Socioecological revitalization of an urban watershed

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Older, economically troubled urban neighborhoods present multiple challenges to environmental quality. Here, we present results from an initiative in Baltimore, Maryland, where water-quality improvements were rooted in a socioecological framework that highlighted the interactions between biogeophysical dynamics and social actors and institutions. This framework led to implementation of best management practices followed by assessment of changes in human perception, behavior, and education programs. Results suggest that such an initiative can improve both water quality (eg reductions in nitrogen and phosphorus runoff) and quality of life (eg increased involvement in outdoor recreation by residents and improvements in student environmental literacy and performance) in urban neighborhoods. However, proposed solutions to the water-quality problems in such neighborhoods have (1) typically emphasized the need for stormwater facilities that are difficult to build and maintain and (2) comprehensively addressed neither the issues related to aging infrastructure and hydrologic complexity nor the benefits derived from linkages between resident perception of environmental improvements and behavior and water-quality outcomes.

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Interest in the socioecology (study of the interaction of biogeophysical dynamics with associated social actors and institutions in human-dominated ecosystems; Redman *et al*. 2004) of urban watersheds has increased over recent decades, as a result of four factors. First, the increasing area of urban and suburban land cover (Brown *et al*. 2005), and its effects on hydrology and pollutant fluxes (Paul and Meyer 2001), have raised concerns about associated impacts on adjacent water bodies (Paerl *et al*. 2006). Second, the vast majority of human–environment interactions now occur in cities, which makes urban areas fertile ground for exploring linkages between environmental quality, human well-being, and sustainability (Liu *et al*. 2007; Ostrom 2009; Alberti 2010). These socioecological interests are particularly relevant in cities undergoing dynamic cycles of development, decay, and redevelopment (Pickett *et al*. 2004). Third, governmental policy, regulation, and funding stemming from the US Clean Water Act have required municipal governments to develop innovative, effective, and inexpensive approaches to improve stormwater management. Stormwater-associated infrastructure effectively reduces flooding risk in cities, but it also creates problems with receiving water quality and aquatic ecosystem integrity (Walsh *et al*. 2005). Finally, economically troubled communities have been taking action in recent decades through the encouragement, education, and resources shared by non-profit organizations that facilitate local, hands-on restoration projects.

Small-scale community-driven projects have produced anecdotal evidence that there are critical links between ecological and socioecological revitalization. Efforts such as vacant lot conversion to parks, the planting of street trees, stream cleanups, and community gardens appear to create social cohesion, increase access to municipal services, and create positive feedbacks for ecological, physical, social, and economic improvements. Understanding the mechanistic nature of these links could have important implications for urban management and sustainability. This understanding should include analysis of which types of ecological interventions produce the greatest social impacts, and articulation of the mechanistic links between environmental change and human perception of

In a nutshell:

- Dense, underserved urban neighborhoods with aging sanitary sewer and stormwater infrastructure are "hotspots" (ie areas of special concern) for water pollution
- These neighborhoods process stormwater and associated contaminants in complex and unexpected ways
- Solving water-quality problems in these neighborhoods requires "retrofits" of stormwater infrastructure that can be difficult to design, implement, and maintain
- Implementation of best management practices to address water-quality problems while considering neighborhood social dynamics, resident values and goals, and institutions can improve water quality, increase residents' satisfaction with the environment, foster participation in outdoor activities, and enhance environmental education among students

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that change, knowledge, and behavior (McGrath and Pickett 2011).

Here, we describe the Watershed 263 (WS263) project, carried out in the greater Baltimore, Maryland, area, which attempted to integrate the social and environmental dimensions of urban watersheds. The project focused on revitalizing urban communities using interventions that improve both water quality and quality of life at lower costs than traditional engineering practices for stormwater management structures, which are often hidden underground and provide no other benefit to local residents. The original idea for the WS263 project came from the Baltimore City Department of Public Works (DPW) as a way to meet the requirements of the National Pollutant Discharge Elimination System (NPDES), a program that aims to control water pollution by regulating point and non-point sources that discharge pollutants into US waters.

Like many older cities, Baltimore has experienced a marked population decline, social change, and economic challenges in recent decades (Bontje 2004). The DPW recognized that in urban watersheds in Baltimore, both natural and human components of the ecosystem needed to be improved. They had observed the work of the Parks & People Foundation (hereafter Parks & People), an organization that has recruited Baltimore residents to participate in vacant lot conversion to parks and gardens and tree planting projects for several years. Parks & People is a non-profit organization that creates and supports educational, recreational, and environmental programs and partnerships that work to unite citizens, academics, and government agencies to improve the open spaces of Baltimore. City officials wondered whether the Parks & People community-based "greening" program could be strategically expanded to improve water quality as well as quality of life over large areas of the city. Greening programs use vegetation and soil to manage rainwater and provide other environmental amenities related to stormwater management, flood mitigation, air quality, and aesthetics.

To test their ideas about linkages between social and ecological revitalization of urban watersheds, DPW and Parks & People developed collaborations with the US Department of Agriculture (USDA) Forest Service Urban Forestry Work Group and the National Science Foundation funded an urban Long Term Ecological Research project, the Baltimore Ecosystem Study (BES). The USDA Forest Service (USFS) has supported an urban forest research unit since 1978, with offices in Syracuse, New York, and in Baltimore, where a group of scientists has worked as part of the BES since 1998. The BES conducts research on metropolitan Baltimore as an ecological system, integrating biological, physical, and social sciences (Pickett *et al.* 2011). Together, DPW, Parks & People, the USFS, and BES set out to: (1) model and measure the result of best management practices (BMPs) on water quality (these practices were designed to reduce storm flows and pollutant loads); (2) identify suitable indicators for determining existing environmental quality and quality of life; (3) help citizens understand how to apply knowledge about ecosystem processes related to soil, plant, and water dynamics to help revitalize their communities; (4) determine whether a greening strategy affects the community and helps residents to relate to water-quality issues; and (5) develop educational activities associated with greening of schools. The organizations mentioned above then used mapping and analysis of previous community improvement projects and city-owned vacant lots, as well as knowledge of the capacity and willingness of the community to engage in greening activities, to identify WS263 as one of the most appropriate pilot watersheds for this project, with the potential to transfer results to other urban watersheds. In this paper, we describe the greening "interventions" that were implemented in WS263; present biophysical and social responses to these interventions; describe education and outreach activities associated with the project; and summarize what we have learned about the social, economic, and ecological aspects of urban watershed revitalization.

■ Study site and greening interventions

WS263 is one of Baltimore's 355 major storm sewer watersheds (376 hectares [ha]) and drains to Baltimore Harbor and the Chesapeake Bay (Figure 1). The watershed is drained by 21 km of storm drains of over 0.9-m diameter that converge into one 7.5-m diameter outfall. Two 15-ha subwatersheds (Lanvale Street and Baltimore Street) with buried, piped streams within WS263 were used to measure stormwater runoff in the context of management efforts. Greening interventions, stormwater facilities, and street sweeping were more aggressively implemented in the Baltimore Street subwatershed, as described below.

WS263 covers all or parts of 11 neighborhoods. In 2010, the watershed was home to 27 870 people, a decline from 31 644 in 2000 and 40 518 in 1990 (US Census Bureau 2010). Populations in the Baltimore Street and Lanvale Street subwatersheds were 1399 and 973 individuals, respectively. The area included in the WS263 project is entirely urbanized; over 60% of the area in the watershed is impervious surface with residential, commercial, industrial, institutional, and open space uses as well as 2000 vacant or abandoned residential properties, approximately half of which are city-owned. Public open space, including schools and parks, accounts for approximately 30% of the watershed land area and is unevenly distributed. WS263 has 19% grass cover and only 5.9% tree canopy cover, as compared to 27% tree canopy cover city-wide.

A variety of BMPs were implemented beginning in 2004, including efforts by Parks & People and DPW to plant 800 street trees, renovate over 200 vacant lots by planting grass and street trees, remove ~10 ha of asphalt from schoolyards, and install 12 advanced bio-infiltration

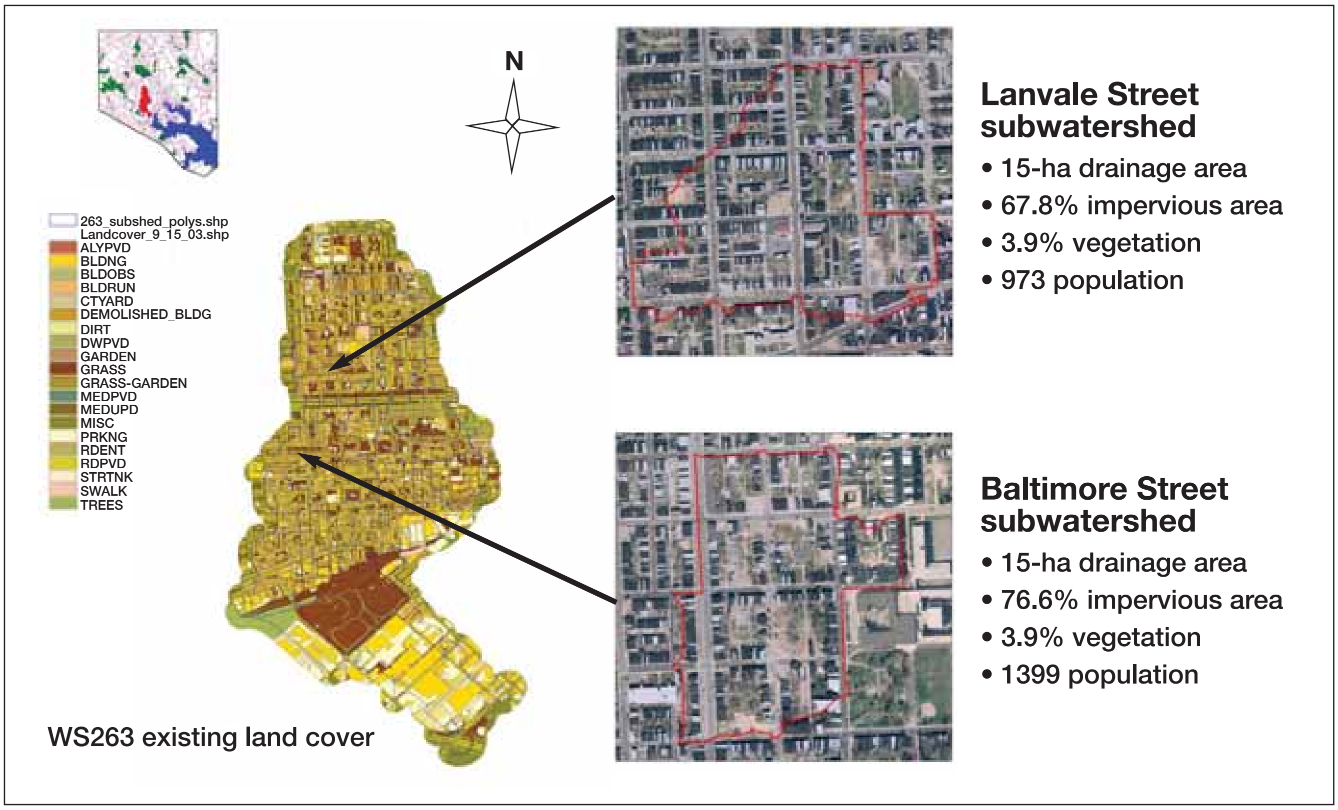

Figure 1. *Study design for the WS263 project. Two 15-ha subwatersheds (Lanvale Street and Baltimore Street) were sampled; these were nested within the larger 376-ha WS263 storm-drain watershed (or sewershed). Greening interventions were more aggressively implemented in the Baltimore Street subwatershed. The location of WS263 relative to Baltimore City is shown at top left (red area). Land cover for the overall WS263 drainage area is shown lower left (courtesy KCI Technologies Inc); also shown are the locations of the Lanvale Street and Baltimore Street subwatersheds. Aerial views and catchment data for the subwatersheds appear on the right.*

(vegetated areas created to foster infiltration of stormwater into soil) units (Figure 2). Greening projects and street sweeping (5 days per week) were concentrated in the Baltimore Street subwatershed (with a goal of approximately 25% of impervious area treated); no such projects were carried out in the Lanvale Street subwatershed.

The engineered bio-infiltration projects were a primary focus for DPW, as there is great interest in the stormwater control community in the potential of retrofits for remediating stormwater in older, highly developed neighborhoods. DPW collaborated with several other organizations (EA Engineering, Science, and Technology, the Center for Watershed Protection, Bon Secours Foundation, Parks & People) to have WS263 serve as a demonstration site for projects throughout the region. The six bio-infiltration projects constructed in WS263 involved substantial design and implementation costs (Figure 2), which provided insights into the challenges associated with retrofits in urban neighborhoods. These challenges included lack of acceptance of native plants or other design elements by local communities, the difficulties associated with access to private property versus access to public rights of way, effects on traffic and parking, construction equipment access into busy and confined urban spaces, interference with above- and belowground utilities, and vandalism. The dominant lesson learned was that structural stormwater improvements in dense urban areas are always going to be complex and expensive to implement. However, there are currently few alternatives to these approaches unless large-scale urban redevelopment or infrastructure improvement projects are undertaken. An emerging supplemental approach is to encourage residents to undertake small-scale projects in their yards and in community-managed open spaces. Community engagement, which can be facilitated by municipal policy and procedural changes, may be particularly useful for addressing maintenance and vandalism problems.

An additional insight from the bio-infiltration projects was that basic maintenance is a considerable challenge that should not be overlooked. We found that the projects accumulated a large amount of litter as well as being a new place for deliberate dumping of trash, which can substantially reduce the effectiveness of these facilities if not cleaned out often. As designed, many of the bio-infiltration projects are hard to access and service for maintenance. An overall practical conclusion is that many small projects are much more difficult to maintain than are a few large ones (eg stormwater ponds) for a given treatment runoff area. In WS263, maintenance represents a major budgetary investment to the city because maintenance activities are an ongoing cost and do not generate credits for local efforts to achieve water-quality goals in the Chesapeake Bay watershed.

A final consideration is whether stormwater management efforts provide a particularly promising ecological intervention and/or catalyst for socioeconomic change in underserved neighborhoods. While stormwater management can be expensive and complex, these are highly visible projects that attract community attention, with successful implementation requiring considerable interaction with neighborhood residents. An ongoing question is which types of ecological interventions and revitalization activities are most effective and efficient for both water-quality goals and for catalyzing socioeconomic revitalization.

Figure 2. *Examples of advanced bio-infiltration projects established in the Baltimore Street subwatershed of WS263. Photos show (a) curb extension with three underground tree boxes and (b) bioretention BMP installations. Total costs for the curb extension installation were over \$79 000, including over \$16 000 for design. Total costs for the bioretention installation were over \$170 000 and included over \$38 000 for design.*

Hydrologic responses

Automatic water samplers were installed in storm drains at the outflows of the Lanvale Street and Baltimore Street subwatersheds to quantify watershed hydrologic response to rainfall events. One of the most reliable hydrologic responses to urbanization is an increase in "flashiness" associated with increases in impervious surface area, whereby streamflow rapidly increases in response to precipitation (Walsh *et al.* 2005). The percentage of precipitation that leaves the watershed as runoff, rather than through evapotranspiration or soil storage, also increases with urbanization. For example, in a forested watershed, 40% of annual precipitation might be exported as runoff, whereas 70% or 80% might be exported as runoff in a watershed where 70% of surfaces are impervious, as is the case in WS263 (Carey *et al.* 2010).

Surprisingly, runoff patterns in WS263 were much more complex and variable than expected (Figure 3). For example, for seven rainfall events ranging from very small (2.3 mm) to large (55 mm), runoff export varied from 6% to 91% of precipitation in the two subwatersheds. While the overall mean runoff in the Baltimore Street subwatershed (62%) was very similar to what would be expected for an urban catchment where 70% of the surface is impervious, overall mean runoff from the Lanvale Street subwatershed (18%) was much lower than anticipated, suggesting that conceptions of urban watersheds as relatively simple systems that rapidly convert precipitation into runoff are inaccurate. Rather, we need to recognize that urban watersheds contain a complex mosaic of surface features and soil characteristics, as well as a dense three-dimensional (3D) labyrinth of urban water infrastructure for water supply and sanitary sewer and storm drainage that interacts with natural groundwater and streams to complicate hydrologic dynamics (Figure 4; Kaushal and Belt 2012). Furthermore, degraded urban watersheds with vacant and collapsed housing and aging infrastructure create an urban "karst" topography, featuring complex flowpaths and connections between surface and groundwater, and with highly variable water residence times (Kaushal and Belt 2012). These complications are apparent when stormwater moves into sanitary sewer pipes, when sewage leaks into stormwater pipes, or when water supply pipes leak, contributing to stormwater runoff. The human population density of the Lanvale Street subwatershed is lower than that of the Baltimore Street subwatershed, possibly reflecting higher rates of housing abandonment in this subwatershed. Abandonment likely increases infrastructure degradation and contributes to hydrologic complexity.

These results suggest that there is a strong need for more sophisticated and accurate mapping and assessment

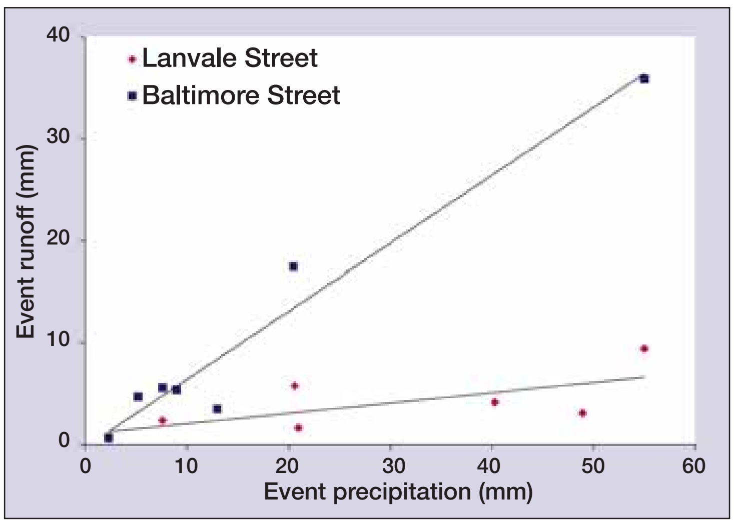

Figure 3. *Runoff versus precipitation for seven precipitation events in the Lanvale Street (r = 0.69, P < 0.08) and Baltimore Street (r = 0.97, P < 0.0002) subwatersheds of WS263 between May and August, 2005. Water yield (runoff/precipitation) was higher (P < 0.0012) in the Baltimore Street subwatershed (62% versus 18%).*

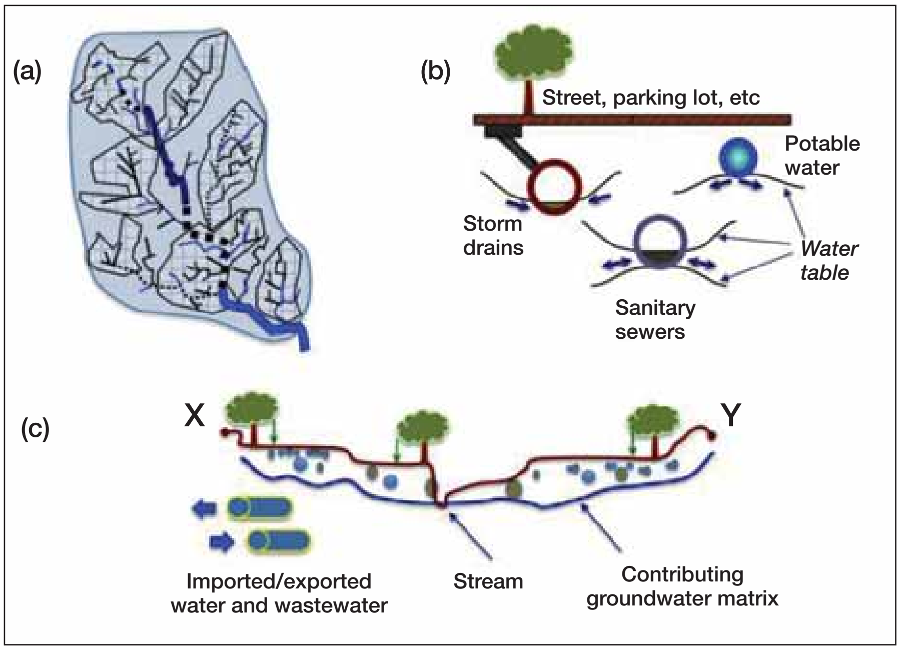

Figure 4. *(a) Conceptual diagram of an urban watershed, showing how artificial drainage networks add drainage areas that are directly connected to streams. The complexity of water supply, sanitary sewer, and storm drainage infrastructure in the subsurface is shown schematically in (b), and in (c) interactions between this infrastructure and natural streams and groundwater are shown to exert an impact across the entire watershed (ie from ridgeline X to Y). In (a), thick dashed lines indicate buried streams; solid lines indicate surface streams; hatched areas and lines depict storm-drain networks that effectively expand the drainage network; blue unhatched areas depict uplands where rainfall infiltrates naturally into groundwater that may not reach a stream. In (c), blue and gray circles represent a wide assortment of urban water infrastructure that potentially impacts shallow groundwater across the watershed. The imported/exported water and wastewater pipes in the lower-left inset represent the large part of the water budget that can enter and leave a watershed without regard to the surface-water drainage boundaries. Arrows represent the ability of vegetation to influence runoff volume and quality as it drains to streets (flat parts of the brown surface line), storm drains, and streams.*

of impervious surfaces, hydrologic flowpaths, water infrastructure connectivity, and historical context in urban watersheds. Managers need to know where water is flowing, how long it remains in different components of the watershed, and what physical, chemical, and biological processes affect the water that passes through these different components. Time must also be considered as an important fourth dimension in this 3D system. The age and condition of infrastructure is a critical controller of hydrologic dynamics in urban watersheds, as these will play major roles in long-term above- and belowground fluxes of pollutants and, in consequence, will influence the effectiveness of management facilities and efforts (Kaushal and Belt 2012).

Results and insights from the WS263 project increase emerging interest in the role of groundwater in urban watersheds and in how we manage water-borne pollutant fluxes (Kaushal *et al.* 2011; Kaushal and Belt 2012). While the focus on impervious surface area and runoff has dominated analysis and management of urban watersheds, it is important to recognize that a considerable amount of precipitation passes through groundwater, rather than moving directly into streams via surface runoff in these watersheds (Ryan *et al.* 2010) and subsequently plays a key role for infiltration-based BMPs (Clark and Pitt 2007). Management must start to address the underground aspects of stormwater, yet almost nothing is known about the flowpaths and residence times of and biogeochemical transformations in urban groundwater.

Water quality

Long-term monitoring of multiple forested, suburban, and urban watersheds in the Baltimore region by BES provides context for evaluating the nature and extent of water-quality impairment in WS263. From 2004 to 2009, USFS and DPW staff conducted weekly or biweekly "grab sampling" – a single sample taken at a specific time – of baseflow as well as limited stormwater sampling with automated samplers at the outlets of WS263's Baltimore Street and Lanvale Street subwatersheds. Samples were analyzed for total nitrogen (N) and phosphorus (P) by persulfate digestion followed by colorimetric analysis of nitrate and phosphate. The grab samples are comparable with ongoing grab sampling of a range of other BES watersheds (Groffman *et al.* 2004; Kaushal *et al.* 2008; Shields *et al.* 2008).

Results from 6 years of sampling and analysis show that the WS263 subwatersheds had notably high concentrations of total N and P (Figure 5). While it is not surprising that water draining from WS263 has higher concentrations of N and P than the BES forested reference watershed, the comparisons with other suburban and urban BES watersheds were more notable. For example, Gwynns Run is considered to be one of the most highly sewage-contaminated streams in the city, yet it had much lower total N and P concentrations than WS263. These results suggest that urban neighborhoods with vacant housing and aging infrastructure are potential "hotspots", or areas of special concern for nutrient export to receiving waters.

One noteworthy result from water-quality monitoring in WS263 was a significant improvement in the quality of the water draining the Baltimore Street subwatershed, which was the focus of BMP implementation. Concentrations of total N ($r = -0.65$, $P < 0.0001$) and total P ($r = -0.25$, $P < 0.0007$) decreased by more than

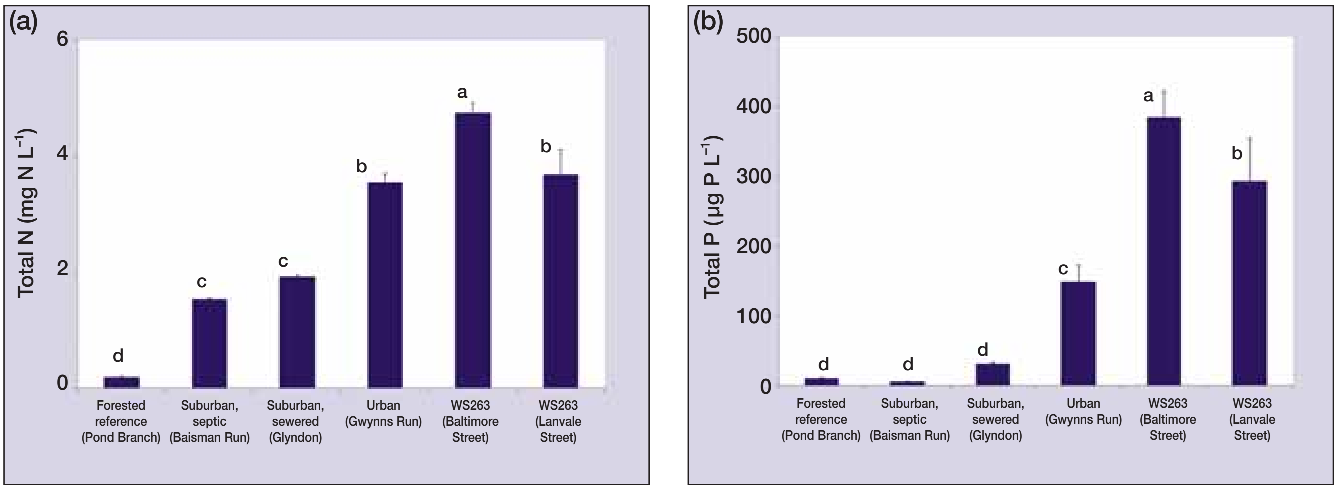

Figure 5. *(a) Mean total N and (b) mean total P concentrations based on approximately weekly "grab samples" taken from March 2004 to May 2009 in forested reference, suburban (served by septic systems), suburban (served by sanitary sewers), urban, and WS263 subwatersheds in the Baltimore metropolitan area. Values (mean ± standard error) with different letters are significantly different at* P *< 0.05 in a one-way analysis of variance, with a Duncan's multiple range test to determine specific site differences.*

50% in the Baltimore Street subwatershed, but there was no significant change in the concentrations of these constituents in the Lanvale Street subwatershed ($r = -0.07$, $P < 0.38$ for total N; $r = 0.01$, $P < 0.88$ for total P). If the changes in concentration data are coupled with water flow, calculated from precipitation and measured runoff ratios, the changes between 2004 and 2009 represent declines of more than 3.0 g N m^{-2} yr^{-1} and 30 mg P m^{-2} yr^{-1} in watershed export.

These observed decreases in N and P baseflow export from the Baltimore Street subwatershed are large relative to regional atmospheric deposition estimates (~1.0 g N m^{-2} yr^{-1}; Groffman *et al.* 2004) and total watershed export in baseflow and stormflow from other catchments in the area (which range from 0.5 to 1.5 g N m^{-2} yr^{-1} [Kaushal *et al.* 2008] and 2.8 to 83.7 mg P m^{-2} yr^{-1} [Duan *et al.* 2012]). They are also large relative to expected declines for the BMPs that were implemented in the watershed. The only N and P source large enough to account for the reductions is the flow of sewage through sanitary wastewater infrastructure, but this source was not targeted by any of the BMPs that were implemented (Kaushal *et al.* 2011).

■ Social responses

Assessments of community response to efforts to improve water quality were an important part of the WS263 project. Such assessments included measuring changes in levels of recreational activity, watershed knowledge, participation in watershed improvement activities, perceptions about environmental quality, overall quality of life and satisfaction, social capital (the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions), and neighborhood desirability. A household telephone survey that was a key component of the BES long-term monitoring program was administered in 1999, 2000, 2003, and 2006. The completed sampling size was ~1500 in 2003 and ~3300 in 2006. Residents living within the boundaries of WS263 were more intensively sampled in 2003 (sample size = 86) and 2006 (sample size = 107). The overall response rate for the survey was about 36% in both 2003 and 2006. Comparisons of the sociodemographic characteristics of survey respondents and US Census estimates for the general population of the surveyed area indicate that those sampled were generally representative of the overall population of the area in terms of age, gender, race, income, and education. The estimated sampling error for results was ± 5% in 2003 and ± 3% in 2006. Additional details about the 2003 survey can be found in Vemuri *et al.* (2009).

The structure of the survey allows for comparative analysis of changes over time in WS263 with all of Baltimore City (hereafter referred to as "City") as well as with the entire Baltimore metropolitan region ("region"). The survey showed major changes in people's behavior in WS263 that may be related to efforts to improve water quality in the watershed. Of particular interest was an increase in outdoor recreation activities in WS263 relative to the City and the region (Figure 6). Though these results are preliminary, the differences between WS263 and the City and the region are relatively large and generally exceed the estimated error in our sampling. We hypothesize that the focus on environmental restoration associated with the WS263 project, as well as coincident changes in City policy and practice for residential sanitary trash pickup in WS263, increased awareness and neighborhood suitability for outdoor recreation. We also observed marked improvement in "neighborhood satisfaction" in WS263 relative to the City and region (ie the percentage of people who were "satisfied" with their neighborhood increased more in WS263 than in the City or region between 2003 and 2006). There was also a notable decline in residents "willingness to move out" of

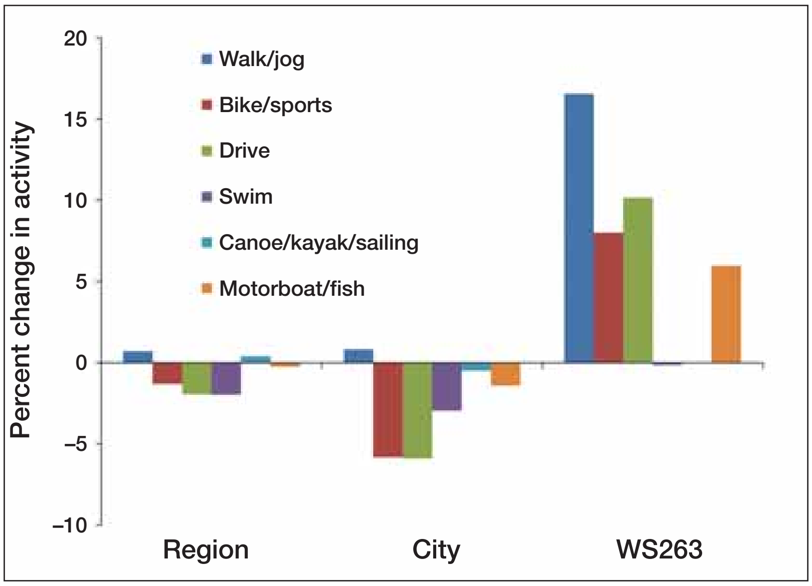

Figure 6. *Changes in participation in outdoor recreation in WS263, Baltimore City, and the Baltimore metropolitan area region, 2003–2006.*

WS263 relative to the City and region. These results suggest that there is a correlation between ecological and socioeconomic revitalization and that improvements in environmental quality can lead to changes in human activities that promote health and social cohesion. Interestingly, environmental knowledge did not appear to be critical to these linkages and improvements; awareness of the fact that residents "live in a watershed" actually declined in WS263 between 2003 and 2006, while increasing elsewhere in the City and region.

Education initiatives

The research in WS263 was coupled to an extensive program of environmental and ecological education (Panel 1) and provided an opportunity to examine potential synergies between education and socioecological revitalization efforts. A major question for future research is whether those apparent synergies were catalyzed by the links to K–12 education programs. Overall, more than 1.6 ha of asphalt were removed and replaced with trees, gardens, and lawns at five schools located within WS263. In one example, approximately 0.56 ha of asphalt was removed from Franklin Square Elementary/Middle School and replaced with green spaces, followed by the construction of a student-designed "reading circle" (Panel 1). This initiative has been very favorably received by the residents of WS263. To date, over 10 ha of asphalt have been removed and re-greened at 19 schools across the region as a whole.

Students at Franklin Square Elementary/Middle School showed particularly marked improvement in environmental science and literacy assessments following the conversion of asphalted areas to green spaces, suggesting that this change to their schoolyard may have enhanced the students' environmental awareness and understanding. While it appears logical that revitalization efforts targeted at schoolyards, together with education programs directly related to highly visible infrastructure improvements in neighborhoods, should have pronounced effects on human environmental perceptions, knowledge, and behavior, further study will be required to determine whether formal and informal education activities act as a primary factor driving linkages between ecological and socioeconomic revitalization in underserved neighborhoods.

Conclusions

Experiences from the WS263 project suggest that there is an important relationship between the ecological and social revitalization of urban watersheds. Revitalization efforts can improve both water quality and the quality of life in urban neighborhoods. Water quality can benefit from social engagement if interaction with the community during planning, implementation, and maintenance improves the long-term effectiveness of BMPs and if behavior change results in "cleaner" neighborhoods. Likewise for quality of life, we see clear evidence of a disproportionate increase in outdoor recreational activities and neighborhood satisfaction in WS263 as compared with elsewhere in metropolitan Baltimore that may be related to both actual and perceived environmental improvements. Linkages between BMP implementation and education may also have improved student environmental literacy. These results suggest that environmental restoration has unambiguous potential for contributing to the revitalization of underserved urban neighborhoods. Moreover, environmentally based revitalization is more "bottom up" and "community based" than is more traditional urban renewal-, gentrification-, or immigration-based approaches to neighborhood improvement.

Many challenges remain, however. Solving water-quality problems in older, dense urban neighborhoods requires an emphasis on retrofits that can be expensive to implement and maintain. Planning and implementation is further complicated by the realization that the hydrology of old urban neighborhoods is much more complex than previously thought, with major uncertainties about flowpaths, residence time of water in different compartments, and transformations of stormwater and associated contaminants. An additional problem arises from aging and failing infrastructure, which contributes to the hydrologic complexity. Still, our results suggest that BMP implementation that is solidly rooted in a true socioecological framework and that includes community education and awareness campaigns and support for community action can be an effective vehicle for bringing substantial improvements to both water quality and the quality of life in urban neighborhoods.

Panel 1. Education programs in WS263

Education programs active in WS263 between 2004 and 2009 included a Math and Science Partnership (MSP) project, KidsGrow, Project BLUE (Baltimore Lessons in Urban Ecosystems), and Schoolyard Habitat and Education professional development.

Three teachers from two WS263 schools were involved in the MSP project, which focused on environmental science literacy using carbon, water, and biodiversity as key themes and included a mix of teacher professional development programs on those themes as well as extensive education research.

KidsGrow was a Parks & People-supported after-school ecology education program for ~75 students in grades 2–5 of the Baltimore City Public Schools. The program used the "My City's an Ecosystem" curriculum developed by BES educators, interns, and fellows to teach students the foundations of urban ecology. The program was highly "place-based", with a major site at the Franklin Square Elementary/Middle School in WS263, which had been a KidsGrow site since 1994, and was a site from which asphalt paving was targeted for removal. KidsGrow students helped design a "reading circle" as the first phase of the removal process (Figure 7).

Figure 7. *A student-designed "reading circle" established as the first phase of an asphalt removal project at the Franklin Square Elementary/Middle School.*

Project BLUE was another Parks & People program that focused on the interactions between humans and natural resources within the urban environment. The program served grades 2–8 and was active in two elementary/middle schools in WS263: Harlem Park and Franklin Square. Core BLUE concepts include the idea that Baltimore is an urban ecosystem where living, non-living, and human-made things interact; that Baltimore is a part of the Chesapeake Bay Watershed; that we all live in a watershed; that people are dependent on natural resources for clean water, clean air, and food; that human actions can affect the health of the ecosystem; and that stewardship can promote a healthy and safe environment for Baltimore residents and other organisms. Educational assessment of Project BLUE participants showed improved understanding of ecological concepts and improved school attendance. Student improvement on environmental science and literacy assessments was particularly marked at Franklin Square Elementary/Middle School, supporting the idea that the asphalt removal in the schoolyard may have enhanced the students' environmental awareness and understanding.

Parks & People implemented a Schoolyard Habitat and Education professional development program for elementary teachers that integrated schoolyard investigations and habitat installations at three WS263 schools. The program connected students to the watershed and to the natural and cultural history of the area. Parks & People also developed an off-campus field investigation program that was site specific to the Gwynns Fall Trail, a 15-mile greenway in west Baltimore that traverses the lower third of WS263. These activities helped schools fulfill criteria for becoming Maryland Green Schools under a state certification program.

Neighborhood education included stormwater community workshops conducted by Parks & People in 2009–10. A series of workshops held at Franklin Square and Harlem Park Elementary/Middle Schools introduced parents and community members to the concept of stormwater runoff and the impact it has on water quality.

Acknowledgements

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