Annual Report for 2001
Baltimore Ecosystem Study
Urban LTER: Human Settlements as Ecosystems: Metropolitan Baltimore from 1797 - 2100

Revised: October 2001

Participants: People and Organizations
- People
- Partner Organizations
- Other Collaborators

Activities
- Training and Development
- Outreach Activities

Findings

Publications and Products
- Journal Publications
- Book or Book Chapter
- Presentation at Scholarly Meetings
- Invited Seminars
- Report to Agency or Organization
- Articles
- Websites

Contributions

Participants: People and Organizations

People

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Ms. Jessica Hopkins, Towson University
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Mr. Justin Freedman, Towson University
Ms. Zandra Huston, The Johns Hopkins University
Ms. Barbara Johanson, University of Delaware
Ms. Elizabeth Klein, Morgan State University
Ms. Marla Knox, Frostburg State University
Mr. Amani McHugh, Cornell University
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Mr. Taj Reid, Howard University
Mr. Anthony Spano, The Johns Hopkins University
Ms. Nikki Traylor-Knowles, The Johns Hopkins University

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Mr. Wilfred Ndifon, Morgan State University
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Ms. Andrea Raglin, Towson University
Ms. Amanda Shaw, Towson University
Mr. Tausi Suedi, Towson University
Mr. Victor Ukpolo, Jr., Morgan State University
Ms. Mary Jane Valentino, The Community College of Baltimore
Ms. Charity Watkins, Towson University

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Ms. Natalie Boulware, Xavier University
Ms. Suzanne Palmer, Ohio University
Ms. Sarah Placella, The Johns Hopkins University
Ms. Summer Smith, The Johns Hopkins University
Ms. Candiss Williams, Tuskegee University

Partner Organizations

Baltimore City Department of Public Works: Collaborative Research
Baltimore City Public Schools: Facilities; Collaborative Research; Personnel Exchanges
Bureau of the Census: Collaborative Research
Environmental Protection Agency: Financial Support; Collaborative Research
University of Toronto: Collaborative Research
University of Maryland, Baltimore County: Facilities; Collaborative Research

USDA Natural Resources Conservation Service: Financial Support; Facilities; Collaborative Research

Ohio University: Collaborative Research

Johns Hopkins University: Collaborative Research; Personnel Exchanges
Towson University: Collaborative Research
USDA Forest Service - Northeastern Forest Experiment Station and State and Private Forestry: Financial Support; In-kind Support; Facilities; Collaborative Research; Personnel Exchanges
University of Massachusetts, Amherst: Collaborative Research; Personnel Exchanges
University of North Carolina at Chapel Hill: Facilities; Collaborative Research; Personnel Exchanges
University of Maryland: Facilities; Collaborative Research; Personnel Exchanges
William and Mary College: Collaborative Research
Maryland Geological Survey: Personnel Exchanges
Purdue University: Collaborative Research; Personnel Exchanges
Indiana University: Collaborative Research; Personnel Exchanges
Western School of Environmental Science: Collaborative Research

Other Collaborators

Army Corps of Engineers
Baltimore Alliance for Great Urban Parks
Baltimore Area Master Gardeners
Baltimore City Department of Planning
Baltimore City Department of Public Works
Baltimore City Department of Recreation and Parks
Baltimore City Development Corporation
Baltimore City Police Department
Baltimore City Public Schools
Baltimore County Department of Environmental Protection and Resource Management
Baltimore County Department of Recreation and Parks
Baltimore County, Maryland Demographic Information Systems Office
Baltimore County Public Schools
Baltimore Environmentors, Baltimore City
Baltimore Metropolitan Council of Governments
Baltimore Neighborhood Indicators Alliance
Canton Middle School
Center for Poverty Solutions, Baltimore, Maryland
Central Arizona-Phoenix LTER Program
Chesapeake Bay Program
Center for Liveable Cities, Baltimore, Maryland
Citizen Planning and Housing Association, Baltimore
Coalition for Science in the Baltimore City Schools
Community Planning and Housing Association, Baltimore City
Cooperative Research Centre for Freshwater Ecology, Canberra, Australia (Dr. Peter Cullen, Director)
Cornell University, Environmental Project
Coweeta LTER Program
Department of Housing and Urban Development - Community Builders
Environmental Protection Agency
Eotvos University, Budapest, Hungary
Fortin, Dr. Marie Josee, Université de Montréal
Frederick Douglas High School
Global Learning and Observations to Benefit the Environment, GLOBE Program
Glyndon Elementary School

Gwynns Falls Watershed Association
Herring Run Watershed Association
Historic East Baltimore Community Action Coalition
H. J. Andrews Forest LTER Program
Institute for Ecological Research - Chile, Chile (Dr. Juan Armesto)
Irvine Natural Science Center
Jones Falls Watershed Association
Junior Tree Troops
Kids Grow
Landcare Research, New Zealand
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Manpower Demonstration Research Corporation (Sandtown-Winchester Neighborhood)
Maryland Department of Natural Resources and Forest Service
Maryland Institute College of Art
Maryland Geological Survey
Maryland State Department of Education
McDonogh School, Inc.
Merganthaler High School
Morgan State University, Department of Landscape Architecture
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National Aquarium in Baltimore
National Center for Ecological Analysis and Synthesis
National Water Service, Washington-Baltimore Office
Natural Resource Conservation Service
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Parks and People Foundation
Project RAISE
Revitalizing Baltimore
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Roland Park Country School
Safe and Sound
Save Our Streams
Seaton-Keough School
Southeast Middle School
St. Stephen University, Budapest, Hungary
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Super Kids Camp
Towson University
United States Geological Survey, National Research Program
University of Maryland, Baltimore County - Women's Center
Washington Council of Governments
Western High School of Science and Technology and Environmental Science
Yale University School of Forestry and Environmental Sciences

Activities

How urban and suburban areas function as 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) uses two research approaches to build ecological knowledge of urban systems. First, social and economic processes are linked 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 issues 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.

The scientific knowledge gap, scientific opportunities, and public responsibility 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 fourth year we have continued 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 (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. We list key activities under each of our three guiding questions.

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:

- Assess spatial heterogeneity and quantify patchiness along multiple gradients.
- Characterize the internal structure of patches.
- Link patch structures based on biogeophysical, socio-economic, and built components.
- Discover changes in land use, land cover, and key biotic populations using historical records, land surveys, and paleoecology.
- Assess spatial heterogeneity using models.
- Compare spatial patterns between Baltimore and 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 in Box 1, and are described in the research section of the BES web page at http://www.ecostudies.org/bes.

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 can be 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 in Box 2 and described on our web site.

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 formal and non-formal education activities.
- 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 role of partnerships is 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 in Box 3 as well as on our web page.

Training and Development

The BES education program includes: the School/Community Partnership Program, the Neighborhood Science Program, college and university programs, and collaborations with other education initiatives. The Partnership Program links BES scientists, teachers, students and community groups to engage youth in on-going studies of the local environment. Teachers who participated in past BES workshops implemented their action plans during the 2000-2001 school year, and five partnership schools received financial assistance for equipment, materials and supplies, and software to support student research in their schoolyards. During 2001, we re-structured our workshops into the Investigating Urban Ecosystems series of short courses, offered for stipend or graduate credit in conjunction with a proposed certificate program in environmental education at the University of Maryland – Baltimore County. Four courses were offered in 2001: 1) Soil Ecology, 2) Modeling Ecosystem Services, 3) Animal Life in Urban Landscapes, and 4) Plants and People in Urban Ecosystems.

The Neighborhood Science Program focused on work with the Rognel Heights Cultural Center. BES members continued facilitating the collaboration there with the Cornell University Garden Mosaics project, and supported an internship there in summer 2001 to work with youth, adults and leaders at the Center on understanding sustainable agriculture and ecology in the urban setting. Field activities, cross-generational exchanges, community gardening and writing are a part of that program. We also are working closely with the Washington Village/Pigtown community on a new neighborhood science initiative there.

College and university based education involved 3 Research Experiences for Undergraduates students, and 12 students who are part of the Baltimore Collaborative for Environmental Biology, a UMEB program based at Towson University.

BES is collaborating with a number of education initiatives and institutions in the Baltimore region:

- BES Education is an active partner in the development of a field station at the Carrie Murray Nature Center. In the summer of 2001 we supported an intern through the Urban Resources Initiative who helped plan exhibits and other education programs Carrie Murray.
- We are a partner in the National Aquarium at Baltimore's EPA-supported EMPACT project that will provide the general public with web-based access to BES data and interpretations.
- We are an active member of the Coalition for Science and Mathematics Education of the Baltimore City Public Schools.
- We are working with the Teaching Institutes for Elementary Science based at the Friends School.
- We are working with the Center for Urban Environmental Research and Education at the University of Maryland – Baltimore County– on a range of education initiatives.

Outreach Activities

Education and outreach are 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 10 yr social science and community restoration research program in Baltimore predating the LTER effort, that informing and working with communities and constituencies is required to site ecological research in the city and suburbs. Hence we conduct a wide variety of community and educational activities.

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. A quarterly newsletter, entitled Baltimore Ecosystem News, and written in plain language, was initiated and widely distributed to the public. The distribution of the Gwynns Falls Ecological Resource Atlas to public libraries was accompanied by an educational seminar series at each library.

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.

Belt, K.T. 2000. Urban Hydrology. SUNY ESF. February 10. Belt, K.T., A. Berkowitz, and J. Wolfson. 2000. Stream Ecology Workshop. Towson University. Baltimore, MD. June 20.

Boone, C. 2001. Linking public health and ecological change in Baltimore. Canadian Association of Geographers 50th Annual Meeting. Montreal, Canada. June.

Boone, C. 2001. Public health and environmental changes in Baltimore. American Society of Environmental History Annual Meeting. Durham, NC. March.

Boone, C. 2001. Environmental equity research: Historical and GIS methods. Association of American Geographers Annual Meeting. New York, NY. March.

Boone, C. 2000. An examination of toxic releases and population characteristics in Baltimore City: A case study in environmental equity research. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 26-27.

Boone, C., J.M. Grove, and M. Ratcliffe. 2000. Census data as a core demographic, social, and economic dataset for long term ecological and social research. Baltimore Ecosystem Study Annual Meeting. Baltimore, MD. October 26-27.

Boone, C. 2000. Contributions of historical geography to Long Term Ecological Research in Baltimore. Eastern Historical Geographers Association. Bar Harbor, ME. October.

Boone, C. 2000. Baltimore and the crisis of environmental equity research. Department of Geography and Environmental Engineering, The Johns Hopkins University. September.

Brush, G. 2000. Ecosystem based management. Maryland Department of Natural Resources and University of Maryland College of Agriculture and Natural Resources. September 13.

Brush, G. 2000. Reconstructing the environmental history of a small rural-urban watershed in Baltimore. University of Maryland Center for Estuarine and Environmental Studies. Horn Point, MD. October 4.

Brush, G. 2001. Riparian vegetation along a rural-suburban-urban gradient. Canadian Association of Geographers Meeting. McGill University. June 2.

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

Burch, W.R., Jr. 2000. The unifying influence of social ecology in ecosystem studies. NSF-CAP/BES LTER Integrating the Social and Biophysical Sciences Meeting. January.

Burch, W.R., Jr. 2000. Vine of life, ax of hope- Lessons of restoration from country and city. The Restoration Agenda: Blueprint 2000. Yale University. March 29.

Burch, W.R., Jr. 2000. The importance of trails and volunteer coordinator systems in ensuring sustainable ecosystem restoration. Fairmont Park Commission/William Penn Foundation. Philadelphia, PA. February 1-2.

Burch, W.R., Jr. 2000. People as an ecosystem component- lessons from Baltimore, New Haven and Philadelphia. Cuyahogs Valley National Recreation Area Ecosystem Research Consortium. April 14-15.

Burch, W.R., Jr. 2001. BES/LTER research as pathway for connecting disciplines, science, art and people. Duke University. January 8-10.

Carrera, J.M. 2001. The community component of BES Question Three. Presentation for the National Science Foundation Review Team. Baltimore, MD. February 18.

Carrera, J. 2001. Field Safety and Community Awareness Training Seminar. Parks and People Foundation. Baltimore, Maryland. May 31.

Costanza, R. 2001. Valuing the earth: Reintegrating the study of humans and the rest of nature. Linacre College, Oxford, England. February 26.

Costanza, R. 2001. Designing a sustainable and desirable America. Champions of Sustainability Lecture Series, sponsored by Sustainable Pittsburgh. Pittsburgh, PA. March 14.

Costanza, R. 2001. Ecological economic modeling and valuation or urban ecosystems: the Baltimore Ecosystem Study.

University of North Carolina, Greensboro. April 12.

Costanza, R. 2001. Reintegrating the study of humans and the rest of nature. Sustainable Cities Program at the University of Southern California. Los Angeles, CA. April 16.

Costanza, R. 2001. Ecological economics and the human dimension of coastal zone management. NOAA Coastal Services Center, Human Dimensions Initiative. Charleston, SC. May 16.

Costanza, R. 2001. What are catchments, waterways and estuaries worth? Estuaries: Where Catchments Meet Coast- An Envirolinx Features Forum. Bairnsdale, Australia. May 22.

Costanza, R. 2001. The coastal zone- Earth's most important boundary. IGBP Global Change Open Science Conference: Challenges of a Changing Earth. Amsterdam, Netherlands. July 10-13.

Grove, J.M. 2000. Beyond raking: Tools and strategies for sustaining our parks. The City Parks Association of Philadelphia. Philadelphia, PA. October 21.

Grove, J.M. 2000. What are urban ecosystems? Scale, time-lags, feedbacks, and spatial connectivity. The Four Musketeers of Urban Ecosystem Research and Understanding. Ecological Cities Conference. Boston, MA. November 10-11.

Grove, J.M. and S.T.A. Pickett. 2001. The need for environmental history in the NSF LTER. Annual Meeting of the Society of Environmental Historians. Durham, NC. March 29-April 1.

Grove, J.M. 2001. Scale, time-lags, feedbacks and spatial connectivity: Key concepts for the study of human ecosystems. DNR MANTA Seminar Series. Annapolis, MD. April 11.

Grove, J.M. 2001. We have met the forest and the forest is among us. Grow with grace. Steve Sinclair Department of Forests, Parks and Recreation Agency of Natural Resources State of Vermont. Killington, VT.

Hager, G. 2001. Revitalizing Baltimore and the Baltimore Ecosystem Study: Revitalizing urban ecosystems. U.S. Forest Service Tour. Baltimore, MD. June 27.

Hinson, K.H. and J.M. Grove. 2000. Using a social ecology approach to urban ecosystems. Annual Meeting of the National Science Teachers Association. Baltimore, MD. November 17.

Nowak, D.J., J. Pasek, R. Sequeira, D.E. Crane, and V. Mastro. 2001. Potential effect of an Asian long horned beetle (Anplophora glabripennis) on urban trees in the United States. 12th USDA Interagency Research Forum on Gypsy Moth and other Invasive Species. Annapolis, Maryland.

Nowak, D.J. 2000. Urban Forests of the United States. EROS Data Center. Sioux Falls, SD.

Nowak, D.J. 2000. Carbon storage and sequestration by urban trees in the United States. Advances in Terrestrial Ecosystem Carbon Inventory, Measurements, and Monitoring. Raleigh, NC.

Patterson, T., R. Boumans, and J.M. Grove. 2000. Modeling human ecological systems: A review of social capital approaches for dynamic modeling. International Conference of Geographic Information Systems and Environmental Modeling (GIS/EM4). Banff, CA. September 2-8.

Villa, F. 2000. Integrating modelling architecture: A declarative framework for multi-scale, multi-paradigm ecological modeling. Modelling Complex Systems Conference. Montreal, Quebec. August.

Villa, F. 2000. Calibration techniques for complex simulation models. IALE Conference. Ft. Lauderdale, FL. March.

Villa, F., and Costanza, R. 1999. Calibration of large spatial -models: A multi-stage, multi-objective optimization technique. Association of American Geographers (AAG) 95th Meeting. Honolulu, HI. March 23-37.

Findings

Included in this report are new findings for 2001, and those described in previous annual reports are not repeated. Findings will be organized by the three core questions guiding the Baltimore Ecosystem Study (BES).

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?*

We are approaching patch definition and delimitation from two angles. The ecological approach has required us to develop a novel classification method that separates structural from functional components. We found that previous land cover classifications were developed for larger spatial extents and were motivated primarily by commodity concerns. Our new approach is more consistent with assumptions and scales of metropolitan areas and, in combination with the careful separation of structure and function, will facilitate our goal of understanding the relationship of ecological structure and function of urban areas. We are testing this classification method in two contrasting areas of the Gwynns Falls Watershed (GFW) that differ in stage of urbanization. In addition, we are defining our classification by quantifying the elements of heterogeneity in each patch type so that the approach can be readily applicable to any urban area.

The social sciences approach to patch definition and delimitation is highly compatible with the ecological approach described above. Social patches have a high degree of internal homogeneity locally but are highly heterogeneous at coarser scales. The patch analysis has resulted in a more rigorous identification of social groups as ecological agents that actively modify systems and that respond to ecological structures and functions. One of the crucial factors in regulating the behavior of humans as ecological agents is the alteration of the property regime. Property regime refers to how people actually control territory which may differ from ownership. The property regime indicates who actually makes environmentally important decisions about particular parcels. Property regimes are much more complex and multilayered than ownership, and they respond to a whole range of social and economic factors. Because it responds to so many factors and because there are so many components of property regime, it provides a useful tool for understanding social patch structure.

Patch change has been addressed through paleoecology and historical records. We discovered that floodplain accretion in the GFW occurred between 1847 and 1912, implicating both agricultural and urban sources of sediment. Pollen profiles revealed a past dominance of *Dryopteris* and *Osmunda*, both wetland ferns. Few other species were present. Current species composition indicates that riparian zones have become drier with urbanization. Riparian zones in urban areas are now dominated by upland trees, whereas the non-urbanized riparian zones are dominated by wetland trees. The presence of exotic species differs between canopy layers. There are only 8 exotic tree species but more than 50 % of the species in the herbaceous layer are exotics.

Comparisons of urban ecosystems have been done along two dimensions. The first is within the Baltimore metropolitan area and uses a gradient of urbanization from the highly urbanized downtown out to the surroundings that are rapidly converting to housing or are remaining in agriculture. These comparisons are mentioned throughout this document and will not be addressed here. The second axis of comparison relates Baltimore with other cities. The Urban Forest Effects model (UFORE) has been applied to several cities in addition to Baltimore including cities in the U.S., Canada, China, and Chile. Estimates of damage to city trees by the Asian long-horned beetle average $2.3 billion per city, and as much as 34 % of the canopy is at risk. In addition the BES has organized and participated in a workshop to identify interactions that will be pursued with urban research zones in France.

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

There are a diversity of fluxes that are being examined in BES. We begin by describing the fluxes of social processes. New findings can be reported for the network analysis of natural resource organizations and agencies and for research on questions of environmental equity. The natural resources management regime in GFW comprises 45 core organizations and 109 other organizations. Of these groups, 50 % are non-profit agencies. Most of the groups focus on 1-2 projects, but 12 % of the organizations are involved in 8-16 projects. Within GFW there are 111 distinct public, natural resource management projects. Twenty seven percent of these projects focus on vegetation management, 23.4 % on water issues, 14.4 % on land management and 13.5 % are mainly educational.

Environmental equity research has focused on Toxic Release Inventory (TRI) facilities. A surprising result of this research is that, at the fine scale, these facilities are associated with white working class neighborhoods. As the scale of analysis changes, the social correlates of TRI sites change. At larger units of analysis, such as a half mile radius around TRI sites, differences in race characteristics decrease. Using the census tract level as a unit of analysis reveals that race is the most significant population characteristic followed by income and education. The proximity of TRI sites to white working class neighborhoods may be explained by the long history of residential and occupational segregation in the area.

BES is also measuring biogeophysical fluxes. A comparison of stream chemistry between GFW and an adjacent forested reference watershed indicates that all sites with any human use have much higher nitrate and phosphate concentrations than the reference site. Nitrate concentrations are highest in agricultural catchments, next highest in urban and suburban catchments, and lowest in the forested reference catchment. In contrast, nitrate concentrations at gauging stations on the main stem of the Gwynns Falls decreased downstream, corresponding to an increase in urbanization. Phosphate concentrations decreased through the rural and suburban portions of the watershed but increased at the urban end.

Riparian zones are important components of the landscape because they can control fluxes between terrestrial and aquatic ecosystems. Riparian zones have also been shown to prevent the movement of pollutants from upland systems to streams in many areas. Denitrification was measured in grass and forest riparian soils located in urban and rural areas. Denitrification is a microbial process that converts nitrate, a common water pollutant, into nitrogen gas. Denitrification potential did not differ between urban and rural riparian soil or between forest and grass riparian soil. However, the variability in potential denitrification was much greater in urban compared to rural sites. We suggest this is due to greater soil moisture variability among the urban sites and because soil moisture is positively related to denitrification potential.

The water table depth at urban and rural riparian zones is lower than that of the forested reference watershed. Lower water tables are a common urban effect for reasons associated with increases in impervious surfaces: 1) an increase in upland surface runoff to streams, 2) a decreased infiltration to groundwater, and 3) stream down cutting as a result of greater runoff volume and rates. Consequently, groundwater in urban riparian zones is moving deeper in the soil profile and these soils may be hydrologically isolated from adjacent uplands and streams. Because denitrification rates are much lower at deeper depths, riparian soils in urban systems may have lower capacities for pollutant removal.

In addition to flux measurements in riparian zones, biogeochemical fluxes have been quantified in a network of intensive permanent plots including eight forest plots and five grass plots. Nitrogen mineralization and nitrification did not vary among the forest plots. However, soil nitrate concentration was higher in urban than in rural plots. These results are consistent with urban-rural contrasts observed in the New York metropolitan area and highlight new research questions such as, are the observed patterns caused by differences in soil type, earthworms, N deposition, or land use history? These results can also serve as a springboard for studies in more modified sites such as yards, empty lots, and lawns.

A comparison of nitrogen dynamics in forest, grass and agricultural plots revealed that forest and grass plots had low levels of soil nitrate compared to agricultural plots. High levels of organic matter and soil microbes under grass may create a carbon sink for nitrate. The high spatial and temporal variation in grass plots requires long-term assessment.

Parameters to model atmospheric flux and productivity were measured in 200 extensive permanent plots. These data were combined with weather and pollution concentration data in the UFORE model to calculate vegetation functions of carbon dioxide storage and sequestration and air pollution removal and formation. From this model, it was calculated that Baltimore's urban forest stores 529,000 tC with an annual net sequestration of 10,800 tons tC.

The first permanent tower to measure carbon flux in an urban area began operations as part of BES. Continuous carbon dioxide and water profile measurements began in January 2001 and have now been expanded to capture 10 profile levels. In May 2001 continuous carbon dioxide, water vapor, heat and momentum flux measurements were begun. Comparisons are arranged with the more rural tower at the Smithsonian Environmental Research Center in Edgewater, MD.

Several models are being developed and tested as part of BES. One, the UFORE model, has been discussed earlier. In addition, the Gwynns Falls Landscape Model (GFLM) was tested against new data available from the Villanova stream gauge on the Gwynns Falls and there was good agreement. The GFLM was compared to the Hydrological Simulation Program Fortran (HSPF) model, an industry standard for hydrological flow models for built environments. The spatially distributed GFLM performed better than the HSPF. Data on human population dynamics, and the dynamics of built, social, and human capital are being collected to test models at regional (GFLM) and global (Global Unified Metamodel of the Biosphere, GUMBO) scales.

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?*

Assessment of how ecological knowledge discovered or disseminated with the help of BES affects environmental decisions in Baltimore will be a major result of activities answering question 3. Results to date are primarily the development of an information network for knowledge exchange, and the successful transfer of information between BES and its various constituents. The broad array of institutions, agencies, and communities we must work with makes this a time intensive and developmental part of our project. We highlight exchanges in key areas.

In the realm of education, we have accomplished information exchange in several kinds of areas. We conducted workshops for teachers on topics such as “Plants and People in the City,” and “Stream Ecology.” Education has also included the training of 5 graduate and undergraduate summer interns as well as Research Experiences for Undergraduates students. We conducted a project at the Calverton School (Calvert, MD) to measure water quality, relate it to land use, and to share the results with county authorities. Field crews in paleoecology worked with high school teachers, and BES provided a field trip for the National Science Teachers Association. Collaborations with the University of Maryland, Baltimore County’s new Center for Urban Environmental Research and Education have established new linkages for information exchange and education based on BES work.

Our interactions with agencies have extended from federal to local levels. For example, in Baltimore City we provided environmental data and interpretations to the Mayor’s weekly CityStat meetings, where activities relating to environmental quality and management are reviewed. Working with the Baltimore City Department of Recreation and Parks, we have provided amendments and guidebooks for their Rules and Regulations. The open space report produced last year was presented and discussed with the city Housing and Community Development Commissioner. We have contributed to the development of the Baltimore City Protected Reservoir Management Plan, involving collaborations with the Department of Public Works, and the Maryland State Forestry Department. BES has provided data to the Maryland Department of Environment to support validation activities for a eutrophication model of Baltimore Harbor. Results at the federal level are illustrated by our becoming a founding collaborator in the Chesapeake Bay Cooperative Ecosystem Studies Unit (CESU). This program facilitates interactions between scientists in federal agencies, land managers, and researchers in non-federal institutions. Sharing of resources and expertise, and the improved efficiency of federal science resources are major goals of the CESU program. The Baltimore Ecosystem Study brings expertise in urban and urbanizing lands, and experience in multi-agency interactions to the program. The cooperative agreement will facilitate exchanges with federal scientists and resource managers, and can ease our participation in research programs that may be established to promote the goals of CESU. In particular, the goals of the CESU include:

- Enable federal scientists to maintain offices and labs at participating institutions;
- Foster multi-disciplinary and multi-agency research;
- Increase the diversity of the scientific workforce; and
- Facilitate the transfer of research funds from federal agencies to partner institutions.

Interactions with communities are crucial to the success of an urban ecosystem project. Interactions range from a single community, to consortia, to neighborhood-bridging associations. We have worked with the Baltimore Neighborhood Indicators Alliance to enhance environmental data and indicators available to communities. We have worked with the Village Center in the Washington Village/Pigtown neighborhood to map environmental and social features of the area and train neighborhood youth in GIS. BES contributed to and helped implement a user survey of the Gwynns Falls/Leakin Park and the Gwynns Falls Trail. We participated in the Gunpowder Watershed Festival with a public booth and by leading a nature walk. We have provided guidance to the technical advisory committee of Maryland Save Our Streams, and to workshops on habitat and organism identification for volunteers participating in Save Our Streams work.

Modeling efforts in BES are beginning to include ecological services, which will enhance the utility and interest of our models to the public. In addition, we have begun a program in mediated modeling which will involve stakeholders in the construction and improvement of our rigorous mathematical models.

The BES information manager redesigned the web site to improve public access to BES information and data, and has added an intranet function to enhance communication within BES (In addition to the new BES website, we have collaborated with the USDA Forest Service to create a new web-based research collaboration system called the “Open Research System” (ORS, www.open-research.org). The publication by Schweik and Grove (2000) describes the concept behind ORS. The ORS is designed to allow geographically dispersed BES researchers the ability to submit metadata (data about data or documents) to a central server and, optionally, the datasets themselves. The ORS has a series of metadata input forms for various types of data: Geographic Information Systems (GIS) data, non-spatial data (such as spreadsheets), and citations to publications. There is also a facility to allow researchers to post a review of various web sites of interest to BES researchers and people in the community. The system provides three different ways for users to search for BES data: by keyword, geographic (map based) and a graphical search mechanism. The graphical search is structured around the Human Ecological Framework that guides BES research. The search facilities are available for anyone who accesses www.open-research.org. Therefore any data posted to ORS is immediately made available to the general public.

Our Information Management program has contributed to enhancing Internet connectivity in partner organizations that are involved in BES research and education, and are located in under served neighborhoods. We are developing a "Web-Accessible Knowledge Base for Integrated Analysis and Valuation of Ecosystem Services -- the Ecosystem Database (ESD)". This is a user-oriented tool that compliments and interacts with existing components of the BES information management system.

We have produced the first issues of a plain language newsletter highlighting ecosystem research and understanding resulting from BES. This newsletter is distributed to members of the public and community groups that have expressed an interest in BES or are working on related issues. These were delivered via the web and through mass electronic and postal means.

Publications and Products

Major Scholarly Journal Paper

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Boone, C. 2001. Environmental equity research: Historical and GIS methods. Association of American Geographers 97th Annual Meeting. New York, NY. March.

Boone, C. 2001. Linking public health and ecological change in Baltimore. Canadian Association of Geographers 50th Annual Meeting. Presentation. Montreal, Canada. June.

Boone, C. 2001. Public health and environmental conditions in Baltimore. American Society of Environmental History Annual Meeting. Durham, NC. March.

Brush, G. 2001. Riparian vegetation along a rural-suburban-urban gradient. Canadian Association of Geographers Meeting, Mc Gill University. Montreal, Canada. June 2.

Costanza, R. 2001. Ecological economic modeling and valuation of urban ecosystems: the Baltimore Ecosystem Study. University of North Carolina at Greensboro Symposium on: Open Spaces in an Urban Setting. Greensboro, NC. April 12.

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Grove, J.M. 2000. Involving people in neighborhood assessments to avoid alienation of key groups and misguided data collection. Beyond Raking: Tools and Strategies for Sustaining our Parks. The City Parks Association of Philadelphia, PA. Philadelphia, PA. October 21.

Grove, J.M. 2000. What are urban ecosystems?- Scale, time-lags, feedbacks, and spatial connectivity: The four musketeers of urban ecosystem research and understanding. Ecological Cities Conference. Boston, MA. November 10-11.

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Hager, G.W. 2001. Revitalizing Baltimore and the Baltimore Ecosystem Study: Revitalizing Urban Ecosystems. U.S. Forest Service Tour. Baltimore, MD. June 27.

Heisler, G., P. Groffman, L. Band, KT. Belt, V. Fabiyi, G. Fisher, R. Grant, and S. Grimmond. 2000. A reference meteorological station for urban long-term ecological research, Baltimore Ecosystem Study. American Meteorological Society Meeting of the Third Urban Environment Symposium. Davis, CA. August 14-18.

Heisler, G.M., R.H. Grant, and W. Gao. 2001. Urban tree influences on ultraviolet irradiance. UV Ground- and Space-Based Measurements, Models, and Effects. The International Society for Optical Engineering, Bellingham, WA. San Diego, CA. August 1.

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. Poster. Amsterdam, The Netherlands. July 9-13.

Nowak, D.J. 2000. Carbon storage and sequestration by urban trees in the United States. Advances in Terrestrial Ecosystem Carbon Inventory, Measurements, and Monitoring. Raleigh, NC.

Nowak, D.J., J. Pasek, R. Sequeira, D.E. Crane, and V. Mastro. 2001. Potential effect of an Asian longhorned beetle (Anplophora glabripennis) on urban trees in the United States. Twelfth USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species. Annapolis, MD.

Patterson, T., R. Boumans, and J.M. Grove. 2000. Modeling human ecological systems: A review of social capital approaches for dynamic modeling. International Conference of Geographic Information Systems and Environmental

Modeling (GIS/EM4). Banff, Alberta, Canada. September 2-8.

Schweik, C.M., and J.M. Grove. 2000. Fostering open source research and modeling collaboration over the web. 4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs: Banff, Alberta, Canada. Boulder, CO. September 2-8.

Tague, C.L. and L.E. Band. 2001. The spatial structure of nitrogen cycling and export for urbanizing watersheds: A GIS/physically based modeling study for small watersheds in Baltimore County. Annual Meetings of the Association of American Geographers. New York, NY. March.

Villa, F. 2000. Integrating modelling architecture: A declarative framework for multi-scale, multi-paradigm ecological modelling. Modelling Complex Systems Conference. Montreal, Quebec, Canada. August.

Villa, F. 2000. Calibration techniques for complex simulation models. IALE Conference. Fort Lauderdale, FL, March.

Villa, F. and R. Costanza. 1999. Calibration of large spatial models: A multi-stage, multi-objective optimization technique. Association of American Geographers 95th meeting. Honolulu, HI. March 23-27.

Invited Seminar

Boone, C. 2000. Baltimore and the crisis of environmental equity research. Department of Geography and Environmental Engineering, Johns Hopkins University. Baltimore, MD. September.

Brush, G. 2000. Ecosystem based management. Maryland Department of Natural Resources and University of Maryland College of Agriculture and Natural Resources. Baltimore, MD. September 13.

Brush, G. 2000. Reconstructing the environmental history of a small rural-urban watershed in Baltimore. University of Maryland Center for Estuarine and Environmental Studies. Horn Point, MD. October 4.

Costanza, R. 2001. Valuing the earth: Reintegrating the study of humans and the rest of nature. Linacre College, Oxford University. Oxford, England. Feb. 26.

Costanza, R. 2001. Designing a sustainable and desirable America . Champions of Sustainability 2001 Lecture Series, sponsored by Sustainable Pittsburgh. Pittsburgh, PA. March 14.

Costanza, R. 2001. Reintegrating the study of humans and the rest of nature. University of Southern California, Sustainable Cities Program. Los Angeles, CA. April 16.

Costanza, R. 2001. Ecological economics and the human dimension of coastal zone management. NOAA Coastal Services Center, Human Dimensions Initiative. Charleston, SC. May 16.

Grove, J.M. 2001. We have met the forest and the forest is among us. Growth with grace—Using an ecosystem-based planning process for Vermont communities. Steve Sinclair Department of Forests, Parks, and Recreation Agency of Natural Resources State of Vermont. Killington, VT.

Grove, J.M. 2001. Scale, time-lags, feedbacks, and spatial connectivity: Key concepts for the study of human ecosystems. Maryland DNR Seminar on Human Ecosystems. Annapolis, MD. April 11.

Nowak, D.J. 2000. Urban forests of the United States. EROS Data Center. Sioux Falls, SD.

Report to Agency or Organization

Belt, K. 2000. Guidance Manual for the BES Sensitivity and Field Safety Training.

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Belt, K.T. 2000. Baltimore Ecosystem Study water quality and urban hydrology initiatives-Stream studies along an urban rural gradient in the Gwynns Falls and Baisman Run Watersheds. Maryland Water Monitoring Council Programmatic Coordination Newsletter December. http://mgs.dnr.md.gov/mwmc/nl12_00.html .

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Websites

http://md.water.usgs.gov/BES/
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Contributions

Contributions within Discipline

In the fourth year of the Baltimore Ecosystem Study we have continued to extend the scope of ecology to the ecologically neglected urban realm. The worldwide increase in urbanization 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 give examples in historical and long-term dynamics, flux of materials in ecosystems, spatial heterogeneity in systems, and the role of scale.

Ecology has increasingly recognized the value of historical records and long term perspectives. We have used such long term data to integrate social, physical and biological processes. For example, we are using U.S. Census data to show how environmental processes and human or demographic processes have interacted and changed through time in Baltimore. This approach places the demographic information contained in the census into a broader environmental context by combining it with physical environmental data and biological data. Therefore, the novel integration shows an additional value of the census data that is more useful for understanding urban areas as ecological systems. An additional advance has been achieved by overlapping paleoecological data and historical data. The overlap exposes changes in urban landforms, biota, land uses, and infrastructure from pre-settlement to contemporary times. The integration of these processes allows us to tease apart the drivers, feedbacks, and results of urban dynamics.

Our contribution to the understanding fluxes of materials in ecosystems is exemplified by carbon cycling. The role of urban and suburban environments in the global carbon budget is poorly understood. Yet they may contribute significantly to balancing this budget. In order to measure carbon in urban and suburban environments we have installed the first flux tower in an urban system. In addition, because our models and measurements of carbon fluxes must deal with heterogeneous landscapes and topographies, the tools we produce will be useful in making carbon flux models more widely applicable.

The understanding of spatial heterogeneity is one of ecology's greatest challenges. One of our major contributions is to combine an understanding of ecological, social, and hydrological heterogeneity. Our research is enhancing the measurement, modeling, and predictability in these disciplines. For example, our hydrologically based models consider both the vegetated and impervious source areas and mixtures of the two. Not only are these models incorporating mixtures of land cover but they are also doing it in a spatially explicit way in order to increase predictability. Our research also targets the role of 'hot spots' in urban systems, such as riparian zones that may be critical to nutrient transfers in urban areas. We have also discovered that an improved understanding of spatial heterogeneity in urban ecosystems requires new ways to classify land use and land cover that readily combine social, physical, and biological structures and that disentangle structural and functional components of urban landscapes.

Our research contributes to the understanding of scale in ecological systems. We have adopted a patch dynamics approach within each of the disciplines contributing to BES and this fosters the integration of these disciplines. Patch dynamics allows us to scale measurements and models to locate spatial discontinuities or to discover processes that
operate similarly over a wide range of scales. Our quantitative models, including the General Human System Model, can be used to examine the full range of scales in urban systems. In addition, a model performance index has been

developed as a practical tool to optimize parameters, to include spatially explicit approaches, and to incorporate multiple objectives in integrated models. Because parameter choice, spatial units, and identification of objectives are often linked to particular scales in models, a tool to evaluate these model features improves the scalability of those models.

Contributions to Other Disciplines

Due to the highly multidisciplinary nature of this project we have discussed disciplinary and interdisciplinary contributions in the first section of this report pertaining to contributions within discipline.

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, we train Research Experiences for Undergraduates students, and provide 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 2001: 8 African Americans, 1 Asian American, and 8 Caucasians.

Contributions to Resources for Science and Technology

Our contributions to information for science include databases and integrated models. Unique databases we have made available include a digital basin geological map, and digital maps of the original land grants and witness trees, and data from hydrological networks to analyze spatial variability in soil moisture. BES also acts as a conduit for scientifically useful data available in public and community hands. Interactions with the Baltimore Neighborhood Indicators Alliance, for example, provides access to such databases.

Integrated quantitative models are based on the conceptual frameworks that have been developed within BES and in collaboration with scientists from other programs. For example, the Human Ecosystem Framework has formed the basis of a quantitative General Human Systems Model (GHSM). This dynamic model organizes data collection in social, ecological, hydrological, and economic realms, and indicates novel connections between them. Our integrated models provide an approachable way to share results with the larger scientific community.

Another novel contribution of BES is the development of urban ecological field stations. These are based on interactions with communities and agencies to provide access by scientists to sites and intellectual resources in the city, as well as to provide access by citizens to scientists and to scientific information. It is important to have physical locations to facilitate such exchanges and to provide sites in which urban research can be securely pursued. Our developing urban field stations include one with a community group and one with a municipal agency. Thus, urban field stations are considered a network of individual sites, and are based on mutually designed projects, reciprocal information exchange, effective Internet connectivity, and a shared concern for ecological function in the urban environment.

Contributions 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 the public is 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.

Our contributions to public welfare take three forms: 1) interactions with an immediate network of collaborators, 2) understanding the needs of a broader public so that scientific products can be tuned for general use, and 3) interactions with other organizations who have access to high-quality data that are useful for scientific research.

Contributions with our immediate collaborators include such projects as providing technical assistance to several state and municipal agencies, including the Maryland Department of Natural Resources, Revitalizing Baltimore, the Baltimore County Department of Environmental Protection and Resource Management, the Baltimore City Department of Recreation and Parks, the Baltimore City Department of Public Works, and various watershed associations. Community interactions include assistance with environmental mapping in the Pigtown neighborhood, technical training for Maryland Save Our Streams volunteers, and sharing database management strategies with the Baltimore Neighborhood Indicators Alliance.

Contributions based on an understanding of the needs of a broader technical and lay public include several examples. Our work has contributed to an improved understanding of environmental equity issues in Baltimore by exposing dimensions other than current demographics. The unexpected finding that the location of Toxic Release Index sites correlate to white working class neighborhoods in Baltimore demonstrate the historical importance of both occupational and residential segregation. An additional refinement includes discovering changing demographic correlations with scale of measurements. A second example comes from a network analysis of organizations involved in natural resource management in Baltimore. This analysis revealed the key interactions and complementarity among agencies and nonprofits working on natural resource issues. Finally, the creation of an ecosystem services database and improved meteorological and climate prediction in urban areas are expected to bring public benefits.

Our interactions with public agencies and community organizations are making high-quality data available to scientists who would not otherwise have access. The ecosystem services database includes some data of this sort. Our interactions with agencies and organizations are also making data on infrastructure, property regimes, census, and marketing choices available for integrated scientific research. Thus, our contributions to public welfare, in reality, benefit both science and the public.