Urban Ecosyst
DOI 10.1007/s11252-014-0363-2

Using a bird community index to evaluate national parks in the urbanized national capital region

Sarah E. Goodwin · W. Gregory Shriver

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Abstract Land managers and conservationists face two challenges in protecting land: first balancing human needs against conservation goals, and second demonstrating protected areas are meeting those goals. In this paper, we address the second challenge, using the National Parks of the highly urbanized mid-Atlantic as an example. We detail a comprehensive measure of overall ecosystem integrity, the bird community index, and demonstrate how it relates to the underlying habitat structure. We use community bird data collected from point counts to generate a single, comprehensive metric that we show is significantly correlated to habitat features, making it an effective tool for evaluating ecological integrity. Next, using the metric, we compare bird communities within and outside of protected status, and find that National Parks maintain higher integrity bird communities. This result provides evidence that even smaller parks in highly urbanized areas afford a conservation benefit. More broadly, we find that this rapid and cost effective assessment tool, the bird community index, shows great promise in helping land managers evaluate protected areas.

Keywords Birds · Ecological integrity · National Parks · Protected · Community

Introduction

Land conservation and protection is often at odds with pressures for food production, living space, transportation, and various other human needs. In urban areas, where land is at a greater premium, there are inevitable tradeoffs in land use decisions, and a balance between maximizing protected areas and meeting human needs is most challenging. Despite these obstacles, world governments have successfully protected between 10.1 and 15.5 % of the total terrestrial habitat (Chape et al. 2005; Soutullo 2010; Armsworth et al. 2011), a large step in meeting conservation needs. After land is protected, however, a second challenge emerges. How do

S. E. Goodwin (✉) · W. G. Shriver
Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE 19716, USA
e-mail: segoodwi@cns.umass.edu

Present Address:
S. E. Goodwin
Graduate Program in Organismic and Evolutionary Biology, University of Massachusetts Amherst, Amherst, MA 01003, USA

Published online: 27 April 2014

managers demonstrate that protected areas are indeed effectively conserving the biota and systems contained within?

Protected areas are evaluated along three major lines of assessment; park design, management strategies, and direct measures of biota (Ervin 2003). Park design (e.g. Pressey et al. 1993; Powell et al. 2000; Rouget et al. 2004) and management strategies (e.g. Singh 1999; Hockings 2003; Rao et al. 2002) can inform on how well a protected area should perform, but a more thorough evaluation of performance should also consider if conservation goals are actually achieved, often via direct measures of individual biota, or more comprehensively, a systems' ecological integrity (Gaston et al. 2006, 2008). Ecological integrity refers to the ability of a given ecosystem to support and maintain a community of organisms comparable to those of natural habitats (Karr and Dudley 1981), and can provide a complete report on ecosystem health (Ordonez and Dunker 2012). Direct estimates of ecological integrity present the clearest indication that protected areas are effective at conserving biota, but such intensive study can be prohibitively costly and time-consuming for managers (Margules and Austin 1990). Some features indicative of ecological integrity are more easily measured than direct counts of biota, for example landscape scale changes, which can be inferred from satellite imagery (Figueroa and Sanchez-Cordero 2008; Gaveau et al. 2009; Maiorano et al. 2008; Bruner et al. 2001). Studies of animal communities are less common, by contrast, likely due in large part to the logistical challenges involved in detecting animals and the variation associated with these estimates (Thompson et al. 1998). Avian communities, however, can be readily measured by auditory methods and provide robust measures of population density (Ralph et al. 1995). Perhaps because of this relative ease of assessment, bird communities are more commonly evaluated in protected areas (Devictor et al. 2007; Greve et al. 2011), and these data can provide insight into the overall health and integrity of ecosystems.

Avian communities are composed of a mosaic of feeding, foraging, and other life history guilds, and changes in the habitat or environment can differentially affect these groupings of species (Severinghaus 1981; Verner 1984; Minor and Urban 2010). As guilds increase or decrease in population density, those changes are reflected in the community as a whole and can be an index of underlying environmental change or ecological integrity (Karr 1991). For example, avian communities have been used as indicators of condition in riparian-wetland habitats (Croonquist and Brooks 1991; Bryce et al. 2002; Bryce 2006), marshes (DeLuca et al. 2004), rangelands and grasslands (Bradford et al. 1998; Coppedge et al. 2006), forests (Canterbury et al. 2000; O'Connell et al. 2000), and in varying human-dominated landscapes (Glennon and Porter 2005).

One reason bird communities provide an index to environmental change is that communities change in predictable patterns in response to increased urbanization. In highly developed areas, a suite of species known as urban adapters become widespread and abundant, whereas forest interior species are largely absent (McKinney 2002, 2006). Furthermore, the shift towards a greater abundance of urban adapters in developed areas tends to favor non-native species at the expense of natives (Blair 1996; Donnelly and Marzluff 2004). Changes in habitat, particularly vertical structure in forests, affect the abundance of different functional guilds (DeGraaf and Wentworth 1986). For example, highly urban areas typically host fewer ground nesting, insectivorous, single-brooded, and migratory species (DeGraaf and Wentworth 1986; Huste and Boulinier 2007). It follows then that a metric that evaluates the bird community as a whole might track underlying habitat change, particularly those changes associated with the multi-faceted impacts of urbanization.

Here, we confirm the utility of a bird community index in evaluating the ecological integrity of National Parks in the National Capital Region of the highly urbanized mid-Atlantic, US. We first address how well the bird community correlates with vegetation and landscape features,

verifying that the bird community is a valid indicator of ecological integrity. We then provide an application of the bird community index, asking how bird communities and therefore ecological integrity varies within and outside these National Parks.

Methods

We selected eight National Parks located in Washington DC, Western Maryland, Northern Virginia, and West Virginia (Fig. 1). National Parks in this region are predominately situated in a highly urbanized landscape. To more precisely quantify this urban context, we measured the land use classifications within a 1 km buffer around every National Park, using ARCGIS 9.2 (ESRI 2004) and the 2001 National Land Cover Database. At this distance, 30.5 % of land is in some form of development, confirming the high degree of urbanization. Parks also varied in total area, perimeter, and forest cover (Table 1). We selected 77 forested sampling locations in each park using a Generated Random Tessalation-Stratified scheme (Stevens and Olsen 2004), following the avian monitoring protocol for the National Capital Region. All locations were at least 250 m apart.

To evaluate the forest breeding bird communities within National Parks we performed three-minute point counts at each park service monitoring location from one half hour before dawn to five hours after dawn during the breeding season of 2009 (mid-May through mid-July). We recorded all birds detected within 100 m from the observer during the point count. We did not survey for birds in strong wind (Beaufort score of>3) or rain. To evaluate bird communities outside of National Parks, we used Breeding Bird Survey data, a large-scale, long-term monitoring effort conducted by trained volunteers across the U.S. and Canada (Sauer et al. 2011). Surveyors conduct roadside sampling along routes of 24.5 miles, with survey stops at every 0.5 miles. We selected four Breeding Bird Survey routes in the same ecological region as the National Parks (level II, Southeastern Plains, level III Northern Piedmont and Southeastern Plains). These routes were Wheaton and Randallstown in Maryland, Schwensksvill in Pennsylvania, and Hall in Virginia (Fig. 1). At Breeding Bird Survey locations, volunteers conducted three-minute point counts, and recorded all birds detected within a 0.25-mile (400 m) radius.

Patch and landscape variables

At all within park locations the National Park Service collected patch variables following methods in Schmit and Campbell (2007). Variables included the percent of exotic cover, volume of coarse woody debris, seedlings/ha, saplings/ha, shrubs/ha, trees/ha and total tree species. We derived landscape scale variables in ArcGIS 9.2 (ESRI 2004), using the 2001 National Land Cover Database with a 500 m radius circle around each monitoring location. The National Park Service provided other necessary data layers, including park boundaries and infrastructure locations. Landscape variables included in analyses were distance to nearest road, nearest park boundary, and nearest forest edge, as well as the percent forest cover, developed land, and impervious surface.

Bird community index estimation

We calculated a bird community index (BCI) at all sampling locations using a previously developed metric for this region (O'Connell et al. 2003). Extensive details on the development of the BCI metric are available (O'Connell et al. 2003) and here we provide a brief summary of

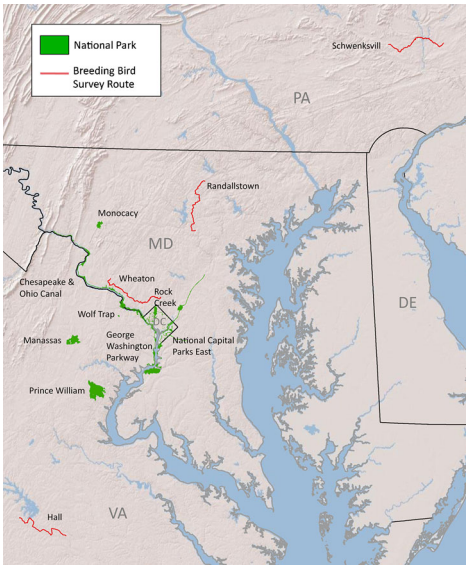

Fig. 1 The geographic extent of the study region. National Capital Parks are identified in green, and the Breeding Bird Survey routes are in red

how the metric is used to estimate forest bird community integrity. We first categorized each species detected into the appropriate structural, functional, and compositional guilds (Harrison 1975; DeGraaf et al. 1985; see O'Connell et al. 2003 for details on guild assignments). We then summarized the proportional species representation for each guild at each site, and assigned a rank score based on that proportion. For example, specialist guilds such as forest interior birds score a higher rank with a higher proportional species representation. We repeated this for each guild following the rank values for our study area as established by O'Connell et al. (2003). We then summed all ranks across the functional, structural, and compositional guilds and converted that value to a percent of the maximum possible to build a community profile of the site and to quantify the ecological integrity with a final BCI score (Table 2). We estimated a BCI score for 77 within park locations and 111 breeding bird survey stops located outside of parks (Table 3).

Statistical analyses

To evaluate how the BCI score correlated with habitat features, we first reduced the habitat variables using a principal components (PC) analysis, after confirming BCI scores met assumptions of normality. We used the cumulative variance in each additional eigenvector, as well as Monte Carlo permutations of eigenvalues to compare simulated distributions of eigenvalues to the original values to determine how many principal components to retain (McGarigal et al. 2002). We then used linear regression to compare PC scores (habitat) against BCI scores (bird community).

To address how the BCI scores varied within and outside parks, we first confirmed that forest cover did not substantially vary among sites. We compared forest cover at a 500 m radius between sites located within and outside parks, and found no difference in total forest cover (t-test, t=1.435, df=186, p=0.153). To evaluate how roadside counts affect total BCI score (i.e. a roadside bias), we used a t-test to compare BCI scores of a Breeding Bird Survey that traversed the inside of a larger National Park (Breeding Bird Survey route "Prince William

Table 1 National Parks of the National Capital Region, their purpose, size, and percent forest cover for all monitoring locations evaluated

National Park	Fundamental Purpose*	Size (ha)	Forest Cover (%)	n
Chesapeake and Ohio Canal National Historic Park	To preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal (Public Law 91–664 91st Congress, H.R. 19342, January 8, 1971 Section 3 a)	7,788	31 %	24
George Washington Memorial Parkway	To preserve the Potomac River shoreline from pollution and commercial development…To provide for the protection and preservation of the natural scenery of the Gorge and Great Falls of the Potomac, and preservation of the historic Patowmack Canal 1930, the Capper-Cramton Act (46 Stat. 482)	3,198	31 %	15
Manassas National Battlefield Park	To protect the battlefield site of the First and Second battles of Manassas during the war between the States	2,064	33 %	14
Monocacy National Battlefield	To commemorate the Battle of Monocacy, Maryland, and to preserve for historical purposes the breastworks, earthworks, walls, or other defenses or shelters used by the armies	667	14 %	1
National Capital Parks-East	To preserve the flow of water in Rock Creek, to prevent pollution of Rock Creek and the Potomac and Anacostia Rivers, to preserve forests and natural scenery in and about Washington, and to provide for the comprehensive systematic, and continuous development of the park, parkway, and playground system of the National Capital	4,378	33 %	15
Prince William Forest Park	President Franklin D. Roosevelt transferred lands in several states to the Secretary of the Interior to become a part of the park system of the National Capital and its environs'	7,518	33 %	2
Rock Creek Park	To provide for the preservation from injury or spoliation of all timber, animals, or curiosities within said park, and their retention in their natural condition, as nearly as possible	1,100	25 %	5
Wolf Trap National Park for the Performing Arts	A park for the performing arts and related educational programs, and for recreation use in connection therewith	53	41 %	1

*National Park Service. 2005. Long-term Monitoring Plan for Natural Resources in the National Capital Region Network. Inventory and Monitoring Program, Center for Urban Ecology. Washington DC

Route", n=50) to the BCI scores generated by the National Park monitoring locations in that parks' interior (monitoring locations inside Prince William Forest Park, n=132). To address how the BCI varies within and outside of parks, we used a generalized linear model with the BCI score as the response variable, and protected status, percent forest cover within 500 m, and park or route identification as predictor variables (Quinn and Keough 2002). We chose to statistically control for forest cover in the GLM analysis in addition to proactively selecting similarly forested sites because we wanted to be conservative in our assumptions of what levels of forest cover birds may respond to. We also described the average avian assemblage

Table 2 To calculate a BCI score, percent species representation determines the rank value for that guild at each site. An example site calculation is provided below

Guild		Rank				
		1	2	3	4	Example Score
Structural	Forest Interior	0–10.0 %	10.1–20.0 %	20.1–28.0 %	**28.1–100%**	(**33.3%**)
	Pine Associated	0 %	0.1–2.0 %	2.1–5.0 %	**5.1–100%**	(**16.7%**)
	Urban/Suburban	60.1–100 %	47.1–60.0 %	20.1–47.0 %	**0–20.0%**	(**16.7%**)
Functional	Bark Prober	0–9.0 %	9.1–16.0 %	**16.1–20.0%**	20.1–100 %	(**16.7%**)
	Upper Canopy Gleaner	0–4.0 %	4.1–12.0 %	12.1–18.0 %	**18.1–100%**	(**33.3%**)
	Ground Gleaner	**0%**	0.1–3.0 %	3.1–7.0 %	7.1–100 %	(**0%**)
Compositional	Single Brooded	0–16.0 %	16.1–34.0 %	34.1–46.0 %	**46.1–100%**	(**50.0%**)
	Nest Disrupter	23.1–100 %	16.1–23.0 %	0.1–16.0 %	**0%**	(**0%**)
	Exotic	11.1–100 %	1.1–11.0 %	0.1–1.0 %	**0%**	(**0%**)

Ranks are then summed in the guild subcategories to determine overall BCI score. Rank values from O'Connell et al. (2003). BCI score for a single survey location calculated as an example with rank categories shown in **Bold**

To calculate BCI score: Structural =(4+4+4)/4=3, Functional =(3+4+1)/4=2, Compositional =(4+4+4)/4=4

Sum sub-scores =(3+2+4)=8, divided by 9=0.88, standardized as percent of maximum =**85.15**%

differences within and outside parks, and evaluated the strength of association between guild representation and protected status using a discriminant function analysis (McGarigal et al. 2002). All analyses were conducted in R (R Development Core Team 2013).

Table 3 Average (+SE) BCI score by National Park or Breeding Bird Survey route

Survey Locations	sampling locations (n)	Average BCI score
National Parks		
Chesapeake and Ohio Canal National Historic Park	24	58.02 (3.16)
George Washington Memorial Parkway	15	41.98 (5.49)
Manassas National Battlefield Park	14	51.32 (3.58)
Monocacy National Battlefield	1	*40.74*
National Capital Parks-East	15	41.23 (4.81)
Prince William Forest Park	2	72.22 (5.56)
Rock Creek Park	5	20.00 (7.37)
Wolf Trap National Park for the Performing Arts	1	*33.33*
Breeding Bird Survey Routes		
Wheaton	31	20.43 (3.62)
Randallstown	30	16.35 (2.43)
Schwenksvill	31	8.48 (1.68)
Hall	19	31.19 (3.62)

Results

BCI scores ranged from 0 to 89, and were normally distributed (Shapiro-Wilks test, p=0.432). The first PC of habitat variables explained 30.6 % of the variance and was the only significant principal component generated as determined by permutation procedures and graphically inspecting the reduction in the percent variance explained with cumulative components. The variable loadings on PC1 were ecologically meaningful, with strong positive structure correlations with variables indicating more intact forest (i.e. distance to park boundary and distance to road), and strong negative structure correlations with variables indicating more developed land (i.e. percent impervious surface, Table 4). We found a strong positive relationship (R^2= 0.25, df=75, p=<0.001, Fig. 2) between the PC scores and the bird community index.

BCI scores did not differ between off road (mean BCI =72.67, SD =10.17) and roadside locations at Prince William Forest Park (mean BCI =74.45 SD =17.87, t-test, t=0.839, df= 180, p= 0.402). BCI scores from within National Parks (within parks mean BCI =47.76, SD = 19.64) were 2.6 times greater than those outside park locations (outside parks mean BCI = 17.90, SD =15.18, $F_{12,\ 174}$=24.35, p<0.001, Fig. 3). The discriminant function analysis grouped the bird community into within and outside of parks (multiple R^2=0.468, $F_{1,185}$= 162.7, p=<0.001) with a 0.834 classification rate. Structure correlations for the function loaded strongly negatively for guilds more associated with forest birds, and more positively for guilds associated with urbanization (Table 5).

Discussion

Our main findings were that the forest breeding bird community index provided an assessment of ecological integrity in our study area, and that protected areas maintain greater bird community integrity than do areas outside of protected status. The BCI was strongly positively associated with both patch and landscape variables, confirming the ability of this metric to track habitat change. The BCI score was 2.6 times greater within the National Parks than in adjacent areas, even after controlling for the amount of forest cover. Areas sampled outside of the National Parks had bird communities with a greater representation of species in urban guilds (i.e. urban/suburban associated, and exotic species), while areas within the National Parks had greater species representation in forest guilds (i.e. upper canopy gleaners, and single brooded species).

Such measureable conservation benefits of protected areas remain both understudied and difficult to achieve. To evaluate how well a park protects its biota, detailed monitoring

Table 4 Variable loadings for the principal component derived from habitat variables. Variables more associated with human development loaded more negatively, and those variables associated with more intact forest more positively

Habitat Variable	PCI variable loadings
Percent forest cover	0.398
Distance to road	0.356
Distance to forest edge	0.213
Distance to park boundary	0.201
Trees/ha	0.173
Seedlings/ha	−0.235
Percent impervious surface	−0.510
Percent developed	−0.525

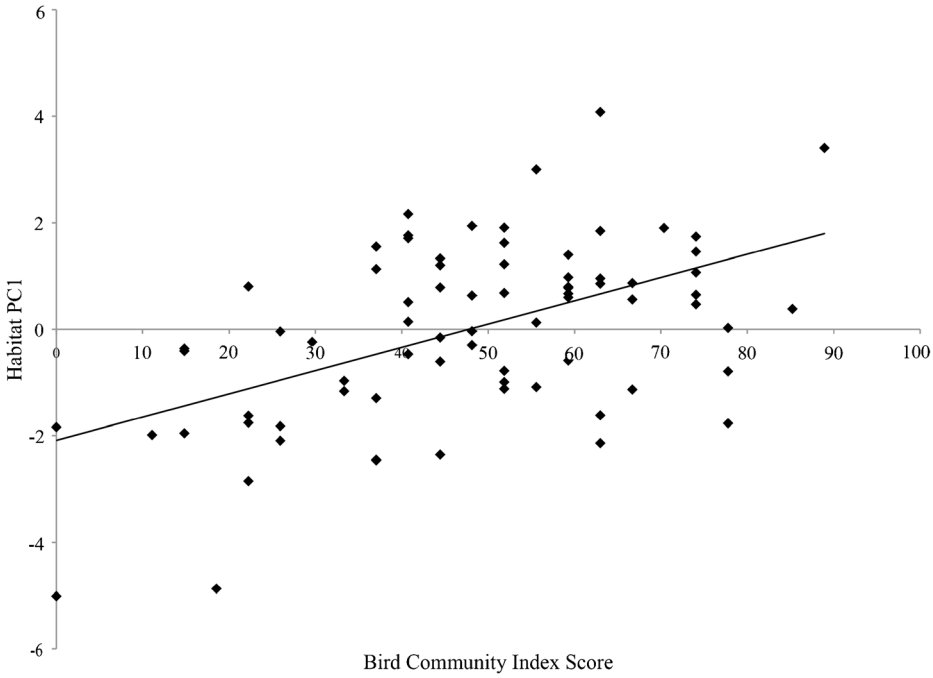

Fig. 2 BCI scores were related to the underlying habitat structure (PC1), such that with more natural habitats (increasing PC1 scores), the BCI score increased (R^2=0.27, df=75, p=<0.001)

programs are required, and such an undertaking is time-consuming, expensive, and most importantly, may yield data that are still not informative to park managers. The U.S. National Park Service's Inventory and Monitoring program is charged with monitoring park natural

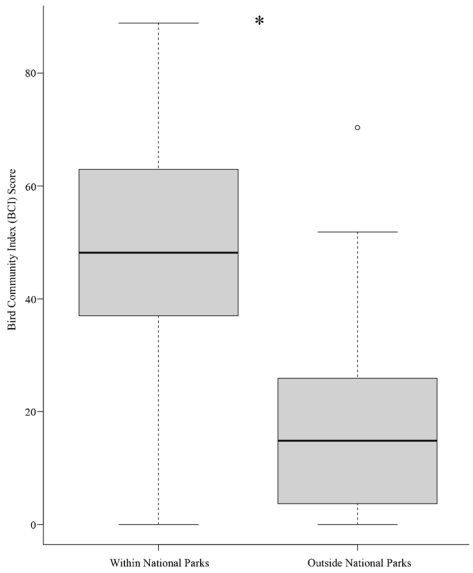

Fig. 3 Boxplot of bird community index (BCI) scores within versus outside National Parks. Gray areas are 25 % quartiles and the whiskers extend to the range of the data. BCI scores were greater within National Parks than outside National Parks, controlling for forest cover and route (GLM, $F_{12,\ 174}$=24.35, p<0.001)

Table 5 Canonical structure correlations for each guild used in the discriminant function analysis, indicating how groups (within or outside park) were separated, and the amount of variance in the canonical function explained by each guild

Avian Guild	Canonical Structure Correlations
Singled Brooded	0.877
Upper Canopy Gleaner	0.670
Forest Interior	0.661
Bark Prober	0.571
Ground Gleaner	0.173
Pine Associated	0.126
Nest Disrupter	−0.394
Exotic	−0.571
Urban Suburban	−0.919

resources (Fancy et al. 2009), and provides the types of information that can be used to assess park effectiveness in protecting natural resources. With the application of a BCI such as this, managers could use monitoring information to evaluate park condition, set management goals, and evaluate how avian guilds change over time and space. This "scorecard" type approach to assessment is already being adopted for its utility in synthesizing large data-sets into easily understood metrics that can be standardized and applied regionally (Parrish et al. 2003; Tierney et al. 2009). We envision this approach being applied in a similar manner elsewhere with the continued goal of documenting and quantifying the value of protected areas and in prioritization of future protected areas.

Our analysis of the bird community supported the prediction that protected areas do in fact host higher integrity bird communities than areas outside of protected status. What are the factors that could contribute to this higher community integrity? Forest cover at all survey sites was similar, but the total amount of forest cover within 500 m of the sites was low (10–50 %). If we considered forest cover at a larger scale (e.g. increasing the radius around the site), within park sites would likely contain a larger amount of forest and birds may be responding to the amount of forest cover at these larger scales (Lee et al. 2002). Furthermore, these National Parks are likely protecting continuous pieces of forest rather than the small parcels that dominate the landscape outside the parks, and this fragmentation may be a factor that the bird community responds to (i.e. Boulinier et al. 2001; Fernandez-Juricic 2004).

In our study region, the major land-use is urban development, which often results in smaller land areas available for protection. Indeed, many of these parks are small in total area, or are a collection of smaller parks with historical or cultural mission statements (see Table 1). This region, like many others, continues to be under increasing pressure from expanding human populations with extensive and growing infrastructure needs. In the later part of this century, for example, human development in the Washington DC area increased by 22 km^2 per year (Masek et al. 2000), creating a more expansive urban matrix. However, despite being located in an urbanized matrix, the National Parks retain greater forest bird community integrity than the Breeding Bird Survey routes, indicating that these protected areas are contributing to biodiversity conservation in the region. With such intense human development in this region, these small protected areas are ever more critical for birds and other taxa as appropriate habitat dwindles. (i.e. Shafer 1995; Turner and Corlett 1996).

Forest birds face considerable challenges in human dominated landscapes. Nearly 22 % of all forest birds are species of conservation concern, including 11 federally listed as endangered or threatened (North American Bird Conservation Initiative 2009). Small protected areas, like the ones surveyed in this study, may provide critical habitat for these threatened species. However,

one limitation to this BCI approach to assessment is the absence of survival and reproductive success data for the species detected. An obvious criticism of this result then is that we may be documenting a high integrity bird community, but are unaware of the underlying source/sink dynamics (Dias 1996). Indeed, recent modeling work suggests fragmentation and edge effects could infiltrate at a 10 km radius and reduce population growth for 20 species across our entire study area (Lloyd et al. 2005). However, a bird community index such as this one is not intended to capture these population level processes, instead, we envision it as a metric for ecological integrity that can be improved by more intensive monitoring of reproductive output of these species. Until then, however, we can conclude that these National Parks located in a heavily urbanized area supported greater bird community integrity than similar sites just outside the parks.

Acknowledgments We thank Pat Campbell of the National Park Service Inventory and Monitoring Program for support and providing access to the avian monitoring data. Geoff Sanders (National Park Service I&M, National Capital Region) provided data management and assisted in QA/QC of the avian data. The staff at the Breeding Bird Survey provided data for off park sites which was greatly appreciated. We thank the numerous volunteers of the Breeding Bird Survey and field assistants of the National Park Service for undertaking these surveys. Thanks also to Tim O'Connell and the Podos lab for providing feedback on an earlier draft of this manuscript. We also thank the staff at Chesapeake and Ohio Canal National Historic Park, George Washington Memorial Parkway, Manassas National Battlefield Park, Monocacy National Battlefield, National Capital Parks-East, Prince William Forest Park, Rock Creek Park, and Wolf Trap National Park for the Performing Arts for logistical support. This work was funded by the National Park Service's National Capital Region Inventory and Monitoring Network.

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