URBAN VACANT LOTS: ECOLOGICAL QUALITY AND SOCIAL OPPORTUNITIES IN BALTIMORE, MARYLAND

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CHRISTINE C. BRODSKY

Dr. Charles Nilon, Dissertation Supervisor

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

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Presented by Christine C. Brodsky,

a candidate for the degree of Doctor of Philosophy,

and hereby certify that, in their opinion, it is worthy of acceptance.

____

Dr. Charles H. Nilon
School of Natural Resources, University of Missouri

____

Dr. Dylan C. Kesler
School of Natural Resources, University of Missouri

____

Dr. Frank R. Thompson
United States Forest Service, University of Missouri

____

Dr. Christopher K. Wikle
Department of Statistics, University of Missouri

____

Dr. Paige S. Warren
Department of Environmental Conservation, University of Massachusetts

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Description of Chapters

The chapters of this dissertation were written as independent manuscripts, with the intention to submit to peer-reviewed journals. For this dissertation, I have included an introduction and conclusion to tie together the overarching research question and findings. Because each chapter was written as an independent manuscript, some portions of their introductions, methods, and references may overlap in content. Each chapter is also followed by its own list of references in the citation style of the intended journal. The dissertation was also written using plural proper nouns to indicate co-authors.

Abstract

Urban vacant lots are a ubiquitous feature in cities worldwide and quickly are becoming a topic of discussion regarding their ecological and social impacts. Vacant lots are typically viewed as discarded spaces within the city and locations for crime, trash, and overgrown vegetation. I suggest, however, that vacant lots are important informal greenspaces for bird habitat and potential locations for social cohesion. I visited 150 vacant lots over three years in Baltimore, Maryland to understand the following objectives: 1) assess the current context and uses of vacant lots, 2) determine the quality of these informal greenspaces as bird habitat, and 3) determine the social implications of vacant lots via the community's perception, and evaluation of possible environmental justice links to vacant lot distribution and composition. In order to determine habitat quality of vacant lots, I conducted community multivariate analyses, N-mixture abundance modeling, nest success modeling, and a body condition analysis for common songbirds. To describe the social implications of vacant lots, I distributed a perception survey to local residents, in addition to a spatial analysis to determine in which neighborhoods vacant lots are clustered and the natural features of such lots. I found that vacant lots have a high variation in their setting and natural features, which provided multiple opportunities for their current and future uses for local residents. Vacant lots also provided important bird habitat features. Specifically, vacant lots within areas of high tree cover and those with closed canopies best supported bird communities and populations, while lots with high shrub densities best supported nesting success. Socially, residents preferred vacant lots with more green features and clear management efforts; and vacant lots were found more often in Hispanic neighborhoods, while lots in poor, African American neighborhoods

had fewer green features. Overall, I found that vacant lots offer enormous potential for supporting native bird communities and they are also important spaces for residents within their neighborhoods. Management efforts should thus continue to promote diverse bird communities along with ways to satisfy the public's needs. Across my studies, I would recommend management efforts within vacant lots to focus on providing large areas of open space for perceived safety and neatness, planting trees throughout the site, and incorporating areas with dense shrub vegetation. These actions could have the greatest impacts for vacant lots within neighborhoods with high Hispanic, African American, and young family populations, as those groups were disproportionately exposed to more vacant lots with fewer green features.

Introduction

Vacant lots have a ubiquitous presence in cities around the country; however, few studies have explored their ecological implications (Burkholder 2012). Typically viewed as a social problem with associations to crime, trash, overgrown vegetation, and abandonment, vacant lots are generally thought to have a negative presence in many city neighborhoods (Accordino and Johnson 2000). However, vacant lots may instead serve as informal greenspaces and provide locations to improve urban biodiversity and ecosystem services, while increasing social capital (Kremer et al. 2013, Nassauer and Raskin 2014, Rupprecht et al. 2015). I investigated vacant lots for their habitat features, specifically for the bird community, while researching how vacant lots are perceived by urban residents and their environmental justice implications. My research was located in Baltimore, Maryland within the construct of the Baltimore Ecosystem Study, a long-term ecological research project.

In Chapter 1, I described the overwhelming variation in vacant lots, in regard to their context and compositional patterns throughout Baltimore. I found that vacant lots were not all dilapidated, small plots of useless land. Here, I summarized the different kinds of settings, vegetation sources, biotic contents, and uses of vacant lots found within Baltimore. I plan to submit this paper to *Landscape Journal*.

In the following two chapters, I discuss the ecological impacts of vacant lots by assessing how bird populations and communities use these spaces. In Chapter 2, I evaluated how birds responded to the habitat features of vacant lots across multiple scales. In this chapter, I used both multivariate analysis of the bird community and population abundance modeling to determine at which scale management should occur to promote diverse urban bird communities. Then in Chapter 3, I further explored the ecological trends of nesting success and body condition of common bird species as indicators of habitat quality across vacant lots. I plan to submit Chapter 2 to *Urban Ecosystems* and Chapter 3 to the *Wildlife Society Bulletin*.

Because humans and the environment are intrinsically linked within cities, I also explored the social and justice implications of vacant lots within Chapters 4 and 5. In Chapter 4, I conducted a social survey in order to determine how residents active within community and ecological organizations perceived vacant lots. I plan to submit Chapter 4 to *Human Dimensions of Wildlife*. In my last chapter, I analyzed how the distribution and composition of vacant lots represents an environmental injustice regarding unequal access to vacant greenspaces. This chapter is currently in review in *Urban Ecosystems*.

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Chapter 1: Sources of Urban Opportunity: Vacant Land Characteristics and Uses in Baltimore, Maryland

Abstract

When most people hear the term "vacant lot", the mind goes to a dilapidated, small urban lot, devoid of promise. We suggest this perception needs to be shifted instead to locations of urban potential, because vacant lots provide broad ecological, social and economic opportunities within neighborhoods. We evaluated the role of context and compositional patterns of vacant lots in Baltimore, in regard to their use. With their large variation, current and future uses of vacant lots are extensive, yet generally dependent on the lot's setting, vegetation sources, and biotic composition. The opportunities are plentiful regarding the use of vacant lots as greenspaces within a city, as they offer spaces for ecological conservation, community cohesion, and future economic development.

Introduction

Even with the global increase in urbanization, populations within many urban cores have been on a slow decline between 1950 and 2010 (Hall 2010; Seto, Güneralp, and Hutyra 2012). The loss of business, deindustrialization, and residential movement into the suburban periphery over this period has resulted in a sudden increase in urban vacant lands. Out of 83 cities across the United States, 15% of a city's land was classified as vacant in 2000 (Pagano and Bowman 2000), and urban vacancies have risen over the past decade, aided by the resulting impacts of the foreclosure crisis (Mallach 2010; Németh and Langhorst 2014). Some cities have an overabundance of vacant land, such as Detroit where approximately one third of the city is vacant, while others have less. However, the presence of vacant land is a ubiquitous feature in all cities, regardless of its abundance (Pagano and Bowman 2000).

The term “vacant land” generally applies to any vacant parcel within the city, whereas the term “vacant lot” typically refers to parcels located within residential areas of the city, rather than vacant industrial lands, which are referred to as “brownfields”. The ecological and social properties of vacant lots within Baltimore, Maryland are highlighted here as a case study. Vacant lots are highly exposed to residents and found in most, if not all residential neighborhoods within Baltimore in varying degrees (Rega-Brodsky and Nilon in review).

Why should we care about these discarded scraps of the urban matrix? Public interest and policies usually focus upon built or heavily landscaped sections of the urban landscape. Thus, vacant lots are unique spaces that fall between the cracks and are typically labeled as wasted and underappreciated land. Many residents view these lots as problems to be fixed, eyesores, uninviting, a waste of space, and places to attract illegal activities (Accordino and Johnson 2000; Németh and Langhorst 2014). Even with this complex set of issues, we would argue that vacant lots are valuable neighborhood assets and prime locations for urban renewal (Burkholder 2012; Corbin 2003). Specifically, we suggest that vacant lots should be viewed in the context of their ecological, social, and economic opportunities.

Context of Urban Vacant Lots

Vacant lots in cities are surrounded by a complex set of issues. Because vacant lots span across urban landscapes and socioeconomic areas, one vacant lot is considerably different in its context and composition, as compared to another in an adjacent neighborhood.

Issues surrounding vacant lots are thus dynamic, resulting from their location, land use legacy, and time since abandonment, leading to unique structures, sources of vegetation, and biotic features (Nassauer and Raskin 2014). Most literature on urban vacant lots focuses on the lot's ecology, social, and economic impacts within neighborhoods and across cities. Within each of these contexts, we would argue that vacant lots can be beneficial to the neighborhood and as such, should be viewed as opportunities for management.

Urban vacant lots are one major component of informal urban greenspaces (Rupprecht, Byrne, et al. 2015). These lands contain a major amount of green infrastructure and above-ground biomass, providing many ecosystem services. For example, vacant lots serve as locations for air pollution removal, carbon sequestration and storage (Kim, Miller, and Nowak 2015; McPhearson, Kremer, and Hamstead 2013), storm water infiltration (Németh and Langhorst 2014), ambient temperature reduction (McPhearson, Kremer, and Hamstead 2013), wildlife habitat (Rega, Nilon, and Warren 2015), and much more. From our concurrent studies of vacant lots for bird habitat, we have found that the urban bird community uses these sites extensively for habitat resources (Chapter 2) and nesting opportunities (Chapter 3).

Socially, vacant lots serve as an opportunity for community empowerment and neighborhood activities. Transforming or maintaining green features of vacant lots generally improve the neighborhood and empower its residents via area beautification, food provisioning, and reduction of crime (Branas, Cheney, et al. 2011; Choo 2011; Garvin, Cannuscio, and Branas 2013; Nassauer and Raskin 2014). Additionally, when vacant lots are managed and visible indicators of care are present (Nassauer 1995; 2011), residents tend to take better care of their neighborhoods. For example, the Philadelphia Horticulture Society conducted a vacant lot greening program which cleaned and managed vacant lots, which resulted in less crime and vandalism, as compared to control vacant lots (Branas, Cheney, et al. 2011).

Community gardens are another popular social use for vacant lots and can vary extensively, from a few garden plots to a total lot transformation, like the Sunflower Village (Figure 1). Flower gardens are the most popular, but urban agriculture has quickly become a popular use of vacant lots (McPhearson, Kremer, and Hamstead 2013). Small-scale community farms can provide fresh fruits and vegetables to inner-city "food deserts" where opportunities for fresh produce are otherwise limited (Choo 2011). This strategy for vacant lot improvement may not be possible for all lots, as some lot may contain soil contaminants making food production unsafe.

Greening vacant lots or maintaining the present vegetation is highly beneficial for the neighborhood socially and economically. Since vacant land itself represents the plight of the neighborhood and city as a whole, active use of vacant lots, or perceived use, is instrumental to improving the negative view of vacancy (Heckert and Mennis 2012). Most negative words used to describe vacant lots are the result of the lack of perceived management at the site (Chapter 4). As described by the "broken windows" theory, visible signs of neglect and decay in unmanaged vacant lots promote feeling of neighborhood instability (Wilson and Kelling 1982), driving down property values. When compared with other control neighborhoods, property values increased at a greater rate in neighborhoods with greened vacant lots (Heckert and Mennis 2012). Use of vacant lots, either in an ecological or social construct, would thus promote the economic improvement to the neighborhood and city as a whole, if promoted widely. This would then result in increased residential or commercial building and economic growth, consequently decreasing the total amount of vacant land, while cherishing the lots that were adopted by the community.

Objectives

As some cities deal with the abundance of vacant lots, urban land managers should start to focus on the benefits of vacant lots in order to maximize such benefits for the community. Prior to such management efforts, understanding the setting and biotic characteristics of vacant lots in the city is extremely important regarding the lots' ecological and social importance, and future uses. The goal of our research was to evaluate the role of context and compositional patterns of vacant lots in Baltimore, in regard to their current and future uses. By describing vacant lot features and uses with examples from Baltimore, we sought to answer the following questions: How do vacant lots vary in terms of their settings, vegetation sources, and biotic characteristics? What contextual considerations must be made regarding the lot's current and potential future uses as urban greenspaces?

Study Area

Considered a shrinking city, Baltimore has lost 34% of its population since its peak in 1950 (U.S. Census Bureau 2014; Pallagst et al. 2015) due to loss of manufacturing jobs, increasing crime rates, and movement into the adjacent county. This loss of population and jobs since 1950 caused an increase in vacant lots throughout the city to its current level of 16,500 vacant parcels, comprising over 1,700 hectares (Figure 2). A vacant lot is defined by the Baltimore City Code Article 11 § 1 (2013) as "an individual parcel of real property that is unimproved by an assessed building" or any parcel of land that has the potential to be built upon. Vacant lots range in size, shape, and use across the city (Figure 3).

Methods

We randomly selected 150 vacant lots to evaluate for this study (Figure 2). Each lot was selected randomly for a bird composition and nesting study, as a part of the Baltimore Ecosystem Study Long Term Ecological Research (LTER) project. Sites were visited at least weekly during May – July of 2013 – 2015.

During the site visits, we photographed the vacant lot, spoke with nearby residents, explored the entirety of the lot, monitored bird activity, and measured vegetation. Within each lot, we sampled vegetation within three 0.04 ha plots spaced evenly 20 m from the lot's center (0°, 120°, 240°) to capture the lot's heterogeneous vegetation composition and structure. We measured 17 vegetation variables on each plot: canopy cover, canopy height, shrub density, ground cover composition and height, and tree species richness, count, and diameter-at-breast-height. Measurements from the three plots were averaged for one site value.

We identified unique classes of vacant lots, regarding the lot's setting, biota, and resulting uses (Francis 2001). In order to classify vacant lots by their setting, we used descriptions provided by Spirn and Pollo (1991) as an initial guideline, and then described unique settings and uses found within Baltimore. We amalgamated the 150 lots into six settings: vacant block, inner block, corner lot, missing tooth, suburban yard, and waysides. A vacant block was categorized when an entire city block (> 0.4 ha) was vacant or when a vacant lot was completely bordered by a roadway. Inner vacant blocks were those surrounded by a square of rowhomes within a city block. Corner lots were lots adjacent to buildings, located at the corner of a city block. Missing tooth vacant lots were those found within rowhome neighborhoods in which a vacant lot was located between two buildings. Suburban yards were vacant lots located within suburban residential communities, between private landowners, single family homes, or other residential units. Waysides were vacant lots bordering roadsides or railway lines.

We used categorizations provided by Zipperer and colleagues (1997) to determine the lot's vegetation source. By evaluating the vegetation composition and structure of the lot, we categorized each lot by their observed vegetation sources: emergent, planted and remnant as described by Zipperer et al. (1997). Emergent vacant lots were those that were dominated by pioneer and small diameter trees, only recently cleared during site development. Planted lots were those with clear gardening efforts, usually with planted trees, flower gardens, and intensively managed (i.e. having grass cover). Remnant lots existed before development of the area, usually with large diameter trees and minimal lot management (Zipperer et al. 1997). One vacant lot may have sections of different vegetation sources due to periodic removal of development surrounding the lot.

We determined the current use of vacant lots through observations during each site visit, and noted key structural features that indicated how the lot was used. From our observations, we identified eight vacant lot uses: passing through, meeting places, parking lot, playground and recreation, personal gardening, forested paths and nature areas, community gardens and urban agriculture, and no apparent use.

Results

The ecological, social, and economic context of vacant lots was directly dependent on the lot's physical and biotic characteristics. Many kinds of vacant lots existed within Baltimore, varying extensively by their settings, vegetation sources, and biota. The combination of these features results in distinct lots that represent different opportunities and limitations. The following sections elaborate on these variations with example lots found within Baltimore.

Vacant Lot Settings

Vacant Block

The most common vacant lot setting was the vacant block, in which an entire block is vacant (Figure 4). The size of vacant blocks can range from an entire city block of an acre, or even greater (Spirn and Pollo 1991). Vacant blocks are usually surrounded by roads, delineating the site. Many times, blocks are left vacant when land parcels are oddly shaped, contain a steep hill, or located in a floodplain or on other soil instabilities (Vessel and Wong 1987). In vacant brownfields, development may also not occur due to soil toxicity or other lingering industrial pollution. Even though vacant blocks are only present on land considered unbuildable or in areas with extreme economic declines, they are the most common vacant lot in Baltimore (Table 1).

Depending on the location within the city and the circumstances surrounding their vacancy, the contents and use of vacant blocks are highly variable. If the block is vacant due to unbuildable land and covers a large area, the lot has often been vacant for some time resulting in a remnant forest stand. These forest stands are highly valuable ecologically (Kim, Miller, and Nowak, 2015), however some residents may not favor those vacant parcels due to their density (Chapter 4). When small and oddly shaped, such as a triangular lot in downtown Baltimore, these lots are often mowed and planted with a handful of shrubs or trees for decorative purposes. As with corner lots, city bus stops often occur on these vacant blocks. Other small and triangular blocks in East Baltimore have been converted to community gardens and small park-like lots with benches and pathways with efforts from organizations such as Parks and People, Baltimore Office of Sustainability, Baltimore Green Space, and other groups.

Otherwise, when the vacant block is buildable, these lots are extremely valuable for future economic growth and only recently became vacant due to demolition or clearing for building. Potential for vacant lot use is greatest in vacant blocks, as a large amount of land (> 0.4 ha) sits unused in a typically dense residential area.

Inner Blocks

The second most common kind of vacant lots in Baltimore is the vacant inner block (Table 1). This kind of vacant lot occurs within the interior of a block, surrounded by rowhomes. Baltimore's rowhouse architecture has characterized the city over the past 200 years (Hayward and Belfoure 1999). Two kinds of rowhomes were built in block squares in order to create a walkable community and provide homes for people across social and economic classes in the early 19th century. Lined along the main street, three-story rowhomes were occupied by the mid-upper classes, while lower-class residents lived in smaller two-story "alley" rowhomes built behind the larger, along the block's interior alley (Hayward and Belfoure 1999). Over time, these smaller interior units were demolished and made into inner block parks during the urban renewal of the 1960s. Most of these inner block parks have since been abandoned (Figure 5). Especially in neighborhoods of West and East Baltimore, the presence of inner block vacant lots are extensive as the majority of housing still consists of rowhomes situated in square blocks.

The size of these inner blocks averaged 0.15 ha (1500 m^2). The contents of vacant inner block are highly variable and greatly dependent on the residents within the block. One common feature for most vacant inner blocks is the presence of parked cars, as a small drivable alleyway is often intersecting the lot. Beyond the presence of parked cars, these vacant lots can range in use and contents from play areas, hanging clotheslines, small personal or community gardens, sites for illegally discarded trash, or used as extensions of the resident's backyard. Vegetation composition is typically dominated by lawn, usually surrounded by shrubs and trees around the periphery.

Corner Lots

Corner lots are also quite prominent within the neighborhoods dominated by rowhomes, but they are found throughout the city. This type of vacant lot occurs when there is a lack of building at the corner of the block, adjacent to buildings on each side. These sites are typically open, have ample sunlight, dominated by lawn, and usually a few street trees. As these sites are extremely exposed to traffic and pedestrians, clear sightlines are preferred for safety (Chapter 4). Thus, vacant corner lots are usually targeted by city management for mowing efforts, even though Baltimore's Department of Public Works is responsible for maintaining city-owned vacant lots by mowing and cleaning the site every three weeks. Located conveniently at an intersection, many of these vacant corner lots are locations for bus stops and other social interactions.

Sizes of corner lots vary extensively with the number of vacant parcels present at the street corner. In rowhome blocks, these lots are often narrow and long when multiple parcels are vacant, adjacent to the windowless exteriors of the rowhome. In other impoverished neighborhoods, many of these lots occur next to vacant homes, with the exposed exterior typically collapsing inward, creating a serious safety concern. Many corner lots also neighbor one another (Figure 6), resulting in a large open area along the roadway.

Missing Tooth Lots

A “missing tooth” vacant lot is one that is created by a vacancy closely surrounded by standing buildings, resulting in defined gaps (Spirn and Pollio 1991). This kind of vacant lot is located within rowhome neighborhoods, as compared to neighborhoods with single family homes where vacancies are considered “suburban yards”, extending from a homeowner’s property.

Similar to corner lots, the size and shape of the vacant missing tooth is dependent upon the number of vacant parcels within the block (Figure 7). With one or two vacant parcels in rowhome-dominated blocks, these lots are long and narrow. This kind of missing tooth lot is often unused, as it is heavily shaded, without clear sightlines, and generally promotes feelings of personal danger, especially if the surrounding buildings are also vacant. Most missing tooth lots are not singular parcels, and instead are connected to vacant corner or inner block lots, extending the vacancy throughout the block in a Swiss cheese-type pattern (Spirn and Pollio 1991). If a block has multiple missing teeth and a vacant inner block, opportunities are much greater for its use as more space is open for larger revitalization projects.

Vacant Suburban Yards

Moving away from the rowhouse-dominated neighborhoods of Baltimore, many vacant lots within the suburban northern and eastern areas of the city are commonly absorbed by residents as extensions of their backyards (Figure 8). These kind of vacant lots are dispersed across residential areas (Rega-Brodsky and Nilon in review), and they are typically adjacent to golf courses, graveyards, forested parks, or water bodies. The majority of these vacant lots are similar in structure to the "missing tooth" vacant lots found within the city block's rowhome. However, home lots in areas further from the city center are larger and contain either single family homes or duplexes. Many of these vacant lots are ripe for future residential development, mainly sitting empty with "For Sale" signs. When not in use, it is typical for neighboring homeowners to become caretakers of these lots to avoid a weedy and disheveled lot next door. Conversely, other residents take the opportunity of a neighboring vacant lot to discard trash, create leaf piles, and park old cars.

Some vacant suburban lots have remained vacant for a number of years, resulting in forested patches or extensions of neighboring city parks and greenspaces. As with some vacant blocks, many of these suburban vacant lots are considered subprime building locations, as they are along floodplains, steep hills, or other unstable conditions (Northam 1971; Spirn and Pollio 1991).

Vacant Waysides

The last category of vacant lots contains the parcels surrounding waysides, such as roadways, driveways, edges of parking areas, and railways (Vessel and Wong 1987). These parcels are often narrow, yet can follow the wayside for miles, thus providing a large amount of edge habitat for urban wildlife (Figure 9).

Vegetation in waysides is typically shrub-dominated, contains a handful of trees, and is maintained on its edges just enough to be open spaces for cars or trains to travel. Many of these species are exotics that have escaped from neighboring backyard gardens. Exotic vines and other weedy plants are often seen climbing electric poles and towers along these waysides. Other properties of vacant waysides include heavy pollution from traveling vehicles and discarded trash.

Only a few waysides were sampled for this study (Table 1), as they were typically too narrow, unsafe, and generally not accessible. Efforts to revitalize vacant waysides are often minor, usually including trash-pickup and small plantings. Even when vacant wayside parcels are connected to larger plots of land, the factor of personal safety limits the development of the parcel and usually is the driver behind the vacancy.

Sources of Vacant Lot Vegetation

Sources of urban lot vegetation can be characterized into three groups: emergent, planted, and remnant (Zipperer, Sisinni, et al. 1997). Vacant lots fit into these groupings well, as the history of the patch greatly varies in terms of age and the degree of human intervention (Figure 10).

The majority of vacant lots are categorized by their emergent vegetation (Table 1). As buildings are demolished or pavement is removed, pioneer plant species establish on the lot. In urban areas, many pioneer species are weedy and often exotic. Common exotic plant species in emergent patches include English ivy, oriental bittersweet, multiflora rose, white and paper mulberry, Japanese knotweed, and a variety of exotic honeysuckle species (Table 2). Especially with the presence of non-native plants, emergent lots are often characterized as dense, weedy and unkempt, which makes them the least preferred within residential areas (Chapter 4). Management efforts in emergent patches vary with the neighborhood in which they occur and the lot's structure. Baltimore City Department of Public Works is responsible for mowing vacant lots every three weeks, but contract disputes during the years sampled for this study delayed this schedule, much to the chagrin of neighborhood residents. Due to this neglect, management efforts have been left to volunteer efforts from residents, or community-sponsored activities.

Planted vacant lots are ones that are not typically associated with the term vacant. Most people would assume that planted lots were parks if they are clearly mowed (Chapter 4). Examples of planted lots include vacant spaces transformed into community gardens, urban agriculture plots, or areas in which local residents have taken on maintenance efforts. These lots are frequently mowed, have clear plantings of either flowering bushes or trees with an otherwise open shrub strata, and are surrounded by street trees. Tree age and size are dependent upon the age of the lot's vacancy.

Vacant lots with remnant vegetation, or those that have been vacant for a long period (> 80 years; Zipperer 2002), commonly fit within the vacant block or suburban yard structural categories. Of the vacant lots sampled, only 11% were identified as remnant patches (Table 1). Remnant patches in Baltimore mainly contained deciduous species, usually dominated by large diameter trees. Baltimore city limits span two ecoregions, which differ in plant composition. The Piedmont forest in northwest Baltimore contains red, white, and chestnut oak, tulip poplar, and ash; while the remaining area within the city limits fall in the Coastal Plain, which contains more pines.

Biotic Characteristics

The biotic features of vacant lots vary extensively with their setting, vegetation sources, and location within the city (Rega-Brodsky and Nilon In review). Of the 150 vacant lots sampled in Baltimore, we found a total of 64 tree species and 46 shrub species, of which 37% species were exotic to Maryland. The most common tree species were white mulberry, hackberry, red maple, black walnut, and boxelder (Table 2). Most shrub species were exotic, the most common being Japanese honeysuckle, multiflora rose, and oriental bittersweet (Table 2). As for vegetation structure, the average vacant lot was dominated by tall grass and forb ground cover, a few shrubs along the lot's periphery, a few medium-sized trees, and partial canopy coverage (Table 3). This vegetation composition and structure provided habitat and nesting locations to 60 bird species (Table 4), the most common being the European starling, chimney swift, house sparrow, American robin, and rock dove.

Other biotic components that were not assessed for the study, such as pollinator species, small mammals, and amphibians, are important components to the urban ecosystem and their documentation could yield an excellent supplement to our study. Ecosystem services that many of these species provide could offer additional insight into the ecological value of vacant lots throughout many cities.

Vacant Lot Uses

Most vacant parcels are small (< 500 m^2), thus their uses are typically restricted to activities that only require a small area. However, that is not to say that these small spaces are unimportant. Vacant lots can serve as important locations for community development, urban agricultural practices, and sites of ecological conservation. Below, we detail various uses of vacant lots throughout Baltimore from our personal observations, beyond locations for new building opportunities. The purpose of this list is to describe how current residents use Baltimore's abundance of vacant lots, and to stimulate thinking about how to use these discarded patches in their current states. This list is not comprehensive, as new uses for vacant lots are found over time and across different cities.

Passing Through

Vacant lots serve as pathways to easily cut through the block. Either a concrete pathway, or dirt path bisecting a vacant lot can provide a shortcut, area to walk dogs, biking path, or areas to stroll through leisurely. Especially for vacant inner blocks, there is often a small inner-block path that can be used to get from one street to the next that can be driven on or used as a walking path (Figure 11). Like meeting places, these vacant lots are usually mowed enough to create a walkable location, as tall grass is a deterrent. Paths often establish with enough use of the site, but gravel, woodchips, or poured concrete can be added for a more permanent pathway and reduces maintenance. Other areas to pass through may also have large trees, with a clear understory, to maintain feelings of safety and allow walkers to have a clear view of their surroundings. Tall and large trees may also provide places for residents to sit under and read a book, or play with children.

No Apparent Use

Many vacant lot parcels have no apparent vacant use for residents (Table 1). Many of these lots include wayside vacant lots and remnant vacant patches that are considered unbuildable. Typically, these vacant lots have dense vegetation that restricts their use. Even though they have no apparent use from a social perspective, these sites may still be valuable in term of their ecosystem services.

Meeting Places

Many vacant lots are situated close to the road and serve as locations for city bus stops and social meeting locations. Meeting places on vacant lots can be as simple as a bench surrounded by a garden to a bus stop at vacant corner lot located at an intersection. Vacant parcels that span multiple blocks, or connect through missing tooth lots have the chance to be used as walking paths for people to meet and walk to and from their home. Meeting places are important for residents to connect with their neighbors and establish a sense of a community. Gardens, parks, and other areas for social activities are all considered meeting places. Like the vacant lot in Mondawmin named the Quite Place (Figure 1), meeting places can also be formal locations within vacant inner blocks that have barbeque pits, murals, small personal gardens, and white-painted buildings for projecting movies during the summer months.

To develop a vacant lot into a place where people meet one another can be a simple task. Providing a bench, spare chairs, and cleaning up the lot provides an outdoor recreation space. Frequent mowing during the summer months, provided by the city, is also necessary to maintain the site to seem welcoming for public use. The openness of these sites provide additional safety, as closed-off, dense lots often elicit negative perceptions of potential crime, violence, and places for people to hide (Chapter 4).

Parking Lots

A common use of vacant lots throughout Baltimore is for parking. As parking opportunities can be limited in the more busy areas of the city, vacant lots are useful parking locations as they are close to home and usually hidden away from pedestrians in a vacant inner block. Vacant lots can be paved or bare ground. On rare occasions, vacant missing tooth lots can be privately owned and used as a formal parking lot with an entry gate and parking attendant, however these would generally be in the city center where vacant lots are uncommon (Spirn and Pollio 1991). Most parking lots that we observed were vacant inner blocks, where people would park daily or use the lot as a storage location for old broken down cars, RV's, and boats (Figure 5). Even though they are convenient, local residents did not prefer vacant lots to be used as parking locations (Chapter 4). Using vacant lots as parking lots may promote the untidy, unmanaged perception of vacant lots as trash heaps, which would further detract public use.

Playground & Recreation

Places for recreation and sports are a common use of vacant lots when they are frequently maintained and mowed. Especially within the more dense areas of the city away from the larger city parks, there may be few suitable locations to play games because most rowhomes have no front yards. Vacant lots can easily serve this purpose, especially if they are vacant inner blocks where parents can easily watch their children from their backyard. Larger, mowed vacant lots can also serve as ballfields, areas to play tag, soccer, and other games (Figure 12). Lots that have small patches of paved areas or adjacent to paved parking lots, games like basketball, hopscotch, and jump rope are all possible. A number of abandoned inner block parks can also be cleaned up, swings can be replaced, and new play structures erected to elicit more use as a formal playground. Those lots can be transformed even further with community murals, park benches, and fencing to delineate playground boundaries. Efforts like these are usually large, expensive, and difficult to maintain over time; however, the social benefits are abundant.

Personal Gardening

Personal gardening efforts allow residents in dense urban centers the ability to have a little piece of nature to themselves. From a social survey to determine how people perceive vacant lots, we found that many residents participate in outdoor activities such as gardening (78%), birdwatching (58%), and feeding birds (31%; Chapter 4). Most personal gardening efforts are minor and restricted to parts of the vacant lot adjacent their backyard. Vacant inner lots, missing teeth, and suburban vacant lots provide the best opportunities for residents, as they are close to homes and relatively private. Gardening costs are usually minimal, as residents use current vegetation as a starting point, often planting flowers shrubs under trees (Figure 13). From our observations, residents often plant small shrubs, use flower plots, hang bird feeders, and set out lawn chairs to create their own sanctuary. Residents use these gardens to create areas to relax, listen to birds, and be at peace in the middle of the city. A few residents remarked that their neighbors are not supportive of their gardening or bird feeding efforts, as they attract unwanted pests, like rats. Even so, residents cherished their gardening and personal efforts to make their local vacant lot even more beautiful.

Forested Paths and Nature Areas

Vacant forested patches can be used for pathways and nature walks. These lots are rare (Table 1), as most forested land is already bound within established city parks. However, the small forested vacant lots found primarily with suburban areas of the city can be useful for relaxation, birdwatching, hiking, and more. Some residents extended their backyards into these vacant lots to maximize their use with chairs, a hammock, bird feeders, and a small fire pit. Many people remarked that they enjoy the presence of trees on a vacant lot, however would prefer to have a designated path rather than a dense forest stand (Chapter 4; Figure 14). These lots are extremely valuable in terms of the ecological benefits, providing a source of wildlife habitat, storm drainage, cooling properties, and much more. Lots used for forested paths only need to be maintained to clear the pathway, which can be done very informally. Otherwise, collection of discarded trash items may be done infrequently to clear the path and maintain its aesthetic qualities.

Community Gardens and Urban Agriculture

On a larger scale, community groups can band together to create community gardens and urban agriculture plots within vacant blocks or other larger vacant parcels. Of the residents that we interviewed for their thoughts on vacant lots, 40% participated in some form of a community garden. A number of local organizations coordinate community garden efforts in vacant lots, such as Baltimore Green Space, local school groups, and numerous neighborhood groups. Usually residents join preexisting community gardening efforts, but vacant lots can be purchased by community groups to start new gardening or urban agriculture plots.

Not only do these gardens create beautiful plots of land within the city, they can also provide fresh fruit and vegetables to local residents. School children can also learn how to cultivate their own food while also learning about the science and nature involved right in the city. Urban agriculture can be a large undertaking, necessitating large areas within vacant blocks or vacant inner lots. Groups such as Baltimore Free Farms, Baltimore Orchard Project, and Baltimore Urban Gardening with Students support local residents and students with public plots to produce fruit trees, and other local produce. Beekeeping efforts can also be a supplement to urban agriculture in vacant lots via a simple registration process with Baltimore City. Urban agriculture can also be a source of jobs, improving the local economy and ecology via soil remediation and pollination services.

Future Management

In order to proceed with vacant lot management in the future, the community should determine what needs are not being met, either ecologically, socially, or economically (Corbin 2003). From there, the future of vacant lots depends on the landowner; however the city owns the majority of vacant parcels. Thus, the future of vacant lots typically fall to local neighborhood groups' and residents' care. Baltimore City and various non-profits offer the opportunity to purchase vacant lots at a nominal cost for neighborhood.

Vacant lots are typically transitional and temporary spaces, thus traditional uses for urban lots may not be the most appropriate (Németh and Langhorst 2014). Additionally, many of these spaces do not allow for traditional development as they may be too small, oddly shaped, or in the "wrong" location (Pagano and Bowman 2000). Even though these characteristics may still apply, active use of many vacant lots may be necessary to alter the perception of the space and transform the community (Németh and Langhorst 2014). As additional vacancies become available after Baltimore's proposed demolition of over 1,500 vacant homes (Wenger 2013), the importance of lot upkeep is monumental for the sake of the aesthetics, safety, and economics of the neighborhood. Even minor management efforts, like cutting the grass, go a long way to transform the perception of vacant lots (Chapter 4). The numerous neighborhood groups, non-profits, and city agencies have made transforming vacant lots into a major goal for the city, and the outcomes of these groups are restoring parts of the city day by day. The opportunities for neighborhood vacant lots are endless.

Conclusion

We described the high level of variation that exists in vacant lot settings, sources, and biotic characteristics. Each vacant lot feature contributes to the context of the lot in its current state, as well as potential future uses. Most vacant lots are emergent, weedy structures located within the urban matrix, typically in residential areas of the city. Even so, each lot offers its own unique potential for use, from informal greenspaces with a walking path and gathering area, to more permanent community gardens and recreational spaces. Each lot should be evaluated for the community's needs and its social, ecological, or economic context. For example, most inner block vacant lots will remain unbuilt and could be the most accessible spaces for block gardens or parks, while vacant blocks may provide the best spaces for future building or nature areas. No longer should these lands be disregarded, instead they should be seen as locations within the city ripe for transformation to foster strong neighborhood connections.

Tables and Figures

Table 1. Characterizations of vacant lots by their settings, sources, and current uses. See Appendix 1A and 1B for descriptions of each individual vacant lot sampled.

	Lot Characteristic	Count	Percent
Setting	Vacant Block	48	32.0
	Inner Block	34	22.7
	Corner Lot	27	18.0
	Missing Tooth	25	16.7
	Suburban Yard	12	8.0
	Wayside	4	2.7
Source*	Emergent	103	68.7
	Planted	38	25.3
	Remnant	17	11.3
Current Use*	Passing Through	73	48.7
	No Apparent Use	39	26.0
	Meeting Places	37	24.7
	Parking Lot	28	18.7
	Playground & Recreation	21	14.0
	Personal Gardening	15	10.0
	Forested Paths & Nature Areas	15	10.0
	Community Gardens & Urban Agriculture	11	7.3

*One vacant lot may have areas with differing sources and uses.

Table 2. Plant species found within vacant lots in Baltimore.

Growth Form	Scientific	Common
Shrub	*Amelanchier canadensis*	Shadblow serviceberry
Shrub	*Ampelopsis brevipedunculata*	Porcelain berry
Shrub	*Berberis thunbergii*	Japanese barberry
Shrub	*Camellia japonica*	Japanese camellia
Shrub	*Euonymus alatus*	Burning bush
Shrub	*Euonymus americanus*	Strawberry bush
Shrub	*Euonymus fortunei*	Wintercreeper
Shrub	*Fallopia japonica*	Japanese knotweed
Shrub	*Forsythia spp.*	Forsythia
Shrub	*Ilex opaca*	American holly
Shrub	*Leucothoe fontanesiana*	Drooping laurel
Shrub	*Ligustrum amurense*	Amur privet
Shrub	*Ligustrum spp.*	Privet species
Shrub	*Lindera benzoin*	Spicebush
Shrub	*Lonicera maackii*	Amur honeysuckle
Shrub	*Lonicera sempervirens*	Trumpet honeysuckle
Shrub	*Magnolia stellata*	Star magnolia
Shrub	*Pseudosasa japonica*	Arrow bamboo
Shrub	*Pyracantha coccinea*	Scarlet firethorn
Shrub	*Rhododendron atlanticum*	Coastal azalea
Shrub	*Rhododendron spp.*	Rhododendron species
Shrub	*Rhus glabra*	Smooth sumac
Shrub	*Rhus spp.*	Sumac species
Shrub	*Rhus typhina*	Staghorn sumac
Shrub	**Rosa multiflora*	Multiflora rose
Shrub	*Rosa spp.*	Rose species
Shrub	*Rubus occidentalis*	Black raspberry
Shrub	*Rubus phoenicolasius*	Wineberry
Shrub	*Vaccinium corymbosum*	Highbush blueberry
Shrub	*Viburnum acerifolium*	Mapleleaf viburnum
Shrub	*Viburnum dentatum*	Arrowwood viburnum
Tree	*Abies balsamea*	Balsam fir
Tree	**Acer negundo*	Box elder
Tree	*Acer platanoides*	Norway maple
Tree	**Acer rubrum*	Red maple
Tree	*Acer saccharinum*	Silver maple
Tree	*Acer saccharum*	Sugar maple
Tree	*Aesculus flava*	Yellow buckeye

Tree	*Ailanthus altissima*	Tree of heaven
Tree	*Albizia julibrissin*	Mimosa
Tree	*Carpinus caroliniana*	American hornbeam
Tree	*Carya cordiformis*	Bitternut hickory
Tree	*Carya glabra*	Pignut hickory
Tree	*Carya ovata*	Shagbark hickory
Tree	*Carya tomentosa*	Mockernut hickory
Tree	*Catalpa bignonioides*	Northern catalpa
Tree	**Celtis occidentalis*	Hackberry
Tree	*Cercis canadensis*	Eastern redbud
Tree	*Chamaecyparis thyoides*	Atlantic white cedar
Tree	*Chionanthus virginicus*	White fringetree
Tree	*Cornus florida*	Flowering dogwood
Tree	*Diospyros virginiana*	Persimmon
Tree	*Fagus grandifolia*	American beech
Tree	*Fraxinus pennsylvanica*	Green ash
Tree	*Ginkgo biloba*	Ginkgo
Tree	*Gleditsia triacanthos*	Honey locust
Tree	*Ilex opaca*	American holly
Tree	**Juglans nigra*	Black walnut
Tree	*Juniperus communis*	Common juniper
Tree	*Juniperus virginiana*	Eastern red cedar
Tree	*Lagerstroemia indica*	Crapemyrtle
Tree	*Larix laricina*	Tamarack
Tree	*Liquidambar styraciflua*	Sweetgum
Tree	*Liriodendron tulipifera*	Tulip poplar
Tree	*Maclura pomifera*	Osage orange
Tree	*Magnolia grandiflora*	Southern magnolia
Tree	*Magnolia virginiana*	Sweetbay
Tree	*Magnolia xsoulangiana*	Saucer magnolia
Tree	*Malus spp.*	Apple tree spp.
Tree	**Morus alba*	White mulberry
Tree	*Morus papyrifera*	Paper mulberry
Tree	*Nyssa sylvatica*	Blackgum
Tree	*Paulownia tomentosa*	Princesstree
Tree	*Picea abies*	Norway spruce
Tree	*Pinus echinata*	Shortleaf pine
Tree	*Pinus nigra*	Austrian pine
Tree	*Pinus strobus*	Eastern white pine
Tree	*Platanus occidentalis*	American sycamore
Tree	*Prunus cerasifera*	Purple leaf plum

Tree	*Prunus serotina*	Black cherry
Tree	*Prunus spp.*	Cherry tree spp.
Tree	*Prunus x subhirtella*	Higan cherry
Tree	*Pyrus calleryana*	Bradford pear
Tree	*Quercus alba*	White oak
Tree	*Quercus falcata*	Southern red oak
Tree	*Quercus palustris*	Pin oak
Tree	*Quercus phellos*	Willow oak
Tree	*Quercus rubra*	Red oak
Tree	*Quercus velutina*	Black oak
Tree	*Robinia pseudoacacia*	Black locust
Tree	*Thuja occidentalis*	Northern white cedar
Tree	*Tilia americana*	American linden
Tree	*Tsuga canadensis*	Eastern hemlock
Tree	*Ulmus parvifolia*	Chinese elm
Tree	*Ulmus pumila*	Siberian elm
Vine	*Calystegia sepium*	Hedge bindweed
Vine	**Celastrus orbiculatus*	Oriental bittersweet
Vine	*Celmatis terniflora*	Sweet autumn clematis
Vine	*Convolvulus arvensis*	False bindweed
Vine	**Hedera helix*	English ivy
Vine	*Hydrangea anomala*	Climbing hydrangea
Vine	**Lonicera japonica*	Japanese honeysuckle
Vine	*Parthenocissus quinquefolia*	Virginia creeper
Vine	*Persicaria perfoliata*	Mile-a-minute
Vine	*Pueraria lobata*	Kudzu
Vine	*Smilax rotundifolia*	Roundleaf greenbriar
Vine	*Toxicondendron radicans*	Poison ivy
Vine	**Vitis spp.*	Grape species
Vine	*Wisteria sinensis*	Chinese wisteria
Vine	*Wisteria spp.*	Wisteria species

*Five most abundant tree or shrub/vine species.

Table 3. Mean and standard error (SE) of vegetation characteristics from 150 sampled vacant lots.

Feature	Variable	Mean	SE
Ground Cover	Artificial Ground Cover (%)	8.23	1.06
	Bare Ground (%)	3.12	0.46
	Forb Cover (%)	33.33	1.32
	Grass Cover (%)	42.37	1.62
	Leaf Litter Cover (%)	0.92	0.26
	Rock Cover (%)	0.19	0.08
	Shrub Cover (%)	9.42	1.26
	Tree Cover (%)	1.41	0.18
	Woody Litter Cover (%)	1.07	0.23
	Water Cover (%)	0.00	0.00
Vertical Structure	Ground Cover Height (cm)	22.85	1.77
	Canopy Height (m)	18.31	0.47
Horizontal Structure	Canopy Coverage (%)	32.95	2.51
	Shrub Stems	24.58	3.39
	Average Tree DBH (cm)	34.04	2.10
	Total Tree Count	2.50	0.26
Tree Species Richness	Species Richness	1.44	0.10

Table 4. Bird species found within vacant lots in Baltimore.

Scientific	Common
Accipiter cooperii	Cooper's hawk
Agelaius phoeniceus	Red-winged blackbird
Archilochus colubris	Ruby-throated hummingbird
Ardea herodias	Great-blue heron
Baeolophus bicolor	Tufted titmouse
Bombycilla cedrorum	Cedar waxwing
Branta canadensis	Canada goose
Buteo jamaicensis	Red-tailed hawk
Buteo lineatus	Red-shouldered hawk
Cardellina pusilla	Wilson's warbler
Cardinalis cardinalis	Northern cardinal
Carduelis tristis	American goldfinch
Carpodacus mexicanus	House finch
Cathartes aura	Turkey vulture
**Chaetura pelagica*	Chimney swift
Coccyzus americanus	Yellow-billed cuckoo
Colaptes auratus	Northern flicker
**Columba livia*	Rock dove
Contopus virens	Eastern wood peewee
Corvus ossifragus	Fish crow
Crovus brachyrhynchos	American crow
Cyanocitta cristata	Blue jay
Dumetella carolinensis	Gray catbird
Empidonax virescens	Acadian flycatcher
Geothlypis trichas	Common yellowthroat
Hirundo rustica	Barn swallow
Hylatomus pileatus	Pileated woodpecker
Hylocichla mustelina	Wood thrush
Icterus galbula	Baltimore oriole
Larus argentatus	Herring gull
Larus delawarensis	Ring-billed gull
Leuconotopicus villosus	Hairy woodpecker
Melanerpes carolinus	Red-bellied woodpecker
Melospiza melodia	Song sparrow
Mimus polyglottos	Northern mockingbird
Mniotilta varia	Black-and-white warbler
Molothrus ater	Brown-headed cowbird
Myiarchus crinitus	Great-crested flycatcher

**Passer domesticus*	House sparrow
Passerina cyanea	Indigo bunting
Picoides pubescens	Downy woodpecker
Pipilo erythrophthalmus	Eastern towhee
Piranga olivacea	Scarlet tanager
Poecile carolinensis	Carolina chickadee
Polioptila caerulea	Blue-gray gnatcatcher
Quiscalus quiscula	Common grackle
Setophaga americana	Northern parula
Setophaga fusca	Blackburnian warbler
Setophaga ruticilla	American redstart
Sitta carolinensis	White-breasted nuthatch
Spizella passerina	Chipping sparrow
Strix varia	Barred owl
**Sturnus vulgaris*	European starling
Tachycineta bicolor	Tree swallow
Thryothorus ludovicianus	Carolina wren
Troglodytes aedon	House wren
**Turdus migratorius*	American robin
Tyrannus tryannus	Eastern kingbird
Vireo olivaceus	Red-eyed vireo
Zenaida macroura	Mourning dove

*Five most abundant species

Figure 1. Examples of vacant lots converted into community gardens and recreation spaces. The Quiet Place (left) is a vacant lot that was turned into a community meeting place with barbecue grills, vegetable and herb garden in the Mondawmin neighborhood. Sunflower Village (right) in the Franklin Square neighborhood was created by a community association-led effort to transform a once decaying vacant lot into a sunflower garden and mural instillations (Photo from: http://communityofgardens.si.edu/).

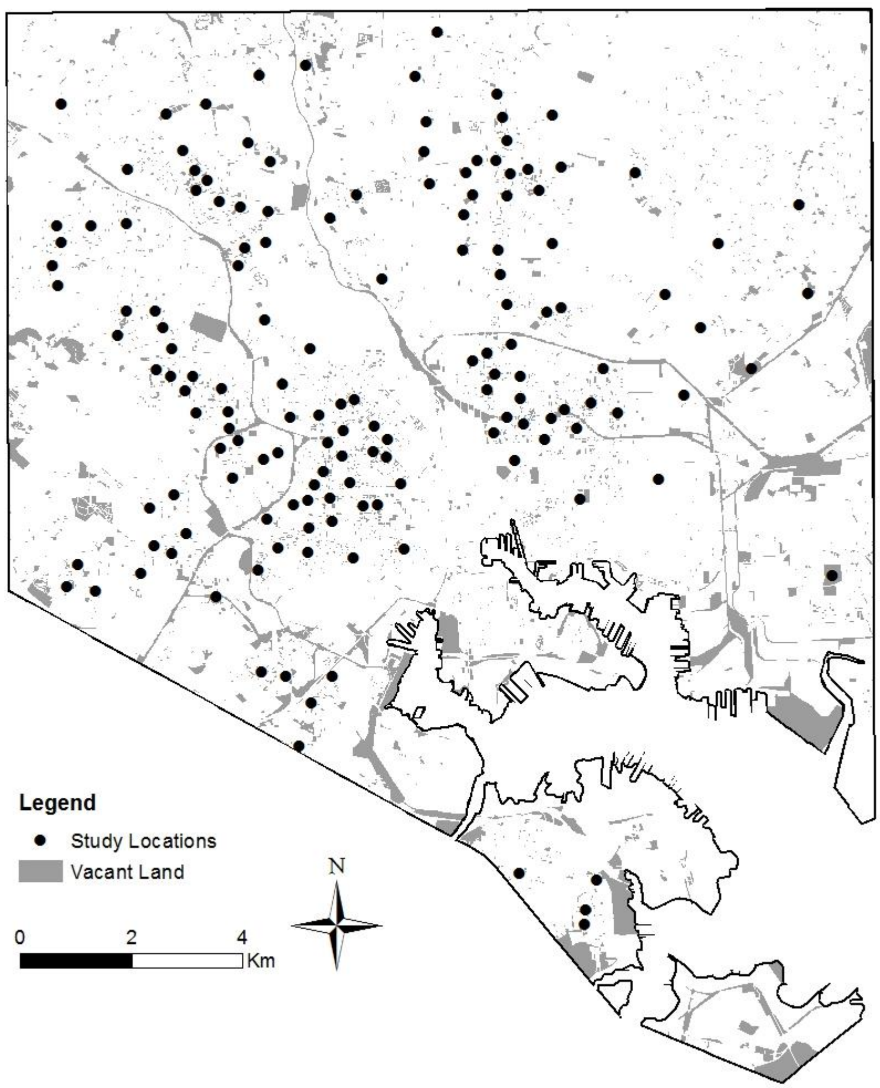

Figure 2. Vacant land and the 150 selected vacant lots surveyed in Baltimore.

Figure 3. Vacant lots (transparent red polygons) in West Baltimore (left) and East Baltimore (right) neighborhoods.

Figure 4. Vacant blocks (dark gray) comprise an entire plot of land, either a city block like in the Penrose neighborhood (top) or a triangular shaped lot on a hill in Hampden (bottom).

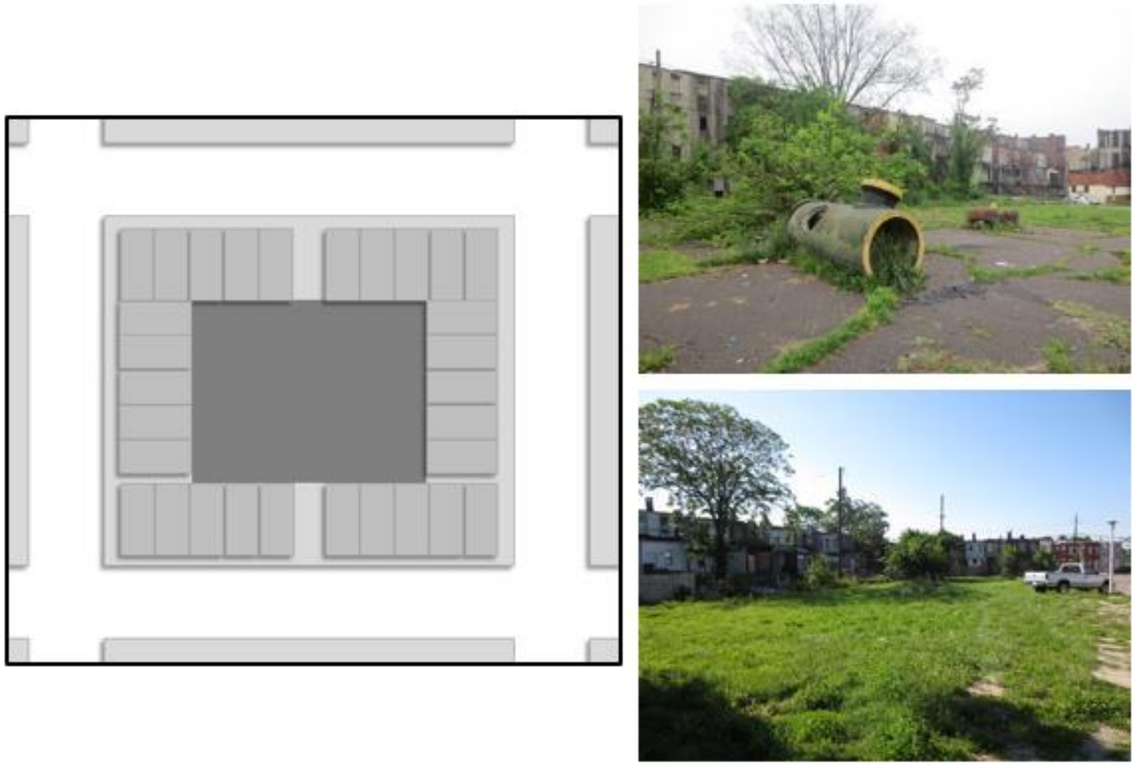

Figure 5. Vacant inner block (dark gray) surrounded by rowhomes (rectangles), with examples from Baltimore: abandoned inner block in Harlem Park (top) and in the Broadway East neighborhood (bottom).

Figure 6. Vacant corner lot (dark gray) with examples from Baltimore in the Upton (top) and Johnston Square East Baltimore (bottom) neighborhoods. The Upton vacant corner lot is flanked by several vacant rowhomes.

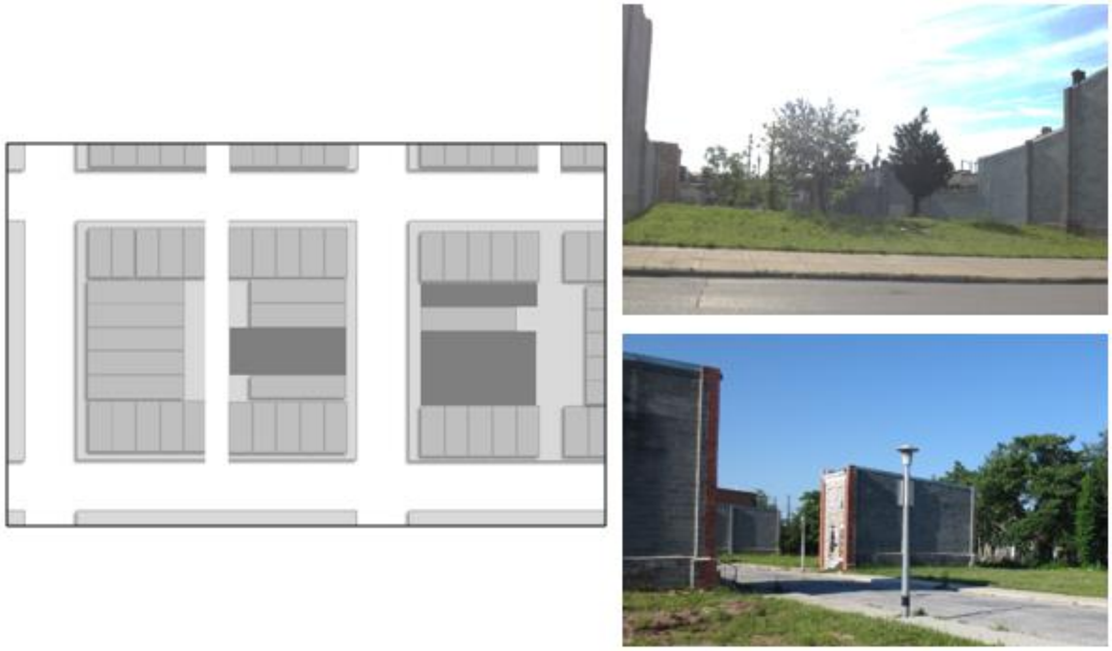

Figure 7. “Missing tooth” vacant lots (dark gray) with an example of two – three missing rowhomes in Carrolton Ridge (top) and extensive missing tooth vacant lots surrounding one remaining rowhome in South Clifton Park neighborhood (bottom).

Figure 8. Vacant suburban lots (dark gray) in a neighborhood adjacent to a city park (green). An example of neighbors attending to a suburban vacant lot was a lot located in the Pen Lucy neighborhood of north-central Baltimore (top). Another suburban vacant lot in the Woodberry neighborhood of northwestern Baltimore was comprised of a forest stand and overgrown with exotic bamboo that escaped from a nearby residential garden (bottom).

Figure 9. A vacant wayside (dark gray) surrounding a railroad track (light gray lines) and roadway (white). Examples of vacant roadways (top; Hampden neighborhood) and railways (bottom; Broadway East neighborhood) are dense and dominated by shrubs and tree vegetation.

Figure 10. Examples of emergent, planted, and remnant vacant lots in Baltimore.

Figure 11. Examples of walking paths in vacant lots. Walking paths can either be made after frequent use (left), be paved thruways across vacant inner blocks (center), or sidewalk-like pavement within the vacant lot behind private backyards (right).

Figure 12. Various vacant lots used as recreational space. Located within the Homeland neighborhood, semi-permanent soccer and lacrosse goals were used in a vacant block (left). Other vacant blocks or corner lots can be used as recreational spaces for frisbee, tag, or other lawn-style informal games, like the vacant lot next to a church in the Lakeland neighborhood of southwestern Baltimore (right).

Figure 13. Examples of personal gardens (left) and community gardens/agriculture (right). Both examples are small efforts undertaken by local neighbors, from planting a few shrubs near a preexisting tree to four flower and vegetable plots.

Figure 14. A forested vacant lot that was used as a pathway between two roads.

Appendix 1A. Description the setting and source of all vacant lots sampled. Approximate addresses are also included for each lot.

		Setting						Source		
Code	Address	Vacant Block	Inner Block	Corner Lot	Missing Tooth	Suburban Yard	Wayside	Emergent	Planted	Remnant
ABBO	1542 Abbotston St				X				X	
ALLE	2267 Allendale Rd			X				X		
ALTO	3416 Alto Rd			X				X		
ANNS	642 St Anns Ave			X				X		
BAKE	615 Baker St	X						X	X	
BANG	2406 Banger St	X						X		
BLYT	4 Blythewood Rd	X								X
BOON	2003 Boone St	X						X		
BREH	3515 Brehms Ave		X					X	X	
BRUN	1452 Brunt St		X						X	
CALH	1300 N Calhoun St			X				X		
CARD	3528 Cardenas Ave		X					X		
CART	2011 Carterdale Rd	X								X
CHES	1308 Chestnut Hill Ave			X					X	
CLAY	3099 Clayton Rd	X								X
CLNS	310 Collins Ave				X			X		
COLL	2400 College Ave	X							X	
COTS	17 Cotswold Rd	X							X	
CRAD	4519 Craddock Ave				X			X		
CRAI	5107 Craig Ave				X			X		
CROF	1315 Crofton Rd	X						X	X	
CYLB	2470 Cylburn Ave				X				X	
DELA	4666 Delaware Ave		X					X		

Code	Address	Setting						Source		
		Vacant Block	Inner Block	Corner Lot	Missing Tooth	Suburban Yard	Wayside	Emergent	Planted	Remnant
DENI	2002 Denison St			X				X		
DIVI	1701 Divison St		X					X		
DUKE	1421 N Dukeland St			X				X		
DUPO	3301 Dupont Ave	X						X		
DUVA	3510 Duvall Ave				X			X		
EAHO	800 East Hoffman St	X						X		
EAST	East 24th St	X							X	
EBID	523 E Biddle St	X						X		
EDDN	1316 Edmonson Ave		X					X		
EDEN	1011 N Eden St	X							X	
EDMO	1827 Edmondson Ave				X			X		
EFED	3511 E Federal St	X						X		
EHOF	East Hoffman St & North Port St		X					X		
ELAF	412 E Lafayette Ave	X						X		
ELLI	Elliot St	X						X		
ENSO	1694 Ensor St				X			X		
EOLI	2039 E Oliver St	X						X		
ETHI	551 E 36th St			X				X		
ETTI	2205 Etting St	X						X		
ETWE	206 E 23rd St	X							X	
FAIR	4027 Fairview Ave			X				X		
FERN	4003 Fernhill Ave			X				X		
FILB	1421 Filbert St					X				X
FIRE	170 Fireside Cir	X							X	
FORD	4000 Fords Ln	X							X	

Code	Address	Setting						Source		
		Vacant Block	**Inner Block**	**Corner Lot**	**Missing Tooth**	**Suburban Yard**	**Wayside**	**Emergent**	**Planted**	**Remnant**
FOUR	711 E 43rd St					X			X	
FRED	2651 Frederick Ave		X					X		
FRVW	3620 Fairview Ave				X			X		
GERT	1782 Gertrude St	X						X		
GOOD	5127 Goodnow Rd					X				X
GORD	2189 Gordon Rd	X						X		X
GREE	5436 Greenspring Ave					X				X
GREN	4115 Grenton Ave					X		X		X
GWAY	3609 Greenway	X							X	
HADD	5001-5099 Haddon Ave			X				X		
HAMP	5010 Hampshire Ave	X							X	
HICK	3352 Hickory Ave						X			X
HILL	4020-4098 Hillcrest Ave				X					X
HOLB	1246 Holbrook St		X					X		
HOME	1446 Homestead St			X				X		
IVAN	4749 Ivanhoe Ave		X					X		
KAVO	5653 Kavon Ave		X					X		
KENN	1913 Kennedy Ave		X					X		
KEYW	2613 Keyworth Ave		X					X		
LETI	1702 Letitia Ave			X				X		
LLEW	1707 Llewelyn Ave						X	X		
MADI	905 East Madison St	X						X		
MARM	3718 Marmon Ave					X		X		
MATT	5521 Mattfeldt Ave	X							X	
MILO	3389 Milford Ave			X				X		

		Setting						Source		
Code	**Address**	**Vacant Block**	**Inner Block**	**Corner Lot**	**Missing Tooth**	**Suburban Yard**	**Wayside**	**Emergent**	**Planted**	**Remnant**
MORL	10 N Morley St			X				X		
MOUN	320 N Mount St		X					X		
MURP	706 Murphy Ln	X							X	
MYRT	1410 Myrtle Ave	X						X		
NAMI	116 North Amity St	X						X		
NBRU	1588 N Bruce St		X					X		
NCAL	163 North Calverton Rd	X						X		
NCRN	203 N Carrolton Ave				X			X		
NMOU	704 N Mount St		X					X		
NORT	5420 Northwood Dr		X					X		
NPAT	1933 North Patterson Park Ave				X			X		
NPUL	1547 N Pulaski St		X					X		
NSMW	2008 N Smallwood St		X						X	
OAKF	3122 Oakford Ave				X			X		
OLDY	4858 Old York Rd		X					X		
OTTE	337 Otterbein St		X						X	
OVER	3 Overhill Rd			X					X	
PALM	5127 Palmer Ave			X				X		
PARH	Park Heights Ave				X			X		
PATA	2464 W Patapsco	X							X	
PKTN	4616 Parkton St	X						X		X
POPL	2000 Poplar Grove St			X				X		
POST	4090 Gwynn Oak Ave				X			X		
PRES	1523 East Preston St				X			X		
PRUD	4751 Prudence St	X							X	

Code	Address	Setting						Source		
		Vacant Block	**Inner Block**	**Corner Lot**	**Missing Tooth**	**Suburban Yard**	**Wayside**	**Emergent**	**Planted**	**Remnant**
PSBY	3251 Presbury St				X			X		
RADN	327 Radnor Rd					X			X	
RAMS	1328 Ramsay St						X	X		
RAYN	2844 Rayner Ave	X						X		
READ	5655 Ready Ave		X					X		
REDF	1452 Redfern Ave					X				X
RIDG	2400 Ridgely St	X							X	
RIGG	1608 Riggs Ave		X						X	
ROLA	1045 Roland Heights Ave				X			X		
ROSL	2209 Roslyn Ave				X			X		
RUTL	1108 Rutland Ave		X					X		
SAIN	4039 Saint Paul St					X			X	
SCGA	524 S Chapel Gate Ln	X						X	X	
SHAN	4245 Shannon Dr	X								X
SHIR	Shirley and Cottage Rd	X						X		
SIEG	151 Siegwart Ln					X			X	
SMAL	285 N Smallwood St			X				X		
SMON	147 S Monastery Rd				X			X		
SPAY	308 South Payson St				X			X		
SPON	1931 Sponson St					X		X		
SPRG	1014 Springfield Ave			X				X		
SPRU	Spruce and Pennington Rd	X							X	
SSWO	201 South Woodington Rd			X				X		
STAL	100 St Albans Way					X			X	
STFD	266 Stratford Rd	X							X	

Code	Address	Setting						Source		
		Vacant Block	Inner Block	Corner Lot	Missing Tooth	Suburban Yard	Wayside	Emergent	Planted	Remnant
STRA	2700 Strayer Ct			X				X		
SWIC	209 S Wickham Rd	X								X
TAMA	4803 Tamarind Rd	X							X	X
THIR	713 E 30th St				X			X		
TIPP	5308 Tippett Ave		X					X		
TOWA	3101 Towanda Ave			X				X		
TOWD	3757 Towanda Ave	X						X		
UNDE	4502 Underwood Rd	X							X	
USFO	3042 US 40	X						X		
VENA	611 Venable Ave				X			X		
WARW	900 N Warwick Ave		X					X		
WBAL	1609 West Baltimore St		X					X		
WBMR	1936 W Baltimore St				X				X	
WCHR	2932 Winchester St		X					X		
WCOL	2511 W Cold Spring Ln		X					X		
WELL	607 Wellesley St						X			X
WHEE	1020 Wheeler Ave		X					X		
WHIT	2322 Whittier Ave		X					X		
WILL	160 Willard St			X				X		
WIND	3210 Windsor Ave			X				X		
WLAF	1444 West Lafayette Ave			X				X		
WLAN	624 West Lanvale St			X				X		
WMUL	3906 W Mulberry St		X							X
WNPA	3153 West Northern Parkway	X							X	
WOLF	46 N Wolfe St		X						X	

Code	Address	Setting						Source		
		Vacant Block	Inner Block	Corner Lot	Missing Tooth	Suburban Yard	Wayside	Emergent	Planted	Remnant
WOOD	702 Woodbourne Ave				X			X		
WSAR	1942 W Sarasota St		X					X		

Appendix 1B. Description the identified uses of all vacant lots sampled. Each vacant lot may have more than one current use.

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
ABBO			X		X			
ALLE		X						
ALTO	X			X				
ANNS	X			X				
BAKE	X							
BANG							X	
BLYT							X	
BOON	X							
BREH	X			X				
BRUN	X		X		X			
CALH	X		X					
CARD			X	X		X		
CART							X	
CHES						X		X
CLAY	X					X	X	
CLNS		X						
COLL	X							
COTS					X			
CRAD		X						
CRAI		X						
CROF	X		X	X	X	X		
CYLB			X					
DELA		X						
DENI	X							

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
DIVI	X			X				
DUKE	X			X				
DUPO	X			X				
DUVA						X		
EAHO		X						
EAST			X					X
EBID	X		X					
EDDN	X							
EDEN	X		X					
EDMO	X							
EFED		X						
EHOF	X			X				
ELAF	X		X					
ELLI	X							
ENSO		X						
EOLI	X		X					
ETHI		X						
ETTI	X		X					
ETWE	X		X		X			
FAIR	X		X					
FERN		X						
FILB							X	
FIRE	X		X					
FORD	X		X					
FOUR			X			X		X
FRED		X						

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
FRVW		X						
GERT				X				
GOOD							X	
GORD							X	
GREE	X						X	
GREN				X				
GWAY	X		X		X		X	
HADD	X							
HAMP	X				X			
HICK		X						
HILL							X	
HOLB	X							
HOME	X		X					
IVAN		X						
KAVO		X						
KENN	X							
KEYW	X							
LETI	X			X				
LLEW		X						
MADI		X						
MARM				X				
MATT	X		X		X	X		
MILO	X		X					
MORL	X		X		X			
MOUN	X							
MURP	X		X					

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
MYRT	X							
NAMI	X							
NBRU	X							
NCAL		X						
NCRN								X
NMOU					X			
NORT					X			
NPAT	X							
NPUL				X				
NSMW			X		X	X		X
OAKF		X						
OLDY				X				
OTTE	X		X		X			X
OVER	X		X		X		X	X
PALM		X						
PARH		X						
PATA			X		X			
PKTN					X		X	
POPL		X						
POST		X						
PRES		X						
PRUD	X							
PSBY		X						
RADN				X	X	X		
RAMS				X				
RAYN	X							

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
READ	X			X				
REDF		X						
RIDG		X						
RIGG						X		X
ROLA						X		
ROSL		X						
RUTL	X							
SAIN						X		
SCGA	X		X					
SHAN		X						
SHIR	X				X			
SIEG				X		X		
SMAL	X			X				
SMON		X						
SPAY		X						
SPON		X						
SPRG		X						
SPRU	X		X					
SSWO	X			X				
STAL					X	X		
STFD	X		X				X	X
STRA	X			X				
SWIC	X						X	
TAMA	X		X		X		X	X
THIR		X						
TIPP	X							

Code	Passing Through	No Apparent Use	Meeting Places	Parking Lot	Playground & Recreation	Personal Gardening	Forested Paths & Nature Areas	Community Gardens & Urban Agriculture
TOWA	X		X					
TOWD	X							
UNDE	X							
USFO		X						
VENA	X							
WARW				X				
WBAL	X							
WBMR	X		X					
WCHR				X				
WCOL	X		X			X		
WELL		X						
WHEE				X				
WHIT	X		X					
WILL		X						
WIND		X						
WLAF	X							
WLAN	X							
WMUL				X				
WNPA				X				
WOLF	X		X		X			X
WOOD		X						
WSAR	X		X	X				

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Chapter 2: Importance of Forest Cover across Multiple Scales for Bird Communities in Urban Vacant Lots

Abstract

Urban vacant lots can vary from dense, shrubby habitats to wooded remnant habitats that provide habitat for a variety of birds. By identifying which features promote diverse bird communities, we can determine at which scale management practices should focus and the necessary habitat structure and composition features. We surveyed 150 vacant lots throughout Baltimore, Maryland for their bird communities, lot vegetation, and landscape-level forest cover. An ordination of the bird community indicated a response to a gradient of canopy cover and canopy height at the vacant lot. We also found that forest cover within 100 m of the vacant lot was the most important predictor of abundance for five bird species of interest. Species richness was spatially autocorrelated among sites, indicating that bird communities may also be driven by species' dispersal and environmental gradients across the city. Overall, bird communities are responding to habitat features across multiple scales, from the vacant lot vegetation, to landscape-level forest cover, to city-wide dynamics. Thus, we recommend management practices to focus on increasing city-wide forest cover in order to increase species richness, yet with awareness regarding where the lot occurs within the city.

Introduction

Understanding the role urban green spaces play for conserving diverse bird communities is essential in today's urbanizing world. Even though larger habitat patches typically result in greater species diversity and richness, small green spaces are more common in the urban landscape and may also provide important foraging and nesting resources for multiple bird species (Strohbach et al. 2013; Lerman and Warren 2011). Vacant lots are a one major component of small urban greenspaces, and are common in declining cities because they are the result of building demolition and serve as locations for future development (Pagano and Bowman 2000). These lots can vary extensively with their contents and structure, as the age of their vacancy creates varying degrees of vegetation succession post-abandonment. Vacant lots may range from newly vacant parcels of land with weedy, invasive vegetation to land parcels that have been vacant for a considerable time and now have an established forest stand. The vegetation contents and structural configuration of these two kinds of vacant lots provide a gradient of habitat quality for urban birds.

Although the abundance of vacant lots is a heavily documented social and economic issue, there are few ecological studies within vacant lots. These sites may be an important, overlooked source of bird habitat, especially in shrinking cities with increasing amounts of vacant lands (Burkholder 2012). Birds are a useful taxa for evaluating the habitat structure and composition in urban areas (Chase and Walsh 2006; MacGregor-Fors et al. 2009). By identifying what habitat factors promote sustainable bird populations within vacant green spaces, these spaces can be managed appropriately to promote diverse avian communities.

Urban bird community composition has been attributed to multiple ecological models that occur over difference scales, specifically patch-scale habitat features (niche assembly), environmental landscape-level gradients (species sorting), and variations along spatial gradients due to dispersion (mass effects) (Boulinier et al. 2001, Leibold et al. 2004, Schlesinger et al. 2008, Szlavecz et al. 2010). We assume that these drivers, across multiple scales, will be associated with community composition at vacant lots. At the patch-scale, vegetation structural complexity (Roth 1976; MacArthur and MacArthur 1961), native tree density (Reis et al. 2012), tree cavity abundance (Strohbach et al. 2013), management intensity (Shwartz et al. 2008; Easton and Martin 1998), and degree of urbanization (Chase and Walsh 2006) are a few factors that may drive community composition. Patch size is another driving factor of community composition, especially for small greenspaces (Strohbach et al. 2013; Donnelly and Marzluff 2004); however, landscape-level habitat and a city's urbanization gradient may play a larger role in resource availability beyond the vacant lot.

Dispersal across environmental gradients may also drive community composition throughout the city, due to variations in habitat availability and quality surrounding vacant lots (Mörtberg et al. 2007; Blair 1996). Across multiple spatial scales, bird communities may respond to forest cover (Melles et al. 2003; Hennings and Edge 2003), urbanization gradients (Ortega-Álvarez and MacGregor-Fors 2009; Blair 1996), and land uses (Rega et al. 2015). Species' dispersal across these environmental landscape gradients may consequently impact bird community composition at a particular site. These relationships indicate that multiple landscape-level impacts may shape the bird community (Minor and Urban 2010).

Understanding these dynamics can play an important role in vacant lot management, specifically by determining whether management efforts at the patch may impact a site's community within a particular landscape. This is principally important for vacant lots, as the presence of these spaces can be clustered within certain socioeconomic areas (Rega-Brodsky and Nilon In review) and play important social, political, and economic roles within the city (Garvin et al. 2013a; Kremer et al. 2013; Heckert and Mennis 2012), in addition to their role in urban bird community dynamics.

We investigated how vacant lots provide habitat and support the urban bird community. We asked three questions about how local and landscape-level features impact the community's composition and species richness: 1) How is bird community composition associated with vacant lot vegetation; 2) What vegetation and landscape variables are related to bird species abundance; and 3) How does bird species richness vary in vacant lots across the city? We conducted our study in Baltimore, Maryland, as a part of the Baltimore Ecosystem Study, a long-term ecological research project. Baltimore was a perfect study location to determine how vacant lots provide habitat for birds across multiple scales due to Baltimore's high abundance and habitat variation of vacant lots.

Methods

Study Area

Baltimore is a shrinking city and has lost 34% of its population since its peak in 1950 (U.S. Census Bureau 2014; Pallagst et al. 2015) due to loss of manufacturing jobs, increasing crime rates, and movement into the adjacent county. This loss of population and jobs since 1950 caused an increase in vacant lots throughout the city to its current level of 16,500 vacant parcels, comprising over 1,700 hectares (Rega-Brodsky and Nilon In review; Baltimore Office of Sustainability 2010; Figure 1). We randomly selected 150 lots from these vacant parcels and then selected a subset that were accessible, larger than 0.05 ha, and had some form of vertical vegetation. Additionally, all sites were located at least 250 m apart to reduce the chance of multiple counts of individual birds (Ralph et al.

1995). We conducted bird and vegetation surveys in 2013 – 2015 at new sites each year (n_{2013} = 45; n_{2014} = 55; n_{2015} = 50) during the breeding season (May – July).

Bird Surveys

We conducted three point count surveys at the center of the site. We conducted five-minute unlimited radius point count surveys between sunrise and 4 h post-sunrise for all observed bird species. We recorded wind speed and direction, temperature, time of observation, observer, and date so we could account for their impacts on species' detection.

Site Habitat Features

Three 0.04 ha vegetation sample plots were evenly spaced 20 m from the lot's center (0°, 120°, and 240°) to capture the lot's heterogeneous vegetation composition and structure. Within each plot, we measured 17 vegetation variables: canopy cover (%), canopy height (m), shrub cover (shrub density), ground cover (%) and composition, and tree species richness, count, and diameter-at-breast-height (dbh) (Table 1). To reduce the number of site habitat variables, we conducted a Pearson's correlation analysis to remove redundant highly correlated ($r > 0.5$; $r < -0.5$) variables. The final site abundance covariates represented variation in management intensity (ground cover height), impervious surface (artificial ground cover), amount of lawn (grass ground cover), site tree coverage (canopy cover), and shrub density (stem count).

Landscape Features

Vegetation characteristics surrounding the vacant lot also may be associated with bird composition at a site. We assessed landscape level tree coverage at local (100 m, 500 m) and neighborhood scales (1000 m) (Ryder et al. 2010; Melles et al. 2003), with each radius centered at the point count location. These three covariates were highly correlated, so we selected the landscape level tree coverage at a local scale (100 m) to indicate habitat availability within and surrounding the vacant lot. Digitized LANDSAT satellite image maps were used to quantify forested land cover features (Parker and Nilon 2012).

Data Analyses

We conducted Bray-Curtis polar ordinations on the bird community composition at the vacant lot in PC-ORD (McCune and Mefford 2011; Bray and Curtis 1957) to assess the bird community's response to ecological gradients. Site vegetation variables that were correlated with the resulting ordination axes were also plotted to illustrate their relationship to bird community composition at the sites. This ordination method was used in order to determine site differences in species composition, while also producing correlation values between species and the ordination axes.

The bird species that correlated with either ordination axes ($r \geq 0.5$; $r \leq -0.5$) were selected for abundance modeling, as they were a description of the ordination and potentially indicators of responses to environmental gradients (McCune and Mefford 2011). We used the N-mixture modeling procedure within the unmarked package in Program R (Fiske and Chandler 2011) in which the effects of the detection variables (σ) were first determined and then incorporated within the abundance (λ) models. Species flyovers were removed from the abundance modeling analysis in order to assess only the species that were actively using the vacant lot.

A priori abundance models included lot- and landscape-level habitat feature covariates (Table 2). We tested the lot-level effects of vegetation management intensity, impervious surfaces, lawn cover, forest cover, lot vegetation density, and the lot's area for impacts on abundance, as these variables are known to influence bird presence and abundance (Strohbach et al. 2013; Chase and Walsh 2006; Donnelly and Marzluff 2004; Jokimäki et al. 2014). We tested for the impact of landscape-level forest cover within 100 m of the vacant lot to indicate habitat availability surrounding the vacant lot (Bolger et al. 1997; Melles et al. 2003). In addition, we tested a model to account for changes in population abundance across sampling years. The candidate model set also included a null model and a fully-parameterized global model with all abundance variables (Table 2). These models were evaluated and ranked with the Akaike Information Criterion (AIC), with the top models ($\Delta AIC \leq 2$) serving as models with the most explanatory power for both detection and abundance (Burnham and Anderson 1998). These top models were then assessed for their fit with Freeman-Tukey goodness-of-fit tests based on a parametric bootstrap for 100 simulations (Fiske and Chandler 2011).

In order to assess city-wide variation in community composition and the interrelatedness of bird communities in adjacent vacant lots, we also conducted a Moran's I analysis to measure spatial autocorrelation of species richness across the city (Moran 1950, ESRI 2011). Moran's I analysis also provided a measure of spatial distribution of bird species richness. Values for this index ranged from +1 (clustered, adjacent similar values), 0 (random, nearby values are unrelated) to -1 (uniform distribution, adjacent dissimilar values) (Sokal and Oden 1978). We also interpolated species richness across Baltimore with a simple kriging model within ArcGIS (ESRI 2011).

Results

We detected 60 bird species among our sites (Appendix 2A). Vacant lots varied considerably with their vegetation composition and structure (Table 1). The majority of the vacant lots were dominated by grass ground cover with a height that indicated a lack of regular mowing maintenance. Canopy coverage was moderate because most sites only had a few trees.

The ordination indicated a separation of study sites' species composition primarily by the presence and abundance of trees at the site. At a threshold of $r^2 = 0.25$, tree species richness, canopy height and canopy coverage were positively correlated with both Axes 1 and 2 (Figure 2).The positive correlation of these variables with both axes indicated a gradient in tree cover, as sites ranged from those in areas with high impervious surfaces and fewer trees (low axes scores) to those within forested areas with high tree cover (high axes scores).

Four species correlated with either ordination axis at the $r \geq 0.5$ or $r \leq -0.5$ threshold: the northern cardinal (*Cardinalis cardinalis*; r = 0.66), European starling (*Sturnus vulgaris*; r = -0.53), white-breasted nuthatch (*Sitta carolinensis*; r = 0.51), and chimney swift (*Chaetura pelagica*; r = -0.50). Two species that approached this correlation cut off and had a high abundance across Baltimore were the mourning dove (*Zenaida macroura*, r = -0.46) and American robin (*Turdus migratorus*, r = 0.45), so we also ran abundance modeling on these species of interest as well. These species were also selected due to their observed nesting efforts in vacant lots (Chapter 3). Because Axes 1 and 2 indicated a gradient of tree cover, cardinals, nuthatches, and robins were associated with vacant lots that had greater tree coverage, while the starlings, chimney swifts, and mourning doves were associated with lots with less tree cover.

Of the six species, all but the nuthatch were selected to evaluate the impacts of local- and landscape-level habitat features on their abundances. The nuthatch was present at 8% of our sites and only detected 16 times, thus not adequate to model ($n < 50$). For the remaining five species, detection was impacted by observers, date and weather variables, and differed across species (Table 3).

Abundance values for all species were best predicted by models that incorporated forest cover within 100 m of the vacant lot (Table 3; Figure 3). The top model for cardinals only included forest cover within 100 m, which was positively related to the species' abundance ($\beta = 0.79$). Similarly, robin abundance was positively related to forest cover within a 100 m radius of the site ($\beta = 0.15$). Other competitive models ($\Delta AIC \leq 2$) indicated robin abundance was associated with increasing canopy cover ($\beta = 0.002$) and grass coverage ($\beta = 0.005$) at the site. European starling abundance was negatively related to the site's canopy cover and to forest cover within 100 m ($\beta_{canopy} = -0.004$ and $\beta_{forest100} = -0.65$).

Chimney swift and mourning dove abundances varied by the amount of canopy cover at the site and forest cover with 100 m surrounding the vacant lot, with greater abundances in areas with less forest cover in the landscape (Chimney swift: $\beta = -0.95$; Mourning dove: $\beta = -0.38$) and variable amounts of canopy coverage (Chimney swift: $\beta = -0.005$; Mourning dove: $\beta = 0.004$) at the lot. Even though the ordination indicated that both of these species were important in explaining trends in community composition across the vacant lots, top models for these two species did not appropriately fit the data (Freeman-Tukey, $P = 0$; Table 3).

Bird species richness observed within vacant lots had significant spatial autocorrelation and indicated a clustered pattern (Moran's I index = 0.26, z-score = 12.70, $P < 0.001$). This signified that bird species richness within a vacant lot was similar to other nearby lots. Lots with the greatest species richness occurred within the forested areas of the city, and away from downtown Baltimore (Figure 4).

Discussion

Our goal was to determine how vacant lots provided habitat for bird communities in an urban ecosystem, by assessing impacts on community composition, population abundances, and city-wide trends. We found that habitat features at the vacant lot and within the landscape were both important in determining bird community composition within vacant lots; however, tree coverage was important across multiple scales and species.

For our first question concerning species composition at the vacant lot, we did not find many variables that were predictors of species composition beyond tree cover. Within vacant lots of increasing canopy cover, canopy height and tree species richness, we would expect more native bird species within the community, such as robins, cardinals, and white-breasted nuthatches. These three species that correlated with the ordination axes all have life history traits that necessitate trees for either nesting or food sources. Other habitat variables, such as the presence of vegetation, foliage height diversity (e.g., MacArthur and MacArthur 1961), and density of understory and shrub layers (Tilghman 1987; Gavareski 1976), may have a positive impact for other urban birds. However, in this study, we did not find that shrub density or ground cover height related to bird community composition or any species' abundance. This could be due to trees serving as a more important resource for birds in search of habitat within the urban matrix (Fontana et al. 2011), particularly valuing large remnant trees (Barth et al. 2015) or tree cavities (LaMontagne et al. 2014).

Our results for our second question indicated that forest cover within 100 m of the vacant lot and canopy coverage at the site had the greatest influence on avian abundance across multiple species. The importance of tree cover across the city is consistent with many other urban bird studies particularly within forested settings (Chase and Walsh 2006), as trees are important nesting, cover, and food sources. Beyond tree cover, robins were the only species that responded to the greatest number of variables at the site and within the landscape-scale. Vacant lot habitat that would best support robins included trees and grass, located within a forested landscape. Shrub cover for robins may not have driven their abundance; however, we found within the same vacant lots that shrub cover was important for successful nesting attempts (Chapter 3). Our results for robins were consistent with other studies conducted in Baltimore, indicating that robin abundance was related to landscape vegetation (Wu et al. 2015), percent tree cover, percent grass cover (Lerman et al. 2014), and small parks (Rega et al. 2015).

Our models for the chimney swift and mourning doves did not fit the data. We suspect that this was due to both species' generalist life history traits and their movement frequency across the landscape. In particular, chimney swifts are a species that may not adequately use vacant lots for their resources and instead focus on landscape-level food availability for aerial foraging. This city-wide trend was indicated within our ordination, as chimney swifts were highly correlated with both ordination axes. We expect that we did not sample resources specific to chimney swift's life history needs; rather, these resources were distributed across the ordination axes.

Our last question focused on city-wide trends in bird species richness. Because our multivariate analysis of bird community composition ignores spatial dependence, this analysis provided spatial trends in the bird community, as a function of species richness. Vacant lots with high species richness occurred within areas of high forest cover and near the large forested parks in Baltimore. High species richness for these sites could indicate greater presence of interior forest bird species, which are rare in areas of the city with small habitat fragments (Chase and Walsh 2006). This species richness gradient from the city center to the periphery can be a function of environmental and urbanization gradients, possibly following the species sorting paradigm of metacommunity theory (Ortega-Álvarez and MacGregor-Fors 2009; Blair 1996; Minor and Urban 2010), while also possibly indicating trends in dispersal across the city. Vacant lots closer together were more similar in bird species richness than those farther apart. This interrelatedness could be a function of similar habitat structures along the gradient. Alternatively, according to the mass effects paradigm of the metacommunity theory (Leibold et al. 2004), nearby lots could share similar species due to source-sink relationships, allowing birds to colonize vacant or lower quality patches from nearby high quality patches. However, we could not adequately assess bird movement during this study to test this paradigm because we did not band birds.

By identifying which features are associated with community composition, we can determine at which scale management practices should focus. We found that bird communities were associated with vegetation at the site and environmental gradients:

canopy coverage at the vacant lot, surrounding forest cover, and city-wide species composition trends across the city. But the question still remains, what matters more? Can management practices be equally as effective across the city and urbanization gradient? We would argue that management efforts at vacant lots, specifically planting trees to increase canopy cover and landscape scale forest cover, would be much more effective within and around vacant lots closer to existing forest patches for increasing native bird diversity at the patch. Management for these vacant lots near forest patches should thus focus on maintaining forest patch size and radiating corridors to support interior forest bird communities and neighborhood-wide forest cover.

As for vacant lots further from the forested areas of the city, planting trees at the site would have a lesser impact on bird community assembly because these sites would lack both landscape forest cover and proximity to large forest patches. We would still suggest planting trees at these sites to increase city-wide tree cover and ecosystem service provisions (Kim et al. 2015). The community and population trends we found in Baltimore would support the argument for forested corridors within cities, because we know that dispersal of bird species and landscape tree abundance are both important to bird community composition (Sandström et al. 2006; Mörtberg and Wallentinus 2000).

Our findings suggest that in order to manage bird habitat, the top priority should be to provide trees within the site and across the city to attract native bird species. The results of this management approach would support two of the Baltimore City's sustainability plan goals: to double Baltimore's tree canopy by 2037 and to protect the city's ecology and biodiversity (Baltimore Office of Sustainability 2009). By increasing city-wide tree cover, we would expect to find an increase in cardinals and robins, and a decrease in starling abundance. Greater landscape tree cover could then result in a shift in community composition and provide additional niche availability throughout Baltimore, especially for species reliant on trees for cavity nesting.

Vacant lots are an excellent place to start these management efforts. Because vacant lots vary so extensively with their vegetation composition and structure (Chapter 1), minor management efforts should be effective for many vacant lots that already have substantial green features. Even if the vacant lot is bare, planting a few trees and corresponding less intensive management effects should be a start for supporting diverse native bird communities at the vacant lot and across the city (Jokimäki et al. 2014; Clergeau et al. 2001).

Not only are vacant lots located across the city, they also occur predominantly in residential land uses. Planting trees within these lots would consequently increase the natural features of these residential communities, which can have many positive effects on the community regarding safety, health, and decreased crime rates (Garvin et al. 2013b; Troy et al. 2012; Dwyer et al. 1991). Tree planting and management efforts in vacant lots can also be done with the assistance of local community groups, many of which currently own vacant lots. Especially for a city that has an abundance of vacant lots like Baltimore, utilizing these spaces for both their ecological and social benefits can have city-wide transformative effects.

Tables and Figures

Table 1. Mean and standard deviation (SD) of vegetation characteristics from 150 sampled vacant lots.

Feature	Variable	Mean	SD
Ground Cover	Artificial Ground Cover (%)	8.23	13.00
	Bare Ground (%)	3.12	5.65
	Forb Cover (%)	33.33	16.22
	Grass Cover (%)	42.37	19.88
	Leaf Litter Cover (%)	0.92	3.14
	Rock Cover (%)	0.19	0.99
	Shrub Cover (%)	9.42	15.42
	Tree Cover (%)	1.41	2.18
	Woody Litter Cover (%)	1.07	2.83
	Water Cover (%)	0	0.05
Vertical Structure	Ground Cover Height (cm)	22.85	21.62
	Canopy Height (m)	18.31	5.74
Horizontal Structure	Canopy Coverage (%)	32.95	30.72
	Shrub Stems	24.58	41.51
	Average Tree DBH (cm)	34.04	25.70
	Total Tree Count	2.5	3.13
	Tree Species Richness	1.44	1.27
Lot Area	Lot Area (ha)	0.48	0.97

Table 2. Detection and abundance models tested with their corresponding covariate descriptions and units of measurement.

	Model	Covariate
Detection	σ(date)	Julian date
	σ(time)	Time of survey (minute)
	σ(date+time)	Overall time in season and day
	σ(temp)	Ambient temperature (°C)
	σ(cloud)	Cloud cover (%)
	σ(temp+cloud)	Overall weather condition
	σ(wind+winddir)	Wind speed and direction (kph, degrees)
	σ(obs)	Observer
	σ(obs+temp+cloud)	Ability of observer to detect in weather conditions
	σ(obs+cloud)	Ability of observer to detect in cloudy conditions
	σ(.)	Null detection model
	σ(global)	All detection variables
Abundance	λ(gcht)	Ground cover height (cm) as a measure of mowing intensity
	λ(gcaavg)	Artificial ground cover (%)
	λ(gcgavg)	Grass ground cover (%)
	λ(canopy)	Canopy coverage (%)
	λ(stemavg)	Number of stems in shrub strata
	λ(lotarea)	Lot area (ha)
	λ(forest100)	Forested land cover within 100 m (ha)
	λ(year)	Annual changes in abundance
	λ(canopy+forest100)	Overall forest cover
	λ(gcht+gcgavg)	Managed lawn cover
	λ(stemavg+canopy100)	Site horizontal and vertical density
	λ(stemavg+gcht)	Ground and shrub strata density
	λ(.)	Null abundance model
	λ(global)	All abundance variables

Table 3. Top models for the five species correlated to changes in community composition across vacant lots. Table includes number of parameters (*K*), Akaike weight (w_i) based on Akaike's Information Criterion, and *P*-values from Freeman-Tukey goodness-of-fit tests for the top ranked abundance (λ) and detection (σ) models. See Appendix 2B for full model results.

Species	Top Model	*K*	w_i	*P*
American Robin	λ(forest100) σ(.)	3	0.24	0.11
Chimney Swift	λ(canopy+forest100) σ(global)	24	0.94	0
European Starling	λ(canopy+forest100) σ(cloud+obs)	19	0.88	0.66
Mourning Dove	λ(canopy+forest100) σ(date)	22	1.00	0
Northern Cardinal	λ(forest100) σ(temp+cloud)	5	0.72	0.95

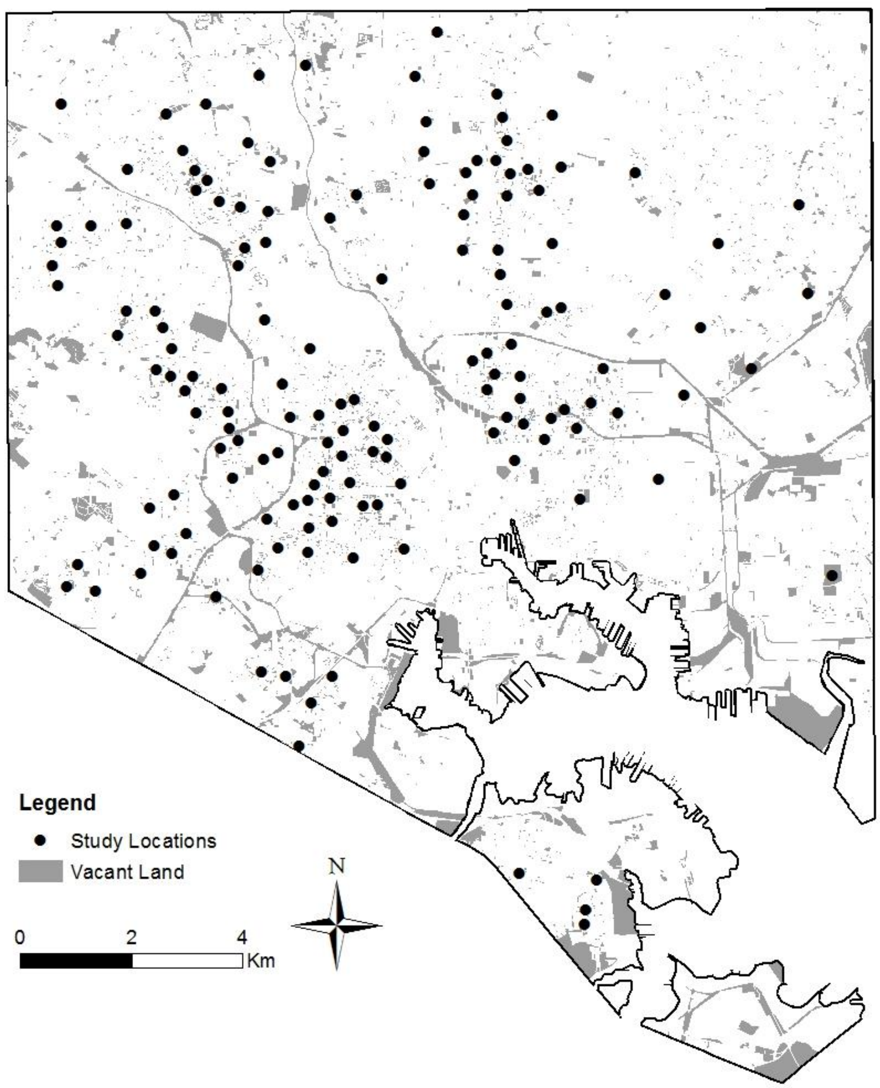

Figure 1. Vacant land cover and study site locations in Baltimore, Maryland.

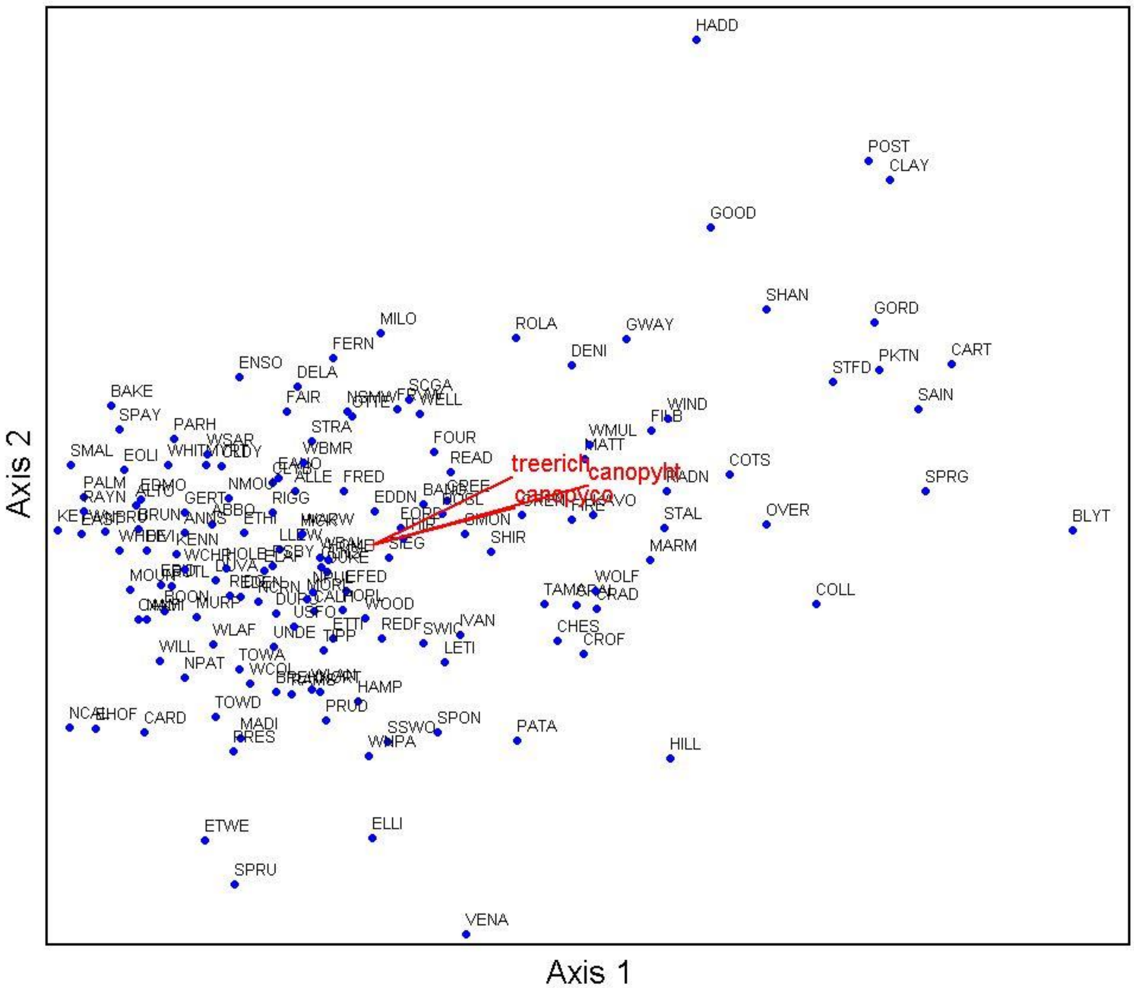

Figure 2. Bray Curtis polar ordination of sites by their bird community (blue circles), and the correlated vegetation variables of tree richness (treerich), canopy height (canopyht), and canopy cover (canopyco; red lines). Four letter codes indicate the site's name. Figure indicates a separation of sites by the lot's canopy height, coverage, and tree species richness across both axes.

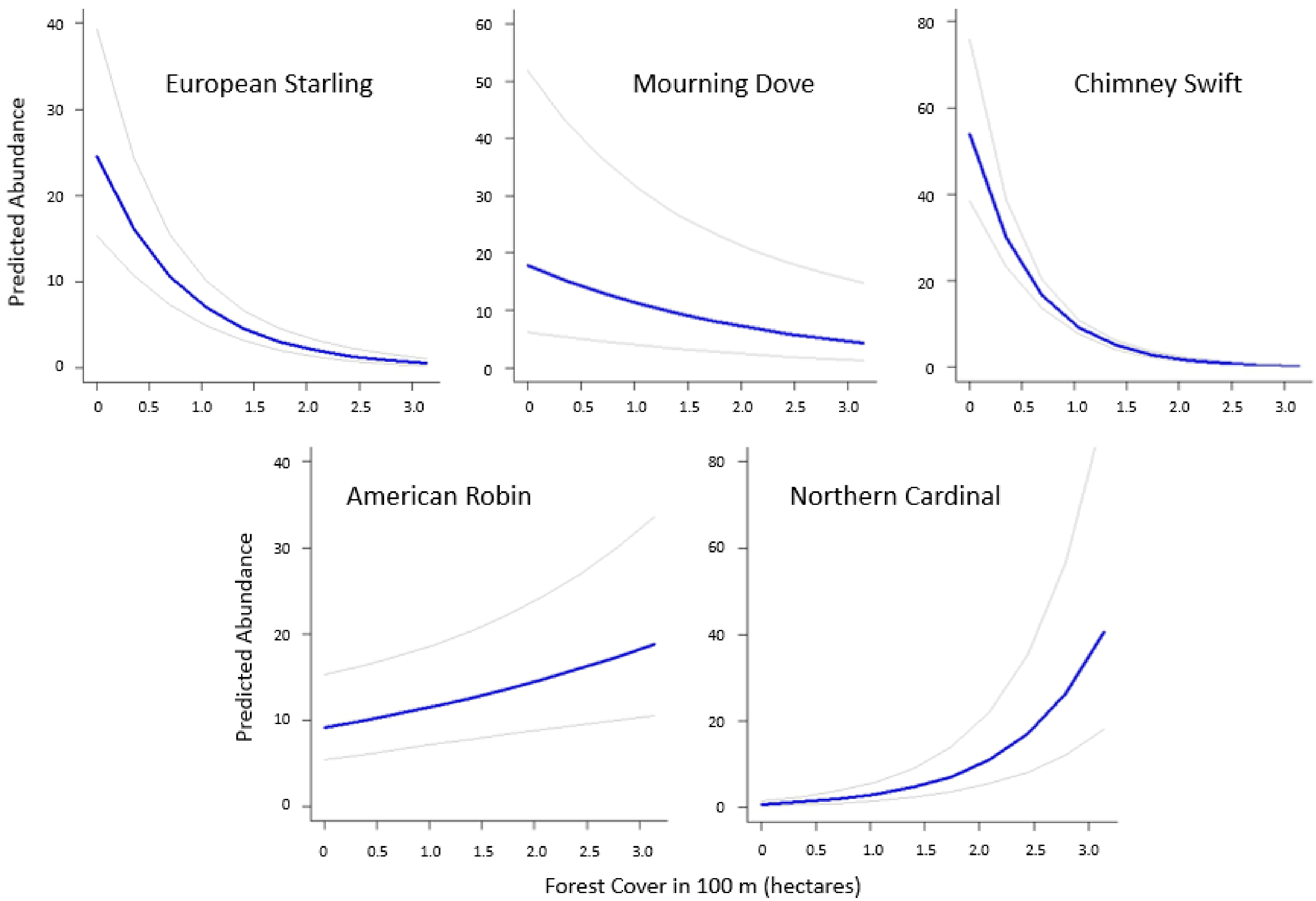

Figure 3. Predicted species' abundance with increasing landscape level (100 m) forest cover for five key species. Gray lines indicate 95% confidence intervals.

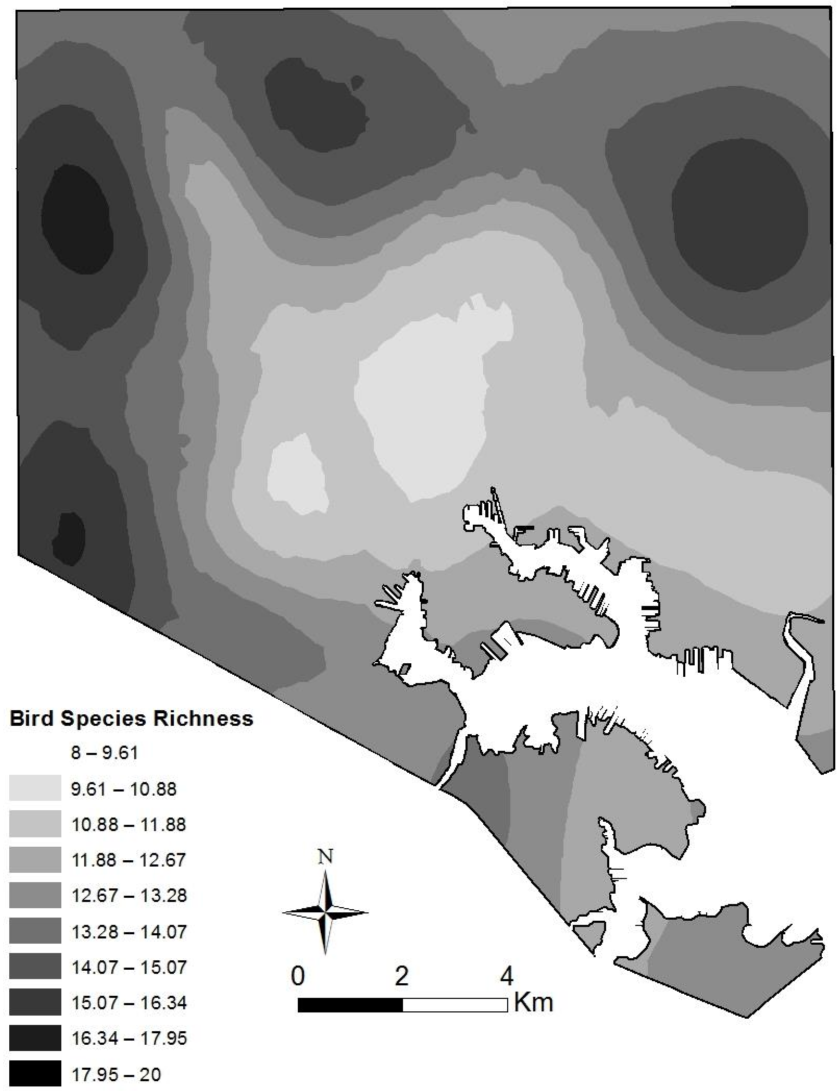

Figure 4. Kriged bird species richness in Baltimore. Areas of greatest species richness (dark gray) occurred in the northern and western areas of Baltimore, which contained greater tree cover.

Appendix 2A. Bird species observed and their total detections within vacant lots. Species with an asterisk (*) were the five most commonly detected species.

Scientific Name	Common Name	Detections
Accipiter cooperii	Cooper's hawk	3
Agelaius phoeniceus	Red-winged blackbird	5
Archilochus colubris	Ruby-throated hummingbird	7
Ardea herodias	Great-blue heron	4
Baeolophus bicolor	Tufted titmouse	37
Bombycilla cedrorum	Cedar waxwing	53
Branta canadensis	Canada goose	11
Buteo jamaicensis	Red-tailed hawk	1
Buteo lineatus	Red-shouldered hawk	8
Cardellina pusilla	Wilson's warbler	1
Cardinalis cardinalis	Northern cardinal	395
Carduelis tristis	American goldfinch	42
Carpodacus mexicanus	House finch	224
Cathartes aura	Turkey vulture	1
**Chaetura pelagica*	Chimney swift	1668
Coccyzus americanus	Yellow-billed cuckoo	2
Colaptes auratus	Northern flicker	16
**Columba livia*	Rock dove	690
Contopus virens	Eastern wood peewee	20
Corvus ossifragus	Fish crow	76
Crovus brachyrhynchos	American crow	122
Cyanocitta cristata	Blue jay	38
Dumetella carolinensis	Gray catbird	329
Empidonax virescens	Acadian flycatcher	3
Geothlypis trichas	Common yellowthroat	8
Hirundo rustica	Barn swallow	23
Hylatomus pileatus	Pileated woodpecker	6
Hylocichla mustelina	Wood thrush	7
Icterus galbula	Baltimore oriole	5
Larus argentatus	Herring gull	1

Appendix 2A. Continued.

Scientific Name	Common Name	Detections
Larus delawarensis	Ring-billed gull	25
Leuconotopicus villosus	Hairy woodpecker	6
Melanerpes carolinus	Red-bellied woodpecker	21
Melospiza melodia	Song sparrow	93
Mimus polyglottos	Northern mockingbird	251
Mniotilta varia	Black-and-white warbler	2
Molothrus ater	Brown-headed cowbird	27
Myiarchus crinitus	Great-crested flycatcher	7
**Passer domesticus*	House sparrow	1445
Passerina cyanea	Indigo bunting	13
Picoides pubescens	Downy woodpecker	44
Pipilo erythrophthalmus	Eastern towhee	2
Piranga olivacea	Scarlet tanager	1
Poecile carolinensis	Carolina chickadee	55
Polioptila caerulea	Blue-gray gnatcatcher	6
Quiscalus quiscula	Common grackle	514
Setophaga americana	Northern parula	6
Setophaga fusca	Blackburnian warbler	2
Setophaga ruticilla	American redstart	4
Sitta carolinensis	White-breasted nuthatch	16
Spizella passerina	Chipping sparrow	30
Strix varia	Barred owl	1
**Sturnus vulgaris*	European starling	2454
Tachycineta bicolor	Tree swallow	5
Thryothorus ludovicianus	Carolina wren	45
Troglodytes aedon	House wren	80
**Turdus migratorius*	American robin	1127
Tyrannus tryannus	Eastern kingbird	15
Vireo olivaceus	Red-eyed vireo	2
Zenaida macroura	Mourning dove	433

Appendix 2B. Full models results for the five species correlated to changes in community composition across vacant lots. Table includes number of parameters (K), Akaike's Information Criterion (AIC), difference in AIC values compared to the top ranked model (ΔAIC), and model weight (w_i) for abundance (λ) and detection (σ) models.

Species	Model	K	AIC	ΔAIC	w_i
American Robin	λ(forest100)σ(.)	3	1622.02	0	0.27
	λ(canopy+forest100)σ(.)	4	1622.5	0.48	0.21
	λ(gcgavg)σ(.)	3	1623.09	1.07	0.16
	λ(canopy)σ(.)	3	1623.46	1.43	0.13
	λ(gcht+gcgavg)σ(.)	4	1624.56	2.53	0.076
	λ(stemavg+canopy)σ(.)	4	1624.87	2.85	0.065
	λ(lotarea)σ(.)	3	1626.57	4.55	0.028
	λ(.)σ(.)	2	1626.91	4.89	0.023
	λ(gcht)σ(.)	3	1627.78	5.75	0.015
	λ(stemavg)σ(.)	3	1628.84	6.82	0.0089
	λ(gcaavg)σ(.)	3	1628.88	6.85	0.0087
	λ(stemavg+gcht)σ(.)	4	1629.64	7.62	0.006
	λ(year)σ(.)	3	1676.9	54.88	3.3E-13
	λ(global)σ(.)	10	1699.47	77.44	4.1E-18
Chimney Swift	λ(canopy+forest100)σ(global)	24	1834.91	0	0.94
	λ(forest100)σ(global)	23	1840.39	5.49	0.06
	λ(canopy)σ(global)	23	1935.5	100.59	1.3E-22
	λ(stemavg+canopy)σ(global)	24	1937.5	102.59	5E-23
	λ(gcaavg)σ(global)	23	1968.71	133.81	8.3E-30
	λ(lotarea)σ(global)	23	1984.72	149.81	2.8E-33
	λ(stemavg)σ(global)	23	1993.49	158.58	3.4E-35
	λ(stemavg+gcht)σ(global)	24	1995.04	160.14	1.6E-35
	λ(gcgavg)σ(global)	23	2003.94	169.04	1.8E-37
	λ(gcht+gcgavg)σ(global)	24	2004.25	169.34	1.6E-37
	λ(null)σ(global)	22	2005.22	170.31	9.8E-38
	λ(gcht)σ(global)	23	2006.16	171.25	6.1E-38
	λ(year)σ(global)	23	2381.34	546.44	2.1E-119
	λ(global)σ(global)	30	2479.13	644.22	1.2E-140

Appendix 2B. Continued.

Species	Model	K	AIC	ΔAIC	w_i
European Starling	λ(canopy+forest100)σ(cloud+obs)	19	1382.36	0	0.88
	λ(forest100)σ(cloud+obs)	18	1386.44	4.07	0.12
	λ(stemavg+canopy)σ(cloud+obs)	19	1428.45	46.09	8.7E-11
	λ(canopy)σ(cloud+obs)	18	1429.3	46.94	5.7E-11
	λ(stemavg)σ(cloud+obs)	18	1450.3	67.94	1.6E-15
	λ(stemavg+gcht)σ(cloud+obs)	19	1451.77	69.4	7.5E-16
	λ(gcaavg)σ(cloud+obs)	18	1464.48	82.12	1.3E-18
	λ(.)σ(cloud+obs)	17	1464.95	82.59	1E-18
	λ(gcgavg)σ(cloud+obs)	18	1465.14	82.77	9.4E-19
	λ(lotarea)σ(cloud+obs)	18	1466.26	83.9	5.4E-19
	λ(gcht)σ(cloud+obs)	18	1466.91	84.55	3.9E-19
	λ(gcht+gcgavg)σ(cloud+obs)	19	1466.97	84.61	3.7E-19
	λ(global)σ(cloud+obs)	25	1579.47	197.11	1.4E-43
	λ(year)σ(cloud+obs)	18	1677.13	294.77	8.7E-65
Mourning Dove	λ(canopy+forest100)σ(date)	5	1123.45	0	0.61
	λ(forest100)σ(date)	4	1125.75	2.31	0.19
	λ(gcaavg)σ(date)	4	1125.97	2.52	0.17
	λ(gcgavg)σ(date)	4	1132.65	9.2	0.0061
	λ(.)σ(date)	3	1132.85	9.4	0.0055
	λ(stemavg)σ(date)	4	1133.61	10.16	0.0038
	λ(lotarea)σ(date)	4	1134.45	11	0.0025
	λ(gcht+gcgavg)σ(date)	5	1134.64	11.19	0.0023
	λ(stemavg+canopy)σ(date)	5	1134.64	11.2	0.0023
	λ(canopy)σ(date)	4	1134.68	11.23	0.0022
	λ(gcht)σ(date)	4	1134.83	11.38	0.0021
	λ(stemavg+gcht)σ(date)	5	1135.56	12.11	0.0014
	λ(year)σ(date)	4	1185.68	62.23	1.9E-14
	λ(global)σ(date)	11	1201.94	78.49	5.5E-18

Appendix B. Continued.

Species	Model	K	AIC	ΔAIC	w_i
Northern Cardinal	λ(forest100)σ(temp+cloud)	5	968.03	0	0.72
	λ(canopy+forest100)σ(temp+cloud)	6	969.89	1.86	0.28
	λ(canopy)σ(temp+cloud)	5	1033.23	65.2	5E-15
	λ(stemavg+canopy)σ(temp+cloud)	6	1034.74	66.71	2.3E-15
	λ(gcgavg)σ(temp+cloud)	5	1041.22	73.19	9.2E-17
	λ(gcht+gcgavg)σ(temp+cloud)	6	1042.4	74.37	5.1E-17
	λ(stemavg)σ(temp+cloud)	5	1042.54	74.51	4.7E-17
	λ(gcaavg)σ(temp+cloud)	5	1042.71	74.68	4.4E-17
	λ(stemavg+gcht)σ(temp+cloud)	6	1043.45	75.42	3E-17
	λ(.)σ(temp+cloud)	4	1044.92	76.89	1.4E-17
	λ(gcht)σ(temp+cloud)	5	1045.59	77.56	1E-17
	λ(lotarea)σ(temp+cloud)	5	1046.07	78.04	8.1E-18
	λ(year)σ(temp+cloud)	5	1146.55	178.52	1.2E-39
	λ(global)σ(temp+cloud)	12	1160.55	192.52	1.1E-42

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Chapter 3: Vacant Lots as a Resource for Urban Birds: Nesting Success and Body Conditions of Songbirds

Abstract

Vacant lots are a common feature throughout many cities, and may provide necessary habitat resources for urban bird populations. We evaluated the quality of vacant lots throughout Baltimore, Maryland by determining how differences in vacant lot properties related to songbird's nesting success and body condition. We observed 130 nests from American robins, gray catbirds, and northern cardinals across the city and assessed body condition of 19 adult robins. Nesting success for all three species was greatest within areas of vacant lots with high shrub densities. For our body condition sampling, the robins' morphometrics did not vary extensively and was not related to any vacant lot site- or landscape-level variables. Even so, we found vacant lots to be actively used by many bird species for a variety of resources, with those containing more shrubs to be the most beneficial for bird species' nesting attempts. Vacant lots should no longer be discarded and underestimated, instead they should be valued for their urban wildlife habitat resources and the locations of small-effort management practices.

Introduction

Vacant lots within cities are often seen as discarded, insignificant plots of land (Accordino and Johnson 2000, Pagano and Bowman 2000); however, these informal greenspaces may be a much needed source of habitat for many wildlife species in the urban matrix (Kremer et al. 2013). Even though vacant lots are typically small in size, they are abundant. Within 83 cities in United States, 15% of a city's land was classified as vacant in 2000 (Pagano and Bowman 2000), and this value is thought to have increased since then due to the foreclosure crisis, among other reasons (Mallach 2010, Németh and Langhorst 2014). Because of their transitional properties, vacant lots can range in habitat from early successional weedy lots to fully forested patches of habitat. With this variation in vegetation features and their abundance, vacant lots may provide a significant source of habitat in cities, particularly for urban bird populations.

A number of studies have explored the importance of small greenspaces within the urban matrix for bird habitat (Strohbach et al. 2013, Rega et al. 2015), which may range in importance depending on the greenspace's contents, structure, and location within the urban landscape (Donnelly and Marzluff 2004). Even though these spaces may provide species' with habitat resources, can they support sustainable bird populations? By assessing the ecological characteristics of vacant lots on this successional spectrum, we can begin to determine how adequate these habitat patches are in supporting urban birds. From our previous study, we found vacant lots with greater tree cover provided habitat for a rich bird community and abundant population sizes for native species (Chapter 2). However, the presence of these species at the vacant lot may not be the only indicator of the lot's habitat quality.

Urban species are impacted by the gradient of habitat quality due to changes in altered food sources and nesting opportunities, in addition to other habitat constraints (Jokimäki and Suhonen 1998, Marzluff et al. 2001, Mennechez and Clergeau 2006). Thus, even if the species occurs at a site, its presence may not correlate with reproduction and survival of the species (Johnson 2007). In order to serve as a habitat resource, most urban sites need to provide adequate habitat features to support songbirds' nesting and food resource needs. If vacant lots fail to do so, they may serve as an ecological trap by attracting species to sites that will ultimately lead to poor nest success rates or poor food sources for survival. In this study, we ask how well vacant lots provide such resources to support successful nesting attempts and body conditions of songbird species.

Many factors play into how effective habitat can be for nesting birds, such as the availability of the nest substrate, protection from nest predators, and adequate nutrition sources for the nestlings (Martin and Roper 1988, Martin 1993, Robinson et al. 1995, Graveland and Drent 1997, Chalfoun et al. 2002b, Tilgar et al. 2002, Bidwell and Dawson 2005). Beyond local habitat features, landscape configurations may also be associated with nest productivity due to habitat fragmentation (Robinson et al. 1995). Since vacant lots vary considerably in vegetation composition, structure, and lot size, we would expect to find a gradient in nesting success across vacant lots. Specifically, we expect to find vacant lots with more trees and shrubs to provide the greatest resources for nest construction and protection, thus increased nest success.

Along with nesting success, vacant lot habitat quality also may be strongly related to the body condition of birds. The body condition of birds can be a useful indicator of habitat quality due to food supply and quality limitations, especially in sedentary species (Johnson 2007). Food resources are not consistent across a range of urban development, so even birds that are usually deemed habitat generalists can have resulting differences in body mass across an urban-suburban gradient (Mennechez and Clergeau 2006, Liker et al. 2008). However, it is unclear whether birds exhibit variation in body condition among different small open spaces in a densely urbanized area.

In order to determine the quality of habitat vacant lots provide, we examined nesting efforts and body condition of bird species throughout vacant lots in Baltimore, Maryland. We hypothesized that the vegetation structure across vacant lots should be reflected in different nest success rates and body conditions of generalist species. We would expect vacant lots with shrubby vegetation and tall trees to provide the greatest quality bird habitat, as compared to either early successional, weedy lots or highly managed vacant lots dominated by lawn. Lots with a shrubby understory and tall trees should provide species with opportunities to nest in concealed locations and ample food sources (Martin and Roper 1988, Martin 1992, Gleditsch and Carlo 2014).

Methods

Site Habitat Characteristics

Out of approximately 16,500 vacant parcels, 150 lots were randomly selected for an intensive urban avian ecology study as a part of the Baltimore Ecosystem Study Long Term Ecological Research (LTER) project (Figure 1). All lots fulfilled the requirements of accessibility, larger than 0.05 ha, and had some form of vertical vegetation were then chosen as a site. All sites were surveyed between May – July in 2013 – 2015.

We located three 0.04 ha plots at the vacant lot's center to measure vegetation structure and composition (James and Shugart Jr. 1970). We measured 15 vegetation variables: canopy cover (%), canopy height (m), shrub cover (shrub density), ground cover (%) and composition, and tree species richness, count, and diameter-at-breast-height (dbh). We conducted a Pearson's correlation analysis to reduce multicollinearity among site habitat variables ($r \geq 0.5$; $r \leq -0.5$). The final vegetation covariates represented variation in management intensity (ground cover height), impervious surface (artificial ground cover), amount of lawn (grass ground cover), site tree coverage (canopy cover), and shrub density (stem count; Table 1).

Landscape level vegetation characteristics may also be related to the presence and success of a species at a site. We assessed landscape level tree coverage at local (100 m, 500 m) and "neighborhood" scales (1000 m) (Melles et al. 2003, Ryder et al. 2010), with each radius centered at the point count location. These three covariates were highly correlated, so we selected the landscape level tree coverage at a local scale (100 m) to indicate habitat quality within and surrounding the vacant lot. Digitized LANDSAT satellite image maps were used to quantify forested land cover features (Parker and Nilon 2012).

Nest Monitoring

We searched for all possible nests in 2013 – 2015 and immediately began monitoring until all individuals fledged or the nest failed (mean nest check interval = 3.2 ± 0.1 (SE) days). A nest was considered successful if at least one nestling fledged. Failed nests were those that either were empty prior to the nestling's expected fledge date, nestlings were found dead within the nest, or if the eggs were punctured. Abandoned nests were those with eggs that never hatched with the absence of adults in the area surrounding the nest.

We recorded the nest's height, supporting vegetation species, and percent concealment. Nest concealment was determined by the percent of the nest covered by vegetation at nest-height level in each of the four cardinal directions, one meter away from the nest while it was active (Burhans and Thompson 1998). We repeated our vegetation sampling procedure centered at the nest to determine if those variables contributed to the nest's success.

Nest Success Modeling

We used MCestimate (Etterson 2010), a Markov chain algorithm program (Etterson et al. 2007a, Etterson et al. 2007b), to estimate daily nest failure rates due to specific covariates. We analyzed the response variable as a binomial (success/failure) response, as the nests considered to be abandoned did not have a sample size large enough to analyze as independent failure categories. There needed to be at least 20 nests within each failure category to run independently (Hensler and Nichols 1981).

We constructed 20 models a priori using site and nest covariates to determine causes of nest failure. Models included those to test for effects of nest placement, site size, site vegetation structure, and landscape-level forest cover, in addition to a null and global model. We also included a model for differences in individual species' nesting success. Models with an Akaike's Information Criterion (ΔAICc) value less than 2 were considered to be plausible as a cause for daily nest failure (Burnham and Anderson 1998). Goodness of fit for the top nest success model was determined the Pearson X^2 with 100 bootstrap iterations. To determine the chance of nest success over the nesting period, we used mean nest cycle (number of days from incubation to fledging) durations (Baicich and Harrison 2005).

Body Condition Analysis

We captured American robins via targeted mist netting with playback, usually surrounding a nest, in the 2013 and 2014 seasons (ACUC Protocol #7621). American robins were selected for this analysis as they are an abundant species, one of the most common species nesting in vacant lots, and prefer foraging in a mix of forested and lawn habitats. We weighed and measured the tarsus length of each captured bird. We took additional measurements that were not used in this analysis to determine overall variation in morphometrics: wing chord (mm), culmin (bill; mm), and head (mm) lengths. All measurements were taken by the primary author. Each bird was also sexed, aged (hatch year, after-hatch year), and received three unique color bands and an USFWS silver band under federal guidelines.

We calculated a body condition index as the residuals from a least-squares linear regression analysis between body mass and tarsus length (Schulte-Hostedde et al. 2005). We conducted Pearson correlations to study the relationships between body condition and the aforementioned vacant lot vegetation and landscape covariates in Program R (R Core Team 2015). Prior to running all individuals in the correlation, we checked to see if body condition varied between males and females with a one-way ANOVA.

Results

Nest Success

We monitored 130 nests from 2013 to 2015 (401 observations, 1276 exposure days). We found nests within 72 of 150 vacant lots. Most nests were American robin nests (*Turdus migratorius*, n = 61), and the remaining nests included gray catbirds (*Dumetella carolinensis*; n = 41), northern cardinals (*Cardinalis cardinalis*; n = 12), mourning doves (*Zenaida macroura*; n = 8), and northern mockingbirds (*Mimus polyglottos*; n = 8) (Figure 2). We fit nest success models for the pooled sample of robin, gray catbird, and northern cardinal nests to ensure an adequate sample size and because these three species are similar open-cup nesters that require a shrub or tree to build their nest.

The most supported nest success model was shrub density surrounding the nest (Table 2; $\beta = 0.01 \pm 0.003$; Pearson X^2, $P = 0.53$). Daily nest survival rate was 96.3% (standard error ± 0.6%), while over the average 24-day nesting period, nest success was

40.9% (standard error ± 6.04%) for these three species. Overall nest success increased with increasing shrub densities; however this model indicated greater variability in nesting success in locations where shrub density exceeded 200 shrub stems (Figure 3). Compared to the average vegetation present at the site, nests were placed within areas with greater shrub densities (Table 3).

Body Condition

Nineteen adult robins were caught and assessed for their body condition within 14 sites (Figure 4). Once banded, many of these individuals were observed at the banding location throughout the summer season, and one male was recaptured at the same location in late summer after banding in early May. Out of the 19 individuals, 11 were males. Females' weight may vary over a season due to egg-laying; however, we did not recapture any females to record any weight changes. We found that body condition did not differ between the sexes (ANOVA: F= 0.015, *P*= 0.90; Table 4).

Variation in weight and tarsus length was minimal across all individuals (Table 4), apart from one individual who weighed substantially less (46.5 g). Due to his weight and observed sickly condition, this individual was removed from our body condition analysis. When comparing body condition to vacant lot variables, we found no strong correlation with any site- or landscape-scale variables (Table 5).

Discussion

In order to assess the quality of vacant lots for bird habitat, we assessed nest success and body condition of various species in Baltimore. We determined that shrub density was most closely associated in determining nesting success across species, while body condition was consistent across all sites and was not related to any site or landscape variable. Our results indicated that vacant lots can provide urban bird habitat and support successful nesting attempts. From other studies located at these lots, we have already found that vacant lots can support rich bird communities and abundant population sizes with the increasing presence of trees at the site and in the landscape (Chapter 2). These data indicated that vacant lots cannot be overlooked for their habitat provisions in the urban landscape.

We found that bird populations, specifically American robins, gray catbirds, and northern cardinals, did have successful nesting attempts in vacant lots, with a relatively high 96.3% daily success rate and 40.9% interval nest success. This rate was consistent with the ~93% daily nesting success for American robins and northern cardinals within urban-agricultural gradient in Ohio (Borgmann and Rodewald, 2004).

Nests placed within areas of high shrub densities (> 25 stems) had high success rates for the three observed species. This follows a number of studies that indicate a relationship between the probability of fledging young and nest concealment (Martin 1992, Hoover and Brittingham 1998, Donnelly and Marzluff 2004) or denser habitat vegetation at the site (Martin and Roper 1988, Martin 1992) due to predation pressures. Urban nest predators are unique compared to rural or suburban communities (Chalfoun et al. 2002a, Marzluff et al. 2007, Ryder et al. 2010), as urban nest failures are commonly attributed to increased levels of predation by feral cats, corvids, and other mesopredators (Chase and Walsh 2006, Marzluff et al. 2007). Thus, nests placed in areas with dense shrubs would best conceal and protect their contents from a variety of ground-dwelling and aerial predators, as compared to open, mowed habitats.

Average shrub density across the vacant lot was low in comparison to shrubs surrounding the nest (Table 3), so we can assume that shrub-nesting species utilizing vacant lots are selecting to nest within dense areas of shrubs, even if the vacant lot is overall open in structure (Rousseau et al. 2015). This nest site selection might be in response to predation pressure within more open areas of the vacant lot; thus, dense areas of shrubs may provide the nesting benefits of visual concealment (Martin 1992;1993, Burhans and Thompson 1998) or increased search area for predators to find a nest within dense habitats (Filliater et al. 1994, Thompson 2007). Because of this pattern, maintaining areas of dense shrubs within vacant lots are important for sustaining nesting success for songbirds, particularly open-cup shrub nesting species.

However, the question still remains if successfully fledged young are equally as successful in these dense vacant lots, as few studies have explored what happens to urban birds immediately post-fledging (Chase and Walsh 2006). Lower nestling weight (Chamberlain et al. 2009), less diverse or insufficient food sources (Schnack 1990), collision with man-made objects (Chase and Walsh 2006, Mennechez and Clergeau 2006), and disease can all affect avian survival post-fledging; however many of these may be species-dependent effects. We recommend future research to explore differences urban nest predator communities in vacant lots and their impacts on post-fledgling survival.

Even though we did not find any links between body condition and habitat features, this relationship has been shown in a number of generalist species. House sparrow body condition declined over an urbanization gradient due to habitat differences in nestling development (Liker et al. 2008), while declines in nesting success due to insufficient food resources to rear young were reported for European starlings (Mennechez and Clergeau 2006). Body condition may vary across different habitats in response to habitat quality (Mennechez and Clergeau 2006, Liker et al. 2008); however, the mobility of these species and quality of adjacent habitats may confound these relationships and result in consistent body condition across sites (Bókony et al. 2012). Additionally, the impacts of habitat quality may only be apparent for nestlings and juveniles' body condition, as they are restricted in their movements across sites (Meillère et al. 2015).

An additional impact to body condition and nesting success of birds may be the presence of exotic plant species that are commonly found with increasing urbanization. The abundance of exotic plant species tend to increase with urbanization (Blair 1996), and they are especially prominent in emergent vacant lots (Vessel and Wong 1987). The impacts of exotic plants on nesting success and the bird community are mixed. Some studies indicate decreasing food availability (Burghardt et al. 2009) and nesting success (Borgmann and Rodewald 2004, Rodewald et al. 2010), and increased risks of brood parasitism by brown-headed cowbirds (*Molothrus ater*) (Rodewald 2009) with increased exotic plant abundance. However, as habitat resources lessen in areas with dense urban development, exotic plant species may increase structural diversity and provide resources that otherwise are not present (Mills et al. 1989, Gleditsch and Carlo 2014). Vacant lots would provide an excellent location to study such trends, as they are locations of high exotic species densities and may turn over for development readily to study the impacts of their presence.

It is our understanding that this study is the first to look at vacant lots specifically for their resources regarding nesting and body condition in songbirds. We have found that dense vacant lots provide the greatest nesting resources for urban birds, which may be positive for native bird conservation in cities, but may not be the best goal for managing vacant lands for community residents. Urban residents prefer greenspaces with clear sight lines and indicators of management due to safety concerns and potential for recreational use (Schroeder and Anderson 1984, Ross and Mirowsky 1999, Garvin et al. 2013a, Garvin et al. 2013b). Finding a balance between providing enough shrub cover for nesting birds and resident preferences for vacant lots may be a challenge; however, is a challenge worth tackling. With the abundance of vacant lots in Baltimore, opportunities are ripe for the taking to provide wildlife habitat while also meeting the needs of local residents.

Management Implications

Identifying nesting and body condition patterns of birds throughout the city provide habitat managers additional information for conserving urban avian populations, through vacant lot modifications. Because vacant lots are found throughout the city and vary so greatly in their vegetation composition and structure, those lacking shrub or tree cover could easily be targeted for improvement. Most ruderal or remnant vacant lots have areas of dense shrubs, and already provide nesting resources. However, dense and weedy vacant lots can be a considerable social problem (Garvin et al. 2013a, Kremer et al. 2013, McPhearson et al. 2013, Rega-Brodsky and Nilon In review), and most groups managing these spaces are local landowners. Thus, balancing the needs of neighborhood residents with urban bird management goals is particularly necessary within vacant lots. By managing these sites (Chapter 4), the community may be more willing to use and conserve the site. Residents also preferred vacant lots with clear sightlines for safety (Chapter 4), so to manage for increased nesting success may require small areas of dense shrubs (>25 stems per 0.04 ha) within an otherwise open vacant lot. Overall, the decisions for vacant lot management will benefit from the knowledge of avian condition and habitat usage across the city to make one large step towards managing for wildlife in urban centers.

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Tables and Figures

Table 1. Nest success and body condition model covariates, and the scale of sampling.

Scale	Covariate	Code
Nest	Bird species	Spp
	Nest height (m)	ht
	Nest concealment (%)	cover
	Year of establishment	Year
Site	Herbaceous ground cover height (cm)	gcht
	Artificial ground cover (%)	gca
	Grass ground cover (%)	gcg
	Canopy coverage (%)	canopy
	Number of stems in shrub strata	shrubstem
	Lot size (ha)	lotarea
Landscape	Forest land cover within 100m	forest100

Table 2. Models for daily nest survival for three songbird species within vacant lots. Table presents Akaike's Information Criterion (AICc), difference in AIC values compared to the top ranked model (ΔAICc), model weight (wt), and the number of parameters (K).

Model	AICc	ΔAICc	wt	K
fail(shrubstem)	274.76	0	0.61	2
fail(Spp+shrubstem)	277.07	2.3	0.19	4
fail(canopy+Spp)	279.4	4.64	0.06	4
fail(Spp)	279.53	4.77	0.06	3
fail(canopy)	280.92	6.16	0.03	2
fail(forest100+canopy)	282.92	8.15	0.01	3
fail(gcg)	283.09	8.33	0.01	2
fail(.)	283.87	9.1	0.01	1
fail(gca)	284.71	9.95	0	2
fail(gcg+gca+gcht)	284.81	10.05	0	4
fail(gcg+gcht)	285.06	10.29	0	3
fail(Year)	285.5	10.73	0	3
fail(ht)	285.68	10.92	0	2
fail(cover)	285.72	10.96	0	2
fail(gcht)	285.76	11	0	2
fail(forest100)	285.84	11.07	0	2
fail(lotarea)	285.86	11.1	0	2
fail(gcht+gca)	286.52	11.76	0	3
fail(cover+ht)	287.6	12.84	0	3
fail(global)	288.46	13.69	0	14

Table 3. Mean and standard error (SE) of vegetation surrounding the nest, compared to mean vegetation variables for all vacant lot sites.

Variable	**Nest**	**Vacant Lot**
Herbaceous Ground Cover Height (cm)	17.98 (2.25)	22.85 (1.86)
Artificial Ground Cover (%)	12.68 (1.50)	8.22 (0.67)
Grass Ground Cover (%)	32.95 (1.95)	42.37 (3.45)
Canopy Coverage (%)	79.60 (2.50)	32.94 (2.69)
Number of Shrub Stems	70.23 (7.07)	24.57 (2.00)
Lot Size (ha)	0.50 (0.04)	0.48 (0.03)
Forest Cover within 100m (ha)	0.74 (0.05)	0.73 (0.05)

Table 4. Morphometric variables and averages (standard error) for all banded robins caught in Baltimore, Maryland.

Variable		n	Mean	SE
Year	2013	8	.	.
	2014	11	.	.
Sex	Male	11	.	.
	Female	8	.	.
Weight (g)		19	73.76	1.62
Wing Length (mm)		19	125.54	0.93
Tarsus Length (mm)		19	32.73	0.37
Bill Length (mm)		19	23.04	0.41
Head Length (mm)		19	48.03	0.28
Body Condition		19	5.55 E-09	0.53

Table 5. Pearson correlation matrix of body condition metrics and vacant lot habitat features. Bolded correlation coefficients are considered strong relationships.

	weight	**wing**	**tarsus**	**bill**	**head**	**resid**	**gcht**	**gcaavg**	**gcgavg**	**canopy**	**shrubstem**	**lotarea**	**forest100**
weight	.	.	.	.	.	.	.	.	.	.	.	.	.
wing	0.341	.	.	.	.	.	.	.	.	.	.	.	.
tarsus	0.494	0.295	.	.	.	.	.	.	.	.	.	.	.
bill	**0.641**	**0.559**	**0.604**	.	.	.	.	.	.	.	.	.	.
head	**0.600**	0.440	**0.682**	**0.643**	.	.	.	.	.	.	.	.	.
resid	**0.870**	0.224	0.000	0.395	0.303	.	.	.	.	.	.	.	.
gcht	-0.475	-0.300	**-0.685**	**-0.529**	-0.482	-0.158	.	.	.	.	.	.	.
gcaavg	-0.458	**-0.661**	-0.468	**-0.595**	**-0.518**	-0.261	**0.645**	.	.	.	.	.	.
gcgavg	0.055	0.550	0.249	0.396	0.282	-0.078	**-0.561**	**-0.664**	.	.	.	.	.
canopy	0.279	0.293	0.125	0.400	0.367	0.250	-0.174	**-0.657**	0.109	.	.	.	.
shrubstem	-0.135	-0.288	-0.130	-0.123	-0.150	-0.081	0.288	-0.059	-0.344	**0.626**	.	.	.
lotarea	-0.185	-0.215	0.010	-0.298	-0.247	-0.219	-0.186	0.455	0.075	**-0.724**	-0.437	.	.
forest100	-0.131	**0.608**	0.049	0.247	0.213	-0.178	-0.189	-0.437	**0.808**	0.071	-0.283	0.135	.

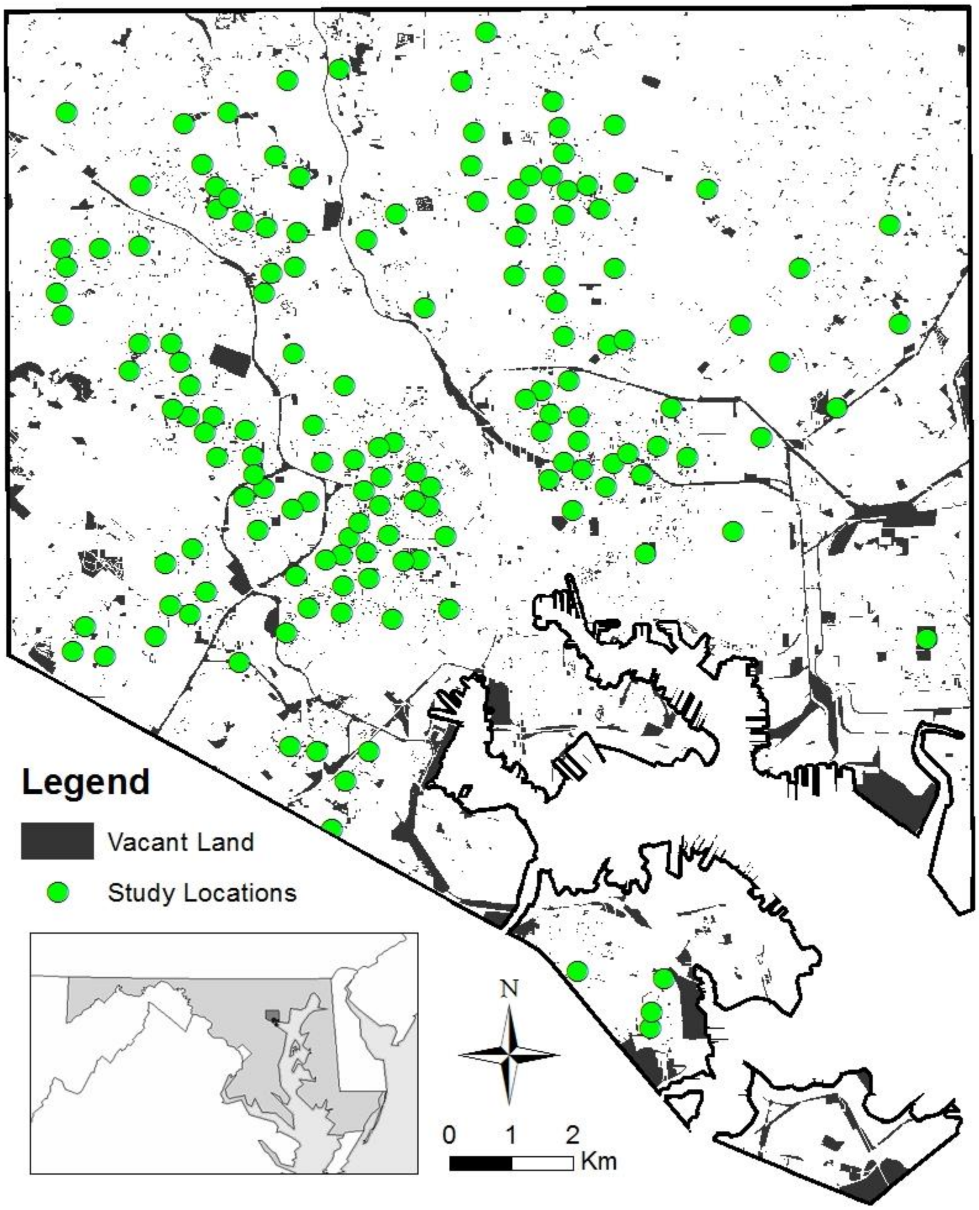

Figure 1. Location of vacant lots and study sites within Baltimore, Maryland (subset: dark gray).

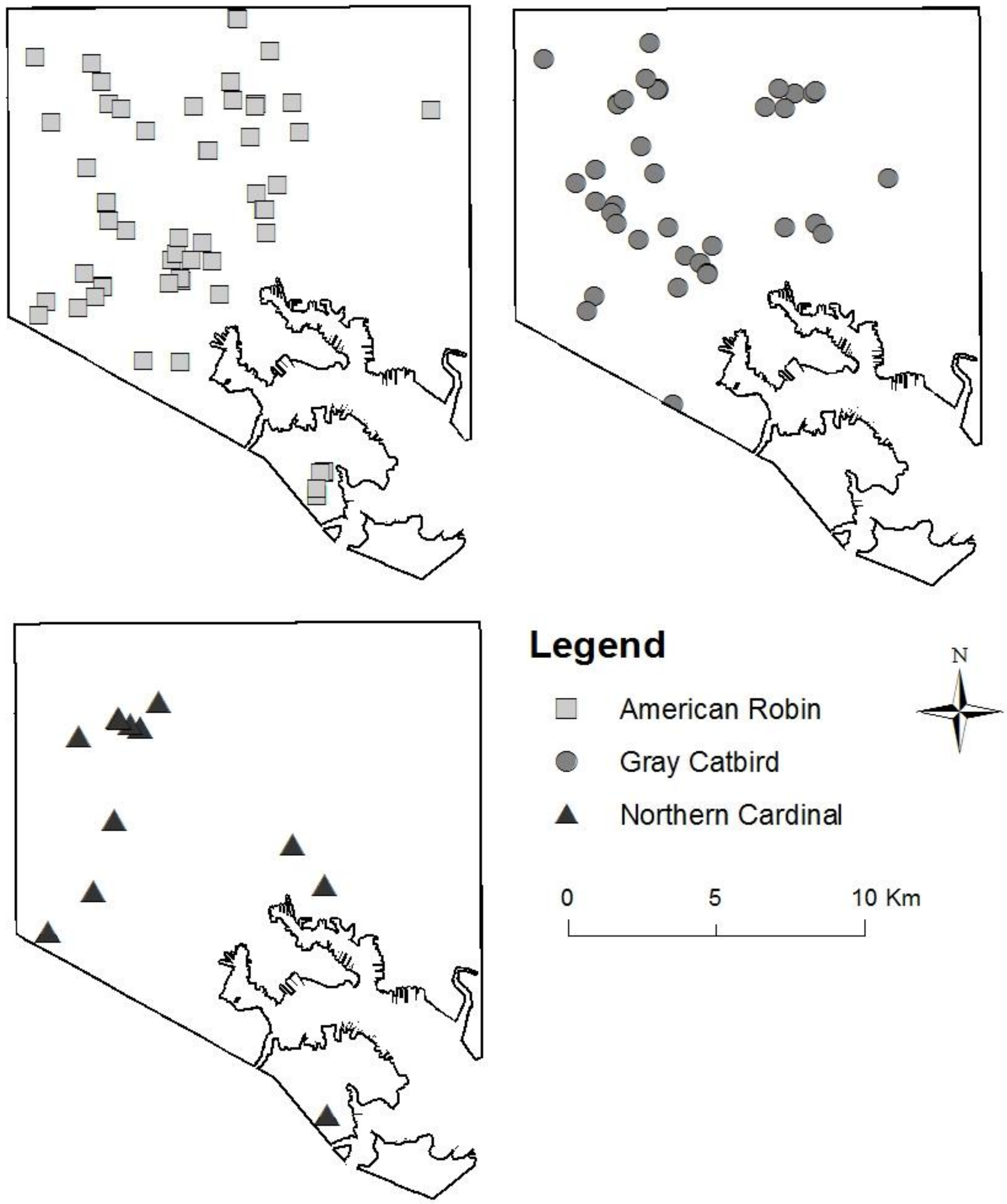

Figure 2. Nest locations for American robins, gray catbirds, and northern cardinals.

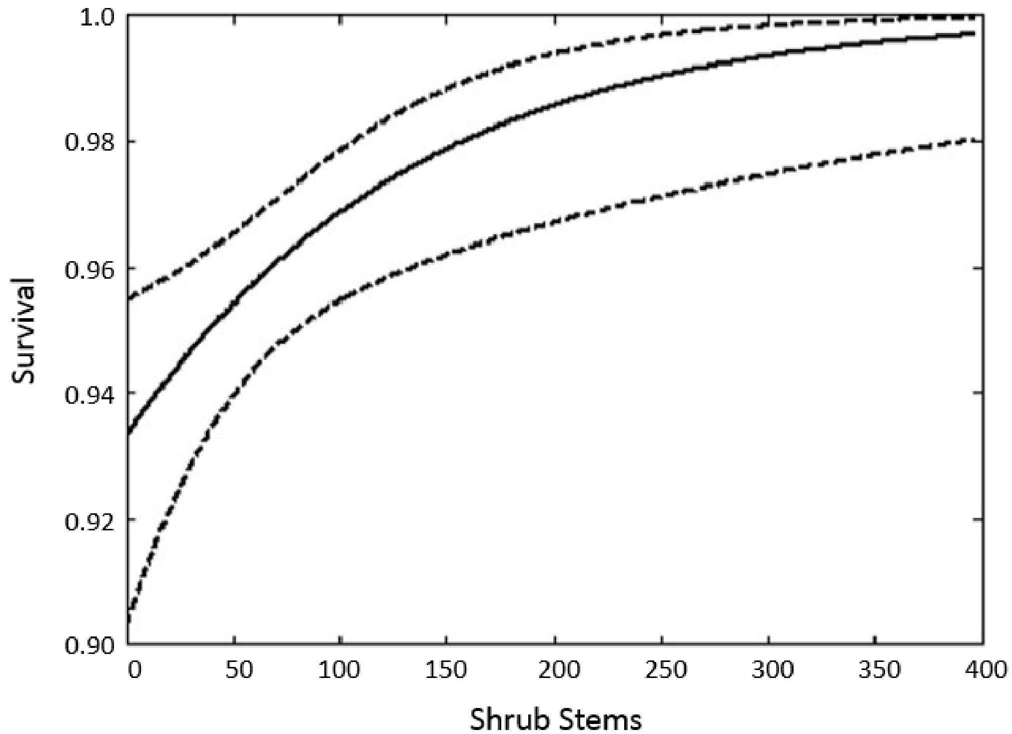

Figure 3. The daily probability of nest success with the abundance of shrub stems surrounding the nest for all nesting species. Error lines (dashed) are 95% confidence intervals.

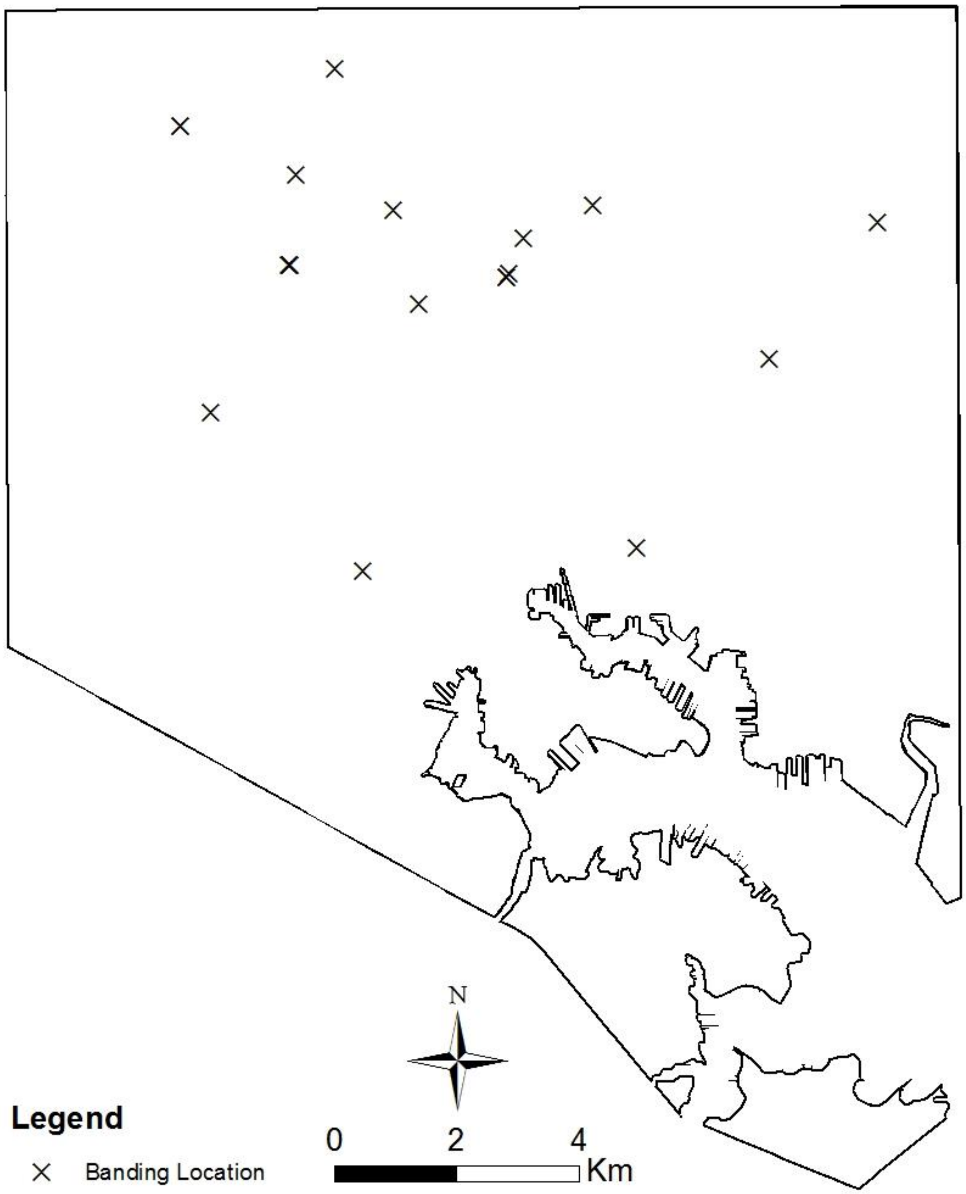

Figure 4. Locations were American robins were banded and assessed for their body condition.

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Chapter 4: Perception of Vacant Lots: Impacts of Lot Structure, Ecology, and Use

Abstract

Even though vacant lots have historically been viewed as urban blight and underutilized spaces, recent literature suggests they may be locations for improving urban biodiversity. However, the perception by the local community needs to be balanced with ecological goals for these spaces before management efforts occur. We determined how residents active within their communities perceived vacant lots, due to the lots' structure, composition, and ecological features. We surveyed 150 vacant lots throughout Baltimore for their vegetation and bird compositions, and selected six sites that varied in composition and structure to include in a perception survey sent out to community and naturalist groups. Residents based their perceptions of the lots around their perceived maintenance and green features, and residents' perceptions focused on the site's structure and ecological implications. We recommend a subset of the large abundance of vacant lots within Baltimore could be managed as parks or community gardens to best meet residents' preferences. Vacant lots within neighborhoods were best perceived if they had cues to care and more natural features, which would jointly improve community interest and support urban wildlife.

Introduction

Vacant lots often are a contentious social issue in cities, as they are often indicators of urban blight, places to discard trash, or visible signs of neighborhood neglect. However, vacant lots can also serve as locations for social and ecological opportunities (Garvin et al., 2013; Kremer et al., 2013; McPhearson et al., 2013). Especially in dense cities, vacant lots may be the only greenspaces within neighborhoods and important locations for neighborhood activities, exposure to urban nature, and wildlife habitat (Spirn & Pollio, 1991). As we start to recognize the values of vacant lots as informal greenspaces, both for urban residents and urban wildlife, it is necessary to understand the local community's perception and preference for vacant lot structure and composition.

Even though dense green spaces like vacant lots could be important factors in providing habitat to urban wildlife, people usually perceive natural-looking landscapes as messy and unkempt (Nassauer, 1995). An ecologically diverse lot may elicit a negative response from a resident who associates physical disorder with lack of care and neighborhood disorder (Ross & Mirowsky, 1999; James et al., 2009; Garvin et al., 2013). Even if the vacant lot is an important source of wildlife habitat, the lot may look neglected, which may suggest to neighborhood residents either that city officials has forgotten about the needs of their neighborhood or adjacent residents are not desirable neighbors (Nassauer, 2011). In some cities, cleanliness and security held greater value to city residents over natural elements of urban green spaces (Breuste et al., 2013), which may be a universal trait to understand for urban landscape planning.

Preferences for landscaping are even more important in human-dominated ecosystems where residents are exposed to neighborhood greenspaces daily. Urban residents tend to prefer environments with more green spaces, however the perception of green spaces may vary with their degree of management and cleanliness (Nassauer, 1995; James et al., 2009). Vacant lots can range from forested lots along roadsides, vacant blocks with lawn vegetation and street trees, and lots used for community gardens and other informal plantings. These spaces can be an importance source of urban wildlife habitat, while serving as a greenspaces to benefit nearby residents socially (Kuo et al., 1998; Sullivan et al., 2004), psychologically (Fuller et al., 2007), and physically (Branas et al., 2011; Kinnafick & Thøgersen-Ntoumani, 2014).

As people tend to prefer habitats with clear stewardship (Nassauer, 1995), simple efforts to transform vacant lots, like mowing the grass and planting flowers, may be positively perceived. These type of actions indicate the site's active use, or a "cue to care", which increases the value of the space to the community (Nassauer, 1995; Nassauer, 2011). However, lawn-dominated habitats are typically species poor and require a high degree of chemical and mechanical inputs, which may not be beneficial to urban wildlife (Bormann et al., 1993; Paker et al., 2013). The question that arises is if these landscaping practices are beneficial for both the residents and the urban wildlife community. Are the lots that are preferred by the public those that reflect rich habitat resources for urban wildlife?

Understanding the associations between vacant land structure and composition, and community perception is important for urban planners and policy makers. According to the theoretical framework proposed by Kaplan and Kaplan (1989), perception is influenced by a site's spatial configuration (e.g. openness of the site) and content (e.g. individual details, such as trees or human influence). Especially in cities with abundant vacant lots, we need to understand what kinds of lots residents prefer and how they perceive such lots, in conjunction with urban biodiversity goals.

We surveyed residents active in their communities or nature-themed organizations on how they perceived different kinds of vacant lots, as we assume these are the groups who would enact change in their neighborhoods. Our research questions for this study were: 1) What ecological features of vacant lots do residents prefer; 2) How do residents perceive vacant lots with variations in lot structure and composition; and 3) How would residents prefer to use vacant lots in the future? Our goal was to determine how these residents perceived vacant lots as an urban greenspace and what can be done with these informal greenspaces to overall benefit both residents and urban biodiversity goals.

Methods

Study Area

We studied vacant lots in Baltimore, Maryland, a city that has a substantial amount of vacant land. Since Baltimore's peak population of 950,000 in 1958, the city gradually lost manufacturing jobs, city residents moved into the adjacent Baltimore County, and crime rates spiked, leaving the city at a current population of about 620,000 (Nilon et al., 2009; Boone et al., 2014). Loss of jobs throughout 1970 – 2000 led to physical and socioeconomic changes in neighborhoods, such as an increase in housing abandonment (McDougall, 1993), which created additional vacant lots.

The Baltimore Office of Sustainability provided the locations of all vacant lots throughout Baltimore (2010). Out of the over 16,500 current vacant parcels (Rega-Brodsky & Nilon, In review), 150 were randomly selected for a three-year study of bird composition and nesting ecology as a part of the Baltimore Ecosystem Study Long Term Ecological Research (LTER) project. Lots were selected for use if they were accessible and had some form of vertical vegetation structure.

Lot Sampling

We used lot vegetation structure and bird species richness as indicators of vacant lot ecological quality. Sites were surveyed in 2013 (n = 45), 2014 (n = 55), and 2015 (n = 50); and each were located at least 250 m apart to reduce possible pseudoreplication of bird counts (Ralph et al., 1995). Three 0.04 ha vegetation sample plots were evenly spaced 20 m from the lot's center (0°, 120°, and 240°). We measured nine vegetation variables within each plot: canopy cover (%), canopy height (m), shrub cover (shrub density), grass and artificial ground cover (%), ground cover height (cm), and tree species richness, count, and diameter-at-breast-height (dbh). We also surveyed the bird community during our initial study due to their positive aesthetic and ecological values across many habitats (Morrison 1986). We conducted three point count surveys in May – July at each vacant lot and determined observed bird species richness.

After surveying these 150 sites, we designed a perception study focusing on eight vacant lots that varied in location, composition, and structure (Figures 1, 2). These lots were selected to test how residents perceive vacant lot's natural features, cues to care, openness, and disorder (Table 1). In order to assess how the presence of natural features influenced perception (Nassauer, 1995; Gobster et al., 2007), we selected two vacant lots composed of remnant forests (Lots A and F). These two lots had a high abundance and richness of tree species, high bird richness, and a closed canopy. The two differed in their indications of human use, as Lot A had a clear path through the center of the photograph which could be a perceived cue to care within a natural environment (Nassauer, 1995; Nassauer, 2011). Two sites, Lot H and B, represented the characteristic vacant lot composition and structure of tall, weedy ground cover. These sites differed by their presence (Lot H) and absence (Lot B) of shrub cover to judge perception of sites lacking clear management and sightline obstructions (Kaplan et al., 1989). Conversely, two sites were selected for their clear management practices with mowed lawns (Lot C) and landscaping (Lot E) (Kaplan et al., 1989; Nassauer, 1995). Both of these lots were relatively open in structure, with limited shrub cover. The remaining two lots were selected to assess the perception of lots that also had an open experience, but had more signs of disorder (Sampson & Raudenbush, 1999) with either vacant homes in the background (Lot G) or deteriorating pavement and slightly overgrown lawn (Lot D) (Wilson & Kelling, 1982; Kaplan & Kaplan, 1989; Ross & Mirowsky, 1999).

Survey Sampling

We emailed an electronic survey to the leaders of 20 community groups (Institutional Review Board Project #2003104). These community groups included residents that participated in park associations (e.g. Friends of Patterson Park), naturalist groups, and community associations located within neighborhoods with a large amount of vacant lots. Contacts for these community associations were often residents that were aware of our sampling efforts, and eventually became our contact source for those neighborhood residents. We asked community leaders to share the survey with members of their organizations. A snowball methodology was also used, as community group members passed the survey along to friends and coworkers living within Baltimore most often via Facebook or email. As our sampled lots occurred throughout the city, we assumed that most city residents encountered vacant lots during their daily lives. No incentive was given to survey participants.

The survey consisted of four parts. The first section contained demographic and socioeconomic questions. The variables of sex, racial or ethnic group, education, home ownership, type of housing, marital status, presence of children at home, and household income were assessed due to their potential influence on vacant lot perception. In a previous study, we found that vacant lots were not distributed equally throughout

Baltimore, thus various socioeconomic groups may perceive them differently (Rega-Brodsky & Nilon, In review). We also collected these data to assess how well the respondent demographics represented Baltimore City residents.

The second section was split into three parts: 1) an assessment of neighborhood and outdoor activity engagement; 2) vacant lot ranking; and 3) preference for future uses of vacant lots. The major part of this survey was for ranking eight vacant lots in terms of the residents' preference. Each lot was presented as a black-and-white photograph without any information on the actual location of the lot within Baltimore, to remove any potential biases (Figure 2). A four-point Likert scale was used to assess how desirable each lot was to the respondent if they were to have the lot in their neighborhood (1 = Very undesirable; 2 = Somewhat undesirable; 3 = Somewhat desirable; 4 = Very desirable). This was followed by an open-ended question as to why the resident selected that particular lot preference. Additionally, we determined what kind of negative management issues residents predicted each lot would have, from unwanted pests to fears of crime, to expand upon their perception justification. All of these preference questions culminated into the last two questions of this section which asked which of the eight lots a resident would prefer to have, and prefer not to have in their neighborhoods and their justification.

The section that concluded the survey assessed how the residents would like the vacant lots to be used in their community, with the options including use as a community garden, park with playground equipment, additional parking spaces, construction for additional residential or commercial buildings, leaving the space as is, or a park with benches, trails and flowers.

Data Analysis

For our quantitative analyses, we used the ranking scores to determine overall preference scores for each vacant lot. For the two vacant lots that were ranked as the most and least preferred, we ran Kruskal-Wallis tests in order to determine if any respondent demographic variable corresponded to their preference score. For the vacant lot structure and composition data, we averaged data from the three sampling plots within the lot to have one site value for each vegetation variable. With these data, we ran Spearman's rank correlations to determine if lot preference was related to the site's biotic composition.

Additionally, we conducted a content analysis (Weber, 1990) to determine what words survey respondents used to describe vacant lots as a whole. We also took the most and least preferred scene descriptions to determine what makes vacant lots desirable or undesirable by residents. For each, we used codes from the words or phrases respondents used in the written preference descriptions of the lots, and then assigned those codes to thematic code categories. We generated a force-directed graph from these codes with the Kamada and Kawai algorithm to illustrate how the use of these coded words or phrases were related (Kamada & Kawai, 1989). All coding was done in RQDA (R-based Qualitative Data Analysis) (Huang, 2014).

Results

Of the sixty-five individuals who started the survey, 44 respondents from 28 different neighborhoods completed usable surveys (Figure 1). The majority of respondents were affiliated with the Maryland Community Naturalist Network or Baltimore Green Space organizations (n = 18).

Demographics

The demographics of the survey respondents differed slightly from Baltimore City census demographics regarding sex, race, education, and income (Table 2). We had more respondents that identified as female, Caucasian, as completed college or above, and those within the higher income brackets ($75,000+) than the average Baltimore citizen, according to the most recent census data (U.S. Census Bureau, 2013).

The majority of survey respondents were active in their communities (89%), such as attending block group meetings or working on a neighborhood project, which was reflected in the majority of respondents indicating that they feel like they can make an impact in their communities (93%). Many respondents also participated in local nature activities, the most popular being planting a garden (83%), participating within an environmental organization (76%), and birdwatching (62%).

Preference Ranking

None of the sociodemographic variables were associated with preference rank ($P > 0.05$). Lots E and A were the two most desirable lots, indicated by their average preference score and selection as a lot that residents would prefer to have in their neighborhood (Table 3). Both of these lots had a clear presence of natural features, cues to care via clear landscaping or a walking path, and low categorization of lot disorder (Table 1). Lot E was a vacant lot used as a community garden and had an open shrub layer with tall trees and lawn habitat. Lot A was a remnant forest with a walking path through the lot. Many respondents used the presence of trees and clear lot management as their justification to rank the sites as desirable.

Residents overwhelmingly ranked lot G as their least preferred vacant lot, and this was the only lot that no respondent selected as one that they would like to have in their neighborhood (Table 3). Lot G is a vacant inner block surrounded by demolished and abandoned rowhomes, which we characterized as having few cues to care and high perceived disorder (Table 1). Out of all eight lots, residents said that they would expect lot G to have the greatest problems with unwanted pests (89%), illegal activities (76%), drugs (78%), and trash (95%). The words that respondents used to describe their least preferred lot selection primarily described the lack of care to the site, lack of safety, neglect, and an area for dumping trash and illegal activities.

Vacant lots with more artificial ground cover, such as asphalt and concrete, were negatively correlated with preference scores (rho = -0.927, $P = 0.001$). Lots with larger trees (dbh) were positively correlated with preference scores (rho = 0.738, $P = 0.045$). Bird species richness and tree species richness were not correlated to the respondent's preference score (bird richness: rho = 0.445; $P = 0.27$; tree richness: rho = 0.395, $P = 0.33$), nor were all other biotic variables (Table 4).

Vacant Lot Perception

Words used that residents used to describe the vacant lot and their corresponding preference were extremely variable. Of all lot descriptions, the words that were most frequently used to describe vacant lots were: "trees" (n = 74), "not cared for" (n = 54), "maintained" (n = 50), "overgrown" (n = 32), and "habitat" (n = 23). When plotted to show relationships between these codes and categories, terms relating to the lot's maintenance, structure, and plants were grouped together (Figure 3). Terms that were less linked to others included "park", "natural", "uninviting", "scary", and "pollinator", indicating their unique use for vacant lot descriptions.

We grouped 117 key words that residents used to describe vacant lots into 10 categories: Maintenance, Structure, Plants, Wildlife, Ecosystem Services, Lot Use, Recreation, Personal Safety, Aesthetics, and Future. Overall, lot maintenance and structure were reoccurring themes in the description of vacant lots. The most used terms to describe these lots included indicators of cleanliness, maintenance, open space, and well-cared for. Of the 45 respondents, 23 positively described their most preferred lots to have those characteristics. Many of these terms were used in support of other themes, such as Plants and Aesthetics.

Words describing the plants and wildlife within the site were used by 53% of respondents to describe their most preferred vacant lot. Trees were commonly used to describe the vacant lot and typically related to how open the site was and how trees provide shade. Residents described these sites as more "natural" and had the following characteristics:

> "Forest, shade, paths, feels park-like."
>
> "I like shade and tree canopy"
>
> "It is a nice mix of trees"
>
> "Mix of open space and trees"
>
> "Natural spaces, interesting with a mix of trees, but safe and somewhat defined in terms of use."

Other trends for how these lots were described included terms indicating value in creating native wildlife habitat in the city.

> "[Lot] A looks more like a mini forest, which is good for wildlife."

"Good habitat for wildlife and ecologically helpful in urban areas where stormwater runoff is such a major concern."

"[Lots] A & E would be nice places to spend a few hours in nature. All three [preferred lots] would be good for reconnecting and observing nature"

Even though most words used to describe the presence of trees and wildlife at the site were positive, some residents used other terms associated with various ecosystem services at the site. Very few residents used words that indicated their dislike of the site was justified due to the vacant lot's perceived lack of ecosystem services:

"Unkept [sites] do not provide max wildlife habitat"

"Concrete prevents water from getting back to the water table. Also it's ugly."

Another theme in describing their most preferred vacant lots included discussions on their general use and for recreation activities, from both an adult and child's perspective. These descriptions also included words describing the site's structure and plant composition to support recreational activities:

"Children in the neighborhood only have alleys to play in, so any open space would be better for them."

"It is a nice open green space, but it doesn't look too open. It has nice trees and a nice space for kids to play. It looks like a nice park and could have some benches"

"Psychological benefits of wooded areas, place for hiking, dog walking, childhood play and exploration, habitat for species"

"Looks well maintained and a great place to grow food and to practice yoga."

The theme of lot use was also related to words used describing the perception of personal safety within the vacant lot (Figure 3), but usually in a negative tone. Words used to describe personal safety were within the same context as the lot's use due to the perception of the vacant lot as a "place to hide" or use by the homeless. Apart from this connection, words describing personal safety were isolated from other thematic categories (Figure 3), which indicated their unique usage in describing vacant lots. Of the 45 respondents, 13 indicated that their least desired site harbored potential for personal danger:

> "They would probably invite illegal activity and might be scary to walk past"
>
> "Looks like great places for drug addicts and the homeless"
>
> "Poorly kept, likely to draw dangerous or illegal activity, not useful as recreation spaces"

Many respondents indicated that the sites in which they perceived a lack of safety also perpetuated a lack of community engagement in their care, as one person indicated, "They are magnets for trash, as no one feels compelled to care for them." The aesthetics of the vacant lot were discussed concurrently with the resident's perception of their personal safety and the lot's overall structure (Figure 3), indicating a direct relationship between these three categories. Typically, sites with open structure were positively perceived due to feelings of safety, while those that were perceived as an open greenspace were described as "beautiful", "clean", and "peaceful" or "serene".

Even though the majority of residents had strong criticism for their least desirable site, typically due to the site's perceived lack of safety and management, a few residents indicated that these sites had potential for the community:

“[Lots] G and H show a large degree of disinvestment, although they are opportunities for community growth and development represented by them.”

“Looks like they would be prime for redevelopment and speculators would love to snatch them up.”

Future Use Preferences

If a vacant lot was in their neighborhood, residents preferred for that lot to be either used as a park with benches, trails and flowers (75%), or a community garden (73%). The least preferable use for the lot was to pave it over to use for more parking spaces (5%), followed by the construction of new buildings (20%).

Discussion

Our goal for this designed study was to determine which features of vacant lots residents preferred, and how residents perceived vacant lots, in regard to their structure and composition. Our results were indicative of Baltimore residents who were active in their communities, usually in a community group or nature-themed organization, and felt as though they could enact change within their neighborhoods. Overall, residents preferred lots that showed clear management efforts, contained trees and less artificial ground cover, and those that had potential for recreational use. Survey respondents overwhelmingly preferred for these sites to be used as a greenspace for community events, while they also valued the vacant lots for their diverse vegetation features and those that supported wildlife.

Our first question focused on how the resident’s preference score related to the ecological features present at the site. Preference rankings were mainly correlated with the degree of perceived maintenance, but words describing the ecological quality of the site were used to justify many preference justifications. Sites E and C had high preference rankings, and these sites displayed clear management efforts of mowing and plantings; while sites A and F had high – moderate preference rankings and high ecological quality, as indicated by the sites' dense vegetation and high bird species richness. Even though other studies have found that overall species richness was a strong factor in determining perceived benefits to greenspaces (Fuller et al., 2007), we found instead that the presence of asphalt and the size of trees were lot variables which correlated with vacant lot preference scores. Since most survey respondents participated in wildlife or nature-themed groups, we assume they were educated in the ecological values of urban greenspaces. Thus, we assume the respondent's preferences of vacant lots follow the ecological aesthetic model, which describes the aesthetic appreciation of natural environments with knowledge of its ecological quality (Gobster, 1999; Gobster et al., 2007; Qiu et al., 2013).

The sites that were preferred overall (E & A) were extremely different from one another in terms of their structure, apparent use, and biological diversity. Lot E was a lot with a clear understory and a handful of large trees and shrubs, while lot A was a dense forest stand. In terms of their ecology, lot A provided much more diverse wildlife habitats within the lot, by providing an abundance of shrub and tree cover, variation in vegetation composition, and less human disturbance. The preference of trees, vegetation complexity, and perceived naturalness is consistent with many studies of landscape preference (e.g. Ulrich, 1986; Kuo et al., 1998; Ode et al., 2009). Lot A also contained a small path through the forest, which could be a minor "cue to care" that would indicate active use of the site. Conversely, the context of lot E was primarily one of human use, with more minor green features. Survey respondents noted that this lot still provided nature within the city, but also noted that the site was there primarily for human recreational use. This dichotomy of contexts of lots E and A indicated that residents valued both built habitats and sites for resident's use, yet overall preferred sites with more natural features and large trees.

It was surprising to find that lot C was not most preferred along with site E. Both of these sites were similar in that they both had tall trees, shrubs, and lawn habitat. Residents disapproved of site C due to its extensive lawn habitat, indicating that it was "boring" and should have included more trees. The reasoning behind these responses was mainly ecological as a lawn-dominated lot would "provide less habitat/food than would a spot like lot B" and indicated the use of pesticides and gas lawn mowers, polluting the area. We would expect that if a more diverse group of residents responded, lots C and E would be the top contenders, as the value of open sightlines and lot management are often valued above the lot's ecology (Schroeder & Anderson, 1984; Breuste et al., 2013).

Our second question focused on the words that residents used to describe vacant lots by assessing lots that varied in their structural and compositional features. Many words were used to describe vacant lots, but several of them converged on the lot's perceived maintenance and structure, use, and ecological contents. Even though many terms were negative regarding the lot's lack of maintenance and associated personal safety concerns, over half of the terms put a positive lens on vacant lots. A positive perception of a site may increase its likelihood to be appreciated and managed regularly (Gobster et al., 2007). Thus, neighborhoods in which vacant lots are a social issue, simple efforts for lot maintenance and planting small gardens by local residents could easily transform the lot and its perception.

Our final question sought to determine how residents would prefer for vacant lots to be used for the future. Input from local residents as to the future of the lot are vital, as residents are the most familiar the lot and may have shared preferences for the lots' future structure and use (Kaplan & Kaplan, 1989; Harrison & Burgess, 1994). Most residents preferred sites to be used for community gardens or parks with benches, trails, and flowers. This indicated that residents preferred urban greenspaces for both social and ecological opportunities. Investing in urban vacant lots as future community greenspaces would not only increase community cohesion and urban nature, it may also improve residents' quality of life and the value of the community (Nassauer & Raskin, 2014).

If vacant lots are to be managed for biodiversity, lots may be perceived as messy and unkempt, and lack of perceived human interventions (Qiu et al., 2013); therefore it may be beneficial to erect signs near vacant lots that would specifically serve as wildlife or pollinator habitat. Knowing the ecological benefits of a landscape can change people's perception of a "messy" habitat (Gobster, 1999; Qiu et al., 2013; Straka, 2015), providing habitat information on a site via a sign or education in local neighborhood newsletters may promote greater appreciation and perception of the site. We also recommend for sites left for human use that they be maintained semi-regularly for use recreationally and feelings of safety (Schroeder & Anderson, 1984). Baltimore City Department of Public Works is responsible for mowing vacant lots every three weeks; however contract disputes during the years sampled for this study delayed this schedule, much to the chagrin of neighborhood residents. This created a large source of contention for residents adjacent to vacant lots, creating more discouragement for the site's care and social conflict.

We were limited in our survey methods as the demographics did not fully represent Baltimore citizens, as African Americans, males, and those who lived in apartments were greatly underrepresented among our survey respondents. Additionally, most residents taking this survey were educated and participated in nature-oriented activities. The fact that the majority of our survey respondents were part of local community organizations or nature groups may have shaped their responses to be more ecologically-minded. Discussions on storm water runoff and the presence of exotic plant species indicated that this sample group was aware of current urban ecological issues. If our sample size was larger and better reflected the actual demographics of Baltimore City, we would expect different words to be used to describe these lots. However, this study does illustrate the perception of vacant lots from the residents who are active in their neighborhoods and within environmental groups, thus the residents most likely to enact changes in urban green spaces.

Conclusion

Three points were necessary to understand how residents perceived urban vacant land and ways to improve such land for social and ecological purposes. First, vacant lots had positive qualities assessed by residents. The view that all vacant lots are decrepit plots of land is a misunderstanding of many urban residents, and knowledge that vacant lots can be a benefit to the urban landscape is transformative. A positive perception of a site increases its likelihood to be maintained as a greenspace, so vacant lots with positive qualities, like trees and shrubs, may be adopted by neighborhood groups and maintained.

Second, lots with some form of maintenance were perceived positively by residents. Lot maintenance is an indication that the site is in a neighborhood that is cared for, a safe space, and conveys a sense of serenity. Third, lots that were ecologically rich were also positively perceived if the lot is full of trees and designated as a forested lot. Lots that had a moderate amount of trees, but mainly full of shrubs and tall grass were negatively perceived because those spaces represented those that can be maintained, but were abandoned. Forested lots on the other hand were put into a category of "nature" and positively associated with that characteristic. Even though our sample size and demographic breadth was small, our results provided key insights for future urban planning efforts. We recommend converting vacant lots into community gardens or parks with natural features for social and ecological improvements within these neighborhoods.

Tables and Figures

Table 1. Characteristics of the selected eight vacant lots within the survey, in regards to the presence of each descriptor, as classified by the authors.

Lot	Natural Features[1]	Cues to Care[2]	Openness[3]	Disorder[4]
A	High	Moderate	Low	Low
B	Moderate	Low	Moderate	Moderate
C	Low	High	High	Low
D	Moderate	Moderate	High	Moderate
E	Moderate	High	High	Low
F	High	Low	Low	Low
G	Low	Low	High	High
H	Moderate	Low	Low	High

1 Nassauer, 1995; Gobster et al., 2007
2 Nassauer, 1995; 2011
3 Kaplan et al. 1989
4 Kaplan and Kaplan, 1989; Sampson & Raudenbush, 1999

Table 2. Sample population demographic and socioeconomic characteristics, and corresponding census data for Baltimore City (U.S. Census Bureau, 2013).

Category	Variable	Responses	Percent*	Baltimore City
Sex	Male	9	20%	47.1%
	Female	36	80%	52.9%
Racial/Ethnic Group†	African-American	7	16%	63.2%
	Caucasian	37	82%	30.3%
	Asian	0	0%	2.4%
	Hispanic/Latino	1	2%	4.3%
	Other: Scotch-Irish	1	2%	-
Education	High School or Below	3	7%	49.4%
	College or Above	42	93%	50.6%
Home Ownership	Own	36	80%	48.3%
	Rent	9	20%	51.7%
Housing	Single Family Home	18	40%	14.5%
	Row/Townhouse	24	53%	52.8%
	Apartment	2	4%	26.8% (2+ Units/Structure)
	Other: Condominium	1	2%	-
Marital Status	Married	27	60%	48%
	Unmarried	18	40%	52%
Children Under 18 at Home	Yes	12	27%	27.2%
	No	33	73%	72.8%
Household Income	Less than $24,999	5	11%	33.2%
	$25,000 - $49,999	12	27%	24.2%
	$50,000 - $74,999	7	16%	17.1%
	$75,000 - $99,999	9	20%	9.5%
	$100,000 or More	12	27%	15.9%

*n = 44 completed surveys

† Category in which multiple answers could be selected

Table 3. Vegetation and avian composition, and resident preferences (n = 44) for each site presented in the survey. Vegetation data represents averages for three plots within each site. Bird species richness represents all species observed at that site throughout three visits.

	Vegetation & Avian Composition										Preference Survey	
Lot	**Ground Cover Height (cm)**	**Artificial Cover (%)**	**Grass Cover (%)**	**Stem Count**	**Canopy Cover (%)**	**Canopy Height (m)**	**Tree Density**	**Largest Tree Size (DBH, cm)**	**Tree Species Richness**	**Bird Species Richness**	**Preference Rank***	**Selected As Most Preferred (%)**
A	6.33	0.00	5.00	76.00	96.70	35.00	19.00	88.90	6.30	15	3.38 (0.12)	67
B	60.00	40.00	18.50	9.50	12.76	25.00	2.50	32.00	1.50	15	2.60 (0.13)	21
C	2.00	0.00	73.00	2.00	9.20	16.00	0.67	85.00	0.67	10	3.29 (0.10)	62
D	17.00	1.00	47.00	21.00	51.82	17.00	2.50	133.00	2.00	14	2.67 (0.11)	33
E	8.00	0.00	67.00	7.33	47.57	19.00	1.67	91.90	1.33	16	3.83 (0.08)	81
F	18.33	3.33	0.00	33.67	93.40	28.00	5.33	75.00	3.67	19	2.74 (0.14)	29
G	5.00	46.67	31.67	7.67	4.51	21.00	0.67	14.00	0.67	11	1.48 (0.12)	0
H	16.67	30.33	16.00	0.67	13.72	10.00	1.33	47.00	1.00	11	2.43 (0.11)	7

* Rankings were from 1 (Very Undesirable) to 4 (Very Desirable). Values are averages (standard error).

Table 4. Spearman's rank correlation results of vacant lot preference ranking and lot structure and composition variables. Bolded correlation coefficients are those that we considered notable relationships.

Vacant Lot Covariate	**rho**	***P***
Ground Cover Height	-0.190	0.664
Artificial Ground Cover	**-0.927**	**0.001**
Grass Ground Cover	0.190	0.664
Stem Density	0.238	0.582
Canopy Cover	0.547	0.171
Canopy Height	0.238	0.582
Tree Density	0.385	0.345
Tree Size (DBH)	**0.738**	**0.045**
Tree Species Richness	0.395	0.332
Bird Species Richness	0.445	0.268

Figure 1. Locations of lots surveyed and photographed for the survey within Baltimore, and neighborhoods of survey respondents (gray polygons).

Figure 2. Photographs of sample vacant lots used in the survey.

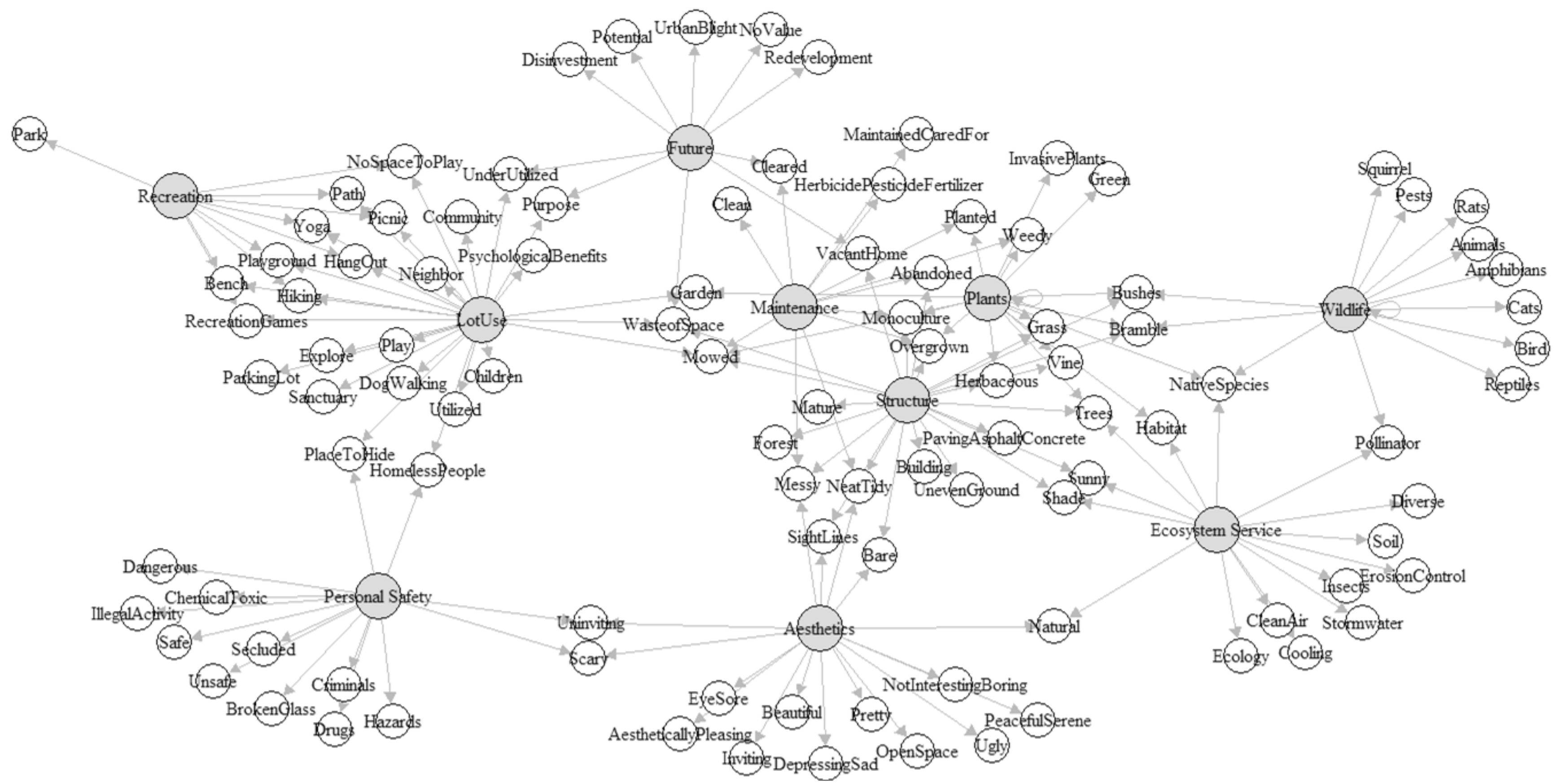

Figure 3. Force-directed graph to illustrate relationships between words survey respondents used to describe vacant lots (small light gray circles) and assigned code categories (large dark gray circles).

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Chapter 5: The Distribution and Composition of Vacant Land in Baltimore City: An Environmental Justice Approach

Christine C. Rega-Brodsky and Charles Nilon

Submitted to *Urban Ecosystems*

Abstract

In today's urbanizing world, many cities deal with the social and economic issue of vacant land. Vacant land is defined as any parcel of land that was once occupied or has the potential to be occupied by development. Unequal access or exposure to vacant greenspaces for certain socioeconomic groups may reflect an environmental injustice due to historical neighborhood ordinances or residents' inabilities to buy themselves out of the neighborhood. We questioned if unequal exposure to vacant land and green vacant lots were occurring in Baltimore, Maryland, a city with a strong history of segregation and restrictive housing ordinances. In this study, we evaluated the distribution of vacant land and biotic composition of residential vacant lots to determine if there were any trends with current land use patterns and socioeconomic variables. Through spatial and habitat analyses, we found that vacant land was primarily clustered within the industrial land use areas of the city and within Hispanic/Latino communities. Vacant land area was negatively related to the African American population and young families; however, residential vacant lots within those areas were poorer greenspaces, characterized by fewer trees and greater artificial ground cover. With a large proportion of vacant land found within residential areas of the city and constantly exposed to residents, more work is needed to determine what habitat changes and community actions could be taken to make these public spaces greener, clean, and safe.

Introduction

Cities make planning and managing decisions about patches of vacant land, comprising a variety of historical sources, properties and land uses (Panago and Bowman 2000). Vacant lands may function as informal urban greenspaces, and satisfy the urban resident's need for nature within the often dense city (Rupprecht et al. 2015); however the variation in vacant land density and composition may not be equal in terms of their qualities as urban greenspaces across neighborhoods. Vacant land can either be empty plots of land resulting from a structure demolition or those that serve as remnant habitat which have lacked any development in recent history (Spirn and Pollio 1991). The features and use of vacant land patches vary greatly within cities, from large tracks of remnant forests, small corner lots within residential areas, and polluted industrial brownfields (Northam 1971; Spirn and Pollio 1991), which all impact their communities in extremely different ways. Thus, we question how the location, structure, and biological contents of vacant land vary across the urban landscape, and describe how these lands provide a patchy network of greenspace resources and urban degradation across neighborhoods of different socioeconomic characteristics.

Vacant lands are a significant portion of the urban greenspace network in some cities. Urban greenspaces have documented positive social (Sullivan et al. 2004; Kuo et al. 1998), emotional (Flouri et al. 2014; Fuller et al. 2007), and health impacts (Branas et al. 2011; Kinnafick and Thøgersen-Ntoumani 2014) on community residents and benefit urban biodiversity, especially those that are regularly managed (Fuller et al. 2007). The opportunities to interact with urban greenspaces are often sought after for resident's aesthetic, relaxation, and recreation needs (Matsuoka and Kaplan 2008), which may be particularly important for young residents in order to foster an appreciation for nature and wildlife (Van Velsor and Nilon 2006). The nearby nature within each neighborhood can greatly shape each residents' sense of place and valuation of local neighborhood attributes (Matsuoka and Kaplan 2008).

Often vacant land offers a glimpse into the natural history of the land prior to urbanization as patches of remnant habitat, such as forests, grasslands, and scrublands. Especially if they are large, remnant patches are important sources habitats for native urban wildlife (Markovchick-Nicholls et al. 2008; McKinney 2002), are generally more productive than the urban matrix (Faeth et al. 2011; Zipperer et al. 1997), and serve as habitat corridors for wildlife conservation (Soulé 1991; Mörtberg and Wallentinus 2000). Remnant lands are also important for urban residents as they provide a nature experience close to home (Di Giulio et al. 2009) and may improve the quality of life resulting from exposure to urban greenspaces (Kaplan and Kaplan 1989; Matsuoka and Kaplan 2008).

Recent studies indicate that unequal access or exposure to greenspaces, whether vacant or not, reflect an environmental injustice for certain urban socioeconomic groups (Taylor et al. 2002; Boone et al. 2009; Davis et al. 2012; Jennings et al. 2012; Landry and Chakraborty 2009; Wolch et al. 2014), as these resources provide important ecosystem services to the neighborhood. Unequal access to vacant greenspaces may either be due to neighborhood legacy effects of intentional discrimination against racial and ethnic neighborhoods, or the inability for residents to buy themselves out of greenspace-poor neighborhoods (Been and Gupta 1997; Boone et al. 2009; Lord and Norquist 2010). These current and past effects resulted in socioeconomic patterns across the city, which may consequently be impacted by corresponding vacant land distribution and lot composition.

Other forms of vacant land have less positive attributes. One case would be emergent brownfields that are typically locations for heavy soil and water pollution within industrial land use areas. These locations not only have negative effects on local fauna (Hofer et al. 2010), they also compromise human health and are associated with unemployment, high crime, and degredated structures (Rowan and Fridgen 2003). Additionally, many vacant land parcels fit into the subcategory of residential vacant lots, which are characterized by small parcels once occupied or have the potential to be occupied by residential development. Due to their location within high population density areas, residents are likely to come into contact with this category of vacant land, often eliciting a negative response. Typically these abandoned lots are located within economically depressed urban neighborhoods, associated with high population densities and low median household income (Kremer et al. 2013; Boone et al. 2014; Locke and Baine 2014). Vacant lots are considered to be a social and economic problem (Spirn and Pollio 1991; Panago and Bowman 2000) that is generally associated with overgrown, trash-ridden lots (Baltimore Office of Sustainability 2010), depressed real estate values, and unwanted activities (Garvin et al. 2012; Accordino and Johnson 2000). The "broken windows" theory proposes that the visible signs of neglect in neighborhoods, such as vacant lands, perpetuate the unwillingness or lack of control residents have of their neighborhood condition (Wilson and Kelling 1982). Vacant properties can also plague cities and residents' well-being with their associations with crime, illegal activities, potential for physical injury, and impacts on mental health, such as anxiety, in residential neighborhoods (Spelman 1993; Garvin et al. 2012); however they also can serve as locations for new ecological and social enrichment opportunities.

With this potential for high variation in vacant land characteristics across a city, from remnant vacant lands to emergent residential vacant lots, differences in lot biotic composition may greatly impact neighborhood residents. Median household income (Heynen et al. 2006), race and ethnicity (Heynen et al. 2006), and crime (Troy et al. 2012) were all related to urban forest canopy, resulting in relationships that indicated residents within poor and crime-rich areas experienced less urban tree cover. Even when controlling for income, areas with greater racial and ethnic minorities encounter greater environmental hazards (Gilbert and Chakraborty 2011; Grineski et al. 2007). These trends highlight the importance for research to determine if urban residents have equal exposure to environmental resources, such as green vacant lands.

After a steady decrease in the city’s population and loss of industrial jobs over the past 60 years (Boone et al. 2014), Baltimore currently has over 30,000 vacant properties of various sizes and composition (Baltimore Office of Sustainability 2010). The city defines plot of land as vacant if it was once occupied or has the potential to be occupied by future development either through private or corporate means. We focused on vacant land throughout the city for a broad overview land use and cover trends, while also concentrating on the subcategory of residential vacant lots to determine what city residents are directly exposed to within their neighborhoods. Our main goal was to determine if there was evidence for an environmental injustice with vacant land associated with a specific socioeconomic group in Baltimore. We addressed this broad goal by 1) determining the socioeconomic characteristics of neighborhoods where vacant land occurred, 2) determining the spatial pattern of vacant land and the relationship to adjacent land uses, and 3) predicting residential vacant lot vegetation structure and bird species richness by neighborhood socioeconomic characteristics within Baltimore, Maryland.

Methods

Study Area

Baltimore, Maryland is located off of the Chesapeake Bay and served as a historically major seaport which still supports extensive industrial and manufacturing locations along the southern shore of the city (Fig. 1). The city is majority African American (64%) and has a deep history of residential segregation by race, religion, and economic class (Boone et al. 2014). Before 1917, local ordinances restricted where blacks could live (Power 1983) and homeowners associations cooperated with one another to prevent blacks, along with other migrants and minority religious groups, from moving into white neighborhoods (Boone et al. 2009). Federal institutions, such as the Home Owners Loan Corporation (Lord and Norquist 2010), also helped to reinforce segregation in the city, further forcing blacks into defined areas of the city with fewer amenities (Boone et al. 2014). The legacy effects of these ordinances are still seen today by clear demarcations in race and class across neighborhoods.

Since Baltimore's peak population of 950,000 in 1958, the city gradually lost manufacturing jobs, city residents moved into the adjacent Baltimore County, and crime rates spiked, leaving the city at a current population of about 620,000 (Boone et al. 2014; Nilon et al. 2009). Loss of jobs and housing throughout 1970 – 2000 led to physical and socioeconomic changes in Baltimore's neighborhoods. Middle-class neighborhoods such as Mount Winans, Lakeland, and Wesport were particularly impacted by this economic change, resulting in construction of row houses, low-income apartments, public housing, and scattered commercial and retail development (Jones 2011). Especially throughout the West Baltimore neighborhood, inner-block parks quickly were abandoned with an increase in housing abandonment (McDougall 1993), causing additional sources of residential vacant lots.

Vacant Lot Socioeconomic Characteristics

We used the Baltimore Office of Sustainability's vacant land map to identify parcels of vacant land in the city, and used neighborhood census data from the 2010 United States census (Open Baltimore 2010). We computed the total area of vacant land (hectares) within each neighborhood (n = 282) with the Intercept function in ArcGIS (ESRI 2011a).

Nine variables were used to represent the socioeconomic and demographic characteristics of each neighborhood (Table 1). Population was expected to be inversely related to vacant land cover, vegetation cover, and bird species richness because vacant land and lots should provide additional greenspace in the neighborhoods with less development. However, if median household income and homeownership are high in the neighborhood, we expected to find greater care taken of neighborhood greenspaces (Blaine et al. 2012; Kinzig et al. 2005), which would thus promote greater vegetation richness and structure to support more bird species. Median household income has historically been used to measure wealth, power and status and has been recently linked to tree cover in cities (Locke and Baine 2014; Martin et al. 2004). We hypothesized that resident age should follow the same pattern, with greater care taken of greenspace by an older demographic. Lastly, with Baltimore's history of racial segregation, we expected to find a positive association of vacant land with the African American communities, as historical laws promoted segregation of non-whites into areas with fewer amenities (Power 1983), and hypothetically fewer public greenspaces.

We conducted a principal component analysis (PCA) to further select census variables. Components with eigenvalues >= 1 were used as a cutoff, while loadings >= 0.4 and <= -0.4 were considered strong loadings within each principal component (Stevens 1992). Poisson generalized linear models (GLM) were then conducted to determine relationships between the dependent variable of vacant land area and independent neighborhood census variables that loaded strongly within each principal component. Descriptive statistics were also taken for each census variable and mapped across neighborhoods to illustrate socioeconomic patterns across the city.

Vacant Land Distribution

In order to determine where vacant land was clustered, we analyzed the spatial autocorrelation and concentration of vacant land with Moran's I and Hot Spot analyses, respectively, in ArcGIS (Moran 1950, ESRI 2011b). We calculated the GiZ score, the z-score from the Gi* test for spatial clusters, for neighborhoods via the Hot Spot analysis and created a map to illustrate areas where vacant land was clustered and dispersed. This map was then overlaid with the most current land use land cover (LULC) map to determine the current uses of areas containing vacant lands. LULC information for Baltimore was obtained from the Maryland Department of Planning (2010).

The 28 original LULC categories were repackaged to reflect the land use and land cover groups that were more meaningful to this study: commercial or institutional, industrial, open forested land, residential, water or wetlands, and other. Vacant lands located within each of these LULCs have unique properties for community residents. Vacant land located in commercial or institutional use areas may indicate poorer economic conditions within neighborhoods, while there may be possible health hazards within vacant industrial lands, or brownfields (Boone et al. 2014). Vacant forested lands and water sources should be beneficial to residents, as they provide open greenspaces within the urban environment. Vacant land within the residential LULC are important to study as residents would experience this kind of vacant land daily within their neighborhoods, which makes this LULC important to address for any negative attributes of vacant lands.

Vacant Lot Composition

We used vegetation structure and bird community richness to assess the quality of vacant lots, a residential subcategory of vacant land. From all accessible vacant lots in Baltimore City, 100 were randomly selected for an intensive urban avian ecology study as a part of the Baltimore Ecosystem Study Long Term Ecological Research (LTER) project (Fig. 2). Sites were surveyed in 2013 (n = 45) and 2014 (n = 55), and each were located at least 250 m apart to reduce possible pseudoreplication of bird counts (Ralph et al. 1995). Three 0.04 ha vegetation sample plots were evenly spaced 20 m from the lot's center (0°, 120°, and 240°). Within each plot, we measured 15 vegetation variables: canopy cover (%), canopy height (m), shrub cover (shrub density), ground cover (%) and composition, and tree species richness, count, and diameter-at-breast-height (dbh, Table 1). We also surveyed the bird community, as birds have positive aesthetic and ecological values across many habitats (Morrison 1986). Throughout May – July at each vacant lot, we conducted three point count surveys for bird community composition and averaged bird species richness into one site value.

A PCA was run on the 15 vegetation variables to reduce their dimensionality. Out of the strong loadings of each principal component, one lot characteristic variable was selected to be regressed against census variables with a Poisson GLM. This selected vegetation variable had the greatest loading value within the principal component. Bird species richness was also regressed against the important census principal component loadings.

Results

Vacant Land Socioeconomic Characteristics

Baltimore had over 1700 ha of vacant land, which comprised approximately 7% of the total area in the city limits. Baltimore still has a large African American community, averaging 59% of the population across all neighborhoods, with a maximum of 99% (Table 1). The northeast and west areas of the city had large populations of African American residents (>88.6% per neighborhood), whereas north-central Baltimore lacked this demographic (< 20%; Fig. 3). Some neighborhoods (n = 22) did not have any residents. Neighborhoods without residents were comprised entirely of city parks, industrial areas, marine terminal, cemetery, business parks, or a sports stadium. Other southern neighborhoods had a large amount of vacant land per resident (Fig. 4).

Three principal components explained 74% of the variance for neighborhoods census variables (Table 2). The first component explained 38% of the variation in neighborhood socioeconomic features, with a negative loading on percent black, percent residents aged 0 – 17, percent families, and percent female-headed households. This indicated a separation of neighborhoods by young, black families with female-headed households. The second component explained 23% of variation and had negative loadings on percent homeowners and median household income, indicating neighborhoods with wealthy homeowners. The third component explained the remaining 13% of variation with negative loadings on population size and percent Latino residents, indicating dense neighborhoods with primarily Latino residents.

All four loadings of the first principal component were related to the amount of vacant land in Baltimore neighborhoods ($R^2 = 0.18$). Percent black residents, residents aged 0 – 17, and percent family were negatively related to vacant land cover (Table 3). Female-headed households were positively related to vacant land cover (Table 3). For the second component, only percent homeownership was significantly related to vacant land cover in the multiple regression, albeit weakly ($R^2 = 0.08$, $\beta = -0.0003$, $P < 0.001$; Table 3). The relationship between median household income and vacant land cover approached significance when regressed with percent homeownership ($p = 0.085$; Table 3). Lastly, the loadings of the third component did not have any significant relationship with vacant land ($R^2 = 0.00$, $P > 0.05$; Table 3).

Vacant Land Distribution

Vacant land within Baltimore neighborhoods had significant spatial autocorrelation and indicated a slight tendency toward a clustered pattern (Moran's I index = 0.066, z-score = 4.848, $P < 0.001$). As indicated by the Hot Spot analysis, vacant land within the city was significantly clustered within the industrial areas of southern Baltimore, while neighborhoods in the Northeast had significant dispersion of vacant land (Fig. 5). The areas in which vacant land was clustered corresponded to those areas with dense industrial development, while the dispersed vacant land fell within neighborhoods that were classified as residential and commercial land uses (Fig. 1).

Vacant Lot Composition

We observed 56 bird and 55 tree species throughout our surveys of residential vacant lots. Vegetation within the vacant lots separated out into five components, which represented 71% of the data's variance (Table 4). The first component explained 30% of the total variance with loadings on canopy coverage and total trees, or a forested lot. These loadings were slightly under the 0.4 eigenvalue cut-off for significance. The second component explained 14% of the total variance, with loadings on grass ground cover, tree average DBH, and tree maximum DBH. This component represents lots with many large trees and grass cover. The third component explained 11% total variance, with loadings on bare ground cover and rock ground cover. These lots were typically forested lots with older growth. The fourth component explained 9% total variance with positive loadings on ground cover height and forb ground cover, and a negative loading on artificial ground cover. These lots were typically those with tall grass and forbs, and mowed at least once per summer season. The fifth component explained only 8% of the total variance and had negative loadings on woody litter and water ground cover, with a positive loading on total number of shrub stems, representing forested lots; however these lots were rare within Baltimore.

We evaluated the relationships between the key socioeconomic variables presented in the strongest loadings within each principal component (Table 2) and the biotic variables of residential vacant lots (Table 4). Neighborhoods with a high population of black residents and female-headed households are associated with vacant lots with fewer trees, smaller trees, and shorter ground cover (Table 5). Neighborhoods with high homeownership contained vacant lots with trees with a larger dbh and those with taller ground cover (Table 5). Lastly, neighborhoods with greater Hispanic populations had residential vacant lots characterized by a greater amount of larger trees (Table 5). These structural and compositional features were evident when visiting lots of each socioeconomic group (Fig. 6). Bird species richness was not predicted by any neighborhood socioeconomic variable at $\alpha = 0.05$ (Table 5).

Discussion

For this study, we determined the distribution and composition of vacant land in order to assess any potential environmental injustices in regard to vacant land exposure. We classified an environmental injustice as unequal access to green, managed, species rich lots which provide positive benefits to residents within those communities (Jennings et al. 2012; Wolch et al. 2014; Boone et al. 2014). Our first goal of this study was to determine if a socioeconomic group experienced a disproportionate amount of vacant land within their neighborhood, and we found that female-headed households and Hispanic residents experienced this potential environmental injustice. These two socioeconomic groups were also found predominately in industrial areas of Baltimore, which could indicate a high density of brownfield vacant lands that often have negative environmental characteristics and potential human health impacts. Although exposure to vacant land was negatively related to black resident dominant neighborhoods, this group still experienced a potential environmental injustice related to the vegetation composition of the vacant lots within their neighborhoods.

The only variable that was positively and significantly related to vacant land within neighborhoods was female-headed households. The selection of where to live by female-headed households is directly linked with expected income, welfare participation, and tax rates (Blank 1988). Areas with greater vacant land may be those with reduced taxes and cheaper rental homes to balance low-incomes of female-headed households. Neighborhoods with greater percentages of female-headed households were also located in the southern, industrial areas of the city, indicating a potential environmental injustice due to pollution effects from brownfields (Bullard 2000).

The percent of Hispanic residents were positively related to vacant land, although this relationship only approached significance. A historical study on the changes in the polluting history in Baltimore found that white and Hispanic populations positively correlated with dense polluting factors (Boone et al. 2014). Even though vacant land was more often located within neighborhoods containing industrial land uses, a greater amount of larger trees were found within Hispanic neighborhood residential vacant lots, indicating positive social values of lower crime rates (Troy et al. 2012) and greater home values (Sander et al. 2010; Mansfield et al. 2005), along with environmental services of carbon sequestration and cooler temperatures (McPherson et al. 1997) with increased tree abundance.

Our second goal was to determine where vacant land was clustered within the city. We found vacant land clustered within the southern neighborhoods, primarily classified as industrial land uses, potentially indicating that a region of brownfields and industrial vacancies largely occurred away from many city residents. Local exposure to these potentially harmful lands was second to residential vacant land across the city, which may overall benefit residents as they would be exposed to fewer brownfields within their neighborhoods. As the majority of vacant land that residents have within their neighborhoods was classified as residential LULC, this indicates the imperative to understand the consequences of vacant land as many residents are exposed to these parcels daily.

Neighborhoods in northeast Baltimore had a high population of black residents, which also corresponded to dispersed vacant land. We were surprised to find a negative relationship between the black population and vacant land within Baltimore. With the city's deep history of racial segregation, vacant land was hypothesized to be clustered within the neighborhoods with a large population of black residents; however the opposite was found. Within the past 40 years, Baltimore neighborhoods with a greater percentage of white residents were surprisingly more likely to experience an environmental injustice concerning industrial pollution, over black neighborhoods (Boone et al. 2014). This relationship was caused by a history of racial segregation, which allowed white residents the benefit of living closer to their manufacturing and industrial jobs (Boone et al. 2014). Our findings indicated fewer black residents within neighborhoods dominated by industrial land uses contributed to less exposure to vacant land.

Even though neighborhoods with more black residents experienced fewer vacant lands, residential vacant lots in these communities did hint at an environmental injustice regarding the biotic composition of these lots. Unlike the park-like residential vacant lots in wealthier neighborhoods, neighborhoods comprised primarily of black residents had vacant lots that looked more unkempt, had fewer trees, and had a mix of forbs and asphalt for ground cover (Table 5, Fig. 6). From our experiences in these lots, they were also more likely to be places for residents to dump their trash and local residents expressed concerns about their safety, in regard to crime, drugs, and rats. Exposure to greenspaces like these has a negative impact on residents who may not have the means to move to other areas of the city, indicating an environmental injustice. Legacy effects of intentional discrimination against racial groups may be one cause of this disparity in vacant lot contents (Bullard 2000). However, we would argue that current local economic and social processes are maintaining this dichotomy of biotic lot contents across Baltimore neighborhoods, further perpetuating Hispanic and black Baltimorian's lack of exposure to a nature experience.

Bird species richness was not a strong component to vacant lots or linked with any socioeconomic variable. This lack of relationship was assumed to be in response to differences in bird community composition, rather than just a richness value alone. Community composition does differ across Baltimore, with more generalist species found within lots with less vegetation in West Baltimore, such as house sparrows, Passer domesticus; European starling, Sturnus vulgaris; and American robins, *Turdus migratorius* (Rega et al. 2015). Relationships with vacant lot vegetation should indicate trends with different bird guilds, which should produce relationships with socioeconomic variables as indicated in our study. For example, wealthier neighborhoods that contain more forested vacant lots should have a greater abundance of woodpeckers, or other forest guild species. Determining differences in bird community composition was not a goal for this current research project, but we intend to further explore these differences in future work.

The weakness of our models suggested high variability of lot contents and census variables in our models. The components of the first socioeconomic principal component (Table 2) consistently had the strongest model when regressed against total amount of vacant land (Table 3) and the vacant lot biotic variables (Table 5). Race and poverty are spatially related in Baltimore, as adjacent neighborhoods can vary greatly in terms of the socioeconomics of their residents (Fig. 3) and greenspace contents, resulting in high variation for a number of key variables (Table 1). These block-level socioeconomic factors may influence landscaping efforts (Kinzig et al. 2005; Williamson and DeGraaf 1981), creating high lot composition variability even within one neighborhood. Even within vacant lots, many other unmeasured variables can greatly contribute to the lot's biotic composition, such as the intensity of resident maintained care and plantings. We attempted to select vacant lots that had the least amount of human influence (e.g. no community gardens) in order to avoid such deliberate variation in lot composition; however, in an urban setting this can only be done to such an extent. Our goal in this study was to inquire into the environmental injustices that may be at play within Baltimore, which is clearly observed in spite of slight weaknesses in model fit.

Now that we are starting to understand the social and environmental implications of vacant land within cities, we should start focusing on transforming these lots from urban eyesores to social and environmental resources (Garvin et al. 2012; Panago and Bowman 2000; Garvin et al. 2013; Spirn and Pollio 1991). Interest in urban agriculture, community gardens, and green infrastructure in cites are quickly becoming popular as a social and cultural trend (Nassauer and Raskin 2014). Our research indicated that vacant land was clustered within the southwest Baltimore and in greater amounts within

Hispanic neighborhoods. These neighborhoods would benefit from a large transformation of vacant land to urban parks, or some kind of social resource, which would greatly benefit nearby residents, however at a large price tag. Neighborhoods within west Baltimore had a high population of black residents (Fig. 3) and, while not significantly clustered, vacant land has a heavy presence within residential neighborhoods. These smaller vacant lots were those with fewer trees and often were places for dumping trash. The close placement of these lots to residents' homes would provide an excellent source of land for small community greening projects or community gardens and may result in a greater social impact than vacant lands located farther from residents.

Residents would socially and physically benefit if exposed to more forested vacant land (Kaplan and Kaplan 1989; Matsuoka and Kaplan 2008; Di Giulio et al. 2009), rather than gray, industrial open spaces. There was a fair amount of open forested land within Baltimore; however this land cover type was not present in large quantities within the center of neighborhoods. Planting trees and shrubs within residential vacant parcels can greatly impact residents closer to their homes and in greater densities within their neighborhoods, allowing residents across socioeconomic groups to benefit from this environmental resource. This not only would benefit resident's health and well-being, planting community gardens or other community-based greenspace efforts would foster community cohesiveness and pride (White 2011). A great example of such an effort is Sunflower Garden within the Franklin Square community of West Baltimore. Within this formally vacant lot, the community took action and created a community garden with new landscaping and large sunflower-themed murals.

Throughout multiple cities, active greening efforts in newly vacant lots have shown to benefit the community with an increase in perceived neighborhood safety, ecosystem services, and greater social capital (Nassauer and Raskin 2014). Neighborhoods with more greenspaces promoted the feeling of safety for residents within the community (Garvin et al. 2013) and resulted in significant decreases in gun violence and vandalism within areas of Philadelphia (Branas et al. 2011). Exposure to green lots in urban areas also improved stress levels (Kinnafick and Thøgersen-Ntoumani 2014), increased use of the lot for exercise activities (Branas et al. 2011), and promoting emotional well-being in poor urban children in early childhood (Flouri et al. 2014). Especially for communities without nearby parks or other greenspaces, vacant lots between homes or corner lots may provide a local patch of vegetation for which residents may use as a playground, playfield, garden, outdoor markets, and community centers (Spirn and Pollio 1991).

As vacant land is continually in fluctuation with new building and demolition events, the relationship between vacant land and neighborhood LULC and socioeconomics will continue to change. The city of Baltimore had a considerable amount of vacant land, with additional acreage expected in the near future with city-wide demolitions of approximately 1,500 abandoned houses (Wenger 2013). With additional vacant land within residential areas, a conscious effort needs to be taken to make these newly vacant lots beneficial to the local community, rather than eye-sores that attract crime and pollution in already disadvantaged neighborhoods.

Conclusion

The implications of this study are great for a city that is dealing with a significant amount of vacant land, with more to come in the near future. Not only are some residents exposed to a disproportionate amount of vacant land within their neighborhoods, other residents are exposed to degraded vacant lots that contain fewer green features, noticeably more trash, and are potential locations for crime and unwanted activities. With a large proportion of vacant land found within residential areas of the city and constantly exposed to residents, this calls for further investigations of the composition of the land itself and drastic actions to make these public spaces clean and safe. This study also extends current environmental justice research by focusing on the equitable distribution of urban vacant lots, building upon a deep history research on the social injustices linked with industrial pollution or hazardous waste distribution.

Tables and Figures

Table 1. Means and standard deviations of 2010 census data of neighborhoods containing vacant lands, and vacant lot structure and composition variables in Baltimore, Maryland.

Category	Variable	Code	Mean	StDev
Neighborhood				
Vacant Land	Vacant Land (ha)	vland	89.66	166.72
Income	Median Household Income (USD)	medhouseinc	41892.96	17087.88
Population	Population	pop	2284.01	2384.84
Race	Black/African American (%)	pcblack	58.9	37.64
	Hispanic/Latino (%)	pclatino	3.82	6.17
Age	Ages 0 - 17 (%)	pcage017	19.94	8.83
	Ages 65 and Over (%)	pcage65	11.67	6.88
Family	Family Households (%)	pcfamily	20.42	7.03
	Female Headed Households (%)	pcfhh	8.94	5.11
Home Ownership	Owner Occupied (%)	pcownhouse	18.87	10.44
Lot/Parcel				
Ground Cover	Artificial Ground Cover (%)	gca	7.85	11.64
	Bare Ground (%)	gcb	3.09	5.25
	Forb Cover (%)	gcf	33.61	17.41
	Grass Cover (%)	gcg	41.2	20.52
	Leaf Litter Cover (%)	gcl	1.32	3.78
	Rock Cover (%)	gcr	0.27	1.19
	Shrub Cover (%)	gcs	9.99	15.32
	Woody Litter Cover (%)	gcw	4.54	1.9
	Water Cover (%)	gce	0.01	0.07
	Tree Count	treect	2.81	3.58
	Canopy Cover (%)	canopycv100	34.9	32.28
Structure	Ground Cover Height (cm)	gcht	22.46	20.91
	Canopy Height (m)	canopyht	18.45	6.05
	Total Shrub Stems	totalstem	29.74	48.4
	Average Tree DBH (cm)	treeavgdbh	33.53	24.45
	Max Tree DBH (cm)	treemaxdbh	48.5	38.26
Species Richness	Bird Species Richness	birdrich	13.01	2.79
	Tree Species Richness	treerich	1.53	1.37

Table 2. Principal Component Analysis of census socioeconomic variables. Bolded variables were considered strong loadings within each principal component (PC).

Loading	**PC1**	**PC2**	**PC3**
Population	-0.120	0.004	**-0.511**
Black/African American (%)	**-0.459**	0.227	0.203
Hispanic/Latino (%)	0.094	-0.130	**-0.754**
Ages 0 - 17 (%)	**-0.470**	-0.014	-0.205
Ages 65 and Over (%)	-0.199	-0.398	0.257
Family Households (%)	**-0.441**	-0.344	-0.105
Female Headed Households (%)	**-0.502**	0.172	-0.002
Own Home (%)	-0.114	**-0.623**	0.061
Median Household Income	0.216	**-0.487**	0.083
Eigenvalue	3.42	2.09	1.15
% Variation	37.97	23.25	12.80
Σ % Variation	37.97	61.22	74.02

Table 3. Multiple regression results for vacant land area regressed against neighborhood census variables. McFadden's pseudo-R^2 values for multiple regressions are listed for each model and significant ($p < 0.05$) values are bolded. Variable codes are listed in Table 1.

Model	R^2	Coefficient	β	*p*
vland = pcblack+pcage017+pcfamily+pcfhh	0.178	pcblack	-0.020	**<0.001**
		pcage017	-0.006	**0.001**
		pcfamily	-0.071	**<0.001**
		pcfhh	0.172	**<0.001**
vland = pcownhouse+medhouseinc	0.084	pcownhouse	-3.78E-02	**<0.001**
		medhouseinc	7.97E-07	0.084
vland = pop+pclatino	0.000	pop	3.99E-06	0.136
		pclatino	4.67E-02	0.062

Table 4. Principal Component Analysis of biotic vacant lot composition and structure variables. Bolded values were the loadings used within multiple regression analyses.

Loading	PC1	PC2	PC3	PC4	PC5
Ground Cover Height (cm)	0.029	0.055	-0.257	**0.533**	0.098
Artificial Ground Cover (%)	0.093	0.185	-0.213	**-0.491**	0.171
Bare Ground (%)	-0.161	0.298	**0.495**	-0.059	0.049
Forb Cover (%)	0.203	0.042	0.306	**0.532**	-0.297
Grass Cover (%)	0.249	**-0.386**	-0.080	-0.253	0.032
Leaf Litter Cover (%)	-0.355	0.135	-0.012	-0.039	-0.246
Rock Ground Cover (%)	-0.115	0.123	**0.493**	-0.187	0.163
Shrub Cover (%)	-0.352	0.137	-0.319	0.159	0.174
Woody Litter Cover (%)	-0.205	0.082	-0.086	-0.136	**-0.364**
Water Cover (%)	-0.173	0.132	-0.178	-0.096	**-0.576**
Canopy Cover (%)	**-0.380**	-0.184	0.057	0.059	0.016
Canopy Height (m)	-0.279	-0.120	-0.245	-0.052	-0.124
Total Shrub Stems	-0.286	0.083	-0.138	0.163	**0.517**
Tree Count	**-0.392**	0.021	0.205	-0.035	0.063
Average Tree DBH (cm)	-0.141	**-0.573**	0.084	0.010	-0.009
Max Tree DBH (cm)	-0.222	**-0.512**	0.168	0.026	-0.013
Tree Species Richness	0.029	0.055	-0.257	0.533	0.098
Eigenvalue	4.75	2.25	1.68	1.44	1.24
% Variation	29.67	14.09	10.51	8.98	7.74
Σ % Variation	29.67	43.76	54.27	63.25	70.99

Table 5. Multiple regression results for biotic variables regressed against census data for the neighborhood of the vacant lot. McFadden's pseudo-R^2 values for multiple regressions are listed for each model and significant ($P < 0.05$) values are bolded. Variable codes are listed in Table 1.

Model	**R^2**	**Coefficient**	**β**	***P***
Number of Trees				
treect = pcblack+pcage017+pcfamily+pcfhh	0.136	pcblack	-0.167	**<0.001**
		pcage017	-0.046	**0.004**
		pcfamily	0.025	0.177
		pcfhh	0.086	**0.010**
treect = pcownhouse+medhouseinc	0.046	pcownhouse	1.80E-03	0.840
		medhouseinc	1.38E-05	**0.004**
treect = pop+pclatino	0.031	pop	-1.26E-05	0.490
		pclatino	4.67E-02	**<0.001**
Tree Size				
treeavgdbh = pcblack+pcage017+pcfamily+pcfhh	0.118	pcblack	-0.004	**<0.001**
		pcage017	-0.048	**<0.001**
		pcfamily	0.070	**<0.001**
		pcfhh	0.023	**0.022**
treeavgdbh = pcownhouse+medhouseinc	0.099	pcownhouse	2.14E-02	**<0.001**
		medhouseinc	3.58E-06	0.018
treeavgdbh = pop+pclatino	0.005	pop	-8.38E-06	0.108
		pclatino	1.44E-02	**0.002**
Bare Ground Cover				
gcb = pcblack+pcage017+pcfamily+pcfhh	0.007	pcblack	0.013	0.760
		pcage017	0.032	**0.055**
		pcfamily	-0.028	0.140
		pcfhh	-0.034	0.320
gcb = pcownhouse+medhouseinc	0.001	pcownhouse	6.52E-03	0.470
		medhouseinc	1.24E-06	0.810
gcb = pop+pclatino	0.015	pop	-3.92E-05	**0.045**
		pclatino	3.34E-02	**0.015**
Ground Cover Height				
gcht = pcblack+pcage017+pcfamily+pcfhh	0.057	pcblack	-0.006	**<0.001**
		pcage017	-0.024	**<0.001**
		pcfamily	0.007	0.402
		pcfhh	0.099	**<0.001**
gcht = pcownhouse+medhouseinc	0.019	pcownhouse	7.16E-03	**0.045**
		medhouseinc	-1.04E-05	**<0.001**

gcht = pop+pclatino	0.001	pop	5.47E-06	0.362
		pclatino	3.94E-03	0.509
Water Cover				
gce = pcblack+pcage017+pcfamily+pcfhh	0.363	pcblack	-0.005	0.650
		pcage017	-0.145	0.950
		pcfamily	0.370	0.640
		pcfhh	-0.270	0.770
gce = pcownhouse+medhouseinc	0.789	pcownhouse	-1.21E-01	0.716
		medhouseinc	3.96E-03	0.988
gce = pop+pclatino	0.000	pop	5.87E-06	0.980
		pclatino	6.17E-03	0.985
Bird Species Richness				
birdrich = pcblack+pcage017+pcfamily+pcfhh	0.020	pcblack	0.002	0.340
		pcage017	0.007	0.391
		pcfamily	-0.003	0.755
		pcfhh	-0.017	0.318
birdrich = pcownhouse+medhouseinc	0.002	pcownhouse	-1.49E-03	0.737
		medhouseinc	2.56E-07	0.918
birdrich = pop+pclatino	0.024	pop	4.44E-06	0.575
		pclatino	8.00E-03	0.298

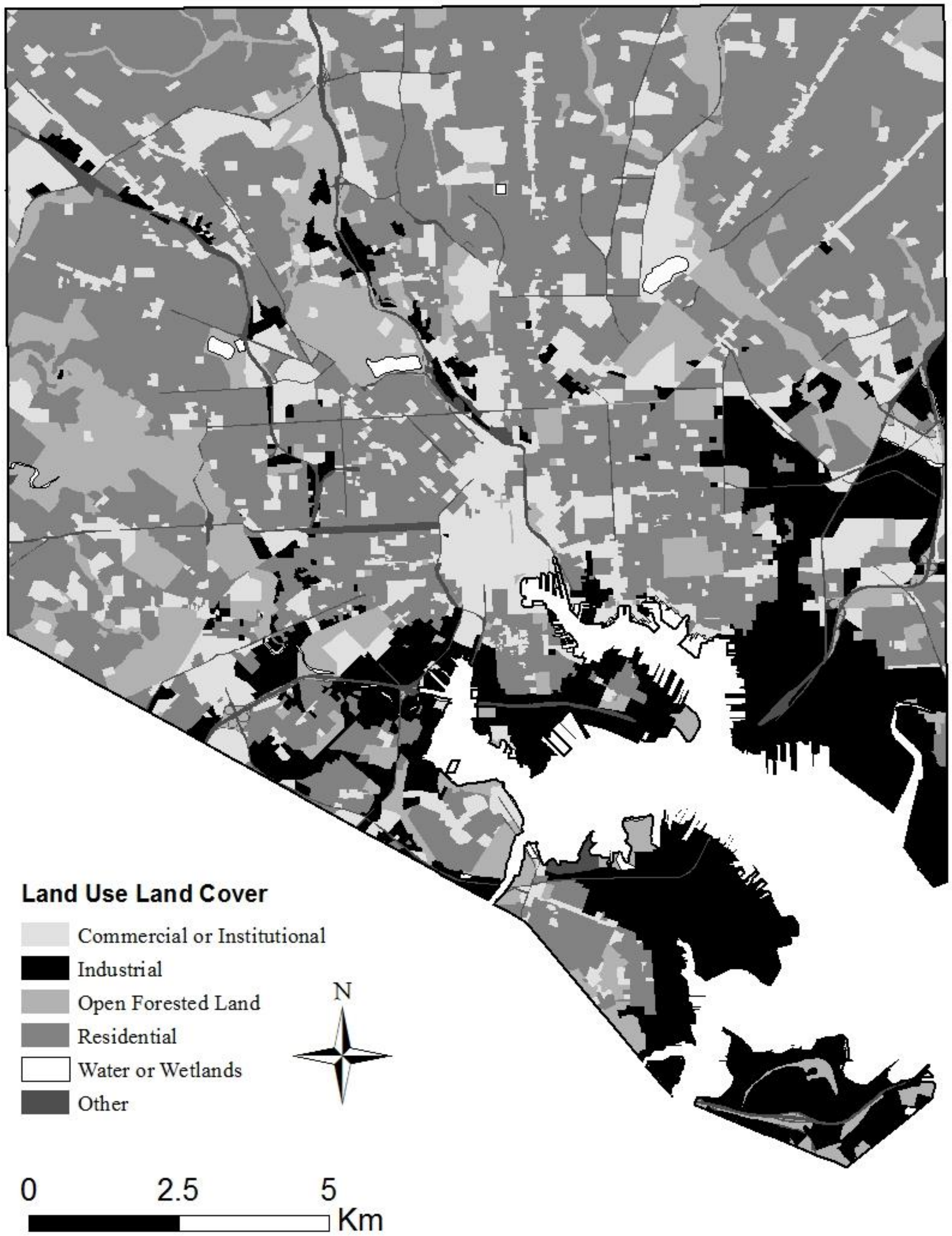

Figure 1. Land use land cover categories within Baltimore, Maryland.

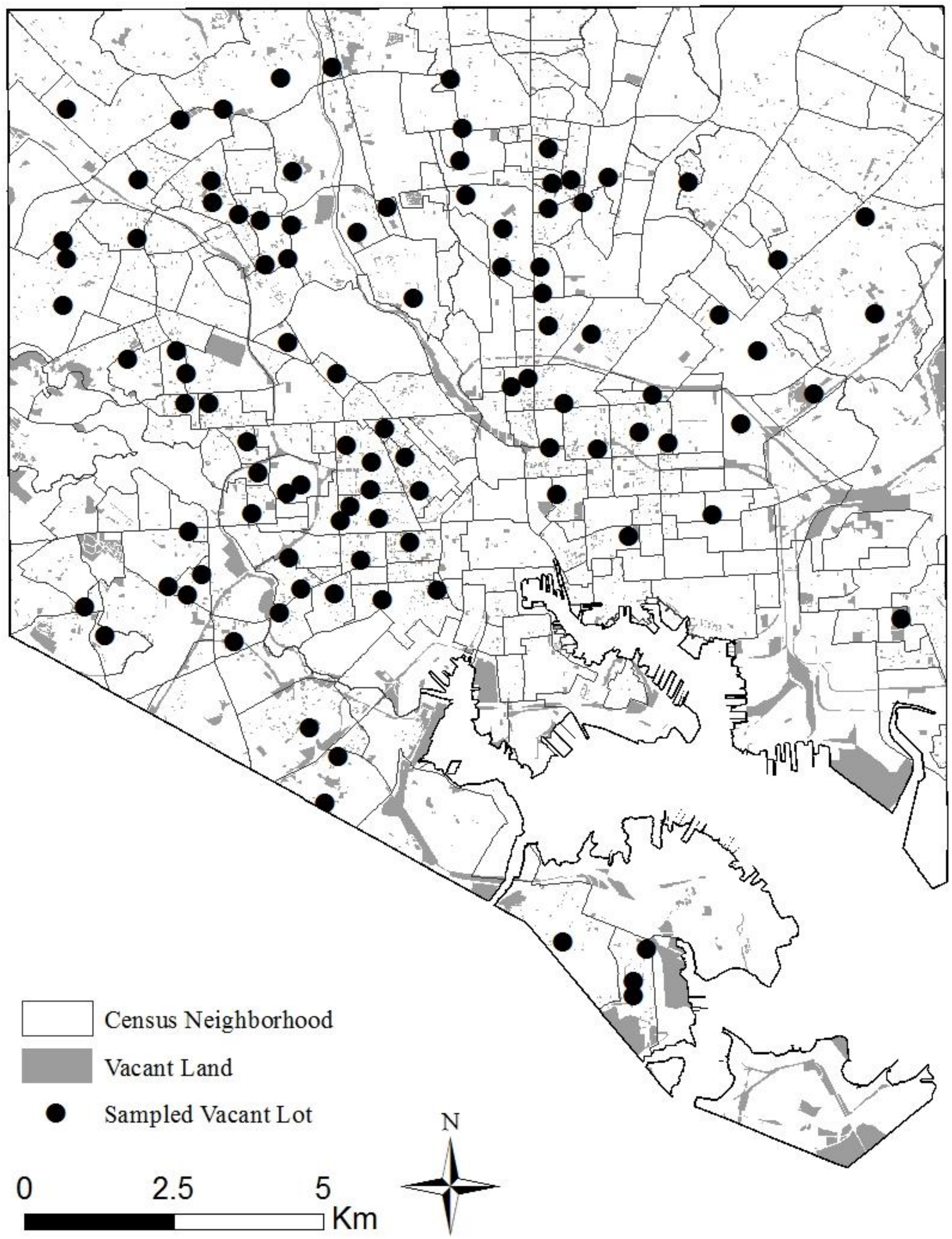

Figure 2. Locations of sampled vacant lots (n = 100), census neighborhoods delineations, and vacant land parcels within Baltimore, Maryland.

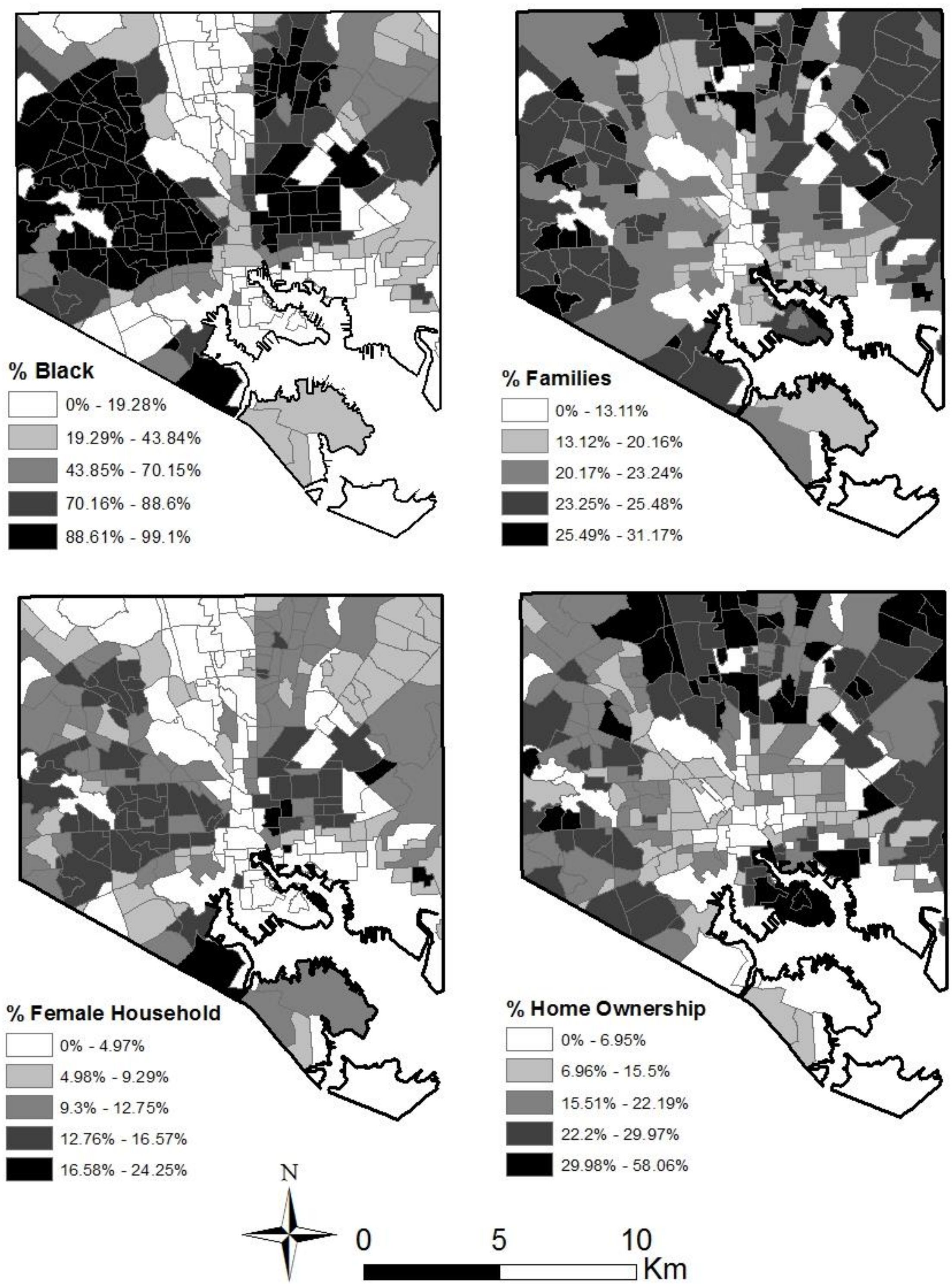

Figure 3. Distribution of four significant variables related to vacant land within Baltimore neighborhoods: percent Black/African American, percent family households, percent female-headed households, and percent home ownership.

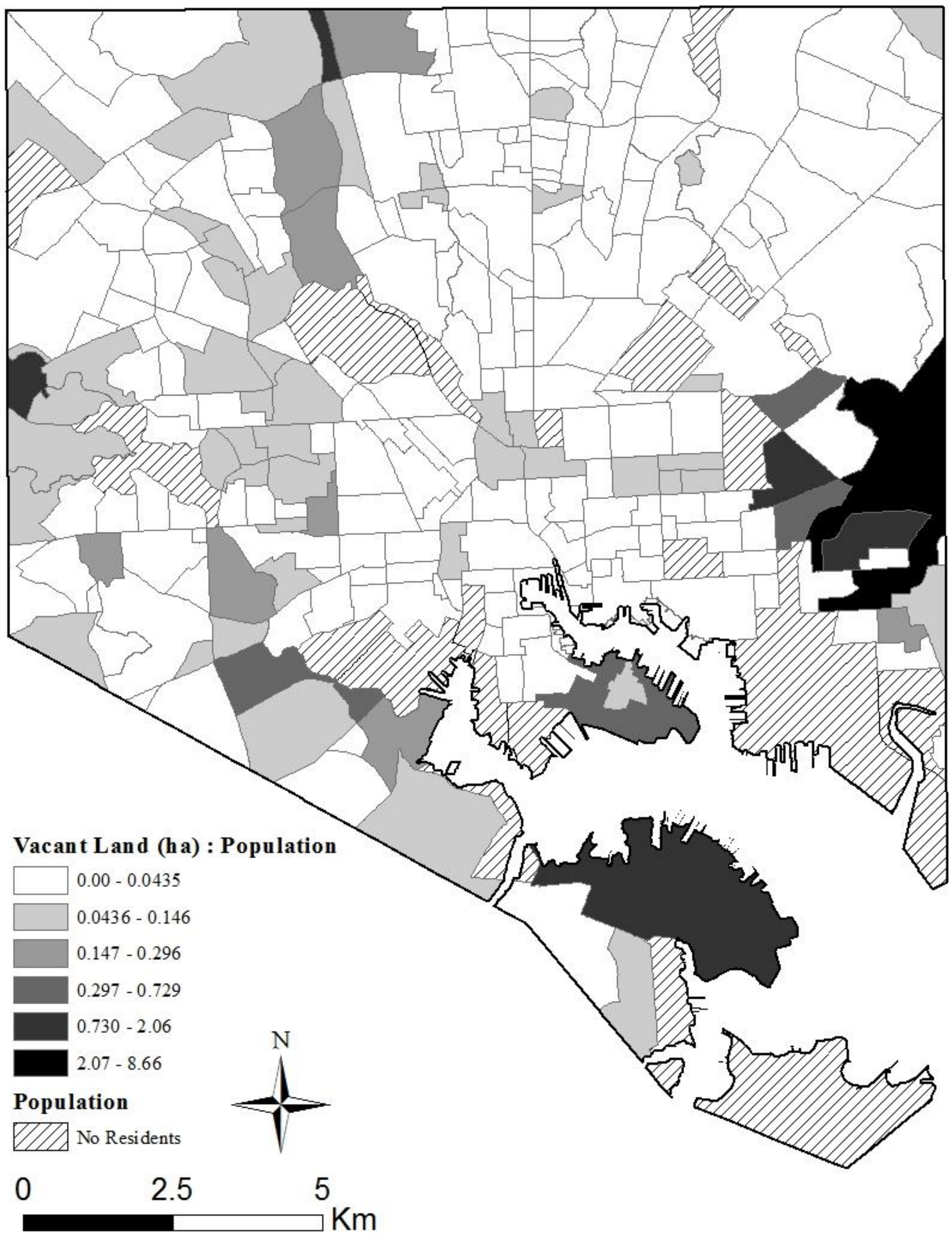

Figure 4. The amount of vacant land (ha) per Baltimore resident within each neighborhood. Neighborhoods with hatching did not have residents.

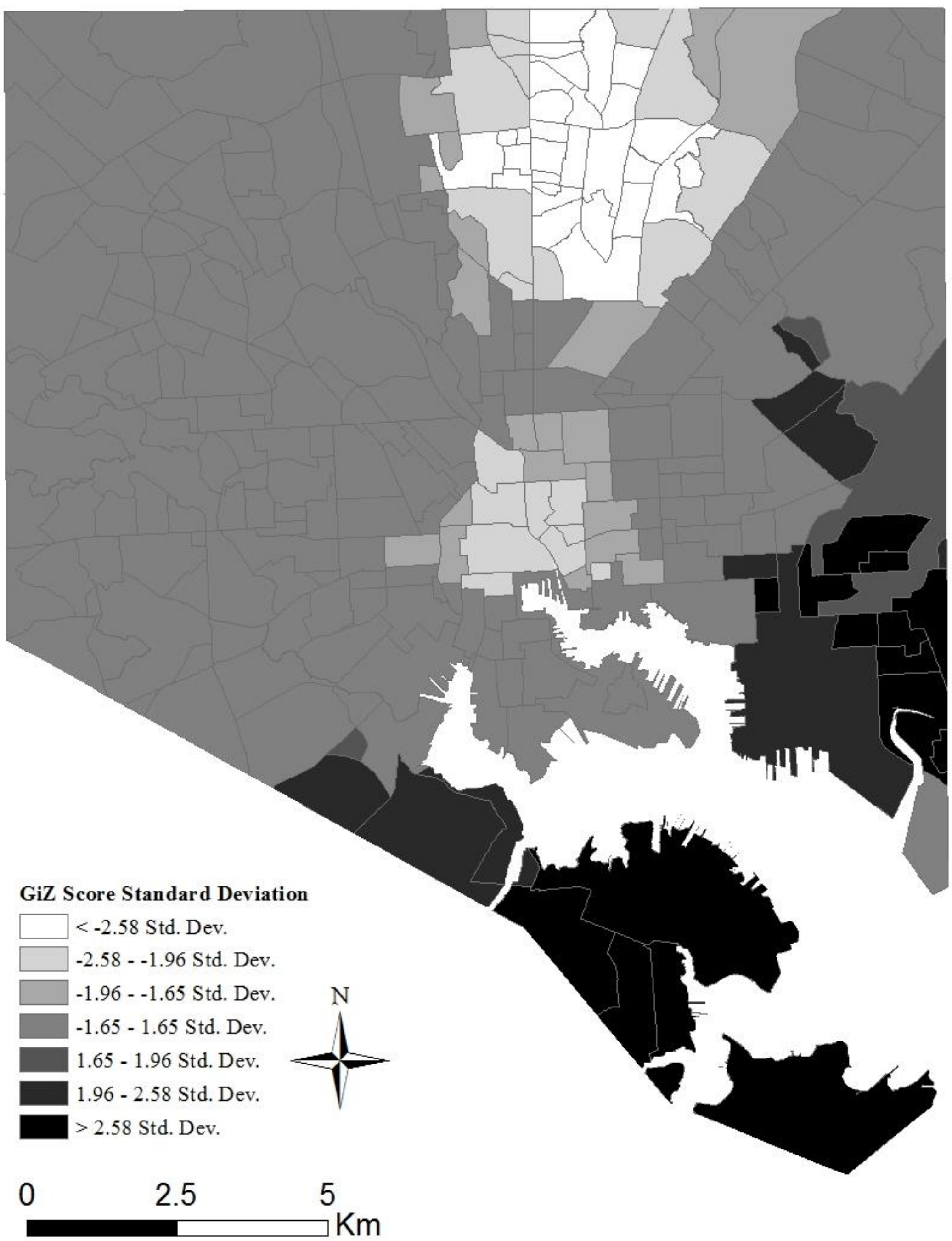

Figure 5. Hotspot analysis (GiZ Score) for vacant land area within Baltimore City neighborhoods, binned by standard deviation. Black polygons indicate neighborhoods with significant clustering of vacant land (> 2.58 standard deviation). White polygons indicate significant dispersal of vacant land within those neighborhoods (< 2.58 standard deviation).

Figure 6. Examples of residential vacant lots within communities of the greatest: a) wealthy homeowners (Guilford neighborhood), b) black residents (Upton), c) Hispanic residents (Ellwood Park/Monument), and d) female-headed households (Oldtown).

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Conclusion

Vacant lots are dynamic spaces within the urban landscape that provide habitat to support the bird community and social opportunities for their use as informal greenspaces. Across my five chapters, I found that the structural features of vacant lots played a large role in their current uses, supporting the bird community, how people perceived the space, and city-wide trends with neighborhood demographics.

A significant finding from these studies was the importance of tree and shrub cover as habitat provisions for birds within vacant lots. Increasing canopy cover at the site and across Baltimore directly impacted community composition and native songbird abundances, in addition to serving as a positive preference feature for local residents. Shrub cover also was important for nesting birds, however the presence of shrubs may make the lot too dense for local residents' use or liking. With these results, efforts should focus on managing vacant lots to provide large areas of open space for perceived safety and neatness, plant trees throughout the site, and incorporate areas with dense shrub vegetation in order to satisfy bird habitat requirements and the public's needs. Management efforts should focus on those vacant lots within neighborhoods with high Hispanic, African American, and young family populations, as those groups disproportionally experienced more vacant lots with fewer green features.

Our findings are significant as vacant lots are quickly gathering attention regarding their urban ecological and social importance (Burkholder 2012, Garvin et al. 2013, Kremer et al. 2013, McPhearson et al. 2013, Nassauer and Raskin 2014, Kim et al. 2015). With the understanding of vacant lots as habitat for abundant native bird populations and nesting success efforts, we now can identify practices to manage and conserve bird communities while also equally addressing the preferences and needs of neighborhood residents. Many of these practices can be done at a local scale, so residents and community groups can make a considerable ecological impact through small-scale greening practices in their local vacant lot. Overall, vacant lots should now be recognized as spaces that offer enormous opportunities for supporting native bird communities and serving as important spaces for residents within their communities.

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Vita

Christine C. (Rega) Brodsky was born in Livingston, New Jersey and attended school in Vernon and Hillsborough, NJ. In 2006, she graduated from Hillsborough High School in Hillsborough, NJ. In May 2010, she received a Bachelor of Science with a major in Biology and minor in Germanic Languages and Literature from the University of Massachusetts-Amherst. There, she wrote her undergraduate research honors thesis on song sharing and vocal performance variation in the swamp sparrow (*Melospiza georgiana*). Immediately following graduation from UMass, she began her Master's degree studying the effects of calcium availability on urban forest bird populations in Newark, Delaware. In May 2012, she graduated from the Department of Entomology and Wildlife Ecology at the University of Delaware with a M.S. in Wildlife Ecology and a Higher Education Teaching Certificate. Following a field season serving as a research supervisor in Newark, DE, she moved to Missouri where she began research on vacant lots as habitat for an urban bird community in Baltimore, Maryland. In May 2016, she received a Ph.D. in Fisheries and Wildlife and a GIS Certificate from the University of Missouri-Columbia.