Available online at www.sciencedirect.com

SCIENCE DIRECT®

Landscape and Urban Planning 76 (2006) 23–44

LANDSCAPE AND URBAN PLANNING

This article is also available online at:
www.elsevier.com/locate/landurbplan

Urban landscape conservation and the role of ecological greenways at local and metropolitan scales

M. Margaret Bryant*

Department of Landscape Architecture, Virginia Polytechnic Institute and State University, 101 Architecture Annex (0113), Blacksburg, VA 24061, USA

Available online 21 December 2004

Abstract

Greenways are promoted for land conservation in both rural and urban areas, but less attention has been paid to the potential of greenways to serve urban biodiversity conservation goals. This paper presents results of a biodiversity planning study of a highly urbanized environment in Washington, DC (USA) that demonstrate the critical role of ecological greenways and parks in urban species conservation. The Cameron Run study raises fundamental questions about the way biodiversity is defined in urban areas, the scale of analysis required in heterogeneous urban environments, the role of sociocultural factors in urban biodiversity conservation, and the importance of regional greenway connections across the urban gradient.

The Cameron Run study is a pilot project for an urban biodiversity information node (UrBIN) in the National Biological Information Infrastructure (NBII) program of the US Geological Survey (USGS). This paper draws connections between the rapidly expanding literature on biodiversity conservation and the smaller, but growing, body of research concerning the ecology of greenways and urban areas, and it does so through the lens of landscape planning. Findings on the Cameron Run watershed are reported, and biodiversity conservation in the watershed is discussed in the context of greenway efforts at local and metropolitan scales.

Keywords: Urban ecological greenways; Urban biodiversity; Conservation strategies; National Biological Information Infrastructure; Landscape conservation; Landscape planning

1. Introduction

Extending green tendrils into the center of cities, organizing metropolitan areas around a green framework, and constructing green spaces where none currently exist are ideas that have driven the work of landscape architects since the profession became established in the mid-nineteenth century. Today, cities around the globe need such interventions as never before, given escalating urban populations and increasing rates of land consumption. Recently, another consideration has entered our consciousness, global threats to biodiversity. What does this mean for the way that we plan green spaces in cities? What does biodiversity mean in an urban context? Can the worldwide phenomena of greenway planning and implementation be harnessed to address this new concern in landscape conservation? The purpose of

* Tel.: +1 540 231 3418; fax: +1 540 231 3367.
E-mail address: mbryant@vt.edu.

0169-2046/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.landurbplan.2004.09.029

this paper is to explore these questions and to identify connections between conservation and recreation interests that might advance the cause of both greenways and urban nature conservation, including biodiversity protection and enhancement.

Greenways can be effective conservation tools at scales ranging from regions to watersheds to neighborhoods. The Maryland Greenways Commission defines the word greenway in a manner than emphasizes its ecological connotations:

Greenways are natural corridors set aside to connect larger areas of open space and to provide for the conservation of natural resources, protection of habitat, movement of plants and animals, and to offer opportunities for linear recreation, alternative transportation, and nature study (Maryland Department of Natural Resources, 2003c).

In many parts of the United States, greenways have been conceived and implemented to serve the limited functions of a recreational trail. This paper is based on a broader interpretation of the greenway concept, like that expressed by the State of Maryland above.

The US Geological Survey (USGS) sponsored a study of the Cameron Run watershed (USGS, 2003; Bryant et al., 2003; Convery et al., 2003) as a pilot project for an urban biodiversity information node (UrBIN) in the agency's National Biological Information Infrastructure (NBII) program. The 42-square-mile watershed is located in the Washington, DC metropolitan area (Fig. 1). The pilot study sought to establish a framework for exchange of scientific information, including remote sensing and other spatial data. It documented the current state of biodiversity in the watershed through synthesis of published studies and original spatial analyses using geographic information systems (GIS). The study included an investigation of the influence of local government policies on land use patterns and the potential for landscape conservation. Results of this study point to the importance of integrating human needs with biodiversity conservation planning through the use of greenways and park systems.

The Cameron Run watershed is contained within the Washington, DC beltway and is highly urbanized. Suburban development in the watershed began in the 1950s, and the watershed was largely built out by the late 1970s. Cameron Run is part of the metropolitan area's urban core, and that fact makes this study of biodiversity quite different from the more typical study of species diversity in largely undeveloped landscapes. Since it is part of the urban core, green spaces in Cameron Run are prized for a variety of reasons, and they are intimately tied to the recreational needs and aesthetic values of the local residents.

In the following sections, an overview of urban biodiversity is presented, the methods and results of the Cameron Run study are summarized, and the findings are set in the context of other greenway and landscape conservation programs in the greater Washington, DC metropolitan area. The study of Cameron Run made it clear that a metropolitan scale perspective is essential both for documenting biodiversity status and for developing meaningful conservation strategies. The paper concludes with recommendations for urban ecological greenways that can help conserve biodiversity across the urban gradient, from urban core to urban fringe.

The objectives of this paper are to:

(1) explore the concept of biodiversity in a heavily urbanized environment through a case study of the Cameron Run watershed;
(2) illustrate ecological greenway planning opportunities related to urban biodiversity conservation through a survey of local- and metropolitan-scale land use policies, programs, and regulations;
(3) develop recommendations for integrating conservation tools that can lead to creation of urban ecological greenways.

It is argued in this paper that local conservation actions, like the development of greenways, are critical for addressing the biodiversity crisis and that greenways are especially important in urban areas. NatureServe reminds us that "conservation is a quintessentially local activity" (2002, p. 3) in its report, *States of the Union: Ranking America's Biodiversity*. Success in halting the loss of species is perhaps most likely to be found in the actions of those working at the scale of local communities. This is especially true in the United States, where most land use decisions are made at the local government level (Theobald et al., 2000). The advantage offered by local conservation action is that it can take place regardless of the political vicissitudes that may occur at national and international levels.

Greenways are one of the most successful community-level conservation strategies of the past two decades. Greenways and other conservation strategies can be undertaken now, even though our knowledge of natural systems in cities is incomplete. Such actions are vitally important given the current rate of landscape change occurring worldwide.

2. Literature review

What is biodiversity? A commonly accepted definition of biological diversity, or biodiversity, is the following:

Biological diversity is the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance (US Congress, Office of Technology Assessment, 1987, p. 3).

In the investigation of the Cameron Run watershed, biodiversity was interpreted as the number and frequency of habitat types and the number of plant and animal species present.

Protecting biodiversity is considered one of the most critical missions in the quest to maintain the health of the planet. Burgeoning human populations and their associated landscape changes and consumption of natural resources have led to what some scientists call the sixth great wave of extinction, the first instigated by a single species (Kirby, 2003; Royal Society, 2003). The World Conservation Union reports that one-quarter of the world's mammal species and one-tenth of its bird species are threatened with extinction (IUCN, 2002). In the United States, it is estimated that one-third of plant and animal species is at risk, and over 500 species are already extinct (Stein et al., 2000). Habitat loss is the single greatest cause of the threat, and alien species invasions are second.

The following sections review research on urban ecology, urban biodiversity, and the ecological roles of greenways. There are few intersections between the literature of biodiversity conservation and the literature of greenways, but the Cameron Run study results suggest that, in urban areas, strategies to protect biodiversity should be closely linked to greenway implementation and integrated with existing programs that conserve other urban natural resources like surface water. The Cameron Run study identifies an overlap between the goals of biodiversity conservation and those of greenway development, and that coordination of both research and implementation activities would prove beneficial in addressing multiple planning objectives. The aim of this literature review is to draw connections between urban ecology, biodiversity conservation, and greenway planning.

2.1. Ecology of cities

What is urban? While the term may be interpreted in many ways, it typically refers to an area that is densely populated by humans. Historically, cities have contained densely populated cores, with densities declining with movement away from the city center. While decline of the urban core has altered this pattern in some cities, the Washington, DC area and the Cameron Run watershed exhibit this pattern of density. The term urban fringe typically refers to the interface between urban and rural environments at the edge of a city. Urban–rural gradient is a term used to describe a cross-section of a city, extending from the city center, through the suburbs, to the rural outskirts, or urban fringe.

Until recently, only a small percentage of ecologists studied cities. Instead, researchers focused on the ecology of more pristine, wilderness areas where the effects of humans are minimal. This situation is rapidly changing as the ecological effects of unprecedented levels of land consumption in urban areas and loss of native species due to urbanization are recognized. Cities can no longer be ignored. One sign of the growing momentum in urban ecology research was the launch of the journal *Urban Ecosystems* in 1997.

From 1992 to 1997, the rate of land development in the United States doubled over the previous 10-year period, with approximately 3 million acres being converted annually (Environmental Protection Agency, 2000). For US cities with populations over 1 million, "urbanized land area has grown on average 2.65 times as fast as population has" (2000, 2-2). Land consumption is a term used to describe conversion of land from non-agricultural or undeveloped uses to developed uses like residential, commercial, and industrial. This phenomenon of the rate of land consumption exceeding the rate of population increase at the metropolitan scale is how sprawl is defined by the US Environmental Protection Agency (2004). The social, economic, and environmental effects of sprawl have been documented by many researchers over the past three decades (Frumkin, 2002; Benfield et al., 1999; Ewing, 1994; Council on Environmental Quality, 1974).

Research by the National Wildlife Federation (2001) found that sprawl is the leading cause of species endangerment in California. According to the report, for 188 of the 286 species listed by the federal government as threatened or endangered in California, urban sprawl is a significant cause of imperilment. This finding would not surprise conservation biologists who have called attention to the connection between urbanization and decline in biodiversity for over a decade (Pickett et al., 1992; McDonnell and Pickett, 1993). Even with this recognition, Miller and Hobbs found that only 6% of papers published between 1995 and 1999 in the journal *Conservation Biology* "described work conducted in urban, suburban, or exurban areas or studies in which human settlement was considered explicitly" (2002, p. 330).

The critical relationship between cities and biodiversity will only grow in importance as more of the world's population move from the countryside into cities (United Nations et al., 2000). In this century, for the first time, a majority of the world's population will live in cities, prompting some to call it the "first urban century" (Hall et al., 2000). A better understanding of the ecology of cities is one component of a strategy to address the impacts of urbanization and to find better ways to accommodate development in an ecologically sensitive manner.

Grimm et al. (2000) highlight the significance of the relationship between urban areas and global environmental health:

Although urban areas account for only 2% of Earth's land surface, they produce 78% of greenhouse gases, thus contributing to global climate change. Cities also play a central role in alteration of global biogeochemical cycles, changes in biodiversity due to habitat fragmentation and exotic species, and changes in land use and cover far beyond the city's boundaries (i.e. within the urban 'footprint') (2000, 572).

Grimm et al. (2000) distinguish between two different categories of urban ecology research: studies of "ecology in" cities and studies of the "ecology of" cities. Studies of ecology in cities tend to contrast the characteristics of urban environments with those of undeveloped areas. Emphasis is placed on impacts of urbanization on natural systems, and common topics include surveys of flora and fauna, investigations of edge effects, and pollution and construction impacts. In this vein, numerous studies of the ecology in European cities have been conducted (Zerbe et al., 2003; Pyšek, 1993, 1998; Sukopp and Hejný, 1990; Gilbert, 1989). A growing body of research is now aimed at the ecology of cities, research that examines the city as an ecosystem unto itself, rather than an imposition on the natural landscape (Grimm et al., 2000; Lord et al., 2003). Grimm et al. (2000) note the seminal study of Hong Kong (Boyden et al., 1981) as an example of this kind of urban ecology research. Other examples are the ongoing urban studies in the National Science Foundation-funded Long-Term Ecological Research (LTER) program that seek to enhance the understanding of the US cities of Phoenix and Baltimore as ecosystems (Grimm et al., 2000). A network of natural and social scientists direct the urban LTER studies that are designed to monitor and assess long-term ecological changes over a minimum period of 30 years.

While long-term ecological studies like those being conducted through the LTER program are needed, it is also true that changes are occurring every day in cities without the benefit of considering the ecological implications. Local governments need to be able to perform a more rapid assessment of a site's ecology (Lord et al., 2003) and understand the relative importance of a site and its contribution to the regional ecosystem. The goals of the NBII program and its urban ecological node respond to this need. The Cameron Run study demonstrates the extent to which such assessment is possible given currently available data and typical capabilities of urban planning agencies. Future UrBIN studies will build upon this knowledge and help identify what researchers, government agencies, and grassroots organizations need to support research and land use decision making.

2.2. Effects of urbanization on biodiversity

Numerous studies have documented the physical environment, flora, and fauna of cities. Such studies informed the Cameron Run study, and they are briefly summarized here.

Four major effects of urbanization on the environment are an increase in temperature (urban heat island effect), increased runoff due to impervious surfaces, lower levels of native species diversity and higher levels of non-native species, and increased production of carbon dioxide (Whitford et al., 2001; Douglas, 1983; Bridgeman et al., 1995). Gilbert (1989) noted the high spatial variability of the physical environment of cities, including variability in soil temperature and moisture levels, solar radiation and humidity, and wind speed and direction. Soils in cities are typically highly altered and possibly contaminated by previous land uses. Patches of pre-development soils are interspersed with areas that have been extensively graded and filled.

The patchiness, or spatial heterogeneity, of cities exhibits some degree of organization along gradients that run from city center to city edge (McDonnell and Pickett, 1990). Metrics used to quantify physical changes that vary across the urban–rural gradient include: "road density, air and soil pollution, average ambient temperature ('heat island' effect), average annual rainfall, soil compaction, soil alkalinity," (McKinney, 2002, p. 884) impervious surface coverage, and the amount of energy and materials imported for use by the human population. The effects of urbanization persist longer than other types of habitat disturbance such as agriculture because of the relative permanence of the built environment (McKinney, 2002).

Changes in the physical landscape of cities produce changes in habitats for plant and animal species. As farmland, forests, and pasture in the suburbs and exurbs are developed, natural habitats are fragmented, and biodiversity is compromised. Urban development impacts biodiversity through land disturbance and conversion to impervious surfaces, removal of native vegetation, introduction of non-native exotic species, and fragmentation and isolation of remaining natural areas. Efforts to manage urban biodiversity aim to minimize and mitigate those impacts, protect and connect remaining habitats, and restore damaged natural areas (Bryant and Randolph, 2002).

Examining plant composition in Brussels over a 60-year time period, Godefroid (2001) found that plant species distribution and abundance were affected by human activities, with the decline or disappearance of some species, but also with the appearance of new species, many of which were aliens. Godefroid found that alien plant species were favored in cities because of their increased tolerance of nitrogen, light, drought, heat, and alkaline soils.

In numerous studies of the flora of European cities, both native and non-native species have been inventoried, and conclusions support the idea that cities have more species than the surrounding landscape (Pyšek, 1998). Beyond inclusion of non-native species in the inventory, the explanation usually given for this diversity is spatial heterogeneity (linked to intermediate disturbance theory), especially in the urban fringe where agricultural land, forest, and developed lands of varying intensity are juxtaposed (McKinney, 2002; Pyšek, 1998; Zerbe et al., 2003). In a study of the flora of German cities, Kuhn et al. (2004) provide another possible explanation. They examined geological diversity in relation to species richness and concluded that German cities are "naturally species rich" as a result of the historical siting of these cities in "biodiversity hotspots" (2004, p. 749).

Various studies offer differing conclusions about the level of biodiversity found in the suburbs (see the review by McKinney, 2002). Location-specific variables, including physical conditions, composition of the biotic community, and timing and scale of disturbance, affect the level of biodiversity found in suburban and exurban areas. Despite the divergent conclusions about the suburbs, there is some degree of consensus on the low diversity of native plant and animal species in the urban core and the fact that non-native, often invasive, species are pervasive in the city center (McKinney, 2002).

Despite the impacts of urbanization, even landscapes near the urban core exhibit levels of spatial heterogeneity that result in a wide variety of habitat niches for species to exploit (Bradshaw, 1999). It is clear that habitat diversity and life-support conditions vary greatly across the urban–rural gradient. For conservation purposes, it is important to consider the full spectrum of environmental conditions, from urban core to urban fringe, when planning interventions. Urban ecological greenways can be designed in a way that responds to these variable conditions.

2.3. Greenways as a conservation tool

During the same time period that concern over biodiversity losses became fodder for newspaper headlines, the word greenway entered the American lexicon. In fact, as the special issues in *Landscape and Urban Planning* demonstrate, the greenway concept has been embraced worldwide (Fábos and Ryan, 2004; Fábos and Ahern, 1995). Greenways for America (Little, 1990) documented the beginning of the greenway movement, and substantial numbers of greenways have been planned and implemented in the years since. In the United States, this process has been aided significantly by changes in federal transportation legislation in the early 1990s that created funding sources for alternative modes of transportation. While greenways may be implemented in either rural or urban locations, they have been especially popular in cities where they can meet needs as varied as transportation, active and passive recreation, and connection to "near nature." Fábos (2004) identifies three major types of greenways: "ecologically significant corridors, recreational greenways, and/or greenways with historical and cultural values" (2004, p. 321). Urban greenways might logically be extended to serve as a mechanism for conserving urban biodiversity. In this case, greenway design would have to mitigate or minimize possible conflicts between recreation and conservation.

A survey of greenway literature reveals a number of studies that demonstrate planning processes appropriate for greenways, including ecological greenways. For example, Miller et al. (1998) describe a greenway suitability analysis method, and Ndubisi et al. (1995) detail a greenway planning process for environmentally sensitive areas. Others emphasize the importance of landscape ecological networks (Jongman et al., 2004; Linehan et al., 1995). Jongman identifies the components of greenways that serve as ecological networks as "core areas, corridor zones, buffer zones and, if needed, nature rehabilitation zones for the re-establishment of nature" (1995, p. 169). Several studies emphasize the importance of a regional perspective in greenway planning as well as the role of vision, leadership and advocacy (Fábos, 2004; Erickson, 2004; Bueno et al., 1995).

Ahern (1995) discusses greenways as a conservation planning strategy to address multiple issues, including biodiversity. He describes the need for an "ecological infrastructure" that is "structured by a 'patch and corridor' spatial concept which includes corridors and stepping stones to connect isolated patches and thus help to counter the effects of fragmentation" (1995, p. 131). The use of greenways as an ecological network is rooted in concepts of landscape ecology, island biogeography, and population biology. Ahern also states that greenway planning is a "strategy of achieving multiple benefits through combinations of spatially and functionally compatible land uses within a network" (1995, p. 139). Below is a summary of the arguments for and against greenways that Ahern identified.

2.3.1. Advantages

(1) Greenways using a drainage network as a spine can be used to buffer surface water and riparian species from influences of adjacent landscapes.
(2) Greenways can "protect patches of interior habitat from outside disturbances" (1995, p. 135).
(3) Greenways can offset the effects of landscape fragmentation.
(4) Greenways can enhance cultural resources by linking them to form a network or system that maximizes interpretive and/or recreational value.
(5) Greenways provide "visible structure and legibility to the landscape" (1995, p. 136).

2.3.2. Disadvantages

(1) Researchers have raised questions about the value of corridors for species movement and wildlife habitat (as discussed in the paragraphs that follow).
(2) Some conservationists argue that limited resources should be devoted to protection of existing large patches of habitat rather than to creation of corridors.
(3) The type of corridor most commonly mentioned in greenway literature is the forested corridor, and such corridors may be inappropriate in traditionally open, unforested landscapes.
(4) Attention to greenways may shift concern away from other conservation priorities.
(5) Greenway implementation may be politically unacceptable in some circumstances due to private property rights issues.

The debate over the value of corridors for species movement and habitat enhancement is summarized in a guide for land use planners published by the Environmental Law Institute (2003). In addition to the corridor issue, the guide surveys recent literature on the effects of habitat fragmentation and covers questions of adequate habitat patch size, edge effects, and riparian buffer width, all of which have applicability to greenway design (Smith and Hellmund, 1993). Despite lingering questions regarding the function of linear corridors and the desirability of connecting habitat patches, the current state of practice centers on preserving habitat patches that are as large as possible and connecting the patches with vegetated corridors, typically riparian corridors (Noss and Cooperrider, 1994; Meffe and Carroll, 1997; Beier and Noss, 1998). The strategy of connecting habitat patches with linear corridors is the same for rural and urban areas, but the risks of connecting high quality patches with lower quality patches and corridors (as measured by invasive species, for example) may be greater in urban areas given the scarcity of the higher quality habitats. Consideration must be given to the benefits and risks associated with connecting high quality patches with linear corridors if there is any possibility such connections might compromise the integrity of the patch by introducing disease, fire, invasive species, or undesirable predators (Environmental Law Institute, 2003). However, it should be noted that many of the threats to biodiversity in urban areas, such as invasive, non-native plant species, do not need a corridor to become established.

In urban areas, where the landscape matrix is likely to be inhospitable to species other than humans, corridors are likely to play an important role as habitat. Rosenburg et al. (1997) emphasize the habitat role of corridors by calling them "linear patches." These linear patches exist as streamside riparian zones, remnant habitat patches, and urban greenways, and they have values that transcend questions over the use of corridors for species movement (Rosenburg et al., 1997). These values include providing shade for aquatic ecosystems, controlling erosion and sedimentation, creating habitat diversity, and serving nature education needs. It is at this intersection of species habitat and human needs (aesthetic, educational, cultural, and recreational) where the benefits of urban greenways are realized, and this is one explanation for the explosive growth of greenways internationally in recent years.

The potential of urban greenways to serve environmental education objectives is as significant for conservation of urban biodiversity as the importance of urban greenways as habitat. The effects of educating the urban populace could be substantial. In the US, 50% of the US population lives in suburbs and another 30% live within cities (US Census Bureau, 2001). It is thought that the more the urban public is made aware of the value of natural areas and the crisis of declining biodiversity, the more they will support conservation measures at home and in distant locations (Savard et al., 2000). Greenways that are comprised of remnant natural areas and intact natural systems (as opposed to those that are exclusively bike paths) can bring city dwellers into contact with nature. Greenways have the potential to meet both of the objectives identified by McKinney (2002) as worthy goals of urban ecology research: (1) serving as a stimulus for preservation and restoration of urban habitats; and (2) serving as a means of environmental education for visitors to conserved areas.

This review of urban ecology, urban biodiversity, and greenway literature indicates a need for greater understanding of the ecology of cities, the effects of cities on biodiversity, the potential that cities might have for biodiversity conservation, and the contributions that greenways make to this effort. The Cameron Run case study sheds light on the landscape structure of an urban core watershed, conservation planning capacity of both local governments and grassroots non-profit organizations, role of greenways in urban landscape conservation, and areas where a greater understanding of urban ecology is needed.

3. Methods

The motto of the National Biological Information Inventory (NBII) program is "building knowledge through partnerships" (US Geological Survey, 2003). The partnerships formed for the Cameron Run study began with an interdisciplinary team developed from four different programs/institutes at Virginia Polytechnic Institute and State University (Departments of Urban Affairs and Planning, Landscape Architecture, and Natural Resources and the Conservation Management Institute) and scientists and planners at the Metropolitan Washington Council of Governments (MWCOG).

As the project unfolded, this partnership was extended through formation of an Advisory Group that included representatives of local, state, and federal government agencies as well as non-profit organizations.

The study of greenways and urban biodiversity discussed here was conducted at two scales: the watershed scale and the metropolitan scale. The study process is described in Fig. 2. The watershed examined is a major tributary of the Potomac River that runs through portions of Fairfax County and the cities of Alexandria and Falls Church, all of which are in Virginia. The metropolitan scale study focused on greenway initiatives and biodiversity conservation efforts throughout Washington, DC By placing the Cameron Run watershed in its larger context and considering the broader institutional connections that contribute to natural areas conservation, a more thorough understanding of the significance of remnant natural areas in Cameron Run is possible and the implications for the broader metropolitan area are more clear.

The Cameron Run study is a planning study with five main parts: (1) formation of an advisory group to initiate dialogue about biodiversity conservation in the watershed; (2) landscape characterization of watershed features affecting biodiversity and greenway design; (3) land cover/habitat analysis; (4) local landscape policy and program analysis; and (5) regional greenway analysis. One of the purposes of the NBII program is to promote the use of existing biological information for land use planning and research. The Cameron Run study identified what existing information resources and planning structures are available for biodiversity conservation planning and generated new information through synthesis of these findings and through analysis of GIS shapefiles, aerial photographs, and remote sensing images.

A landscape characterization, or inventory, of the watershed was performed using GIS. The following landscape features and qualities were mapped: landform, soils, climate, wetlands, floodplains, surface

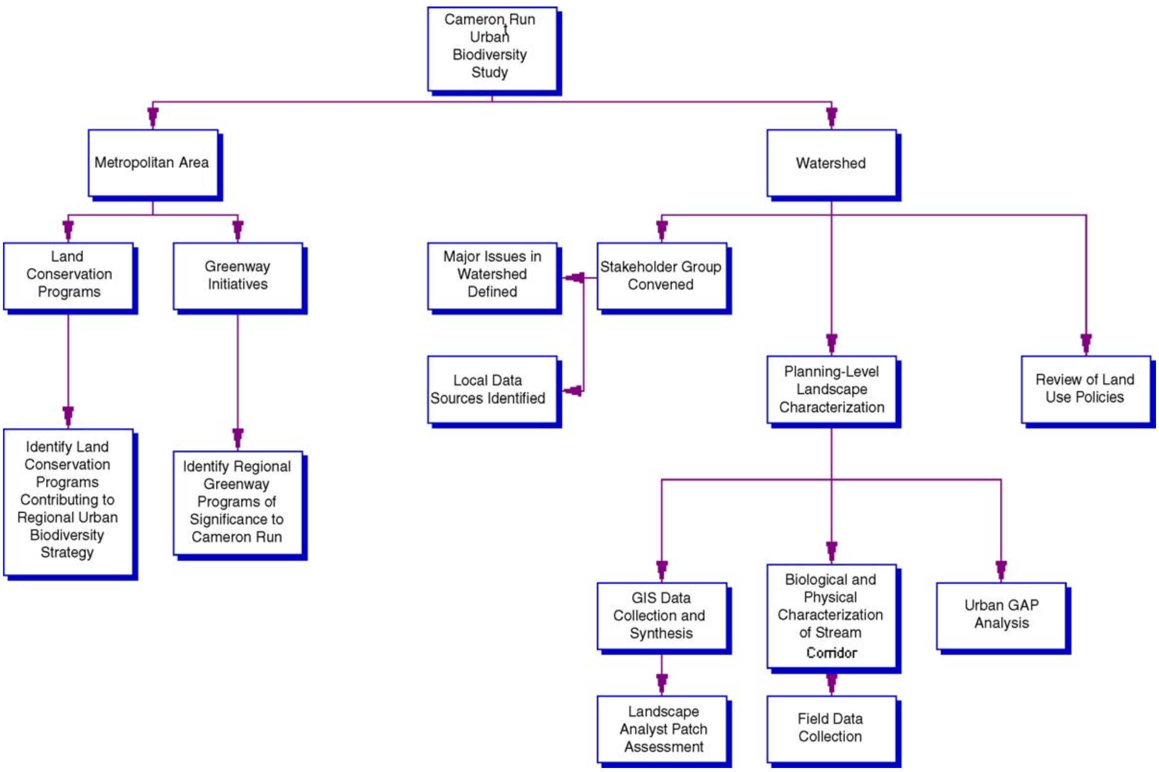

Fig. 2. Study process.

and ground water quality, natural communities, land use, human population demographics, parkland, and transportation. An urban "gap analysis," modeled on the national program sponsored by the USGS (http://www.gap.uidaho.edu/) was conducted using recent satellite imagery, and limited field surveys were also conducted, with comparisons made to a more pristine reference watershed in the vicinity, Quantico Creek. All of these studies were conducted in 2001 and 2002, and they are documented on the following website: http://dc-urbanbiodiversity.nbii.gov.

Biodiversity planning issues were investigated, with particular emphasis placed on local land use policies. Policies for stormwater management, stream buffers, point source pollution control, erosion and sedimentation, invasives management, flood control, urban forestry, and compliance with Chesapeake Bay regulations were reviewed. Greenway planning policies and plans in Fairfax County and Alexandria were also reviewed.

Findings from the watershed-scale analyses made it clear that the significance of the remnant natural areas in the Cameron Run watershed could only be understood in their regional context. Likewise, conservation planning through greenways could not be done without consideration of regional context. To provide the regional perspective, a survey was conducted of greenway and land conservation strategies currently employed in the greater Washington, DC metropolitan area. The survey was facilitated by the Metropolitan Washington Council of Governments (LeCouteur, personal communication, 9-12-03). This survey is not meant to be comprehensive, but instead to demonstrate the breadth of activities at state, county, and local government levels that could augment or be incorporated into the development of urban ecological greenways. Future efforts to protect biodiversity and establish an ecological greenway in the Cameron Run watershed can build upon existing programs and the track record already established in the Washington, DC area.

4. Study results

The Washington, DC metropolitan area covers approximately 3079 square miles, contains more than four million people, and has grown substantially in land area and population over the last 50 years (Lecouteur, 2002). Woodland, meadow, pasture, and cropland have been and continue to be replaced by urban development. Despite significant losses of natural habitat due to development, the Washington area is still rich in natural areas and parkland. The extent of natural areas varies significantly across the urban gradient from exurbs to center city. In a watershed like Cameron Run, vestiges of natural vegetation remain primarily along the stream corridors and larger habitat patches are primarily found in public parks. The following sections summarize findings from the five-part Cameron Run study.

4.1. Stakeholder advisory group

Stakeholder participation was a critical part of the UrBIN pilot study. One goal of the NBII program is to make it easier to find and use biological resources information. Because the program seeks to provide communities with information, data, and tools for managing biodiversity, it was essential to bring stakeholders (government agencies, researchers, and citizens) together to discuss their data and planning needs. It was also essential to have stakeholders contribute their knowledge of the watershed and share data.

Between October 2001 and May 2003, three stakeholder meetings were held, and representatives from over 25 organizations attended. Represented were federal agencies like the US Forest Service and the Environmental Protection Agency (EPA), state agencies like the Virginia Department of Forestry, and local government agencies like the Alexandria Department of Transportation and Environmental Services and the Fairfax County Park Authority. Non-profit organizations included Friends of the Potomac, The Trust for Public Land, and Northern Virginia Conservation Trust. One quasi-governmental organization, the Lake Barcroft Watershed Improvement District, was also an active participant. The high level of participation in the stakeholder meetings suggests significant interest in biodiversity and other conservation issues in the watershed and metropolitan area.

The stakeholder meetings provided a forum for discussion of natural resource planning issues in the watershed. Stakeholder concerns transcended biodiversity and greenways. A list of key watershed issues identified in the first stakeholder meeting is listed in Table 1.

Table 1
Key watershed issues identified by stakeholders

Stormwater runoff
Impacts and planning, management, flooding, stream buffers, impacts to water quality
Development patterns
Land use policy and planning, infill development, modeling of impervious surfaces
Biodiversity and habitat preservation/conservation
Access to data resources
Public awareness, education, and involvement
Watershed and natural resource planning
Master plans, improved implementation of current plans
Jurisdictional coordination
Wetlands and aquatic habitats
Restoration and preservation, reservoir management
Access to funding

What is apparent from this list of concerns is that biodiversity could not be separated from other natural resource concerns, like water quality, in the minds of the stakeholders. Given current strain on funding for programs to address natural resource issues, it will be necessary to create conservation strategies that address multiple problems, and the stakeholders seemed to take the need for integration for granted. Other concerns were about planning and implementation: having access to data, having high quality, appropriate data to answer natural resource questions, having access to funding, and finding ways to implement plans that had already been created.

Stakeholders from the local government agencies were especially helpful in providing GIS data and previously completed planning reports for the landscape characterization component of this study. In fact, one striking aspect of the Cameron Run case study was the institutional capacity of many of the stakeholder groups, including local planning agencies. For example, local governments in the watershed have sophisticated planning staffs and advanced capabilities for data handling. This translates into capacity for conservation planning. While the planning resources in this watershed are exceptional in many ways, other large cities in the US and Europe would have similar capabilities.

4.2. Landscape characterization

In the landscape characterization portion of this study, physical, biological, and social characteristics and features of the Cameron Run watershed were mapped. This inventory provided all of the study participants, including the stakeholders, information on critical conditions affecting biodiversity and helped to identify and quantify the remaining natural habitat in the watershed.

4.2.1. Watershed description

By most measures, Cameron Run is highly degraded and largely built out. Native Americans were the first people to occupy land in the watershed, and European settlers followed as early as 1650. Today there is fairly dense development by US standards, and no portion of the landscape has escaped significant alteration. The areas that appear "natural" are highly fragmented in most cases, affected by various pollutants and stormwater flows, and filled with exotic species. Offsetting some of these assaults on biotic integrity is the fact that a significant portion of the riparian corridor is in public ownership, due in part to its designation as a Resource Protection Area (RPA) by the Chesapeake Bay Preservation Act.

The study area lies in the Middle Potomac-Anacostia-Occaquan basin (Bryant et al., 2003). It is a multi-jurisdictional watershed with 81.6 km^2 (31.5 mile square) of its total estimated area (108.8 km^2 or 42 mile square) lying in the eastern portion of Fairfax County. The remaining area lies in the cities of Alexandria and Fall Church.

Cameron Run is situated inside Northern Virginia's I-495 beltway, and its reaches are alternately identified as Holmes Run, Cameron Run, and Hunting Creek (Fig. 3). The longest stretches of the creek are called Holmes Run (mostly in Fairfax County) and Cameron Run (in the City of Alexandria), with the name Hunting Creek used for the section near the confluence with the Potomac River. For the purposes of this paper, the watershed is identified as Cameron Run because that is the name used by local residents.

The watershed extends across the Coastal Plain and Piedmont Plateau provinces. Landforms vary from rolling hills in the western part, typical of the Piedmont, to flat lands in the eastern part, typical of the Coastal Plain. Two distinct physiographic provinces a flood control channel in lower Holmes Run, lower Backlick Run, and Cameron Run (lower Backlick Run had originally been channelized around 1850).

While the lower portion of the watershed, primarily the portion in the City of Alexandria, is maintained as a flood control channel with a trapezoidal form and frequent dredging, the upper portions of the stream have a natural character. Since much of the remaining habitat in Cameron Run is contained within riparian corridors, surface water quality and biodiversity issues are intertwined. Surface water resources in the watershed are highly stressed from the impacts of urban stormwater runoff. While point source pollution from wastewater treatment plants and industry is not considered to be a significant problem, non-point source pollution is a major threat. Currently, the Cameron Run mainstem and its tributaries "have substantially degraded biological and habitat integrity," according to the Fairfax County Stream Protection Strategy Baseline Study (Fairfax County, 2001). Fecal coliform is the primary pollutant.

4.2.2. Biodiversity and greenways

Terrestrial habitats are found primarily in parklands, open space lands, golf courses, cemeteries, vacant parcels, and low-density residential areas. In terms of wildlife, conditions in the watershed are generally favorable for generalists or adaptable species. Specialists or less adaptable species are uncommon, while those that can successfully inhabit human-dominated environments tend to fare better. Forest trend information indicates a 32% decrease in forest resources in the watershed from 1957 to 1992 (Federal Highway Administration, 2001). Remnant natural woodlands are dominated by oak and hickory species.

Few detailed surveys of vegetation have been conducted in the watershed. A 1974 survey (Parsons Brinckerhoff) notes that one-quarter of the watershed was undeveloped at the time, and scattered islands of woodland, marsh, and meadows were common. A 2001 survey (Simmons et al.) of the Cameron Run channel identified 78 native species of plants and 19 exotic species, most of which were highly invasive. Based on field reconnaissance and review of applicable site surveys, it is clear that invasive species dominate the herbaceous flora of the watershed.

There are no official ecological greenways in Cameron Run, but recreational trails are numerous and well used. These trails are strictly bike and pedestrian paths. An opportunity exists to expand this conception of greenway to include natural areas protection. Biodiversity enhancement programs could be established through community involvement in the planning and design of the greenway(s). The basic structure of ecological greenways does already exist in the watershed in the form of undeveloped riparian corridors, much of which is already in public ownership (Fig. 4).

4.3. Land cover analyses

Using CITYgreen 5.0 (developed by the organization American Forests) and 30 m Landsat imagery from 1992, a land cover analysis was conducted. This analysis revealed that the watershed is still primarily residential (67%). Impervious surface coverage ranges from 23 to 41% across the watershed. Parks and open space comprise 11% of the land area, forested land cover is 30%, and vacant land is 5%. Eighty-five percent of the land in the Cameron Run watershed is developed according to this analysis. The remaining 15% is either parkland (10%) or vacant (5%).

The forest land cover (Fig. 4) co-occurs with a variety of land uses, especially residential. Together with the existing parks and the resource protection areas in the stream valleys, forested patches represent the potential for biodiversity conservation and enhancement (RPA is a legal designation under the Chesapeake Bay Protection Act). An analysis of potential interior forest habitat (Fig. 5), using Landscape Analyst with ArcView 3.2, reveals patches outside the riparian zone that hold promise for conservation. According to land trust representatives working in the area, small parcels, even as little as one-half acre in size, make valuable contributions to landscape protection efforts, especially if they can be connected to land that is already protected. Undeveloped upland habitat is particularly in short supply. Even a small portion of these interior habitat patches could be a valuable addition to an ecological greenway.

Historical landscape change in the watershed from 1973 to 1991 was also analyzed (Lee and Klopfer, 2003) using the North American Landscape Characterization (NALC) triplicate dataset. The images were taken on 8 July 1973; 16 July 1980; 17 June 1987; and 2 June 1991. This analysis indicates an over 30% increase in the amount of developed land uses in the watershed over the 18-year period, with a corresponding population growth of nearly 40%. An interesting

Fig. 5. Potential habitat patches to include in ecological greenway.

4.4.1. Chesapeake Bay Act

One thing that Fairfax County and the cities of Falls Church and Alexandria have in common is the need to comply with environmental regulations protecting the Chesapeake Bay. Designation of Resource Protection Areas and Resource Management Areas (RMAs) and regulation of development within these areas have been undertaken by each local government in the watershed. Development limitations imposed on RPAs and RMAs have resulted in protection of riparian corridors, and these corridors provide a substantial percentage of remaining natural habitat in Cameron Run.

The following land areas are classified as RPAs: tidal wetlands, non-tidal wetlands connected by surface flow and contiguous to tidal wetlands or tributary streams, tidal shores, tributary streambeds, and buffer areas 100 ft. in width for the previously mentioned categories. In most instances, these lands are not available for new development, with the exception of land that is water dependent and permitted in the underlying zone (City of Alexandria, 2001).

In Fairfax County, protection of stream corridors began in the 1980s. Poor water quality and flooding became a countywide problem in the 1970s as the county became more developed. To improve water quality, Fairfax County implemented best management practices (BMPs) in the 1980s that consisted of low-density residential zoning and the creation and/or maintenance of vegetation stream buffers for its most threatened watersheds. By 1993, the BMPs were implemented countywide with the designation of stream corridors as RPAs. Another level of protection for stream corridors in Fairfax County comes from their dual designation as "environmental quality corridors."

4.4.2. Environmental quality corridors

Fairfax County defines "open space" as parks, conservation areas, private open space, and vacant land. In the county, open space has declined by more than 30% from 1975 to 1995. In recognition of the fragmentation of remaining ecologically significant land, the continued loss of open space, and the corresponding loss of environmental resources, Fairfax County has made a commitment to identify, protect and enhance an integrated network of ecologically valuable land and surface waters. This involves adding land to the Environmental Quality Corridor (EQC) system, the core of which is the county's stream valleys. Lands achieving the following purposes that may be included within the system are those that: (1) have a desirable or scarce habitat type or host species of interest; (2) provide connectivity for the movement of wildlife; (3) separate land uses, providing passive recreational opportunities; (4) induce significant reductions to nonpoint source water pollution; and/or (5) affect microclimate control, and/or reductions in noise. Additions to stream valleys shall be selected to augment the habitats and buffers provided by the stream valleys and to add representative elements of the landscapes that are not represented within the stream valleys (Fairfax County, 2000).

4.4.3. Tree cover policy

Fairfax County's tree cover policy has an effect on the quality of habitats found in the Cameron Run watershed. This policy consists of the conservation and restoration of tree cover on developed and developing sites and provision of tree cover on sites where it is absent prior to development.

4.4.4. Conservation easements

Conservation easements are a tool used to achieve a variety of purposes, including the preservation of open space and environmentally sensitive resources. Property owners donate or sell an easement to the local government or to a non-profit organization at the local, statewide, or national level. Open space/historic preservation easements allow individual landowners to permanently protect their land or historic structure while continuing to own and enjoy it. These easements become part of the land title, so they offer permanent protection as the property is bought and sold.

The following public entities or charitable organizations hold easements for the purpose of preserving open space in Fairfax County: Virginia Outdoors Foundation, Potomac Conservancy, Northern Virginia Conservation Trust, Northern Virginia Regional Park Authority, and the National Park Service

4.4.5. Greenways policies

Greenways are a vital part of the open space and recreation planning policies and programs of all three jurisdictions in the watershed. A typical greenway policy statement is found in the Fairfax County Parks Policy Manual:

The Fairfax County Park Authority shall provide leadership for establishment and management of an integrated network of Greenways within the County to conserve open space, to protect sensitive environmental and cultural resources including wildlife habitat, riparian corridors, water quality, archaeological and historic sites and aesthetic values, to control flooding and erosion, and to provide continuity of non-motorized access between places where citizens and visitors live, work and play (Fairfax County, 1998).

However, despite a commitment to greenways, none of the three jurisdictions has an official greenway in the Cameron Run watershed other than a bike or walking path. A commitment to creating an "ecological greenway" would be beneficial for conservation purposes. A framework for an ecological greenway already exists, composed of recreational trails and stream valleys protected as RPAs and, in many cases, owned by the Fairfax County Park Authority or the Northern Virginia Regional Park Authority. Explicit designation of an ecological greenway would call attention to other habitat patches that could be added to the network. The Cameron Run stream valley is identified as a priority for greenway planning by Fairfax County (1998).

The Fairfax County Park Authority is responsible both for maintaining existing parks and greenways and for acquiring new land. In 2001, the Park Authority reached a major milestone in its open space program with 20,000 acres protected (Fairfax County, 2003). This protected land is particularly precious in a county where only 14% of the land remains undeveloped.

It is through a combination of public policies and private efforts, including the actions of land trusts, that biodiversity conservation and enhancement might be achieved in the Cameron Run watershed.

4.5. Metropolitan area greenway initiatives

If urban ecological greenways are to be used to conserve and restore urban biodiversity, they cannot be designed in a piecemeal fashion. An understanding of the entire metropolitan area, at least to some extent, is essential for building a comprehensive conservation program. A brief review of some of the ongoing initiatives in the Washington, DC area was conducted and is summarized below. These policies and programs have enormous potential to contribute to the formation of an ecological greenway network for the entire metropolitan Washington, DC area.

As the National Capital of the United States, Washington, DC has no shortage of public spaces, including the green variety. While there is a significant amount of land that contributes to biodiversity and the ecological health of the metropolitan area, there is no comprehensive inventory or plan that examines the amount, location, function, or connections between these land areas. The first fledgling effort to create such a vision was undertaken in the fall of 2002 with a mapping forum organized as part of the Green Infrastructure Demonstration Project, conducted by the National Park Service and the MWCOG (Lecouteur, 2002; MWCOG, 2003). A comprehensive overview of ecologically sensitive areas, protected lands, and greenways in the metropolitan area is needed if biodiversity is to be protected. A coordinated conservation effort is particularly important in the Washington, DC area where two states, the District of Columbia, seven counties, and ten cities each pursue their own.

As a result of historic open space planning efforts, Washington, DC did have a framework of protected green space in place before the great urban expansion following World War II. The modern programs described below carry on the tradition of recreation and conservation than began two centuries ago. Each of these programs has the potential to contribute to the development of ecological greenways and urban biodiversity protection. Several focus on urban fringe areas rather than more developed locations.

4.5.1. Statewide greenway programs

Maryland has an extensive network of greenways, including ones designated as "ecological" and those designated as "recreational" based on their primary function. For inclusion in the state greenway network, greenways must address ecological functions to some extent, as revealed in the Maryland Department of Natural Resources list of greenway functions:

- riparian/water quality protection;
- wildlife/ecological corridor;
- linear park (can contain natural areas and developed recreation sites);
- trail (as long as it includes a significant vegetated buffer) (Maryland Department of Natural Resources, 2003c).

Also included in Maryland's greenway specifications are the requirements that greenway land must have some form of permanent protection and must have a management plan. Maryland currently has over 1500 miles of protected greenways. Ecological greenways comprise 900 miles of the total. With its specific attention to the potential for greenways to protect ecological functions, Maryland stands apart from what has become the mainstream in US greenway implementation, the recreational trail.

In Virginia, greenways play a prominent role in the state's recently completed Outdoors Plan (Virginia Department of Conservation and Recreation, 2002). In 1999, Virginia launched the first Governor's

Conference on Greenways and Trails, and it has been held yearly ever since. In 2001, the conference expanded to become the Mid-Atlantic Governor's Conference on Greenways, Blueways, and Green Infrastructure. While Virginia defines greenways to include those aimed at ecological protection, few such greenways have been constructed in the state (Bob Munson, Virginia Department of Conservation and Recreation, personal communication, 5-20-03). Despite the enthusiasm for greenways as demonstrated by the Outdoors Plan, recreational trails form the majority of Virginia's greenways.

4.5.2. Smart growth strategies

The State of Maryland has become renowned for its Smart Growth initiatives and Green Infrastructure program (Weber and Wolf, 2000). Two programs that are relevant for protecting natural areas and farmland are the Rural Legacy Program and the GreenPrint Program. The Rural Legacy Program seeks to protect large, contiguous land areas of farmland, forest, and significant natural and cultural resources from sprawl development (Maryland Department of Natural Resources, 2003a). Through public/private partnerships, the program purchases easements and estates from willing landowners.

The GreenPrint Program is a more recent initiative aimed specifically at ecologically significant lands (Maryland Department of Natural Resources, 2003b). GreenPrint is designed to protect 10,000 acres per year for 5 years. The protected lands will comprise a major portion of what the state has identified as "green infrastructure." As part of an evolving terminology for greenways, Maryland seeks to protect "green hubs, green links, and the habitat highway." The US$ 35 million program was established in May 2001 with the objective of preserving "an extensive, intertwined network of land vital to long-term survival of our native plants and wildlife and industries dependent on clean environment and abundant natural resources" (Maryland Department of Natural Resources, 2003b).

With its progressive GreenPrint program, Maryland is mapping parkland, riparian corridors, working farmland and forest land, private open space (e.g. golf courses and cemeteries), lands protected by conservation easements, and vacant land. Both urban and urbanizing communities can follow the same process, and, in effect, discover the potential ecological greenway that already exists. Additional efforts are then needed to establish conservation status for lands not already protected.

4.5.3. Agricultural land preservation

Montgomery County, Maryland still has a significant amount of agricultural land (one-third of the total land area), and it has placed a high priority on preserving it (Montgomery County Department of Economic Development, 2003). Rural landowners can choose from one of five programs to protect their land, including a transfer of development rights (TDR) program.

In 2001, Loudoun County, Virginia adopted a new Revised General Plan that included the designation of rural policy areas (Loudoun County, 2001). Rural policy areas cover one-third of the county, and, in these locations, residential development will be limited so that the county's rural heritage can be preserved. Development restrictions aim to protect farmland, forest, and ecologically sensitive areas. Rural character is given a high priority, and this concern extends even to prohibitions against paving currently unpaved roads.

Agricultural land preservation programs such as these are not commonly thought of as biodiversity conservation measures, but they are a way to conserve a set of habitat types. The variety that agricultural land adds to ecological greenways benefits biodiversity.

While the Washington, DC metropolitan area shares physical characteristics with many other US cities, especially its sprawling suburban pattern, it does differ from many in the variety of land conservation programs enacted by its local governments. As this brief description demonstrates, local government policies and programs are already in place that could form the basis of ecological greenways, although they vary by political jurisdiction. With thoughtful planning, greenways could be developed that span the distance from outlying communities and agricultural land holdings to narrow stream valleys and upland habitat patches in the city center.

5. Conclusion

If you have ever lived in a city and were cognizant of your surroundings, you will recognize Cameron Run. Heavily developed portions of most major cities share some of the problems of Cameron Run. The opportunities for conserving biodiversity are not readily apparent, but in the course of this study some were discovered. First, Cameron Run does have an extensive network of forested riparian corridors. Analysis of forest cover resulted in the identification of patches that have the potential for interior habitat. These are the elements that could form an ecological greenway in the watershed. Stakeholder meetings that were part of the UrBIN study brought together individuals representing over 25 agencies and grassroots organizations. The level of interest in Cameron Run by local residents is certainly an opportunity. The demand for recreation, environmental education opportunities for school children and other residents, and the need for the experience and aesthetic enjoyment of "near nature" all point toward opportunities. Even the fact that new development in the watershed occurs as redevelopment holds promise. As sprawling warehouses are replaced by highrises, there is the possibility of re-creating green space where none has existed for many years. This idea of "reclaiming" green and open space is the foundation of the City of Alexandria's new open space plan (Rhodeside and Harwell Inc., 2002).

The Cameron Run case study reveals the relatively harsh conditions that urban flora and fauna confront. From a biodiversity perspective, the urban adapters and urban exploiters (McKinney, 2002) dominate, and special efforts have to be made to encourage greater species diversity. These efforts include the monumental task of invasives control. The trend in urban ecology research suggests that the knowledge base will grow and that efforts to conserve and restore urban biodiversity will be enhanced.

Despite some obvious constraints on ecological function, Cameron Run has provided important insights into biodiversity conservation in urban areas. Simply put, if you can conserve/restore biodiversity and restore ecological functions to any significant degree in Cameron Run, you can do it anywhere. Even if the goals are modest for such a watershed, the study calls several issues into focus: the fact that watersheds like Cameron Run are the norm for the majority of urban landscapes in the US, that these watersheds are an important part of a regional natural areas network, and that remnant natural areas in such places, however impacted or beset by invasive species they may be, are immensely valued by the urban population. Despite the prevalence of watersheds like Cameron Run, research and data regarding their ecological characteristics and functions are very limited.

The Cameron Run watershed is located in the urban core of a major city. The kind of nature that exists in such a highly urbanized context is very different from the natural areas found on undeveloped land in the urban fringe. While biodiversity is limited in the densely populated urban core, such areas still need to provide parks and protect floodplains and riparian corridors, and these protected landscapes have habitat value.

While urban biodiversity may be viewed as a scientific subject, managing it requires the integration of politics, planning, policy, and design. Stakeholder involvement is a key element of wildlands ecosystem management and is even more important in urban areas where people's perceptions, values, and personal stake in biodiversity protection are significant (Gobster and Westphal, 2004). Groups not only want a "say" in decisions, but they can play important roles in biodiversity protection through citizen monitoring, stream and riparian restoration programs, and private land stewardship. Greenway planning, design, and development are excellent ways to bring local stakeholders to the table. Providing amenities in dense urban areas is generally well-received, and therefore the greenway may provide a vehicle for introducing biodiversity concepts and issues. Promoting citizen interest and creating access to environmental education opportunities would be advantages that urban ecological greenways could offer.

Integrating objectives, tools, and programs is especially critical for conservation and restoration of urban biodiversity because few communities will dedicate large financial resources to biodiversity protection. However, significant resources are available for local, federal, and state programs of which the objectives are very compatible with urban biodiversity protection. These include water quality protection, stormwater management, floodplain management, stream restoration, parks and recreation, urban forestry, and greenway creation, among others. The set of Washington metropolitan area programs reviewed in this paper suggest such a convergence of objectives. The regulatory and non-regulatory tools used by these programs are also appropriate for urban biodiversity protection. They include overlay zoning, stormwater ordinances, land acquisition, conservation easements, education programs, and others. By partnering with these programs, urban biodiversity can be advanced with little or no additional financial investment. In the Cameron Run watershed, the existing biodiversity was dependent on existing local parks and conservation easement programs, the state Chesapeake Bay preservation program, and local government urban forestry efforts.

This paper has highlighted the connections between greenways, especially ecological greenways, and urban biodiversity conservation. The intersection of interests across multiple constituencies can be powerful. Currently, greenway advocates and conservation advocates do not always recognize the overlap of their interests. In cities, where people's recreational needs, aesthetic preferences and desire for contact with nature, and constrained natural areas necessarily co-occur, the opportunity is great for ecological greenways that benefit biodiversity.

Acknowledgements

Lief Horowitz and Rob Dietz of the US Geological Survey provided support for the UrBIN pilot study, and their guidance, as well as the financial support of USGS, is greatly appreciated. John Randolph, David Trauger, and Jeff Waldon of Virginia Polytechnic Institute & State University were the co-principal investigators on the project. Thanks also to Brian LeCouteur of the Metropolitan Washington Council of Governments for providing information on regional conservation and greenway initiatives.