited, relative to most developed areas of the United States.

Improved understanding of urban hydrology may help in risk assessment and planning for mitigation of downstream impacts of urban development.

Through contact with the urban design working group, larger audiences involved in urban design planning, policy and management as well as community design initiatives have access to greater knowledge about socio-natural systems and processes.

Publications and Products

Journal Publications

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Other Publications Related to BES Work

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Databases

HERCULES

HERCULES, version 7, patch array for the City of Baltimore in 2004.
This is a GIS polygon layer that contains the boundaries of land cover using the HERCULES version 7 land cover classification. Each patch is classified according to the relative cover of coarse and fine vegetation, bare soil, pavement and buildings. Each patch is also coded for the type of building in the patch. This data layer is being used by K. Schwarz, a graduate student working on the project. Information will be shared among BES colleagues and others based on requests.

HERCULES, version 7, patch array for the Gwynns Falls watershed in 2004.
This is a GIS polygon layer that contains the boundaries of land cover using the HERCULES version 7 land cover classification. Each patch is classified according to the relative cover of coarse and fine vegetation, bare soil, pavement and buildings. Each patch is also coded for the type of building in the patch. Data layer will be compared to the 1998 patch array to assess patch change in the watershed. Information will be shared among BES colleagues and others based on requests.

HERCULES, version 7, patch array for a 100 m buffer zone around three rivers in the Cincinnati metropolitan area. Data is being shared with Derric Pennington, a graduate student at the University of Minnesota that is researching bird diversity in riparian zones along the three classified rivers. Pennington supplied the images.

Telephone Survey

The 2006 BES Household Telephone Survey was conducted in October of 2006 with a sample of approximately 3,300 responses. The annual updates to Md. PropertyView from Maryland Department of Planning; and the PRIZM classification and Lawncare expenditure data (services and supplies) at the US Census Block Group level were acquired from Claritas. Parcel and building boundaries for Baltimore City and County were acquired, topologically corrected, and documented. Parcel level landcover classification of existing and possible stewardship were created and documented for Baltimore City. A residential landcover/condition survey was conducted for the Gwynns Falls and Baisman Run with a sample of approximately 1,030 observations.

BES Geodatabase

This database includes over one hundred GIS layers, fully quality checked and documented with metadata, for the Baltimore Ecosystem Study region. These layers are organized thematically using in ArcGIS geodatabases. Development has been going on for over four years. In the last year many new layers were acquired, quality checked, documented, and deployed. Data are currently available to all BES researchers by request. We are currently 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.

Meteorological Data

Data are from the BES primary weather station, averaged over every 15-min. The variables include air temperature, humidity, wind speed and direction, precipitation, total solar radiation, photosynthetically active radiation both downwelling and upwelling, net all-wave radiation, soil moisture, soil temperature, soil heat flux. The station has exposure similar to exposure of weather stations at airports. Collection began in April 2000. These data are currently on a BES ftp server, ready for download distribution upon request, and also available through the BES web site, http://beslter.org/pub/meteorology/primary-data/

Daily averages since 2000 of meteorological data from the BES primary weather station and from two National Weather Service stations within the BES area were supplied to ClimDB, an internet-available data set for public access to LTER climate and hydrological data. http://www.fsl.orst.climhy

Software or Netware

Developed Urban Tree Canopy (UTC) analysis tools for the classification of urban areas in terms of existing and possible urban tree canopy for different types of land use and public-rights-of-way. These tools were used by the City of Baltimore to develop an urban tree canopy goal. These tools were subsequently adopted by Annapolis, New York City, Boston, Pittsburgh, and Burlington.

Educational Products

1. ***Investigating Urban Ecosystem Units.*** Draft 2 of the unit, *Exploring Watersheds in Baltimore*, covering urban hydrology and water quality and what they tell us about the land, was completed in 2007. This unit is available on the BES website along with the other units: *Investigations in Urban Soils: Earthworm Ecology*, and *Schoolyard Hydro-Ecology Teachers' Handbook.* These units include detailed guidelines for teachers and can be downloaded from: http://beslter.org/perspective/perspective.aspx?action=all-pages&collection=education

- The units were developed for educators working with K-12 students. They may also be useful for teachers involved in after school, community or summer groups. Some of the materials may be easily adaptable for undergraduate teaching.

- Investigating Urban Ecosystems: Kits & Teaching Materials for Units. Teachers often note that limited access to supplies and materials poses a barrier to students conducting field-based investigations. To address this need BES has equipped Kits with consumable and permanent supplies for the Investigating Urban Ecosystems Units. Kits are currently available for the Investigations in Urban Soils: Earthworms in the City and Schoolyard Hydro-Ecology Handbook

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

During the current reporting period, Alan Berkowitz and Steward Pickett were part of the Principal Investigator Team developing this innovative capstone course for high schools. 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. Teacher guides, a website and family/community materials will accompany the student modules. The curriculum will provide enough material for a yearlong course.

The curriculum will be inquiry-based. Student materials scaffold activities to support all students, particularly those from historically underserved backgrounds, to learn successfully. The design is informed by research on progression in student learning of scientific content and reasoning.

The Baltimore region will be the backdrop for the first case study which is based on a hypothetical scenario at Woodlawn High School; *a proposal to destroy woodlands on the campus in order to create new ball fields.* The students will decide what information they would need to make an informed decision, request and digest the information, and then articulate and defend a position on the proposal. We plan to involve Woodlawn High teachers and students in the development of the case.

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

This is an engaging set of modules that integrate good science, a love of nature and excellent citizenship skills. The modules have been used by several KidsGrow after school programs at six different school sites including elementary and middle school children. While designed for school-based sites which serve their own students, the curriculum is also suited for other types of after-school programs. Outside sites have adopted and used single modules as well. The modules include: Creating an Urban Ecology Center in Our Neighborhood, Habitats, Urban Wildlife, Microclimates and Mesoclimates, Hurricanes, What Happens to Stuff?, Ecology of Food, Agriculture & Nutrition, Phenology, and Water in the City. They are available from the BES Baltimore Education office.

4. ***Groundwater Flow Model.***

The Groundwater Model is an interactive classroom tool that is designed to show the flow of water and toxins though different gradients. It can be used in the classroom as well as by individuals or small groups of students. It will demonstrate flow through confined and unconfined aquifers as well as the effects of pumping on these aquifers.

5. ***GPS/GIS Study Field Kit with 15 GPS/GIS Units.***

Students can get hands-on experience with this technology and gain valuable mapping skills. Students can map trees or invasive species in an urban forest or the schoolyard. Units, manual and instructional video are available from the BES Baltimore Education office.

6. ***Bird Monitoring Data.***

Dr. Paige Warren assisted Chrissa Carlson with her work on developing K-12 classroom materials on urban birds. This curriculum employs the ongoing bird monitoring data.

Physical Collections

Specimens of bees from New York City and Westchester County, NY, housed in part at the American Museum of Natural History in New York City, and in part at the Louis Calder Biological Field Station of Fordham University in Armonk, NY.