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USING A BIOBLITZ TO CONNECT SPECIES RICHNESS AND ENVIRONMENTAL CHARACTERISTICS IN AN URBAN WATERSHED

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ABSTRACT: *Highly developed landscapes with intensive land use have fragmented natural systems, hydrologic impairments, and diminished biodiversity. This research project uses the BioBlitz approach, a one day educational outreach event, to evaluate ecosystems in an urban watershed and a greenway of the Elizabeth River in New Jersey. The results indicate a fragmented landscape with disconnected polygons of small patch sizes of forest and wetlands, less than 1 acre, compromising the ability of the natural landscape to support a diverse ecosystem. Species richness is diminished due to invasive species. While the "snap shot" approach of a BioBlitz is limited, when expanded to include environmental data in a geographic information system, the process can be of significant educational value to university faculty to develop future initiative to preserve the integrity of natural systems.*

Keywords: species richness; geographic information system; greenways; watersheds

INTRODUCTION

Watersheds are appropriate educational (Eflin and Shaeffer, 2006), social and ecological (Pickett *et al*.,1997; Revenga *et al*., 1998) units for evaluating human interaction with ecosystems and rivers. The spatial distributions of greenways that buffer rivers and streams provide significant opportunities to study invasive species and effects on biodiversity (Lackstrom and Stroup, 2009) and to evaluate and restore the riparian corridors (Gregory *et al*., 1991). In this research project, floral species richness is evaluated from data collected during a BioBlitz of the Elizabeth River Parkway, a greenway, in New Jersey in relationship to hydrologic characteristics of the watershed using a geographic information system (GIS).

GIS has emerged as a primary scientific tool for unifying rivers, ecology, biodiversity and the landscape, traditionally interdisciplinary research which includes data that are temporally and spatially connected (Ward *et al*., 2002, Green *at al*., 2006: 34; Huber *et al*., 2012). GIS provides the computational platform to evaluate watershed and riparian corridor characteristics that can be used by organizations for addressing environmental issues (Bourgeois-Calvin *et al*., 2004) and for watershed education (Smith *et al*., 2006). GIS analysis often includes the use of raster data from remote sensing and modeling to determine spatial characteristics (Wood and Smith, 2008) including new metrics to evaluate landscape fragmentation (Shuangcheng *et al*., 2009). Many digital databases use vector format to capture land use and land cover information derived from maps for GIS applications. GIS modeling efforts recently successfully simulated singular land use effects, such as sediment load, and indicator species, ie benthic macroinvertebrates, in an "eco-hydrologic approach to conservation policy" (Randhir and Hawes, 2009) but these studies are limited and do not provide definitive technological, scientific or policy solutions.

GIS provides the ability to examine the spatial heterogeneity and critical resources in urban ecosystem including human population, infrastructure and socio-economic drivers (Grove and Burch, 1997). Census block population and demographic data have been used to evaluate decision-making and environmental justice issues in cities (Pierce and Huber, 2002). Multiple municipalities and counties intersect the Elizabeth River watershed and the riparian corridor greenway which compromises the ability of stakeholders to develop consistent land use level policy and community action. The counties are managed by separate elected county freeholders with distinct decision making processes in managing land use, in particular, open space. Projects to preserve open spaces are not systematically planned or enacted leading to more fragmented landscapes.

The BioBlitz provides an informal educational opportunity for college students and the general public to engage in field work that identifies and documents species. The BioBlitz concept was put into practice in 1996 from scientists from the National Park Service and United States Geological Survey following an inventory of the Kenilworth Aquatic Gardens in Washington D.C. which inventoried approximately 1000 species in a 24 hour period May 31-June 1, 1996 (Patuxent Wildlife Research Center 1996). In Union County, New Jersey, the BioBlitz started in 2004 and has been conducted annually in June at different county-owned lands each year.

The data collected during the Bioblitz can best be categorized as a snap shot of the ecosystem and generally not considered an accurate measure of the biodiversity of an area given the temporal restriction and no measure of species abundance, only number of species. More elaborate evaluations of biodiversity exist using various statistical methods including hierarchical analysis (Noss, 1990) and geometrical indices (Campos and Isaza, 2009) and relationships to land use using multivariate statistical analyses (Bowman-Cutway and Ehrenfeld 2009) . We demonstrate that data on flora and watershed characteristics taken in one 24 hour period, despite its statistical limitations, can be used quantitatively and qualitatively to understand the overall health and integrity of fluvial ecosystems in the context of invasive species at both the watershed scale and along the riparian corridor.

BIODIVERSITY IN URBAN WATERSHEDS

Intensive land use and impermeable land create poor connectivity of riparian corridors resulting in impaired water quality (Ward and Tockner, 2001; Tong and Chen, 2002) and species richness (Bentrup and Kellerman, 2004). The natural landscapes of urban watersheds are highly fragmented resulting in small habitat patch sizes (Soule, 1991: p97). Additionally, urban river channels are often interrupted by dams (Graf, 2001) adversely impacting species abundance and identity and impairing water quality.

The establishment of invasive species in urban areas is occurring at unprecedented rates due to human activities that not only increase the number of introductions, but also provide disturbances to continue the rate of spread of many species (Smith and Knapp, 2001; Alberti *et al*., 2003). The transformation of land associated with urbanization is inextricably linked with biological invasion and human-altered ecosystems provide primary targets for invasions, while some land transformations themselves are driven by biological invasions (Vitousek *et al*., 1997). Species that are not native to a given area are described as “exotic” or “alien” but their origin alone does not make them undesirable from an ecological or economic perspective. Those species that modify species richness, abundance, or ecosystem function are generally called “weeds” or “invasive species”. Weeds are defined by the Weed Science Society of America as “any plant that is objectionable or interferes with the activities or welfare of man” (Hamill *et al*., 2004:1563). A weedy species may or may not be native to the region in which it expresses a weedy behavior, interfering with the values and activities of people (Hamill *et al*., 2004). Invasive species are not native to the ecosystem being considered and are those species whose introduction does, or is likely to, cause environmental or economic harm or harm to human health (Executive Order on Invasive Species, February 2000. National Management Plan: http://www.invasivespeciesinfo.gov/).

The relationship between land use / land cover, development and environmental impact in New Jersey has been modeled spatially using GIS (Hasse and Lathrop, 2003). More field data and testing are needed to confirm models, as in the multiple indicator analysis of a coastal plain stream analysis provided by Zampella *et a*l. (2006). The data collected during a BioBlitz may not fulfill all the needs of biologists, hydrologists, or engineers, however, field data should be encouraged in less traditional ways to encourage collaborations that support ecosystem and wildlife management and planning with the community and stakeholders (Decker *et al*., 2005). Urban ecology and watershed assessments require an understanding the biophysical environment and the societal context of the time (Cutter *et al*., 2002). Large river systems in North America have been particularly exploited (Dynesius and Nilsson, 1994) due to the proximity of cities and rivers historically.

METHODS

Data were collected by teams of scientists coordinated by environmental specialists from the Department of Parks and Community Renewal, Union County, New Jersey during a BioBlitz in 2008. The teams were led by university faculty and students, and naturalists, primarily from the general public, for the following groups of organisms: macro-invertebrates; macro-fungi; micro-fungi; fish; mammals; algae and mosses (macro-level); birds; plants, insects and herptiles (herpetofauna). A team was assembled for environmental modeling which included water temperature, pH and conductivity from a YSI mutli-probe with the locations marked using a Garmin eTrex GPS (accuracy ~5m). Data were collected beginning at 5:00 PM Eastern Daylight Time (EDT) on Friday June 14, 2008 and concluded on Saturday June 15, 2008 at 5:00 PM (EDT). The primary GIS analysis was provided by university faculty.

The BioBlitz was conducted within ~312 acres of parks owned by the County of Union in New Jersey located in the Elizabeth River Watershed (Figure 1). Parks include multiple land use / land cover classes including recreational land, forests, wetlands, and bodies of water including the Elizabeth River and some of its tributaries. The Kean University campus served as the host site for BioBlitz central to manage the data collection, reporting and

recording, and for a public awareness and outreach campaign. Plants were identified in four different sections: Section 1: Lightning Brook, a tributary located northwest of the Elizabeth River; Section 2: Conant Street at the junction of the West Branch with the Elizabeth River; Section 3: Kean University East Campus and nearby Ursino Lake, created by a dam that begins the channelization of the river and Section 4: Prudent Section of Elizabeth and Matano Park, where the head of tide is located and the estuarine habitat begins.

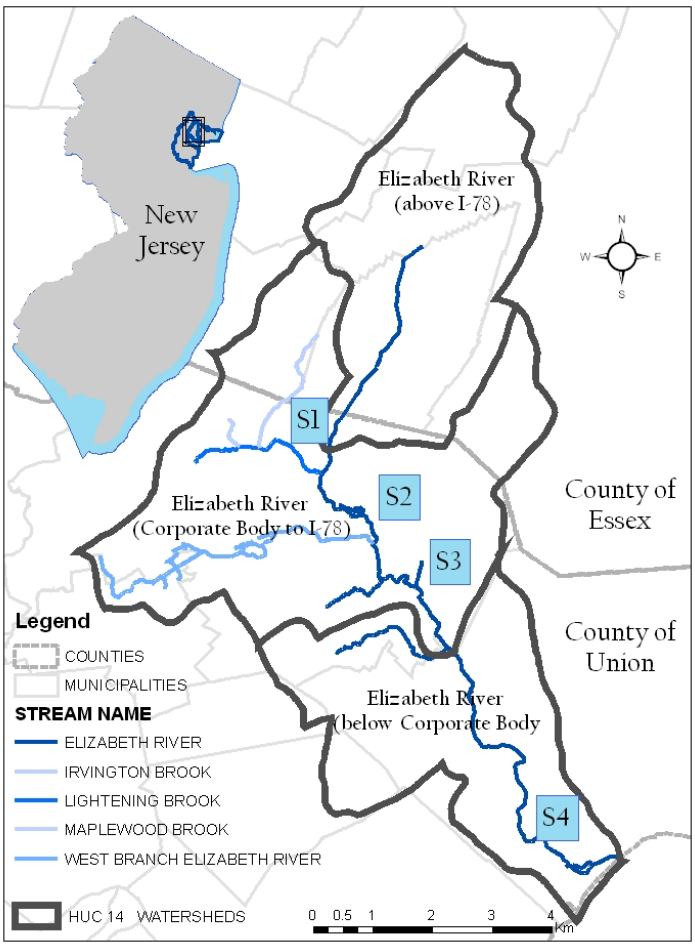

Figure 1: Elizabeth River watershed HUC 11 Code 02030104020, located in northeast New Jersey (inset). The watershed is divided by three HUC 14 boundaries. BioBlitz data was collected at four sections, labeled S1-S4, along the Elizabeth River Parkway.

Standard selection and statistics tools in ArcMAP GIS were used to evaluate land use/land cover, based on a 2002 database from the NJDEP for the watershed using the 11-digit Hydrologic Unit Code (HUC) for the Elizabeth River (HUC code 02030104020) and for analysis of riparian corridor characteristics and connectivity. Land Use Land Cover data classified with Anderson typology are used to determine percent impervious surface and patch sizes of forest, wetlands and urban for the watershed and along the river corridor. The Elizabeth River Watershed is then divided into three HUC-14 sub-watersheds, the Elizabeth River above Interstate 78 (HUC 02030104020010), the Elizabeth River from Corporate Body to Interstate 78 (HUC 02030104020020) and the Elizabeth River below Corporate Body (HUC 02030104020030) to compare patch size, floral species richness and water quality between the different sections of the BioBlitz. Land Use Land Cover data classified with Anderson

typology are used to determine percent impervious surface and patch sizes of forest, wetlands and urban for the watershed and along the river corridor.

WATERSHED ANALYSIS

The Elizabeth River is a 3rd order stream and estuary within tributaries starting at the northern boundary of the watershed at the foot of the Watchung Mountains. The estuary enters the Arthur Kill, part of the NY-NJ Harbor Estuary which reaches the Atlantic Ocean via Raritan Bay. The Elizabeth River watershed is identified by Hydrologic Unit Code 02030104. Twelve municipalities intersect the watershed with total population ranging from a low of 7,675 to a high of 273,546. The mean imperviousness based on the number and the percent imperviousness of each polygon is approximately 44%.

The land use and land cover for the Elizabeth River Watershed is primarily classified as Urban (13,630 acres) and 554 acres are classified as Forest (Figure2). The forest and wetland classes are evaluated for patch size to assess the connectivity of natural landscapes in the watershed and along the riparian corridor. For the watershed, 183 polygons classified as forest ranging in size from 0.000183 acres to 27.4 acres, mean polygon size 3.0 acres. The frequency distribution reveals that 140 polygons are 3.0 acres or less in area. For the watershed, 271 acres classified as wetlands consisting of 141 polygons classified as wetlands ranging in size from 0.012876 acres to 25.9 acres, mean polygon size 1.9 acres.

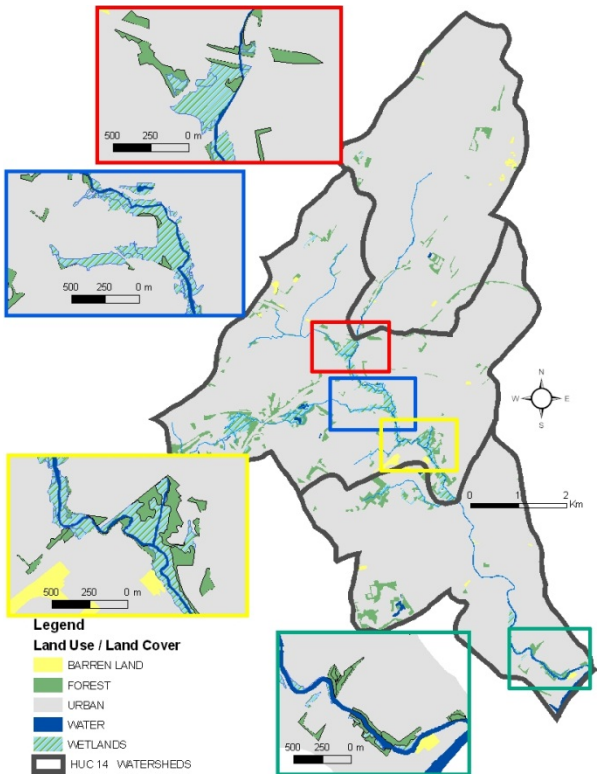

Figure 2: Land Use / Land Cover map for the Elizabeth River Watershed, showing the extent of urban land use and limited amount of forest and wetland cover. Forest and wetland patch sizes of less than one acre are also found within the BioBlitz sections (see inset maps; One acre ~ 4000m^2).

Along the riparian corridor, 224 polygons totaling 3068 acres of intersect streams. Polygons classified as water are removed leaving 141 polygons totaling 2993 acres. Out of these 141 polygons representing land that intersects the stream corridor 62 polygons totaling 2661 acres is urban, with a mean patch size of 43 acres. A total of 332 acres of forest and wetlands intersect streams. Forest polygons intersecting streams total 164 acres, 31

polygons, most of which are less than 0.5 acre, and 167 acres of wetlands intersect streams, 47 polygons, most of which are less than an 0.3 acre. The areas chosen for the BioBlitz contain some of the larger contiguous forest and wetlands along the riparian corridor (see inset maps in Figure 2), however, fragmented landscapes are still evident in each section and from section to section.

During the course of the 24-hour BioBlitz, 167 species of plants were found and identified comprising 29% of the species counted during the Elizabeth River Parkway Bioblitz . This total consisted of 88 species that are classified by the USDA Plants Database (Natural Resources Conservation Center 2011) to be native to the United States, and 79 are not native. A total of 98 (59%) of those species found in the Elizabeth River Parkway are classified as either "weedy" or "invasive" by the USDA Plants Database.

The species most prevalent throughout the sampled area are listed in Table 1. These eight species were found in each of the four sections of the BioBlitz that were surveyed and are all listed as either "weedy" or "invasive" by the USDA Plants Database. Five of the eight most ubiquitous species are not native to the United States, whereas three species are classified as native and weedy. A total of 75 plants were found in only one section during the BioBlitz , of which, 41 were native and 34 were non-native and 38 (51%) were classified as "weedy" or "invasive". Many wetland species, such as the common and poverty rush, *juncos effuses and juncas tenuis*, were unique to the Lightening Brook area. Pachysandra, *pachysandra terminalis*, a garden plant common in areas of residential land use, was only observed in the section of the Elizabeth River downstream of Lightening Brook.

The sections that had the highest number of species were forested riparian areas that had a diversity of habitats including wetland and upland ecosystems (Section 1: Lightening Book with 93 species and Section 2: Conant Street with 92 species). The section with the lowest plant diversity was the brackish wetland, Mattano Park (with 48 species), which was dominated by a few species including the native *Juncus gerardii* (saltmeadow rush), and the locally invasive *Phragmites australis* (common reed).

Table 1: Plant species data for Elizabeth River Parkway BioBlitz.

Common Name	*Scientific name*	*Family*	*Life form*	*Origin*
Wild Garlic	*Allium vineale*	Liliaceae	Forb	Non-native invasive
Blackcherry	*Prunus serotina*	Rosaceae	Tree	Native, weedy
Norway Maple	*Acer platanoides*	Aceraceae	Tree	Non-native invasive
Black Locust	*Robinia pseudoacacia*	Fabaceae	Tree	Native, weedy
Eastern Poison Ivy	*Toxicodendron radicans*	Anacardiaceae	Vine	Native, weedy
Multiflora Rosa	*Rosa multiflora*	Rosaceae	Shrub	Non-native invasive
Japanese Knotweed	*Polygonum cuspidatum*	Polygonaceae	Forb	Non-native invasive
White Mulberry	*Morus alba*	Moraceae	Tree	Non-native invasive

Water quality in the West Branch of the Elizabeth River is impaired with fecal coliform and total phosphorus exceeding acceptable fresh water limits for healthy stream ecosystems (Dobosiewicz, 2007). Water quality was evaluated at ten sites along the Elizabeth River and some of its tributaries. All sites were visited twice after the BioBlitz and the measurements are consistent with the "snap shot" during the BioBlitz. Two sites were in the estuarine environment and eight sites in the fresh water fluvial environment. Temperature, conductivity, pH, dissolved oxygen and ORP were measured using a multi-probe system, the YSI 556 MPS. The dissolved oxygen and ORP measurements are not reported because the values were outside realistic expectations and considered unreliable. Table 2 includes the site locations and the water quality variables. The acceptable level for pH, to support a diverse ecosystem, in a fresh water stream is 6.5-8.0 (Standard Units) (EPA 2011). The average (arithmetic mean) for pH at all ten sites was 7.3960 which is within the EPA criteria for a healthy stream. The only site close to the threshold (pH=6.64) was in the estuarine environment near Matano Park (S4) and should be evaluated in the future. A large outfall pipe enters the stream near the sampling site

The acceptable level for conductivity to support a diverse ecosystem in a fresh water stream is 0.150-0.500 mS/cm (millisiemens/centimeter) with streams across the nation reporting in the range of 0.050 – 1.50 mS/cm (EPA 2011). Conductivity measures ions dissolved in the stream, which can include ammonia, nitrate, nitrite and phosphate. In fresh water environments, conductivity can be used as a non-specific surrogate for non-point source

pollution and nutrient levels because the water does not contain significant salt content. The average (arithmetic mean) for the eight fresh water sites was 0.8079 mS/cm, within the range of values in the nation but exceeding the threshold for a healthy stream. The highest value, 0.896 mS/cm, was found at the upstream end of the Elizabeth River (S1-S2). The values remain high downstream however there is a decreasing trend in the values to a low of 0.817 through the Elizabeth River from Corporate Body to Interstate 78 sub-watershed (S3). The two lowest values, 0.651 and 0.688 mS/cm are found in the Lightening Brook tributary (S1), 0.651 and 0.688 mS/cm. The high conductivity values at Matano Park (24.68mS/cm) and the Elizabeth Marina (32.63mS/cm) are typical of brackish (part fresh part salty) estuarine environments (S4) and cannot be used as a surrogate for non-point source pollution and nutrients levels. We have begun collecting the brackish water data to help evaluate invasive species in the estuarine and specific tolerances to salinity.

Table 2. Temperature, conductivity and pH for water sampling sites in the Elizabeth River.

BioBlitz Locations S1-S4 (upstream to downstream)	*Temperature (Celsius)*	*Conductivity (mS/cm)*	*pH (STD Units)*	*Latitude (DD)*	*Longitude (DD)*
Lightning Brook (S1)	22.50	0.651	7.73	40.7060	-74.2607
Lightning Brook (S1)	21.70	0.688	7.52	40.7033	-74.2520
Elizabeth River (S1-S2)	20.74	0.896	7.37	40.7072	-74.2472
Elizabeth River (S1-S2)	21.70	0.883	7.64	40.7041	-74.2471
Elizabeth River (S2)	19.28	0.887	7.29	40.6978	-74.2465
Elizabeth River (S2)	22.85	0.822	7.35	40.6899	-74.2378
Elizabeth River (S3)	23.45	0.819	7.59	40.6809	-74.2270
Elizabeth River- Ursino Lake (S3)	24.13	0.817	7.50	40.6775	-74.2254
Elizabeth River/ Estuary (S4)	21.73	24.68	6.64	40.6575	-74.2006
Elizabeth River / Estuary (S4)	21.63	32.63	7.33	40.6467	-74.1855

DISCUSSION

The Elizabeth River watershed and river parkway is distinctly urbanized with high percentages of impervious surface, fragmented natural landscapes and impaired water quality. The overall hydrologic characteristics of the watershed contribute to diminishing biodiversity. The Lightening Brook section of the BioBlitz had the highest number of plants with significant number of wetlands species only found in that section such as the common and poverty rush and the lowest observed conductivity in the stream. This supports previous research that plant diversity of riparian zones uniquely adapts to environmental characteristics and dynamics of fluctuating water conditions (Aronson *et al*., 2004). Riparian corridors typically contain disproportionately high species richness by virtue of their role in facilitating the movement of organisms throughout the system (Hood and Naiman, 2000). Previous BioBlitz events in Union County in suburban locations with contiguous habitat had higher overall species richness, 683 different species (Union County BioBlitz 2007) than the Elizabeth River Parkway. The Elizabeth River Watershed is densely populated with intense urban activity and high imperviousness (eg: cities, industrial zoning versus suburban and commercial zoning) and natural landscapes that are small and poorly connected within the watershed and along the riparian corridor. Human development has led to impaired water quality as observed in the highest conductivity value observed at the outlet of the Elizabeth River (above Route 78) watershed with the smallest patches of forest and wetlands. High conductivity measurements are likely due to non-source point pollution that limits riparian biodiversity. Non-native species constitute high percentages of the species richness throughout Union County and threaten the diversity of native species. Human development in the watershed exacerbates the loss of biodiversity by promulgating hearty and opportunistic invasive species creating a monoculture that out-competes natural riparian corridor habitat despite the tendency of river systems to promote biodiversity. Specifically, the relationship between invasive species and specific land use has been documented for wetlands in the Arthur Kill watershed, a regional watershed including the Elizabeth and Rahway River watersheds,

by Bowman-Cutway and Ehrenfeld (2009). Invasive species are more abundant in freshwater wetlands in and near residential areas than in brackish wetlands in industrial sites.

In New Jersey, riparian vegetation has been analyzed in relation to increasing urbanization. Aronson *et al*. (2004) state: "Studies of riparian vegetation patterns provide a valuable way of quantifying the increasingly changes landscapes of urbanizing regions". Disturbance has been correlated with invasion by non-native species in a variety of habitats (Hood and Naiman, 2000) and the disturbances linked to urbanization have become prevalent factors in New Jersey ecosystems (Aronson et al., 2004). The biological effects of urbanization in this state include not only large numbers of non-native species present, but also the numerous sources for re-invasion of exotic species (Ehrenfeld, 2000).

The plant results from this study indicate that those species with the most widespread distributions throughout the Elizabeth River Parkway were considered weedy. All but three of those ubiquitous species are not native to this region. The species of greatest concern in riparian areas of Union County are *Rosa multiflora* and *Polygonum cuspidatum*, both of which were found throughout the Elizabeth River Parkway. Efforts are currently underway to determine the most effective means of controlling these species in Union County because of their aggressive nature in out-competing and rapidly displacing native species, creating monocultures with diminished biodiversity. Perhaps the richness of native species may eventually increase through continued efforts of limiting the cover of these weedy species and reintroducing, monitoring, and maintaining the site for native vegetation.

Overall species richness of an area might increase under intermediate levels of urbanization, at which many native and nonnative species thrive. Diversity typically declines, however, as urbanization intensifies (Blair, 1996; Alberti *et al*., 2003). The exceptionally high levels of urbanization that result in declines in species richness are likely represented by the region of interest in this study. Union County, New Jersey is one of the most densely populated counties in the United States (US Census Bureau, 2000).

Species richness is associated with the connectivity of habitat and intact river corridors. The Elizabeth River Parkway is highly fragmented and species richness is low. Patch sizes are smaller than the edge effects of adjacent urban land uses and therefore natural landscapes do not function as natural forest and wetlands. Circular patch sizes less than 10 ha (25 acres) circular patch have 100% edge effect and 20ha (50 acres) a 95% edge effect (Lindenmayer and Franklin, 2002: 144)). Edge effects are evident in the Elizabeth River watershed along the riparian corridor where forest and wetland polygons are predominantly smaller than 10ha (25 acres), 0.5 acre and 0.3 acre respectively in relation to larger size surrounding urban polygons. Consequently, the edge effect of the urban polygon may extend though the entire forest or wetland polygons. High levels of fragmentation impair biodiversity promoting exotic invasive species that create monocultures along the riparian corridor and throughout much of the "natural" areas of the watersheds. The abundance of *Polygonum cuspidatum along* the Elizabeth River greenway creates such a monoculture.

CONCLUSION

The BioBlitz provides an opportunity for naturalists and the community to collect data about local environments that otherwise would not likely be known. This event creates a context to engage higher education science faculty and students in outreach that can be scholarly, fun and beneficial to planning. Such collaborative programming can be beneficial to managing species in urban ecosystems (Curtis *et al*., 2005). The educational benefits include providing informal education and outreach to the county and stakeholders in our community and fostering student participation in outreach and research at the undergraduate level, establishing a relationships with our local watershed association and the future development of service learning opportunities on the university campus. The scientific benefits of the BioBlitz include identifying rare and unique species, documenting species occurrence, media attention, natural history synergy, agency and scientific community bridge building and estimating species richness (Patuxent Wildlife Research Center 1996). The process can benefit other indices by providing the field work needed support models and indices (Campos and Isaza, 2009).

Natural riparian corridors are diverse and rich in species. High population density, extensive impervious surfaces and fragmented natural habitat from urbanization within the Elizabeth River watershed and along the riparian corridor of the Elizabeth River result in impaired water quality and promote monocultures of invasive species that out-compete the natural flora and fauna that would lead to high species richness and abundance. While significant work on landscape fragmentation exists (Shuangcheng *et al*., 2009), viable research is lacking that couples field data on biodiversity, watershed analysis and GIS to develop a better understanding of the health of urban ecosystems, in particular, those associated with watersheds, river corridors, estuaries, and the relationship between water quality and invasive plant species. GIS provides a manageable and transferable platform for

descriptive spatial and statistical analyses of biodiversity and landscape characteristics, ecotones, connectivity, and fragmentation for the river/estuary corridors in an urban ecosystem that can provide much need baseline environmental and ecology data for urban ecosystems.

Union County continues to support annual BioBlit events. The BioBlitz was held in less developed and more topographically diverse areas of the county in 2009 and 2011, yielding 652 and 635 species respectively.. In 2010, the BioBlitz was held in a primarily suburban location yielding a total count of 601 species, consistent with the tendency of identifying fewer species in areas with more urban than forest and wetland landscapes. Continuing projects are examining the spatial trends across the county to evaluate the possibilities for native species restoration.

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