Baltimore Ecosystem Study Annual Report for 2002

Urban LTER: Human Settlements as Ecosystems: Metropolitan Baltimore from 1797 - 2002

Revised: December 2002

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Ms. Loretta Herbick, John Paul Regional Catholic
Ms. Karen Hinson-Steele, Carver Center for Arts and Technology
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Ms. Susan Lattimore, The Barclay School

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Ms. Diane Pniewski, Roland Park Country School
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Mr. Collin Miller, SUNY Environmental Science and Forestry
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Ms. Summer Smith, The Johns Hopkins University
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Baltimore City Department of Recreation and Parks
Baltimore City Public Schools
Baltimore County Department of Environmental Protection and Resource Management
Baltimore County Department of Recreation and Parks
Baltimore County Public Schools
Baltimore Neighborhood Indicators Alliance
Carrie Murray Nature Center
Cornell University- State
Indiana University
Institute of Ecosystem Studies
The Johns Hopkins University
Maryland Department of Natural Resources and Forest Service
Maryland Geological Survey
McDonogh School, Inc.
Morgan State University
Ohio University
Park School
Parks & People Foundation
Purdue University
Revitalizing Baltimore
Roland Park Country School
Towson University
United States Army Corps of Engineers
United States Bureau of the Census
United States Geological Survey
University of Maryland, College Park
University of Maryland, Baltimore County
University of Maryland Department of Natural Resources Sciences

University of Massachusetts, Amherst
University of Missouri, Columbia
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University of Vermont, Gund Institute for Ecological Economics
USDA Forest Service - Northeastern Research Station, and State and Private Forestry
USDA Natural Resources Conservation Service
Yale University
Washington Village/Pigtown Neighborhood Planning Council

Other Collaborators

Arizona State University
Baltimore Alliance for Great Urban Parks
Baltimore Area Master Gardeners
Baltimore-Chesapeake Bay Outward Bound Program
Baltimore City Department of Planning
Baltimore City Development Corporation
Baltimore City Forest Conservation District Board
Baltimore City Police Department
Baltimore City Water Quality Management
Baltimore County Forest Conservation District Board
Baltimore County, Maryland Demographic Information Systems Office
Baltimore Metropolitan Council of Governments
Canton Middle School
Center for Liveable Cities, Baltimore, Maryland
Central Arizona-Phoenix LTER Program
Civic Works Youth Services, Baltimore
Coalition for Science in the Baltimore City Schools
College of Notre Dame of Maryland
Cooperative Research Centre for Freshwater Ecology, Canberra, Australia
Cornell University, Environmental Project
Coweeta LTER Program
Eotvos University, Budapest, Hungary
Frederick Douglas High School
Friends of Gwynns Falls/Leakin Park
Global Learning and Observations to Benefit the Environment
Glyndon Elementary School
Gwynns Falls Trail Council
Gwynns Falls Watershed Association
Herring Run Watershed Association
Howard University School of Law
Hungarian Museum of Natural History, Budapest
Institute for Ecological Research, Chiloe, Chile
Irvine Natural Science Center
Jones Falls Watershed Association

Junior Tree Troops
Kids Grow Program
Lanzhou University, PRC
Manpower Demonstration Research Corporation (Sandtown-Winchester Neighborhood)
Maryland Department of Communications
Maryland Geological Survey
Maryland State Department of Education
Maryland State Police
Merganthaler High School
Morgan State University, Department of Landscape Architecture
NASA Office of Earth Science
National Aquarium in Baltimore
National Water Service, Washington-Baltimore Office
Neighborhood Design Center
Northern High School
Operation Reach Out Southwest
Oregon Ridge Nature Center
Rognel Heights Cultural Center
San Diego State University
Save Our Streams
Seaton-Keough School
Southeast Middle School
St. Stephen University, Budapest, Hungary
SUNY School of Environmental Science and Forestry
Super Kids Camp
Szent Istvan University, Budapest, Hungary
United States Environmental Protection Agency- Mid-Atlantic Integrated Assessment
University of Idaho, Department of Forest Resources
USDA Beltsville Agricultural Research Center
Western School of Technology and Environmental Science
Woodbury Urban Forest Initiative
World Resources Institute

Activities

How urban and suburban areas function as integrated, ecological systems is poorly known. This gap in knowledge means that basic ecology does not yet understand 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 and restoration in and around cities is limited. The ecological knowledge gap in urban areas is a crucial lapse because urbanization in all its forms is one of the main components of global change, and humans are now a predominantly urban species.

The Baltimore Ecosystem Study LTER (BES) has three components. The first two are the complementary research 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 in an inhabited system. Education satisfies the responsibility to share ecological knowledge with the widest audience. Applying ecological knowledge to management, environmental quality, and social justice acknowledges society's needs. Finally, the use of new ecological knowledge of urban systems in planning and restoration provides an important opportunity to test ecological theory and to improve urban quality of life.

The scientific knowledge gap, new scientific opportunities, and 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 fifth year we have continued and enhanced core long-term activities, and initiated new work that promotes the goals of the Long-Term Ecological Research program. Field studies continue to emphasize the 17,150 ha Gwynns Falls Watershed, with a forested reference watershed at Oregon Ridge County Park, and an urban atmospheric flux tower at Cub Hill (Fig 1). Gwynns Falls includes land that is currently being converted from agricultural to suburban uses, as well as areas that have been intensively urbanized for a long time. 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 spread throughout the city. We list key activities under each of our three guiding questions. Both ongoing and new initiatives are included.

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 one, we are conducting the following major research activities:

•Quantify the patch structure of Baltimore.
•Document patch change.
•Discover biotic changes.
•Survey soil heterogeneity.
•Operate a meteorological network.
•Conduct modeling at various scales.
•Compare gradients within Baltimore, and with other cities.

The activities answering question one address the spatial structure, the temporal dynamics, and the integration of the social, ecological, and physical components of the Baltimore ecosystem. The specific research projects are listed below, and are described in greater detail in the research section of the BES web page at http://www.ecostudies.org/bes.

I. Patch delimitation
   - A. Social patches
     1. Based on:
        - a. Demographic data
        - b. Socio-economic indices
        - c. Market clusters
        - d. Built capital
        - e. Survey of residents' environmental management choices
     2. Scaling of different social data sets
   - B. Ecological-structural patches (surfaces, built, and biogeophysical components)
     1. Employ new, highly resolved, land cover classification system.
     2. Heterogeneity among patches
     3. Heterogeneity within patches (point, and transect methods)
     4. Park and neighborhood survey
     5. Avian biodiversity/patch survey
   - C. Comparison and combination of social and biogeophysical patch approaches
   - D. IKONOS image analysis
   - E. Scoping of vacant lot habitat type

II. Patch change
   - A. Paleoecological cores
     1. ^{137}Cs dating, pH, trace metals, overbank sedimentation.
   - B. Land cover changes
     1. Acquisition and scanning of historical maps
     2. Comparison of archival and contemporary air photos
     3. Agricultural census (Red Run catchment)
   - C. Land surveys and engineering records
     1. Original property claim boundaries
   - D. History of water and sewer infrastructure
   - E. Historical US census data

III. Biotic community change
   - A. Permanent vegetation plots
   - B. Exotic vines and urban forest gap regeneration
   - C. Breeding bird population surveys
   - D. Stream biota
   - E. Riparian forest structure and composition
   - F. Repeated, spatially extensive sample plots (built and biotic components)
   - G. Spatially extensive forest tree data
   - H. Exotic/native soil organisms and their demography

IV. Soil heterogeneity
    A. Soil survey; fine scale, with urban-relevant classes added
    B. Soil invertebrate fauna; composition, demography, feeding and reproduction

    C. Soil and lot contamination

V. Meteorology
    A. Reference station in Gwynns Falls watershed satisfying LTER level 4 standards
    B. Network of rain gauges
    C. Urban UV radiation flux; total solar, photosynthetically active radiation
    D. Substrate temperatures
        1. Streams
        2. Soils
    E. Archival weather data analysis

VI. Modeling
    A. Aggregated hydrological models
    B. Distributed hydrological models
    C. Integrated, spatially distributed models including social and biogeophysical variables
    D. Soil and surface water, ground water
    E. Ecosystem services data base

VII. Comparisons
    A. Urban-rural gradient in Baltimore
    B. Comparisons between cities
        1. French Zone Ateliers (Paris, Lyon).
        2. Budapest invertebrates
        3. Exotic invertebrate demography in Baltimore versus "home" habitat

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 two, we are conducting the following major research activities:

- Document human demographic and social processes.
- Quantify stream flow, chemistry, and key biota.
- 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 and hydrological fluxes in and across contrasting watersheds.

The research aimed at answering question two 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. The specific research projects contributing to answering question two are outlined below and described more fully on our web site.

I. Human demographic and social processes
   - A. Network analysis of environmental organizations and agencies
   - B. Differential distribution of human, social, and economic capital
   - C. Environmental equity
   - D. Health and mortality records
   - E. Institutional development:
     1. Maryland Forest Service origin, philosophy, structure and activities
   - F. Biodiversity and park versus household environmental management

II. Stream measurements
   - A. Relationship to sanitary and storm sewer infrastructure; cross contamination and cross flow
   - B. Reference stations on main stem of Gwynns Falls
   - C. Small catchment process studies
   - D. Flow regime
   - E. Water chemistry
   - F. Stream geomorphology
   - G. Biota
     1. Microbes
     2. Pathogens
     3. Invertebrates
   - H. Test new, high-flow measurement method for storm sewer outfall
   - I. Metropolitan network of 47 stream gauges
   - J. Ground water hydrology
   - K. Upgrade Villa Nova and Carroll Park automatic stream gauges for real time output
   - L. Test new, autoacoustic method for low flow measurements in urban streams
   - M. Hydrology of constructed wetland at mouth of Gwynns Falls

III. Riparian processes
   - A. Vegetation change -- resample established plots
   - B. Water table dynamics and depth
   - C. Stable isotope analysis of water sources for riparian trees
   - D. Nitrogen dynamics (0-100 cm profile)
   - E. Stream channel incision
   - F. Trace gas flux

IV. Biogeochemical fluxes
   - A. Watershed mass budgets
   - B. Permanent plots (upland forest, grass, agriculture)
   - C. Household level fertilizer use and irrigation
   - D. Relation of fluxes to land use and land cover
   - E. Relation of fluxes to exotic species
   - F. Trace gas flux

V. Meteorological fluxes
   A. Cub Hill flux tower - first urban flux tower
   B. Characterization of tower site and footprints

VI. Modeling
   A. Multiple approaches
      1. Research Hydrological Ecological Simulation System (RHESsys)
      2. Gwynns Falls Landscape Model (GFLM)
      3. Urban Forest Effects model (UFORE)
      4. General Human Ecosystem Model for sustainable economic welfare (ecological and economic components).
   B. New model components
      1. Social capital incorporated
      2. Ecosystem services and valuation incorporated
   C. Modeling extends from small catchment/neighborhood, to Gwynns Falls, to Baltimore regional scale
   D. Test using temporal data

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 are conducting 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.
- Conduct mediated modeling that incorporates the concerns of stakeholders.
- Manage information to enhance flow of data and knowledge within BES, and between BES and agencies, communities, and individuals.

In addressing question three, the 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 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. Specific activities we are currently undertaking in pursuit of question three are listed below and detailed on our web page:

I. Education partnerships

A. Approaches
   1. Formal
   2. Non-formal
B. School-community partnerships
   1. Range of schools involved -- city, county, private
   2. Primary, secondary, post-secondary levels
C. Schoolyard Long-Term research facilitation
D. Neighborhood Science Program
   1. Community focus
   2. Washington Village/Pigtown
   3. Garden Mosaics (Rognel Heights)
E. Baltimore Collaborative for Environmental Biology -- college student mentoring
F. Research and education partnerships
G. Curriculum development
   1. Social ecology for high school classes
   2. Offered four short courses for teachers (2 well enough subscribed to run)
H. Resources for educators
I. Training BES natural scientists and student interns to work safely and respectfully in urban neighborhoods

II. Interactions with agencies
A. Facilitation by Parks & People Foundation
B. Diversity of agencies
   1. Federal partnerships
   2. State of Maryland environmental and natural resource management agencies
   3. Baltimore County departments
   4. Baltimore City departments
   5. Formal relationships
      a) Oregon Ridge County Park
      b) Carrie Murray Outdoor Education Center (Baltimore City)

III. Interactions with communities
A. Facilitated by Parks & People Foundation
B. Revitalizing Baltimore
   1. Technology transfer
   2. Link research and community concerns
   3. Public health and environmental processes
C. Stakeholder workshops
   1. Ecological services and valuation
D. Modeling
   1. Ecosystem services and economic valuation database
   2. Mediated modeling with stakeholders

IV. Information management
A. Web page development and management (www.ecostudies.org/bes)
   1. Public accessibility

2. Intranet for BES community
3. Interactions with LTER network

B. Open Research System (ORS) (www.open-research.org)
1. Metadata and data management portal for BES
2. Searches based on keywords, maps, and graphical interfaces

C. Small Watershed Network -- information source for public

D. Partnership with National Aquarium in Baltimore EMAP web based data sharing and interpretation site

E. Internet connectivity to enhance interaction with collaborating organizations

F. Conduct BES Annual Meeting and Quarterly Science meetings open to all partners.

V. Minebank Run restoration project -- before and after
A. Collaboration with Baltimore County
B. Geomorphic stabilization
C. Assessment of ecological processes (N dynamics)

The Following is a List of Presentations to be Considered Outreach Activities

Bain, D. and G. Brush. 2001. Definition of current patch structure drivers from historic land records. Ecological Society of America Meetings. Madison, WI. August 9.

Bain, D.J. 2002. Chromite mining signature in Baltimore riparian sediments. Information Exchange: Sediment and the Chesapeake Bay Watershed From Top to Bottom. Baltimore, Maryland. January 22.

Brush, G. and W. Zipperer. 2001. Riparian vegetation along a rural-urban gradient. Ecological Society of America meetings. Madison, WI. August 8.

Brush, G. S. and W. Zipperer. 2001. Riparian vegetation along a rural-urban gradient. Ecological Society of America Annual Meeting. Madison, WI. August 9.

Brush, G. S. 2001. Using paleoecology to reconstruct the Chesapeake Bay. Institute of Ecosystem Studies. Millbrook, NY. November 9.

Brush, G. S. 2002. Rates and patterns of sediment accumulation in the Chesapeake Bay. Information Exchange: Sediment and the Chesapeake Bay Watershed From Top to Bottom. Baltimore, Maryland. January 22.

Burch, W.R., Jr. 2001. Nanjing: The Second Sustainable Development Leadership Program: Organizer and leader of the academic and research group–work with participants who selected this topic helped them understand and apply a multi discipline approach along the lines of our Baltimore Ecosystem Study LTER effort. China. October 14-22.

Burch, W.R., Jr. 2001. Leadership for sustainable development–Lessons from Tao to Mao. SLDP Lecture. China. October 14-22.

Burch, W.R., Jr. 2001. Research, education and training strategies for sustainable development– Lessons from a case study on professional change. SLDP Lecture. China. October 14-22.

Burch, W.R., Jr. 2001. Organize and lead workshop\field trip exercise to Zhongshan Mountain 'Scenic Spot'. The National Park–Dr. Sun Yat-Sen's Mausoleum–planning, management, development strategies were stressed. China. October 14-22.

Burch, W.R., Jr. 2001. Community and social meanings of forests and forestry in North America from pre-history to present– context and subcontext. Beijing Forestry University. Beijing, China. October 14-22.

Burch, W.R., Jr. 2001. Restructuring social institutions and professional practices for community development within a global economy. University of Edinburgh, International Natural Resource Management Program. Edinburgh, Scotland. November 6.

Burch, W.R., Jr. 2001. Forests and People. RBG, The Royal Scottish Forestry Society, The Institute of Chartered Foresters and The Forestry Commission. Royal Botanic Garden. Edinburgh, Scotland. November 7.

Burch, W.R., Jr. 2001. Forests for people: Effective organization and practice. Forestry Commission Research Seminar, Northern Research Station. Scotland. November 9.

Burch, W.R., Jr. 2001. The world is in our backyard– making global another local annual meeting. Reforesting Scotland. Scotland. November 10.

Burch, W.R., Jr. 2002. Human ecosystem framework as converting science knowledge to human action. UNEP Science Meeting on making global environmental statistics user friendly for local planners and managers. Paris, France. February 5-10.

Burch, W.R., Jr. 2002. Preparation of work of global sustainable development conference in South Africa. UNEP Science Meeting on developing usable science knowledge for environmental planning and management. Prague, Czech Republic. June 12-17.

Burt, R., L.A. Hernandez, R.V. Pouyat, and T. Goddard. 2001. Application of trace metals in the New York City Soil Survey. Symposium on anthropogenic soils. ASA-CSSA-SSSA Annual Meetings. Charlotte, NC. October 21-24.

Carrera, J. 2001. Tour of Jones Falls stream valley. Parks and People with the Jones Falls Watershed Association for foundation, community and watershed leaders, government officials and members of the media. Baltimore, MD. September 6.

Carrera, J. 2001. Hosted Nature in the City Community Forum with speaker Leslie Sauer. Parks and People Foundation. November 13.

Carrera, J. 2002. Organized and hosted tour of Baltimore Ecosystem Study and Revitalizing Baltimore research and project sites for Urban and Community Foresters from the 20 states in the Northeast Region. Baltimore, MD. May 9.

Carrera, J. 2002. Planned and hosted groundbreaking ceremony for phase two of the Gwynns Falls Trail. Tour with governmentials included Baltimore Ecosystem Study water quality monitoring site in Carroll Park. Baltimore, MD. May 29.

Carrera, J. 2002. Field Safety and Community Awareness Training Workshop. Parks and People Foundation. Baltimore, MD. June 4.

Carrera, J. 2002. Organized and hosted 20 business, non-profit and foundation leaders for presentations on BES and Revitalizing Baltimore and tour of field sites. July 9.

Cavigelli, M., J. Teasdale, T. Dao, K. Szlavecz, K. Nichols and P.M. Groffman. 2001. The USDA-ARS Farming Systems Project. Seminar, the Sustainable Agricultural Systems Lab, USDA-ARS. December 12.

Cavigelli, M. et al. 2002. Soil research on the FSP Permanent Plots. Farming System Project Focus Group Meeting. USDA Sustainable Agricultural Systems Lab. Beltsville, MD. March 6.

Costanza, R. 2002. Environmental benefits of energy R&D. US DOE and Oak Ridge National Lab Conference on Estimating the Benefits of Government-Sponsored Energy R&D. Washington, DC. March 5.

Costanza, R. 2002. Sustainability and human behavior: Integrating the study of humans and the rest of nature. Workshop on Sustainability and Industry: Energy, material consumption, and human behavior. Sponsored by USEPA and duPont. Cincinnati, OH. March 26-27.

Costanza, R. 2002. The biggest challenge: Envisioning a sustainable and desirable America (SDA). Commencement address for the School of Natural Resources, University of Vermont. Burlington, VT. May 19.

Costanza, R. 2002. Socio-economic aspects of coastal change. LOICZ Synthesis and Futures Meeting: Coastal Change and the Anthropocene. Miami, FL. May 29-June 1.

Costanza, R. 2002. Ecosystem health and ecosystem services: quantifying, modeling and valuing an essential relationship. Healthy ecosystems, healthy people: Linkages between biodiversity, ecosystem health, and human health. Washington, DC. June 6-11.

Costanza, R. 2002. Canopy ecosystem functions, health, and services: Quantifying, modeling and valuing essential interrelationships. 3rd International Canopy Conference. Cairns, Queensland, Australia (via Interactive Video). June 23-28.

Dickman, D. and D. Rayhnam. 2002. Revitalizing Baltimore: A case study in urban community forestry. Humboldt State University. Arcata, CA. April 4.

Grimmond C.S.B. 2001. Energy and mass flux results from three contrasting urban environments: Marseille, France; Lodz, Poland; and Baltimore, USA. School of Public and Environmental Affairs, Indiana University. Bloomington, IN. October 25.

Grimmond C.S.B., B.Offerle, J. Hom and D. Golub. 2001. Observations of local-scale heat, water, momentum and CO_2 fluxes at Cub Hill, Baltimore. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 25-26.

Grimmond C.S.B., B.Offerle, J. Hom and D. Golub. 2001. CO_2 and Heat Flux observations in suburban Baltimore (Cub Hill). AmeriFlux Annual Meeting, Argonne National Labs. Chicago, IL. October 31.

Grimmond C.S.B., B. Offerle, T. Oke, K. Fortuniak, J. Hom, J. Salmond, and D. Golub. 2002. New energy and mass flux results from three contrasting urban environments (Marseille, France; Lodz, Poland; and Baltimore, USA). Association of American Geographers. Los Angeles, CA. March 23.

Grimmond C.S.B., B.D. Offerle, J. Hom and D. Golub. 2002. Observations of local-scale heat, water, momentum and CO2 fluxes at Cub Hill, Baltimore. 4th Urban Environment Symposium, AMS. Norfolk, VA. May 22.

Grimmond C.S.B. 2002. Measurement of heat, water and carbon dioxide exchanges at three contrasting urban sites: Baltimore, USA; Marseille, France; and Lodz, Poland. Earth Sciences Centre, Göteborg University. Göteborg, Sweden. June 10.

Grimmond C.S.B. 2002. Trace gas fluxes in urban ecosystems (examples of carbon dioxide and water). Ecological processes in urban ecosystems: Toward an international synthesis, IGBP-GCTE Focus 1, Global Change and Terrestrial Ecosystems Meeting. Salt Lake City, UT. July 1.

Groffman, P.M. 2001. Advise summer high school science students on curriculum development projects with students at Roland Park Country School. Baltimore, MD. July.

Groffman, P.M. 2002. Advise high school biology students on soil research projects with students at Roland Park Country School. Baltimore, MD. May 10.

Groffman, P.M. 2002. Lead field trip of Baltimore Ecosystem Study field sites for 20 people at the American Geophysical Union Spring Annual Meeting. June 11.

Grove, JM and W.R. Burch, Jr. 2002. A social patch approach to urban, ecological systems. 17th Annual Symposium of the U.S. Regional Association of the International Association of Landscape Ecology: University of Nebraska. Lincoln, NE. April 24-27.

Guy W. Hager. 2002. Revitalizing Baltimore and the Baltimore Ecosystem Study: Revitalizing urban ecosystems. Presentation for U.S.D.A. Northeast Region Urban and Community Forester tour. Baltimore, MD. May 9.

Hom J., D. Golub, C.S.B. Grimmond and B.Offerle. 2001. Studies on carbon dioxide and air quality concentration measurements in the Baltimore Ecosystem Study. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 25-26.

Hom, J., D. Nowak, D. Golub, G. Heisler, S. Grimmond, B. Offerle, and S. Scott. 2001. Studies on carbon flux in urban forests at the Baltimore Ecosystem Study LTER: Challenges of a changing earth. Global Change Open Science Conference (GCTE). Amsterdam, Netherlands. July 9-13.

Jenkins, J.C., R. Rienmann, P. Groffman, D. Nowak, and R. Pouyat. 2001. What does non-forest land contribute to the global C balance? American Geophysical Union Spring Meeting. Boston MA.

Korsos, Z., Cs. Csuzdi, E. Hornung, and K. Szlávecz. 2002. Colonization of soil invertebrates in urban habitats (a North American case study). Hungarian Biological Society, Zoological Section. Budapest, Hungary. April 4.

Lang, L. and K. Szlavecz. 2001. Habitat assessment in rural and urban forests in Baltimore. Baltimore Ecosystem Study 4th Annual Meeting. Baltimore, MD. October 25-26.

Mullen G. and Rutundo, L. 2002. Effects of Stream incision on Riparian Vegetative Communities. The Johns Hopkins University Research Experience for Urban Teachers Institute Symposium. Washington, DC. August 1.

Offerle B., S. Grimmond, T. Oke, K. Fortuniak, J. Hom, J. Salmond, D. Golub, and C. Walsh. 2001. Energy and CO_2 fluxes from contrasting urban environments (Marseille, France; Lodz, Poland; Baltimore, USA and Vancouver, B.C.). American Geophysical Union. San Francisco, CA. December.

Pickett, S.T.A. and W.R. Burch, Jr. 2002. Toward an understanding of nature and human nature on the urban frontier- Mapping the patches of a hip hop, funk, jazz, Stravinsky, Bach, rhythm and blues dance of ecological science. Seminar Series- The Restoration Agenda: Environmental Justice. Yale University School of Forestry & Environmental Studies. Hartford, CT. February 20.

Placella, S., K. Szlavecz and Cs. Csuzdi. 2001. Sustainable agroecosystems: Alternative farming methods and soil fauna. Baltimore Ecosystem Study 4th Annual Meeting. Baltimore, MD. October 25-26.

Pouyat, R.V. 2001. Anthropogenic soils. Keynote speaker for symposium on anthropogenic soils. ASA-CSSA-SSSA Annual Meetings. Charlotte, NC. October 21-24.

Pouyat, R.V. and W. Zipperer. 2001. New approaches to managing forests in urbanizing landscapes. The Wildland-Urban Interface: Sustaining Forests in a Changing Landscape, University of Florida. Gainesville, FL. November 5-7.

Pouyat, R.V. 2001. Urban ecology. Symposium on the ecological enhancement of urban/suburban green space. The Schuylkill Center for Environmental Education. Philadelphia, PA. November 29.

Sharma, K. 2002. Baltimore City community gardens. Poster presentation at American Community Gardening Association Meeting. New York, NY. July 26-28.

Szlavecz, K., Cs. Csuzdi, E. Hornung and Z. Korsos. 2001. Exotic invertebrates in urban forest soils. 15th Annual Meeting of the Society of Conservation Biology. Hilo, HI. July 29-August 1.

Szlavecz, K., E. Hornung, Cs. Csuzdi and Z. Korsos. 2001. Diversity and dynamics of soil invertebrates in urban forests . Ecological Society of America 86th Annual Meeting. Madison, WI. August 5-10.

Szlavecz, K., Cs. Csuzdi, E. Hornung and Z. Korsos. 2001. Zoogeographical origin, and biodiversity of soil fauna in Baltimore and Budapest: a Comparison. Baltimore Ecosystem Study 4th Annual Meeting. Baltimore, MD. October 25-26.

Szlavecz, K. et al. 2001. Soils and soil organisms in urban environments: Budapest, Hungary. Baltimore Ecosystem Study 4th Annual Meeting. Baltimore, MD. October 25-26.

Szlavecz, K., E. Hornung, Cs. Csuzdi, and Z. Korsos. 2002. Alien invertebrates in urban and rural forest soils. Seminar, Department of Biology. Towson University. Towson, MD. April 9.

Valentino, M.J. and K. Szlavecz. 2001. The relationship between urban and rural leaf litter quality and abundance of Isopods and Diplopods. Baltimore Ecosystem Study 4th Annual Meeting. Baltimore, MD. October 25-26.

Villa, F., and M. Ceroni. 2002. Towards and operational semantics of biological diversity: Integrating structure and function in a web-accessible knowledge base. National Conference for Digital Government Research. Los Angeles, CA. May 19-22.

Walsh, J.M. 2002. Science Fair Judge. St Denis/St Columba School. Hopewell Junction, NY. March 18.

Walsh, J.M. 2002. Macroinvertebrates in Dutchess County Streams. Beekman Elementary School. Hopewell Junction, NY. May 9.

Wilson, M.A., R. Costanza, R. Boumans and R. Portela. 2002. Invited talk: Dynamics and Valuation of Coastal Systems at Multiple Scales. Royal Irish Academy. Dublin Ireland. May.

Wilson, M.A. and R. Costanza. 2002. Invited talk: The geography of ecosystem services: Maximizing the value of landscapes in land use conservation. Society for Conservation Biology 16th Annual Meeting. University of Kent at Canterbury. Canterbury, England. May 15.

Wilson, M.A. R.M. Boumans, W.R. Burch, and J.M. Grove. 2002. Exploring the role of social capital in urban revitalization and ecological restoration. 9th International Symposium on Society and Resource Management, Indiana University. Bloomington, IN. June 4.

Wilson, M. A., R.M. Boumans, W.R. Burch, Jr., J.M. Grove, and A. Walker. 2002. Exploring the spatial and ecological dimensions of social capital: A case study of the Baltimore Urban Ecosystem. Healthy Ecosystems, Healthy People: Linkages between biodiversity, ecosystem health, and human health. First annual meeting of the International Society for Ecosystem Health. Washington, DC. June 10.

Zipperer, W.C. 2001. Application of patch dynamics to land use planning. USDA Forest Service. Gainesville, FL. November 6.

Zipperer, W.C. 2001. Urban influences on southern forests. USDA Forest Service. Gainesville, FL. November 6.

Zipperer, W.C. 2001. Vegetation dynamics of riparian corridors along an urban-to-rural gradient. University of Louisville. Louisville, KY. November 30.

Zipperer, W.C. 2002. Exotic species in urban landscapes. USDA Forest Service. Annapolis, MD. January 15.

Zipperer, W.C. L. Meister, D. Pniewski and C. Daniel. 2002. Plants and people in the city. Baltimore Ecosystem Study, USDA Forest Service. Baltimore, MD. April 26.

Findings

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

1. Patch delimitation

Social patches. Social patch delimitation has used demographic data, socio-economic indices, market clusters, and features of the built capital. These methods that have proven robust for analyzing the temporal, spatial, and hierarchical dynamics of urban social patch dynamics. The approach has also proved useful for emerging interdisciplinary studies in Boston (Urban Ecology Institute) and Canberra (CSIRO, Australia).

Scaling of different social data sets. The data sets for social patch delimitation have been converted to the same statistical and spatial scale. They now link seamlessly into a single, unique data base, which will support analyses of social processes, and the relationship of social with biogeophysical processes.

Structural patches. We have refined the novel, compositionally resolved land cover classification system developed for Baltimore. The refinements were based on ground truthing,

and assessment of internal consistency. The classification is being employed using air photos in four test regions of metropolitan Baltimore. Associated with the patch classification is an evaluation of the components of heterogeneity within patch types. This analysis has confirmed the aggregate differences among patch types, and has stimulated questions for linkage with social processes and structures. IKONOS imagery has been obtained for Baltimore, and initial analyses are underway to make the data available for comparative and integrative studies.

2. Patch change

Land cover changes. In Agarwal et al. (2002), we presented a novel framework for analyzing and categorizing land use/land cover models. A number of land use/land cover modelers and researchers have found this framework useful and prepublication copies of this paper have been used as a course book in graduate seminars in land use/land cover modeling at Pennsylvania State University and University of California, Santa Barbara.

Land surveys and engineering records. The mosaic of original property boundaries in the Gwynns Falls watershed has been mapped on current, georeferenced base maps, and checked against current digitized property boundaries to assure quality. The mosaic of original properties becomes more complex as one moves from the Middle Branch of the Patapsco River to the headwaters of the Gwynns Falls. The mosaic is resilient and might be damping other gradients of landscape heterogeneity resulting from urbanization.

3. Soil heterogeneity

Soil arthropod composition is different in the urban (Leakin Park) and the rural (Oregon Ridge Park) forests. The urban park is dominated by macroarthropods. Terrestrial isopod abundance is especially high in urban forests. In Oregon Ridge, mesofauna (springails, mites, ants) are more dominant. Preliminary data show that both the density and the biomass of earthworms are greater in the urban forest than in the rural forest. Our question is whether this pattern holds up for abundances along a more completely sampled transect. At the same time, diversity is greater in urban forests, due to the large number of introduced species. The proportion of introduced species within the same taxonomical group is greater in cities than in rural areas.

4. Comparisons

Soil invertebrates. The introduction of *Chaetophiloscia sicula* was a recent event. The species must show high plasticity in order to survive the winter in Baltimore, because its original habitat is Mediterranean shrub-grasslands. Activity and reproductive period differ between the region of origin and Baltimore. The "urban ecosystem convergence hypothesis" is being tested for soil fauna in Baltimore and Budapest. The degree of convergence for these organisms is taxon-specific. We tested whether the contrast in composition and density between urban and rural soil invertebrate faunas depended on food abundance or quality. Although soil arthropods respond to the nutritional quality of litter, the contrasts are due to tree species identity rather than location along the urban-rural gradient. Stage of decomposition was a more important factor in consumption rather than urban versus rural origin.

French urban systems. BES scientists were instrumental in interactions that led to the French *Zone Ateliers* joining the International Long-Term Ecological Research network. This formalization has facilitated the initiation of our collaborative work on urban infrastructure and ecological processes between BES, Paris, and Lyon.

Question 2: Fluxes of Energy, Matter, Capital, and Population in the Baltimore Ecosystem

1. Human demographic and social processes

Institutional development. The research on the founding and early work of the Maryland Forest Service (Buckley and Grove 2002) has been applied by current staff of that agency in re-evaluating institutional goals. The Maryland Forest Service's founding director's archives have been located and made available to BES researcher G. Buckley.

2. Stream measurements

Stream, soil, and infrastructural flows. Spatial patterns of surface soil moisture, shallow groundwater levels, stream channel discharge, and stream water chemistry differ between urban and forested catchments. Forested catchments show strong correlation of surface soil moisture with topographic wetness indices, while landscape drainage practices during the agricultural era, and current sanitary and storm drainage infrastructure and road networks cause regular departures in the soil moisture patterns. In developed catchments, bottomland soil moisture is typically lower than areas immediately upslope due to drainage redirection by infrastructure and infiltration of groundwater into sanitary sewer lines.

Long-term watershed studies. Our analysis of the first two years of watershed data on nitrogen (N) and phosphorus (P) losses showed that urban and suburban watersheds had much higher N and P losses than the completely forested reference watershed, with nitrate yields ranging from 2.7-7.1 kg N ha^{-1} y^{-1} and phosphate yields ranging from 9-151 g P ha^{-1} y^{-1} in the urban and suburban watersheds compared with < 1 kg N ha^{-1} y^{-1} and < 10 g P ha^{-1} y^{-1} in the completely forested watershed. Nitrate represented from 60-97% of the total N yield in the urban and suburban watersheds, with the lowest percentages in the most urban watersheds. Only 17% of the N yield from the completely forested watershed was NO_3^-. Phosphate represented 28-61% of the P yield. There was a higher correlation $R^2 = 0.86$, $p < 0.01$) between percent residential land use and NO_3^- yields than between land use and NO_3^- concentration $R^2 = 0.71$, $p < 0.10$), suggesting that hydrologic changes associated with urbanization influence variation in N yields. There was no correlation between land use and PO_4^- yield or concentration. Retention of N was surprisingly high, from 70-80% of inputs, which were dominated by home lawn fertilizer (16-27 kg N ha^{-1} y^{-1}) and atmospheric deposition (7-10 kg N ha^{-1} y^{-1}) (Belt et al., submitted). Detailed analysis of mechanisms of N retention, which must occur in the significant amounts of pervious surface present in urban and suburban watersheds, and which include storage in soils and vegetation and gaseous loss, is clearly warranted.

Flow regime. We have produced a continuous data stream, published annually, with some station data available in near real time.

Water chemistry. Stream nitrate concentrations are highest in low density development (>2 acre zoning) due to the use of septic systems, yielding nitrate levels as high as in agricultural catchments. Despite apparent high loading of nitrate into urbanized streams due to a set of sources including lawns and leaking sanitary systems, even significantly impacted stream channels appear to show appreciable nutrient processing and retention.

3. Riparian processes

Vegetation change. The vegetation in the riparian zone of the Gwynns Falls watershed shows a gradient from species that prefer wetter sites in the upper sections, to species preferring drier habitats in the downstream sections of the valley. A comparison of the average basal area of trees in the Gwynns Falls riparian zone with non-urbanized riparian zones in the Maryland Piedmont shows that the upper reaches with rural and suburban development are more similar to basal area of trees in non-urbanized Piedmont floodplains than are the downstream riparian stands. In the riparian zones, 50% of herbaceous species are exotics. The distribution of each exotic species is highly patchy, with few having widespread distribution throughout the Gwynns Falls valley. The majority of native herbs in the lower reaches of the valley are upland or dry habitat species. The majority of exotic species are of upland origin.

Riparian nitrogen dynamics. In our analysis of nitrate dynamics in three forested urban and suburban and one forested reference riparian zones, two of the three urban and suburban streams were more incised and all three had lower water tables in their riparian zones than the forested reference stream. Urban and suburban riparian zones had higher NO_3^- pools and nitrification rates than the forested reference riparian zone likely due to more aerobic soil profiles, lower levels of available soil carbon and greater N enrichment in the urban and suburban sites. At all sites, denitrification potential decreased markedly with depth in the soil profile. Lower water tables in the urban and suburban riparian zones thus inhibit interaction of groundwater-borne NO_3^- with near surface soils that have the highest denitrification potential. These results suggest that urban hydrologic factors can increase the production and reduce the consumption of NO_3^- in riparian zones, reducing their ability to function as sinks for NO_3^- in the landscape. Two papers on riparian dynamics were submitted for publication (Groffman et al., submitted a, b).

4. Biogeochemical fluxes

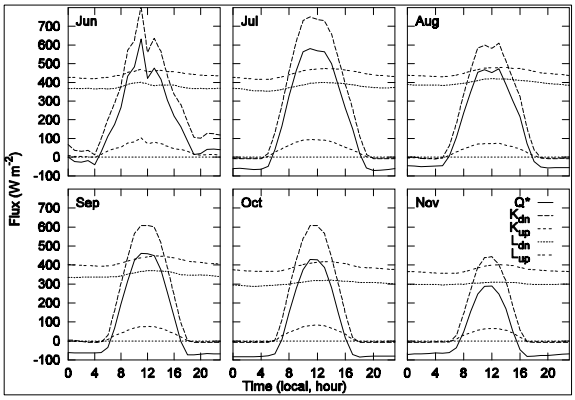
Long-term study plots. Analysis of our two-year *in situ* nitrogen mineralization and nitrification data set showed that growing season (May - November) mineralization ranged from 30 - 50 and that nitrification varied from 4 - 15 kg N ha^{-1} y^{-1}. The magnitude and annual variation in these internal, natural nitrogen processes is significant relative to anthropogenic fluxes of N. For example, annual atmospheric deposition of nitrogen (measured in suburban Maryland by CASTNET) ranged from 8 - 11 kg N ha^{-1} y^{-1} from 1989 - 1999 (http://www.epa.gov/castnet/sites/bel116.html.). Food in and sewage out fluxes for one of our suburban watersheds were estimated to range from 31 - 41 kg N ha^{-1} y^{-1}.

5. Meteorological fluxes

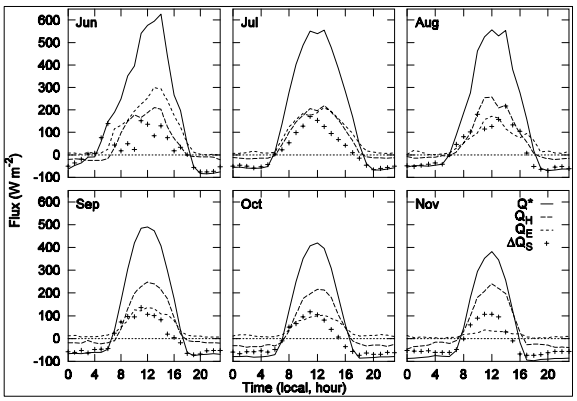
Data from the BES Solar Radiation Monitoring Station have been used for comparison of above-canopy UVB radiation in Baltimore to UVB flux in more rural areas (Grant et al. 2002) in late spring and early summer. Baltimore UVB was lower by approximately 4% than rural Queenstown, MD, with most of the difference occurring during the afternoon. There was a positive correlation between UVB and ozone, although only one of the five highest ozone events corresponded with high UVB, indicating that urban ozone precursors were probably more important than UVB in causing peak ozone. UV radiation in urban ecosystems has several implications for human health. Routine exposure to UV radiation can have adverse health effects, especially for young children (Grant and Heisler 2000). Stratospheric ozone reductions have caused measurable increases in UVB radiation in mid-latitudes.

Cub Hill flux tower - first urban flux tower. Observations began in May 2001. However, data were not collected continuously until September 2001. Data coverage is not complete for June, July, and August.

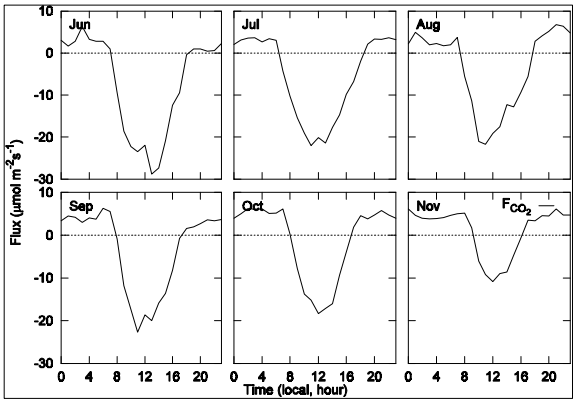
Radiation Balance: Observations of the radiative components show the expected seasonal pattern, with a reduction in net all wave radiation in the wintertime, due to the reduction in the incoming short-wave radiation (Fig 1).



Energy Balance: The seasonal change in radiative energy limits the available energy that can be partitioned (Fig 2). The seasonal data allow us to see clearly how the importance of latent heat flux decreases as the leaves fall off the trees (cf November with summer months). In virtually all months, the turbulent sensible heat flux is the dominant mechanism to remove heat from the surface. The storage heat flux term (ΔQ_S) is determined as a residual in the surface energy balance (SEB). Inevitably this means it accumulates all the errors due to measurement and neglected terms (Grimmond and Oke, 1999). It is a significant term at this site in the summertime, consistent with results at other suburban sites (Grimmond and Oke, 2002)



Carbon dioxide fluxes: Though primarily a residential area, in the flux footprint of the Cub Hill site has patches of forest (their relative importance vary with wind direction). The impact of this is particularly evident in the F_{CO2} in Fig. 3. For all months when leaves are on the trees, the site functions as a net carbon sink. This is an interesting result, highlighting the potential significance of suburban ecosystems to offset the emissions of CO_2 known to occur in urban environments.



Question 3: Development and Use of Ecological Understanding in the Baltimore Region

1. Education partnerships

We offered four short courses for teachers. Two were well enough subscribed to run: 1) Animal Life in Urban Landscapes (Nilon and Middendorf), and 2) Plants and People in the City (Zipperer, Pneiwski, Meister, and Daniel).

2. Interactions with communities

Ecological and environmental valuation has been a keen interest of agencies and some communities. Valuation of trees in urban areas of the United States has been modeled by BES members. Total compensatory value for trees in cities in the US ranges from $101 million in Jersey City, NJ, to $5.2 in New York City. Total compensatory value for urban forests in the 48

contiguous states is estimated at $2.4 trillion, valuing individual trees as structural elements and using standard methods of the Council of Tree and Landscape Appraisers and field data from eight cities (Nowak et al., 2002). Estimates of carbon sequestration by urban trees in the 48 contiguous states of the US amount to 700 million tons C (for a monetary value of $14,3000 million), based on field data from 10 cities (Nowak and Crane, 2002).

3. Information management

Important synergies have developed between the BES database system and other active NSF funded projects. The first, "A web-accessible knowledge base for the integrated analysis and valuation of ecosystem services" is producing the Ecosystem Services Database, capable of hosting data and models under a consistent interface. This system serves as a model exploration tool and a bulletin board where researchers can not only access spatially and temporally explicit data, but also run simulated scenarios and share them along with modifications to the models with others to explore (Villa et al., 2002).

Small Watershed Network. The Small Watersheds Network web page has been created as a prototype watershed based educational tool kit that can be further applied to small watershed in the Baltimore area (http://iee.umces.edu).

Publications and Products

Journal Publications

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R. E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R. K. Turner (In press). Economic reasons for conserving wild nature. Science.

Band, L.E., C. Tague, P. Groffman, K. Belt. 2001. Forest ecosystem processes at the watershed scale: Hydrological and ecological controls of nitrogen export. Hydrological Processes 15: 2013.

Binder C., R.M.J. Boumans and R Costanza. (In press). Applying the Patuxent landscape unit model to human dominated ecosystems: The case of agriculture. Ecological Modeling.

Boone, C.G. (Accepted). Draining the city: The struggle to build a comprehensive sewer works in Baltimore. Historical Geography.

Boone, C.G. (Submitted). An assessment and explanation of environmental inequity in Baltimore. Urban Geography.

Burch, W.R. 2002. Challenges and possible futures for the forestry profession in a global, post industrial social economy– Lessons from Britain. Scottish Forestry Journal.

Boumans R.M., F. Villa, R. Costanza, A. Voinov, H. Voinov, and T. Maxwell. 2001. Non-spatial calibrations of a general unit model for ecosystem simulations. Ecological Modeling 146: 1-3.

Boumans, R., R. Costanza, J. Farley, M. A. Wilson, R. Portela, J. Rotmans, F. Villa, and M. Grasso. 2002. Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO Model. Ecological Economics 41: 529-560.

Boumans, R.M. and D.M. Burdick. (In press). Modeling habitat change in salt marshes following tidal restoration. Special Issue of Estuaries.

Cahoon D. R., R.M.J. Boumans, P. Hensel, J.C. Lynch, and J.W. Day, Jr. (In press). A device for high precision measurement of wetland sediment elevation: 1. Recent improvements to the sedimentation-erosion table. Journal of Petrology and Sedimentation.

Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. Ecological Monographs 72:203-231.

Costanza, R., and S. Farber. 2002. Introduction: The dynamics and value of ecosystem services: Integrating economic and ecological perspectives. Ecological Economics 41: 367-373.

Costanza, R. (In press). A vision of the future of science: reintegrating the study of humans and the rest of nature. Futures.

Csuzdi, C. and K. Szlavecz. (In press). *Diplocardia patuxentis*, a new earthworm species from Maryland, North America (Oligochaeta: Acanthodrilidae). Annales Historico-Naturales Musei Nationalis Hungarici.

DeGroot, R., M.A. Wilson and R.M.J. Boumans. 2002. Ecosystem functions, goods and services: Classification, description and valuation guidelines. Ecological Economics 41: 393-408.

Farber, S., R. Costanza, and M. Wilson. 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics 41: 375-392

Farley, J. and R. Costanza. (In press). Envisioning shared goals for humanity: A detailed shared vision of a sustainable and desirable USA in 2100. Ecological Economics.

Groffman, P.M., M.K. Crawford, W.C. Zipperer, R.V. Pouyat, L.E. Band, M.F. Colosimo. (In press). Denitrification in urban riparian zones. Environmental Science and Technology.

Heisler, G. M. and R.H. Grant. 2000 Ultraviolet radiation in urban ecosystems with consideration of effects on human health. Urban Ecosystems 4: 193-229. [Dated 2000, but not available until 2002.]

Hornung, E. and K. Szlavecz. (In Press). Establishment of a Mediterranean Isopod (*Chaetophiloscia sicula* Verhoeff, 1908) in a North American Temperate Forest. Crustaceana Monographs.

Korsós, Z., E. Hornung, K. Szlávecz & J. Kontschán. (In press). Isopoda and Diplopoda of urban habitats: New data to the fauna of Budapest. Annales Historico-Naturales Musei Nationalis Hungarici.

Limburg, K. R.V. O'Neill, R. Costanza, and S. Farber. 2002. Complex systems and valuation. Ecological Economics 41:409-420.

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Contributions

Contributions within the discipline and to different disciplines

In the fifth year of the Baltimore Ecosystem Study (BES) we have continued to extend the scope of ecology to the ecologically neglected urban realm. The increase in urbanization, both in the United States and globally, makes ecological attention to urban systems both practically and scientifically important. Because BES is such an integrated project involving many disciplines, we combine the discussions of contributions to individual disciplines and contributions to different disciplines. In order to show how the BES contributes to scientific knowledge, we highlight contributions that have emerged or developed during the past year. Many of our contributions are ongoing, and the value of contributions reported in prior years grows with additional years of data collection. The 2001 BES Annual Report highlighted linking historical and long-term ecosystem dynamics, flux of materials in urban ecosystems, spatial heterogeneity in the metropolitan systems, and the role of scale.

The understanding of spatial heterogeneity remains one of ecology's greatest challenges. One of our major contributions is to combine an understanding of ecological, social, and hydrological heterogeneity. This year contributions toward improved understanding of system heterogeneity are these:

- *The construction of scaled, coordinated social data sets*. We have geographically referenced and scaled the data sets we have assembled from various sources, as well as those we have collected ourselves. This coordination of disparate data has taken several years to accomplish. With the completion of this task we have a powerful, multidimensional database on the social, cultural, and economic processes in the Baltimore region. The data base will permit novel integrations with biogeophysical data as well as answering questions concerning the linkages of different social processes.

- *Development of methodology for integrated patch delimitation*. Patch dynamics have been pursued in the past either in biogeophysical sciences or social sciences. In social science the approach is called a "sociospatial" approach. We have developed a method to combine social and biological factors in a single patch assessment. This method promises to provide a unified spatial foundation for integrating social and biogeophysical factors.

- *Development of a novel analysis of land use/land cover models*. Much of contemporary landscape ecology, planning, and environmental prediction is based on common, but rarely evaluated land use/land cover models. Our team has generated the first comprehensive analysis of the successes and limitations of the common models. These analyses are of manifest interest to agencies charged with evaluating environmental quality and risk.

Contributions to education and human resources

We contribute to education and increasing the breath of human resources available to ecology through three methods: 1) we provide tools, 2) we share information, 3) and we train students and teachers. Examples of the tools we share with the educational community include databases, GIS software, and curricular materials. We share information through the Internet, classroom lectures in schools and universities, and field trips for the public and students. We provide workshops and summer institutes for teachers and train students and teachers in use of equipment for environmental monitoring at their schools, at our sites, in community centers, and in nature centers. Finally, BES trains Research Experiences for Undergraduates students, contributes to the training of students in the Baltimore Cooperative for Environmental Biology, and provides summer employment for undergraduates in scientific research. Our commitment to education extends from K-12 through graduate, includes under represented populations, and uses an inquiry based philosophy. Our commitment to diversification of the human resources available for science is exemplified by the demographic break down of our student population for summer 2002: 3 African Americans, 5 Asian American, and 14 Caucasians. Highlights this year include:

- *Providing Internet connectivity.* We established high speed Internet connectivity at the Carrie Murray Outdoor Education Center, a partner with BES in establishing an urban ecology field station. The Center serves a large, diverse population in Baltimore City, and as a node for communicating BES science with the public.

- *Recruited underrepresented populations.* We worked with the Washington Village Community Center to establish a career ladder for city youth, and to help community members generate a local environmental assessment.

- *Provided an educationally valuable website.* The BES website was recognized as an educational resource for grades 6-12 by the American Association for the Advancement of Science, Science NetLinks program. Use of the BES website is integrated into curriculum units. http://www.sciencenetlinks.com/resources_individual.cfm?DocID=341

Contribution to institutional and information resources for science and technology

Our ongoing contributions to information for science include databases and integrated models. BES also acts as a conduit for scientifically useful data available in public and community hands, such as the Baltimore Neighborhood Indicators Alliance. In addition, ongoing work includes the development of a network of cooperating sites in the Baltimore metropolis to act as a dispersed, urban ecological field station. Highlights for 2002 include:

- *Contribution to International LTER network building Zone Ateliers*. BES was instrumental in exploring collaborations with several French research projects of regional scope similar to LTER programs. The French network of Zone Ateliers has now officially joined the International LTER network, and BES PI's and graduate students have begun collaborative research in Paris and Lyon.

- *Establishment and successful operation of first urban atmospheric flux tower.* Flux towers are a major research technology to evaluate climate change and the linkages between soil, vegetation, and atmospheric processes. The "Cub Hill" tower, located just outside the city limit of northeast Baltimore, is positioned to evaluate atmospheric exchanges in an area that has extensive suburban development. This is the first such tower in the nation. A six-month data run on multiple parameters now exists.

- *Estimates of urban forest contribution to global C budgets.* A controversy exists concerning the failure of the global carbon balance to budget. Testing the hypothesis that urban forest may account for some of the discrepancy is underway. Substantial carbon sequestration has been documented in urban forest in Baltimore and other cities.

- *Ecosystem valuations for ecological economics, via web based database.* A new system for determining ecosystem valuation that accounts for urban and non-urban lands has been developed. The system will be deployed on the Internet within the coming months.

Contribution to public welfare beyond science and engineering

Both the general public and governmental agencies desire the integrated spatial models and data we are developing. Through our annual and quarterly science meetings we have learned that significant elements of the public are primarily concerned with pollution, neighborhood restoration, and watershed protection. Agencies are concerned with effective data sources, integrated ecological processes in urban areas, and the effects of different infrastructural features on one another and on the environment. This awareness has shaped some of the research we do, how we communicate the results, and additional interactions we pursue. Highlights of contributions during 2002 are these:

- *Assessment of distribution of exotic species in Baltimore region*. The role of exotic species, either as amenities or ecologically negative agents, is of interest to planners, citizens, and managers in Baltimore. We have documented the contribution of these species to riparian and upland vegetation in various parts of the metropolis, and have discovered patterns that are relevant to management decisions.

- *Assessment of original goals and efforts of Maryland Forest Service.* We have learned from members of the Maryland Forest Service that research on the founder and the early days of the state Forest Service (Buckley and Grove 2001) have been helpful as the agency considers its future course.

- *Headwater N loading*. Understanding of source of suburban N inputs into headwater streams in Baltimore, compared to reduced input in dense urban areas. An early result of the BES stream research program was the detection of high levels of nitrate in headwaters. We have now identified the source of the input, and this information may affect resident and agency management decisions.

- *Established data set on stream quality and flow available for public use*. Our stream

flow and water quality data are available for public use.

- *Identification of changes in, and threats to, urban riparian zones*. This information serves as a reference for current and future restoration efforts and evaluation of management interventions. An important insight is the current inability of urban riparian zones to consume nitrate pollution due to hydrological drought.

- *Record of urban UVB*. Our ambient radiation measurement station at the city's Ashburton filtration plant provides continuous monitoring of UVB radiation, which is a direct concern for health and an indirect concern for its role in ozone pollution.

- *Origin of ozone pollution*. Evaluation of the contribution of UV versus precursors in urban ozone pollution. Ozone pollution is a serious and persistent threat in Baltimore. We have discovered that precursors are more significant in that pollution than UV radiation.

- *Development of small watersheds network* approach to share information on watersheds to local audiences and educators. This network is aimed at the public, and has been developed with non-technical users in mind.

- *Establishment of modeling bulletin board.* This tool will permit sharing models and Ecosystem Services Database, for integrated analysis and valuation of ecological services. Following upon the new system for ecosystem valuation, a web based bulletin board has been developed to share models and data that support those models.