Pieces of the Puzzle: From Backyard Habitat to Landscape Scale

Session III – Concurrent Contributed Papers on Assorted Topics

Room A – Looking to the Landscapes

Room B – See the Trees for the Forests

Room C – Aquatic Systems

From Corn to Crake – Vertebrate Faunal Response to a Landscape Scale Restoration Project in Seneca Falls, New York: 5 Years Post-Baseline

Michael McGraw, Applied Ecological Services, Inc.

Seneca Meadows Landfill, located 45 miles east of Rochester, is the largest active landfill in New York. As part of the permitting process for landfill expansion, the landfill owner/operator was required to compensate for impacts to 70 acres of degraded forested wetland and a channelized reach of Black Brook. The landfill owner agreed to a mitigation ratio of 8:1. Applied Ecological Services (AES) was retained to enhance 350+ acres of these wetlands and to restore a 580+ acre agricultural landscape comprising row cropland and edge and degraded forest to a mosaic of native wetland and upland habitat types. Baseline faunal assessments of vertebrates (birds, reptiles, amphibians, mammals, and fish) were conducted in 2007, construction was completed in 2008, and comparative faunal assessments have been conducted each subsequent year (2009-2012). A realignment of Black Brook to more closely follow its historic footprint was completed in 2012. This project allowed AES to address two major questions: (1) Can the give/take dynamic of wetland mitigation projects provide net contribution to native landscapes via restoration ecology in the short-term? (2) How have native biota (focus on vertebrate fauna) responded to the restored landscape over time (5 years later)?

Restoring landscapes to specific natural settings requires considerable knowledge of past and present local ecosystems and their constituents (soils, flora, fauna, trophic web interactions, disturbance regimes, etc.). How we measure success of a restoration project should largely hinge upon not only what species are supported, but also how they interact and their ability to self-manage (ecosystem functionality) within the newly restored landscape.

AES has documented a tripling in avifaunal species richness and an order-of-magnitude increase in amphibian abundance following restoration, largely due to the addition of complex site hydrology, resultant plant communities and restored connectivity between upland and wetland habitats. New York State-listed marsh birds (crake), such as least bittern (*Ixobrychus exilis*) and pied-billed grebe (*Podilymbus podiceps*), have been successfully breeding on site since 2010 in locations that were row crop corn fields just 2 years prior. Species composition and abundance fluctuations correlate to vegetation establishment (changes in height per year), ecological source modeling, and annual climatic variation. Forested restoration effects are evident, but will require more time (approximate 25 years) to achieve intended ecological conditions. Interim successional habitats are of regional significance and supporting a high diversity of wildlife.

Michael McGraw is a Wildlife Biologist and Ecologist based in the East Coast Office of Applied Ecological Services (AES). With ten years of professional experience and a research background in herpetology, Michael has performed a wide variety of reptile, amphibian, and avifaunal surveys in the Eastern and Midwestern United States, with a strong emphasis on endangered, threatened, and special concern species. Michael is currently the manager and lead biologist on a variety of AES wildlife-related and ecological restoration projects. He achieved his undergraduate degree in Environmental Science at Drexel University in 2001 and is currently pursuing a Master of Environmental Biology degree at University of Pennsylvania. AES is a nationally recognized ecological restoration firm with contracting, consulting, and nursery divisions and over 30 years of experience designing, installing, and monitoring ecological restoration with projects in the Americas, Asia, and Eastern Europe.

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Restoring the Piedmont Prairie in Virginia – Using Site Fire Management Planning and Prescribed Fire to Achieve Restoration at the Landscape Level

James R. Remuzzi, President, Sustainable Solutions, LLC

In the planning process, it was identified that a prairie system is actually native to the region and is both Globally and State rare; due largely to land conversion and fire exclusion. Building on the research conducted by Virginian Division of Natural Heritage and Virginia Department of Conservation and Recreation, Sustainable Solutions used the Piedmont Prairie ecosystem as the reference condition for development of the fire regime for the restoration. This information was also used to inform the placement, frequency, and intensity of the prescribed burns for the site. The resulting site fire management plans incorporate 1000 acres of continuous restoration with linkage with State designated habitat hubs, and represents a major step forward in utilizing prescribed fire for landscape level restoration.

Presentation will include description of the planning process, outline of the reference Piedmont Prairie, and insights on how to effectively use prescribed fire for restoration.

Sustainable Solutions LLC, a Mid-Atlantic based natural resource management company, has been working since 2010 with several large landowners in Fauquier county, Virginia to restore old agricultural and grazing fields to native grasslands.

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Ecological Monitoring and Adaptive Management of the Lehigh Gap Wildlife Refuge/Palmerton Superfund Site

Dan R. Kunkle, Lehigh Gap Nature Center

The Lehigh Gap Wildlife Refuge, owned and operated by the Wildlife Information Center, Inc. (aka the Lehigh Gap Nature Center) is a 750-acre tract on the north slope of the Kittatinny Ridge in eastern Pennsylvania at the gap where the Lehigh River cuts through the mountain. The Refuge is situated within the Palmerton Superfund Site that includes about 3000 acres in total. Much of the hillside within the site was denuded from acid and heavy metal deposition from 80 years of zinc smelting in Palmerton. Without vegetation, severe erosion had also taken place. Beginning in 2003, revegetation of several hundred acres of the Refuge with warm season grasses was attempted. A decade later, the majority of this area is now covered with vegetation, and the successful methods and lessons learned are being applied throughout other parts of the Superfund site.

The Refuge has undergone rigorous monitoring not only to determine if the goals of the EPA Record of the Decision have been met, but also to ensure successful achievement of the additional goals of the Nature Center that include establishing a functioning ecosystem that is open to the public for recreation, education, and research. Monitoring has included biodiversity inventories, analysis of metal uptake by plants, determination of the presence of contamination in the food chain or hydrologic flows, investigations of microclimate effects and of potential impacts of climate change along the Ridge, and several other studies. Unforeseen problems with early successional trees such as *Betula populifolia* (grey birch) and the quick spread of invasive plants have led to the need for adaptive management, including consideration of controlled burns. The Nature Center and EPA have relied on a wide network of collaborators from academe, state and federal agencies, and independent environmental consulting firm, and the public (citizen scientists) for consultation and to conduct the extensive monitoring that has occurred. We believe that both the degree of collaboration and the extent of post-revegetation monitoring are unusual in restoration projects. In this session, lessons learned from developing the collaborations, the ecological monitoring, and the process of developing the appropriate desired future outcomes and adaptive management plans will be discussed.

Dan R. Kunkle has a B.S. in Secondary Education/Biology (1976) and an M.S. in Biology (1980) from Kutztown University. He taught biological sciences at Freedom High School in Bethlehem PA for 28 years from 1976-2004, and was Science Department Chairperson there for 18 years from 1986-2004. He left teaching to become full-time Executive Director of Lehigh Gap Nature Center in 2004. He became the volunteer Executive Director of the Wildlife Information Center (now known as Lehigh Gap Nature Center) in Slatington, PA in 1998 after serving on the Center's Board for 8 years. In 2002, he initiated the Lehigh Gap Restoration Project in which 750 acres were purchased on the Kittatinny Ridge at Lehigh Gap near Palmerton. He has restored vegetation to the areas that were degraded by air pollution, and created the Lehigh Gap Nature Center.

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Climate-Induced Changes in Habitat and Community Compositions: How Do We Begin to Adapt the Fields of Ecology and Restoration?

Diane White Husic, Ph.D., Moravian College

Most restoration work occurs at sites where human activities have *directly* degraded the natural ecosystem. Such sites may be characterized by impairments including contamination, a loss of vegetation, soil loss or damage, diminished native species composition (diversity), new microclimates, and/or altered ecosystem functions and services. In such sites, it is typically relatively easy to delineate the cause and effect relationships that led to the degraded conditions. In contrast, this may be much more difficult when the disturbances result *indirectly* from human activities – e.g., with increasing greenhouse gas emissions and climate destabilization.

Although evidence suggests a role for climate change in disturbances such as forest loss due to pine-bark beetles or damage after Hurricane Sandy, one cannot yet declare a definitive cause-effect relationship. Scientists are unsure of exactly how resilient ecosystems will be or how quickly different species might adapt to climate-induced change. In many cases, changes may be slow and less evident initially (compared to damage caused by extreme weather events). In these cases, it will be even more difficult to connect the dots between the cause and the ecological alteration, but waiting for "proof" of the cause or for a tipping point may lead to irreversible damage. Ecological monitoring of large landscapes may offer useful early indicators of change, but long-term data sets will be needed to substantiate new trends. These studies require funding that can be difficult to obtain and a lot of boots-on-the-ground effort (and expertise).

Increases in temperature, earlier advance of spring, changes in precipitation, and longer growing seasons can be predicted to have effects on vegetation and animal behavior. The Eastern PA Phenology Project, along with other phenology studies, are beginning to gather large amounts of data about the timing of seasonal events, but in many cases, the datasets don't go back far enough to determine whether changes are simply seasonal variations or the start of more significant trends. One exception is bird data – records, which in some cases, go back 50 to 100 years. These records combined with hawk count data, e-Bird records, Audubon data, and PA Breeding Bird Atlas studies give clues as to how avian community composition might be changing.

Our analysis of 17 species of migrating forest songbirds, 50 years of raptor data, and preliminary monitoring of the north and south slopes of the Kittatinny Ridge for differences birds and invasive plant species will be discussed. It is hoped that the list of "next questions" that we have begun to generate will lead to a fruitful discussion on how to conduct the extensive monitoring needed in order to better comprehend how climate change could influence regional ecosystems, community compositions, and current and future restoration projects in the mid-Atlantic region.

Diane Husic received her B.S.in Biochemistry from Northern Michigan University and her Ph.D.in Biochemistry from Michigan State University (1986). In 1988, she accepted a tenure track position at East Stroudsburg University (PA) as chair of the Biochemistry program. In 2004, she became chair of the Department of Biological Sciences and co-coordinator of the Biochemistry program at Moravian College. Since 2005, she has been engaged with undergraduate researchers at the Palmerton Superfund site examining heavy metal uptake in early successional plants and studying the restoration of a functioning ecosystem at a site once devoid of vegetation. She conducts ecological assessments (inventories of plants, birds, butterflies, and invasives), monitors habitat for climate change impacts, and serves as coordinator of the Eastern PA Phenology Project.

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The Influence of New York City Urban Soils on Native Tree Seedling Growth and Survival

Clara Pregitzer[1], Nancy Falxa-Raymond[2], Rich Hallett[2], Tim Wenskus[1]

Centuries of human activity have altered the natural landscape of New York City and with few exceptions all of the city's forests were cleared by the end of the American Revolution. As the land was fragmented and subdivided, New York City's soils have been subject to a wide range of physical disturbances including burial or coverage of natural soil by fill material of varying quality. Recently there has been an increased interest in restoring degraded urban landscapes. Soil quality is one factor being considered when selecting a species palate for reforestation efforts in New York City, yet little is known about which tree species are best suited to urban soils of differing quality.

The goal of this research is to quantify the performance of four commonly planted native tree species growing in typical urban soils collected from restoration sites in NYC. Using a multi-factorial design, we planted seedlings of four native tree species into 13 soil types: one custom-made greenhouse soil and 12 urban soils collected from four typical New York City soil categories (coal ash, urban fill, sandy clean fill, native till). We hypothesized that in a common greenhouse environment we would see 1) quantitative differences in the chemistry of the selected soils, 2) these differences would impact tree growth, health and survival, and 3) tree species would respond differently to the variable quality of the selected soils.

After one growing season we found that tree growth (height) varied significantly ($p < 0.001$) among soil types and the greatest growth was found in coal ash and native till soil and the lowest height growth in urban fill and sandy clean fill sites. Soil type also had a significant effect on Fv/Fm ($p < 0.001$), a measure of chlorophyll fluorescence used to assess plant stress. Overall mortality was low; however one urban fill site had 25% mortality. We also found there to be a significant soil x species interaction indicating species grow differentially by the soil type. Soil pH and total organic carbon could explain some of the variation growth. In addition overall tree health varied significantly across soil types by species. These results will inform future restoration efforts by allowing managers to select species that can best tolerate the sometimes harsh conditions of urban restoration sites.

Clara Pregitzer is a Forester with NYC Department of Parks and Recreation's Natural Resources Group. With the Natural Resources Group she has conducted ecological assessments in over 1,500 acres of New York City Parks. Clara's previous ecological experience spans across riparian, desert and western forest ecosystems with projects across a variety of taxa including insects, mammals, soils and trees. Prior to working for NRG she conducted forest monitoring and ecosystem ecology research with the Colorado State Forest Service, Ecological Restoration Institute and Cottonwood Ecology Group. She has published papers in *Evolutionary Ecology*, *Functional Ecology* and *Ecology and Evolution*. She holds a B.S. in Forestry from Northern Arizona University and a M.S. in Ecology and Evolutionary Biology from The University of Tennessee.

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Forest Restoration in NYC – 28 Years of Lessons Learned

Katerli Bounds, City of New York Parks & Recreation, Natural Resources Group

Since the inception of the Natural Resources Group in 1984, under the guidance of former Parks Commissioner Henry Stern, the City of New York has been at the forefront of urban forest management. We pioneered new techniques in vegetation mapping and analysis and new strategies for upland restoration, and have successfully applied for and received millions of dollars in funding over the last 28 years.

Tim Wenskus (NRG) spoke at the Mid-Atlantic conference several years ago about the history and potential future of restoration in the City. I would like to share the lessons we've learned as practitioners, offer an overview of our current monitoring including a combination of statistical and anecdotal evidence that our strategies work, and answer some of the inevitable questions we get when visitors tour one of our restoration sites for the first time:

- Why do you plant the trees so close together?
- Why do you plant the fast-growers and the slow-growers all together?
- Why plant container trees instead of seedlings/saplings/B+Bs?
- Why plant under mature canopy?
- You really don't water them?

These questions cover a lot of ground, and the answers to them are fundamental to the practice of restoration in an urban area – they highlight some of the unique challenges (heterogeneous soils and microclimates, the importance of site specific solutions, the need to isolate the factors that are limiting the success of the system on its own), and the importance of keeping good records and using them to guide long-term adaptive management.

Katerli Bounds is the Director of Forest Restoration for the Central Forestry, Horticulture & Natural Resources division of New York City Parks. She is responsible for the planning and implementation of restoration across the City's 5000+ acres of naturalized forest, including managing over five million dollars annually in grant-, mitigation- and city-funded projects. Katerli earned a Master's degree in Library and Information Science from Pratt Institute, and dual B.A.s in International Relations and Philosophy from the University of Southern California. She is an ISA-certified Arborist, and DEC-certified Pesticide Applicator. Prior to working for Parks, she worked at a plant nursery and on a U.S. Forest Service trail crew in Montana, where she grew up. Katerli began working for Parks in 2004, when she was part of the inaugural group of the Green Apple Corps.

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Creating Diverse and Structurally Complex Forest Interior Habitat on the Urban Fringe

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The Hopewell Big Woods Partnership is a public-private conservation partnership focused on permanently protecting at least 15,000 acres of unbroken forest on the northwestern fringe of the Philadelphia metropolitan area. The Partnership is currently closing in on the Desired Condition for contiguous forest acres, but is still laboring over condition assessment and progress toward Desired Condition for the 15,000 acres as a whole.

The sustainability of this Desired Condition depends upon creating equal portions of early successional growth, maturing forest, mature forest, and, ultimately, old growth forest. Our restoration approach uses silviculture to enhance forest structural complexity to simulate old growth conditions while allowing forests to mature beyond their current age of about 100 years. We also document and categorize areas of forest (particularly along riparian areas) that have already achieved a good measure of structural complexity without intervention using a Light Detection and Ranging (LiDAR) approach.

One large challenge to using silviculture for forest restoration is opening the forest canopy to a point where non-native invasives proliferate. Two protected areas within this landscape are currently being sustainably harvested to provide income and better habitat for neotropical migrant birds. This forest habitat improvement employs selective harvest (with a portion of the income going to invasive suppression) to advance regrowth beyond the stage of invasive susceptibility. At the same time, at least a quarter of the forest area is being allowed to mature toward old growth as these even-aged stands senesce and break up into al-aged ”old growth” forest.

Jim Thorne holds degrees from University of Rochester, University of Wisconsin-Madison, and Yale, most recently in Forest Ecology and Forest Soils. He spent six years in the Department of Landscape Architecture and Regional Planning at University of Pennsylvania before moving to the Nature Conservancy in 1993. There he held a number of Directorships before joining the Natural Lands Trust in 2001. He is currently the Senior Director of Science for the Natural Lands Trust and Coordinator of the Hopewell Big Woods Partnership.

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i-Tree: Comprehensive Assessment of the benefits of Ecosystem Restoration with Data-Driven Analytical Software

Jason Henning, The Davey Institute and USDA Forest Service

The benefits of ecological restoration are often characterized from aesthetic or biological viewpoints. However, there are many more benefits that are difficult to quantify. The i-Tree suite of software tools provide a method for a more comprehensive assessment of the ecosystem service benefits of restoration projects involving trees and forests.

i-Tree is a state-of-the-art, free, peer-reviewed software suite developed by the USDA Forest Service to provide urban and community forestry analysis and benefits assessment. Within the suite of i-Tree tools, i-Tree Eco is specifically designed to combine field data collected within an area of interest with local air pollution and weather data to quantify forest structure, environmental effects, and values to communities. The resulting analysis includes estimates of air pollution removal, carbon sequestration and storage, species diversity, canopy rainfall interception, public health benefits, pest risk and economic value. This information can be used for planning, monitoring, and justifying a restoration project. An i-Tree Eco assessment could also be used to account for changes in ecosystem services following restoration or to estimate the benefits of a proposed project. This talk will explore the potential of i-Tree software to assess the benefits of ecosystem restoration projects.

Jason Henning is an urban research forester with the US Forest Service and The Davey Tree Expert Company. He has a Ph.D. in Forestry and an M.S. in Statistics from Virginia Tech. He spent six years at the University of Tennessee teaching courses in forest and natural resource inventory, and researching methods for quantifying and modeling forest resources. Recently, he returned to his home state of Pennsylvania and his current position at the US Forest Service Philadelphia Urban Field Station. His current work focuses on applied science and communication of scientific topics to support the informed management of urban forests. He is also responsible for support and outreach involving the i-Tree Suite of tools. The i-Tree tools were developed by the US Forest Service and The Davey Institute to facilitate assessment of urban forest ecosystem services across a diversity of scales and user groups.

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Strawberry Run Stream Restoration: The Good, Bad, and Downright Ugly

Claudia Hamblin-Katnik, Ph.D., City of Alexandria, VA

The Strawberry Run stream restoration was a partnership between a developer of single family homes and the City of Alexandria. The restoration was done in a public park in conjunction with redevelopment on adjacent lands and served as the fulfillment of the water quality requirements for the development. The stream exhibited characteristics typical of degraded urban streams – with the channel having vertical sides of over eight feet in height and a receding bed. One of the outfalls into the stream had eroded a 12-foot deep channel from the outfall to the stream; very dangerous as it was next to the footpath but overgrown with invasive vines. The City desired to save the pedestrian bridge over the stream so it was removed, the touch points to the stream were artfully stabilized with imbricated boulders and then the bridge was replaced (and repaired). Due to previous development within the Resource Protection Area (RPA) some portions of each new home were allowed to encroach into the RPA. A condition of approval was that no decks were to be allowed and all improvements within the RPA would need to be pervious. Very creative pervious stairs and patios now populate the RPA. Other low impact development techniques employed were pervious concrete driveways and the trail through the RPA to and from the bridge is Flexipave, a pervious material.

While most of this project was an ecological success there were elements of failure also. One of the cross vanes filled in with cobbles during the first storm indicating that there was insufficient fall between the structures for efficient sediment transport. The stream may be adjusting to the flows with different meanders than planned, but the floodplain is wide and connected so there is no danger to adjacent properties. One of the banks stabilized to save a large tree thwarts every natural stream design effort to maintain the root structure. Invasive species removal was part of the original scope but follow-through has been sporadic so this continues to remain a problem. Regardless, the City hails this restoration as an overall success as do the neighbors and neighborhood.

Claudia Hamblin-Katnik has a strong history of environmental work. She has been employed as an environmental planner in Guam, for the City of Colorado Springs, Fairfax County and now the City of Alexandria. She obtained a Ph.D. from George Mason University in Environmental Science and Public Policy (ESPP) with a specialization in aquatic toxicology. After a year in the Netherlands she returned to teach graduate courses in Environmental Policy and Administration, Watershed Management, and Ecology while she was the Assistant Director of Graduate Programs in ESPP. Claudia has also experienced the non-profit world as the Director of a watershed association and then a conservation alliance group while living in Hawaii. Presently she is the Watershed Program Administrator for the City of Alexandria administering programs and activities to fulfill the requirements of the Chesapeake Bay Act. She is particularly interested in stream restorations within urban corridors and the community engagement/education process necessary to facilitate their success.

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Establishing Goals and Success Criteria in Urban Stream Restoration

Joe Berg, Biohabitats, Inc.

Stream restoration in urban watersheds is an area of intense interest by funders, restoration practitioners, researchers, and resource/regulatory personnel. The urban stream network has been simplified by loss of many headwater streams. In addition, urban watersheds have a dramatically changed watershed hydrology, including reduction of watershed rainwater storage and infiltration, increased peak discharge, and reduced stream flow duration. The increased volume of urban stormwater runoff generally results in stream channel enlargement through bed and bank erosion.

The best standard approach for stream restoration involves the construction of a bankfull conveyance channel, sized to transport water and associated materials (sediments, nutrients and pollutants) associated with runoff from a range of storms up to the ~1.5 year return interval storm. This restoration approach results in a stable, protected reach which conveys water downstream to an unprotected reach. Often, the primary goal of this stream restoration approach is to 'fix' stream channel erosion and create a stable channel bed and banks. Most often, these stream restoration projects are presented as having restoration goals including stable bed and banks, reduction of erosion, water quality improvements, aquatic habitat improvements, and more. Many researchers, drawn to the field of stream restoration by the billions of dollars invested, have criticized stream restoration as an unproven solution based on inflated goal statements, an absence of goals, and/or an absence of documentation. Other researchers have documented relationships between stream restoration elements (e.g., floodplain connection, residence time, presence of carbon, etc.) and improved stream functional performance for a variety of elements, including nutrient reduction.

This presentation will describe and document an approach to stream restoration which replicates the elements of material processing headwater streams documented as so important to stream functional performance. This approach is designed to modify the urban hydrologic regime through increasing storage along the flowpath, increasing the surface area to volume ratio of the channel reach, increase runoff water exposure to organic carbon, increase hyporrheic flow, etc.. A method for evaluating restoration benefits introduced and summarized, and representative before and after photographs and monitoring results of several urban stream restoration projects will be presented.

Joe Berg is an ecosystems ecologist with more than 25 years' experience in the assessment and analysis of natural resources; development, preparation, and implementation of restoration plans; and the range of studies, documentation and permitting experience required. The focus of his efforts have been the restoration of stream, wetland, and floodplain functions as a means to deliver ecosystem services to society, increase natural capital, and integrate local community needs with an appreciation of natural resource values.

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Facing the Storms: Ecological Mitigation Techniques

Eugene T. McColligan, PWS, Environmental Connection, LLC
William E. Young, PWS, Young Environmental, LLC

Beaches, dunes, wetlands, and waterways along the mid-Atlantic coast were significantly impacted by Hurricane Sandy, as were the plant and animal communities that rely on them for habitat. These natural resources are the mid- Atlantic region's first line of defense against future storms and underpin the coastal area's heavily impacted tourism and fisheries industries. Integrating the restoration and conservation of the area's beaches, dunes and wetlands, into recovery efforts at multiple scales will limit longer-term economic losses and avoid additional environmental impacts. As communities initiate recovery planning efforts, they would be wise to implement planning approaches that emphasize resilience will reduce costs of future disasters, build in adaptation to sea level rise, and promote other sustainability goals.

Gene McColligan is a respected environmental scientist with 36 years of progressively responsible positions in the public and private sector, including FEMA and the New Jersey Departments of Environmental Protection (NJDEP) and Transportation (NJDOT). He has a solid technical knowledge of the issues involving riparian buffers, stormwater management, and ecological concerns, including wetlands, vegetation, habitat assessment, and threatened and endangered species. He holds a Bachelor of Science Degree in Environmental Science/Human Ecology (Ramapo College, 1976) and a Masters of Arts Degree in Environmental Management (Montclair State University, 1983). He has instructed field biology classes at William Paterson University and has lectured at the University of Pennsylvania, Monmouth University, and Rider University. He also instructed a variety of short courses on ecological and regulatory issues at Cook College (Rutgers University).

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Bill Young is a recognized leader in the environmental field with more than 25 years of experience as a project manager, designer, and wetland specialist. He has experience in construction, design, and planning in both the public and private sector. His expertise includes habitat restoration on disturbed lands, wetlands monitoring and construction, botanical inventory, wildlife assessment, streambank restoration, and erosion and sediment control. Bill also performs site assessment and hydrological studies for site selection on wetland mitigation and master planning. He is an adjunct professor at the University of Pennsylvania, School of Design.

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Effects of Integrated Stormwater Management and Stream Engineering on Nitrogen Uptake and Denitrification in Streams

Tamara A. Newcomer, University of Maryland
Sujay S. Kaushal, Paul M. Mayer, Peter M. Groffman, Melissa M. Grese

Restoring urban infrastructure and managing the N cycle represent major challenges for biogeochemistry and society. We investigated how stormwater best management practices (BMPs) integrated into urban stream networks can influence removal of N pollution. We hypothesized that stormwater BMPs are greater "hot spots" for N removal through denitrification than connected floodplain areas because they have ample organic carbon, low dissolved oxygen levels, and high residence time. We tested this hypothesis by examining N cycling in 2 urban stream networks with stormwater BMPs and a forested reference watershed with a pond at the Baltimore Long-Term Ecological Research (LTER) site. At all 3 sites, we used a combination of: (1) 250 stream reach scale mass balances of N conducted monthly for 2 years across streamflow, (2) 6 in-stream tracer injection studies to measure seasonal nitrate uptake and groundwater inputs, and (3) 72 ^{15}N *in situ* push-pull tracer experiments to measure seasonal N removal via denitrification in stormwater BMPs and floodplain features. The stormwater BMPs at Spring Branch were inline wetlands installed below a storm drain outfall and at Gwynns Run were a wetland and wet pond configured in an oxbow to receive water during high flow events.

As hypothesized, total dissolved nitrogen (TDN) concentrations decreased consistently across sampling dates as water traveled through stormwater BMPs; TDN concentrations decreased from 3.13 ± 0.67 mg/L to 1.87 ± 0.23 mg/L (mean ± SE) at Spring Branch and from 3.15 ± 0.15 mg/L to 1.47 ± 0.22 mg/L at Gwynns Run. Contrary to our hypothesis, mean TDN retention at Spring Branch was higher in a stream reach with connected floodplains, 2.01 ± 0.77 kg/day (mean ± SE), than in the stormwater BMPs, 0.053 ± 0.025 kg/day. Similarly, at Gwynns Run, mean TDN retention (and export) were 3 orders of magnitude higher in the stream reaches, 2.00 ± 1.6 kg/day (mean ± SE), than in the stormwater BMPs, 0.005 ± 0.597 kg/day. Mass balances and in-stream tracer injections produced consistent results for TDN uptake ($\mu g\ N \cdot m^{-2} \cdot s^{-1}$) and both methods demonstrated that groundwater contributed 30-70% of water to the urban streams. Surprisingly, mean ^{15}N *in situ* denitrification rates were significantly higher in connected floodplain areas of the streams, 133.8 ± 32.4 $\mu g\ N \cdot kg\ soil^{-1} \cdot day^{-1}$ (mean ± SE), than in stormwater BMPs or the reference pond, 79.2 ± 22.1 $\mu g\ N \cdot kg\ soil^{-1} \cdot day^{-1}$. Our forest reference site had lower rates of mass uptake, export, and denitrification than urban sites—likely due to low N concentrations.

We learned that floodplains can be important "hot spots" for N removal at a watershed and stream network scale; this is likely because these areas receive perennial flow through the groundwater-surface water interface during baseflow and storm events while the BMPs receive intermittent flow associated only with storm events. Future studies of N removal aimed at evaluating effectiveness of engineered features should consider the importance of groundwater-surface water interactions at the watershed scale.

Tamara Newcomer is a Ph.D. Candidate at University of Maryland, College Park in the Marine Estuarine Environmental Science Department. Her research interests include ecosystem restoration, water resources, urban ecosystems, environmental education, science communication, and public outreach. For her Doctoral Dissertation, she is studying how stream restoration and stormwater management influence transport and transformation of nitrogen pollution in stream networks in the Chesapeake Bay watershed. In addition, she has examined the influence of natural and novel organic carbon sources on denitrification in restored streams.

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