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Recreational Trails Reduce the Density of Ground-Dwelling Birds in Protected Areas

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Abstract Recreational disturbance associated with trails has been identified as one of the major factors causing a decline of native biodiversity within protected areas. However, despite the negative impacts that recreation can have on biodiversity, providing public access to nature is critical for the future of the conservation of biodiversity. As such, many protected area managers are looking for tools to help maintain a balance between public access and biodiversity conservation. The objectives of this study were to examine the impacts of recreational trails on forest-dwelling bird communities in eastern North America, identify functional guilds which are particularly sensitive to recreational trails, and derive guidelines for trail design to assist in managing the impacts of recreational trails on forest-dwelling birds. Trails within 24 publicly owned natural areas were mapped, and breeding bird communities were described with the use of point count surveys. The density of forest birds, particularly of those species which nest or forage on the ground, were significantly positively influenced by the amount of trail-free refuge habitat. Although management options to control trail use in non-staffed protected areas are limited, this study suggests that protected area managers could design and maintain a trail network that would minimize impacts on resident wildlife, while providing recreational opportunities for visitors, by designing their trail network to maximize the area of trail-free habitat.

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Introduction

When the Brundtland Report was released in 1987 (World Commission on Environment and Development 1987), it established a target of 12 % for a global protected area network. At the time, that was seen as a 'stretch goal' for the conservation movement, as it represented a tripling of the amount of land in formal protected areas. Since that time however, that goal has been reached (Bertzky et al. 2012). Notwithstanding the fundamental insufficiency of 12 % as a target to ensure the protection of global biodiversity (e.g., Svancara et al. 2005; Solomon et al. 2003; Desmet and Cowling 2004), the amount of coordinated effort, public awareness, policy development, and financial investment globally needed to achieve this target represents a major success for the global conservation movement.

Although protected areas can be an effective mechanism for reducing habitat loss by reducing or preventing the clearing of native vegetation, they are not always effective at protecting resident wildlife (Newmark 1995; Rivard et al. 2000; Raynor et al. 2014). A number of stresses impact wildlife resident in protected areas, including land use changes surrounding the protected area (Czech et al. 2000), water pollution (Venter et al. 2006), changes in disease occurrence (La Marca et al. 2005), and emerging stresses associated with global climate change (Burns et al. 2003). Within protected areas themselves, increased human presence for recreation can lead to additional stresses on wildlife (Losos et al. 1995; Kangas et al. 2010; Reed and Merenlender 2011). The creation and use of recreational trails in protected areas can impact vegetation communities through a loss of vegetative cover (Cole 1995), a decrease in root, shoot, and leaf biomass of stressed plants, or damage to tree and shrub seedlings (Sun and Liddle 1993). Impacts to faunal communities can include a decrease in reproductive performance (e.g., Gutzwiller et al. 1994), a shift in habitat selection (e.g., Rogala et al. 2011), or changes to predator–prey dynamics (e.g., Miller and Hobbs, 2000; Rogala et al. 2011). These disturbance factors may act to reduce the amount of available habitat for species within protected areas (Frid and Dill 2002).

Despite the negative impacts that trails and trail use can have on biodiversity within protected areas, providing public access to nature is critical for the future of conservation of biodiversity. Having access to natural areas tends to promote a greater level of awareness and concern in the general public on issues related to environmental and biodiversity conservation (e.g., Nisbet et al. 2009; Halpenny 2010; Davis et al. 2011). In many cases this extends to an increase in pro-conservation behaviors, ranging from recycling in the home (e.g., Halpenny 2010), to joining environmental non-governmental organizations (e.g., Zaradic et al. 2009), to participation in direct conservation action such as planting trees (e.g., Raymond et al. 2011).

In order to ensure that nature remains accessible to the public, and to ensure that biodiversity is maintained within natural areas, many governments have developed policies requiring protected area managers to balance the needs of visitors with the needs of native biodiversity, such as Canada's *Canada National Parks Act*, and the United States' *National Park Service Organic Act*. To achieve that balance however, protected area managers need information on the impacts of recreational use on native biota, and tools to help support decision-making. Information commonly used to navigate this balance is provided by studies on wildlife behavior, and its changes in the presence of trail users (e.g., Gutzwiller et al. 1998; Fernández-Juricic et al. 2001, 2005). For example, in the case of forest-dwelling birds, alert distance (the distance between a bird and a human at which point the birds begins to exhibit alert behaviors in response to the human; Fernández-Juricic et al. 2001), and flight distances (the distance between a bird and an approaching human at which point the bird initiates flight; Gutzwiller et al. 1998) have both been used as metrics to monitor the impacts of recreation (e.g., Gutzwiller et al. 1998; Miller et al. 2001; Fernández-Juricic et al. 2004; Campbell 2011). These metrics lend themselves well to protected area planning tools (Fernández-Juricic et al. 2005), however this approach is relatively labor intensive and tends to be restricted to common species to allow the collection of sufficient data for statistical analysis. Supplementing this approach with a community-level approach will assist protected area managers in making informed decisions in areas where such data is not available.

The objectives of this study were to (1) examine the impacts of recreational trails on forest-dwelling birds in eastern North America, (2) identify functional guilds which are particularly sensitive to recreational trails, and (3) derive guidelines for trail design or management to assist in managing the impacts of recreational trails on forest-dwelling birds.

Methods

Study Area Description

This study took place in central Ontario, Canada, in the Lake Simcoe watershed, in the counties of York, Durham, and Simcoe (79.362°W, 44.219°N). This landscape is dominated by agricultural land use and natural areas, with scattered urban settlements. Remnant forests are predominantly deciduous, composed of sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*), with species such as white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), red maple (*A. rubrum*), red oak (*Quercus rubra*), eastern hemlock (*Tsuga canadensis*), and white pine (*Pinus strobus*) as sub-dominants in the canopy. Forests in low-lying, riparian, or poorly drained areas support communities composed of black ash (*F. nigra*), silver maple (*A. saccharinum*), American elm (*Ulmus americana*), and white cedar (*Thuja occidentalis*) (Johnson 1997). The current population density in this area is 228 people per square kilometer (Statistics Canada 2012), but it is one of the most rapidly growing areas in Canada (Ontario Ministry of Infrastructure 2006). With this increased population density comes a burgeoning increase in trail use as a form of recreation (e.g., Town of Georgina 2004; Town of East Gwillimbury 2009; Town of Aurora 2010).

Twenty-four publicly owned natural areas in this region were randomly selected as study sites to examine the impacts of the presence of trails on forest-dwelling birds (Table 1). In order to ensure study sites provided a range of trail density representative of this region, publicly owned natural areas in the study region were a priori classified as being of three types: having no recreational trails; supporting local use only (with no parking lots, and typically low levels of trail development); and recreation destinations (with formal marked trail networks, parking lots, and trail heads). Eight publicly owned natural areas were randomly selected from each class. To reduce the confounding effects of habitat diversity on bird community composition, areas of relatively homogeneous forest communities were delineated and one such community was randomly selected

Table 1 Description of study sites in central Ontario, Canada

Study site	Protected area size (ha)	Forest patch size (ha)	Trail length within forest patch (m)	Maximum trail-free area within forest patch (ha)
Baldwin	29.4	5.7	528	1.2
Brozic	8.4	6.7	0	6.7
Case Woodlot	28.2	28.4	5539	3.2
Durham Forest—Brookdale Tract	40.7	33.3	2409	7.8
Durham Forest—Main Tract	365.4	52.4	8450	5.0
Durham Forest—Norton Tract	19.5	8.2	1467	4.1
Durham Forest—Roseville Tract	80.7	63.8	6994	11.1
Durham Forest—Timbers Tract	41.8	41.6	3317	11.5
Durham Forest—West Tract	45.8	28.0	2604	10.6
Holland Landing	9.2	3.9	20	3.5
Mabel Davis	10.6	2.0	301	1.1
Newton	66.6	28.5	0	28.5
Peggy's Woods	7.3	7.3	947	3.0
Pottageville Swamp	214.5	32.4	0	32.4
Rogers Reservoir	16.8	7.1	1595	2.6
Scanlon Creek—Main Tract	85.3	9.2	611	4.2
Scanlon Creek—North Tract	23.2	1.7	0	1.7
Scanlon Creek—Studholme Tract	62.8	34.7	0	34.7
Sheppard's Bush	26.1	5.2	1323	1.5
Simcoe Forest—Hodson Tract	49.2	41.9	9604	5.6
Thornton Bales	19.8	11.9	1170	3.5
Whitchurch	11.0	3.1	117	2.1
York Forest—Hollidge Tract	83.0	35.1	5258	10.7
Zephyr Creek	162.1	35.7	0	35.7

from each protected area for study (hereinafter called 'forest patches').

Recreational trails within the study areas were mapped using a handheld GPS unit and aerial photographs. Trails within the study sites are natural-surface trails, ranging from 0.5 to 3 m wide. Although trail use levels have not been monitored in these natural areas, all (with the exception of those lacking any trails) support a mix of recreational uses including hiking, mountain biking, and dog walking. Motorized use of the trails is prohibited in all cases. While dogs are required to remain leashed at all times, lack of staffing in these natural areas leads to limited enforcement; a pattern common in other un-staffed natural areas (e.g., Reed and Merenlender 2011) Although forest-dwelling birds vary in their response to trail use (e.g., Klein et al. 1995; Blumstein et al. 2005), a study conducted in nearby protected areas (Campbell 2011) found that many species of songbirds in this region initiated flight when trail users came within a distance of approximately 15 meters. As such, the mapped trail network was buffered by 15 m in ArcMap 10.0 (ESRI), and the remainder of the study forests' area was defined as being 'trail-free'. The total trail length, the total area of the forest patches, and the total area of each protected area were calculated in ArcMap 10.0.

Field Methods

The breeding bird community in each of the study forest patches was described with the use of a series of point count surveys. Point counts were randomly located within the forest patches, at least 100 m from the edge of the forest patch to ensure the entire point count circle was situated within the patch. Point counts were established at a density of one point count per 4 ha. At each site, a 5-min point count with a fixed 100 m radius was conducted. All birds seen or heard, except birds only flying over the plot, were identified to species and recorded. All point counts were conducted by the author between 0500 and 0900 on days of suitable weather (i.e., no precipitation with little or no wind). In the interests of conducting a complete inventory of both early-season and late-season breeding bird species in these forests, each site was surveyed twice (once in the second to fourth week of May, and once in the first to third week of June). While the length of time between visits prohibited calculating detection probabilities for each bird species, the final tally of the number of birds recorded at each survey location was based on the maximum number of each species observed over the two survey periods. These data were converted to density estimates by averaging the records for each species over all point count locations in each forest patch.

Data Analysis

Multiple linear regression was used to assess the influence of forest patch size, trail density, and total area of trail-free habitat on the richness and density of the breeding bird community, as well as the richness and density of guilds representing the substrate used for nesting (i.e., ground-nesting and canopy-nesting) and foraging (i.e., ground-foraging and canopy-foraging) based on Ehrlich et al. (1988) (Table 5 in Appendix). Forest patch area and amount of trail-free habitat were square-root transformed prior to analysis, and point count data were log transformed, to meet the assumptions of normality inherent in the multiple regression model.

To minimize impacts due to potential collinearity between forest patch area and amount of trail-free habitat, multiple linear regression without step-wise selection was used. Smith et al. (2009) have demonstrated that standardized partial regression coefficients provide the most unbiased estimates of the relative importance of collinear habitat variables. The variance inflation factor (VIF) of each covariate was calculated as well, as a measure of the overall collinearity of each covariate with all others in the model. Forest patch type (i.e., deciduous, coniferous, or mixed) was also included as a covariate, to determine if the response of the density or richness of birds to trail presence varied by forest community type. A sequential Bonferroni adjustment was applied to the results of the linear regression analyses to avoid a group-wide type I error (Rice 1989). Analysis was limited to native passerine species, as raptors and waterfowl may be under-represented in point count surveys (Ralph et al. 1993).

Results

The twenty-four forest patches randomly selected for study ranged in size from 1.7 to 63.8 ha. The extent of recreational trails in these forests varied substantially, resulting in a range of trail density from 0 to 254 m/ha. The amount of trail-free habitat ranged from 1.3 to 43.5 ha (Table 1).

The amount of trail-free habitat in each patch was significantly correlated ($r = 0.48$; $P = 0.017$) with the area of the forest patch. Trail density was not significantly correlated with either patch area or amount of trail-free habitat (Table 2). Variance inflation factors for each covariate in the model ranged from 1.3 to 1.85 (Table 2), indicating that covariates in the regression model are non-orthogonal but not highly correlated with one another.

Species richness of birds within forest patches ranged from 4 to 34 species, and density from 4 to 22 birds per 100-m point count circle (Table 3). Canopy-nesting birds were the most commonly observed in this study area, averaging 10.3 individuals per point count circle. Ground-nesting and cavity-nesting birds were less commonly observed, represented by only an average of 2.1 and 3.8 birds per point count, respectively. Foraging guilds were more equally represented, with ground-foraging and canopy-foraging species with an average of 7.0 and 9.4 birds observed per point count, respectively.

Although forest patch size did not significantly influence total bird density, there was a significant positive influence of the area of trail-free habitat, even with forest patch size as a covariate in the regression equation (Table 4; Fig. 1b). Similarly, the area of trail-free habitat had a significant influence on the density of ground-foraging species observed (Table 4; Fig. 1d).

Both forest patch area and area of trail-free habitat positively influenced the density of ground-nesting birds observed in these study sites (Table 4; Fig. 1e, f). The standardized partial regression coefficients indicate that forest patch size had a slightly stronger influence on the density of ground-nesting birds than did the amount of trail-free habitat (Table 4).

Species richness was a less sensitive response variable than density to either forest patch size or trail-free habitat in these study regions. In no cases were these relationships statistically significant (Table 4). Trail density had no significant influence on the richness or density of birds or functional guilds. Similarly, forest community type (i.e., coniferous or deciduous) had no significant influence on functional guild richness or density.

Discussion

Birds that nest or forage on the ground exhibited the greatest response to the presence of recreational trails in this study. Studies elsewhere have found that birds foraging or nesting near the ground responded to the presence of recreationists at a greater distance than birds foraging or nesting higher in the canopy (Fernández-Juricic et al. 2004, 2005; Gutzwiller et al. 1998; Banks and Bryant 2007; Kangas et al. 2010; Wolf et al. 2013). This may be because ground-dwelling organisms are more wary of the risk associated with walking or running predators than other species (Fernández-Juricic et al. 2004, 2005; Gutzwiller et al. 1998). Conversely, studies of canopy-nesting and canopy-foraging birds have found no or minimal impacts of trail use on species in these functional guilds

Table 2 Variance inflation factors (VIF) and pair-wise Pearson correlation coefficients among covariates describing forest patches and their trails in central Ontario, Canada

	Forest patch size (VIF = 1.85)	Trail density (VIF = 1.30)	Amount of trail-free habitat (VIF = 1.53)
Forest patch size		0.04	0.48*
Trail density			0.34
Amount of trail-free habitat			

VIF represents the predictors overall collinearity in a regression model with all other predictors

* $P < 0.05$

Table 3 Average and range of songbird density, and members of various foraging and nesting guilds, observed within 100-m point count circles in publicly owned natural areas in central Ontario, Canada

	Average	Standard deviation	Minimum	Maximum
Total species	18.8	7.6	4	34
Total birds	14.2	4.7	4	22
Ground-foraging birds	7.0	3.1	1	14
Ground-nesting birds	2.1	1.8	0	6
Canopy-foraging birds	9.4	4.9	1	23
Canopy-nesting birds	10.3	4.1	3	16

Table 4 Results of multiple regression assessing the impacts of habitat type, forest patch size, and area of trail-free habitat on richness and density of forest-dwelling birds ($n = 24$)

Variable	Habitat type	Patch size	Trail-free habitat	Model	
				P	R^2
Species richness				0.38	0.01
Ground-nesting richness				0.12	0.13
Canopy-nesting richness				0.11	0.13
Ground-foraging richness				0.5	0.02
Canopy-foraging richness				0.5	0.02
Total birds			0.99***	<0.001§	0.95
Ground-nesting density		0.47**	0.34*	<0.001§	0.52
Canopy-nesting density				0.02	0.27
Ground-foraging density			0.91***	<0.001§	0.62
Canopy-foraging density				0.024	0.26

Standardized partial regression coefficients are presented for each significant model (after Bonferroni correction). The P value for each variable and for the overall model are presented. Significance tests for overall models have been adjusted by a sequential Bonferroni correction

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.0001$, § significant at alpha = 0.05 after sequential Bonferroni correction

(Gutzwiller et al. 1994; DeLuca and King 2014), consistent with the current study. It is common for studies of the response of birds to trail use to collect data on all species present within study sites, then restrict analyses to species which provide sufficient sample sizes for statistical analyses (Campbell 2011; DeLuca and King 2014). However, significant community-level responses can be masked if the analyzed species do not represent a range of behavioral guilds.

The probability of detecting songbirds during point count surveys can be influenced by seasonality, time of day, and observer experience (Farnsworth et al. 2002). The effect of observer experience on detectability has been reduced by having all point counts surveyed by the same researcher, and the effects of seasonality and time of day have been reduced by constraining surveys to a 4-h period during one early and one late season, each 3 weeks in length. However, detection probability can also decline with increasing density of conspecifics (Farnsworth et al. 2002). As detection probability was not accounted for in this study, a bias may have been introduced in more populous habitats, underestimating relationships between

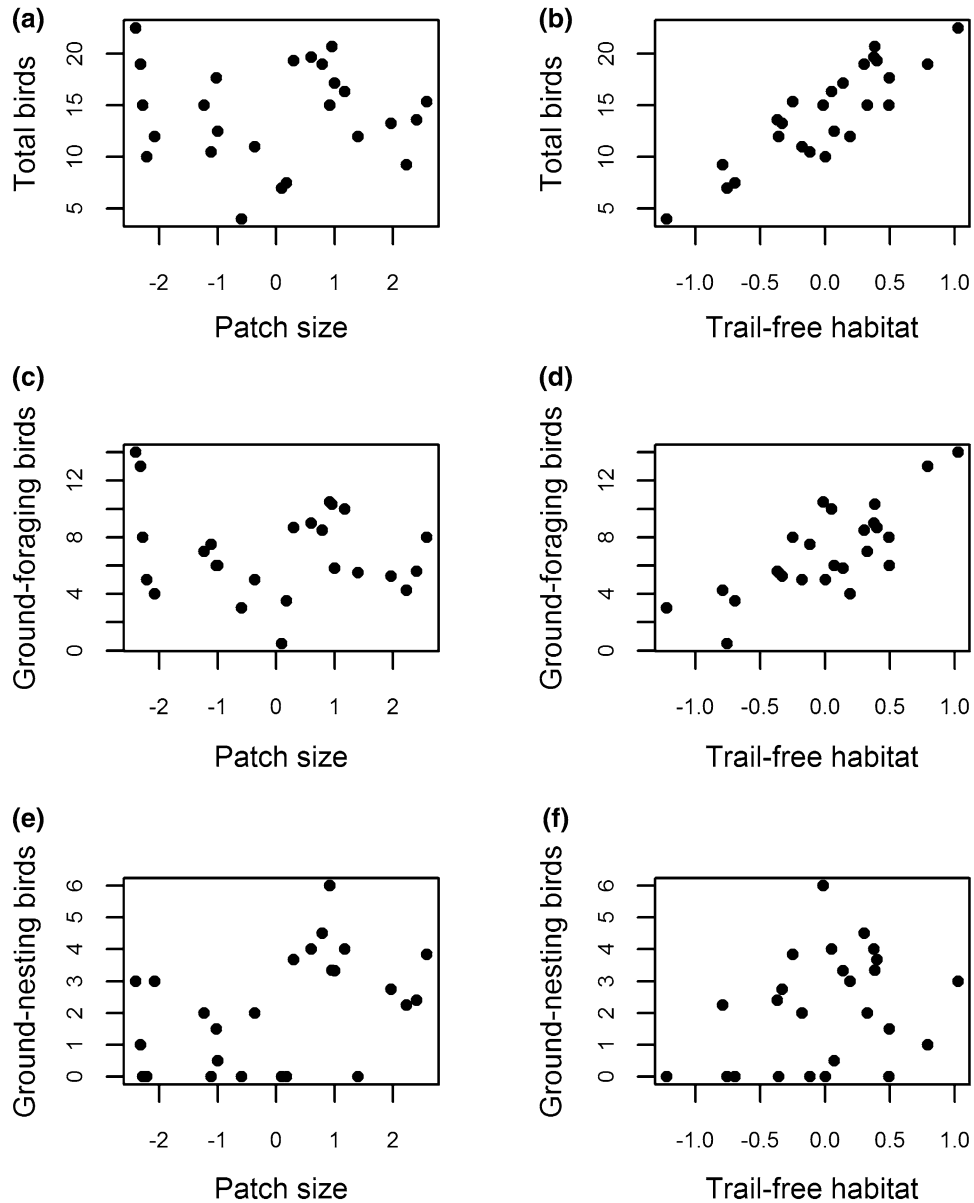

Fig. 1 Partial regression of the influence of **a** forest patch size and **b** total amount of trail-free habitat on forest bird density ($R^2 = 0.95$, $P > 0.05$, and $P < 0.001$, respectively), the influence of **c** forest patch size and **d** total amount of trail-free habitat on density of ground-foraging birds ($R^2 = 0.62$, $P > 0.05$, and $P < 0.001$, respectively), and the influence of **e** forest patch size and **f** total amount of trail-free habitat on density of ground-nesting birds ($R^2 = 0.52$, $P = 0.08$, and $P = 0.05$, respectively). Study completed in 24 forested protected areas in central Ontario, Canada

habitat area and songbird density (Fig. 1). Richards (1981) also suggests that vegetation density may influence the probability of detection of songbirds. Loss and Blair (2011) reported changes in vegetation density near trails; however, this does not appear to be substantial enough to influence detection probability of songbirds along trails (DeLuca and King 2014).

Although this study examines the response of forest birds to the presence of trails, it does not determine the mechanism of trail impact on breeding bird communities. Studies elsewhere have suggested that the impacts associated with trails may be due to interference with breeding behavior (Gutzwiller et al. 1994), a reduction in foraging time during the alert period (Gutzwiller et al. 1998; Frid and Dill 2002), alteration to vegetation structure near trails (Fernández-Juricic et al. 2001; Loss and Blair 2011), the introduction of invasive species (Loss and Blair 2011), increased the presence of nest predators (Miller et al. 1998; Miller and Hobbs 2000), or some combination of factors (Gutzwiller et al. 1994; Loss and Blair 2011). Although the ultimate cause of impact may vary among protected areas (Miller and Hobbs 2000), if the proximate cause of disturbance is the presence of recreational trails, protected area managers can manage those impacts by designing and maintaining trail networks to minimize disturbance to resident wildlife.

Other studies examining the relationship between recreational trails and wildlife disturbance have suggested that the impacts associated with recreational trails could be reduced by managing use levels (e.g., Reed and

Table 5 Nesting and foraging guilds of bird species observed in publicly owned natural areas in central Ontario, Canada (guild membership based on Ehrlich et al. 1988)

Scientific name	Common name	Frequency of detection ($n = 24$)	Nesting guild	Foraging guild
Zenaida macroura	Mourning Dove	0.29	C	G, C
Coccyzus erythropthalmus	Black-billed Cuckoo	0.25	C	C
Melanerpes carolinus	Red-bellied Woodpecker	0.04	V	B, C
Sphyrapicus varius	Yellow-bellied Sapsucker	0.21	V	B
Picoides pubescens	Downy Woodpecker	0.17	V	B
Picoides villosus	Hairy Woodpecker	0.21	V	B
Colaptes auratus	Northern Flicker	0.46	V	G, C
Dryocopus pileatus	Pileated Woodpecker	0.38	V	B
Contopus virens	Eastern Wood-pewee	0.79	C	O
Myiarchus crinitus	Great Crested Flycatcher	0.58	V	G
Cyanocitta cristata	Blue Jay	0.96	C	G
Poecile atricapillus	Black-capped Chickadee	0.92	V	C
Sitta carolinensis	White-breasted Nuthatch	0.67	V	B
Certhia americana	Brown Creeper	0.33	C	B
Troglodytes aedon	House Wren	0.21	V	C
Troglodytes troglodytes	Winter Wren	0.38	V	G
Catharus fuscescens	Veery	0.33	G	G, C
Catharus guttatus	Hermit Thrush	0.13	G	G, C
Hylocichla mustelina	Wood Thrush	0.58	C	G, C
Turdus migratorius	American Robin	0.75	C	G, C
Dumetella carolinensis	Gray Catbird	0.21	C	G, C
Bombycilla cedrorum	Cedar Waxwing	0.04	C	C
Vireo solitarius	Blue-headed Vireo	0.08	C	B, C
Vireo gilvus	Warbling Vireo	0.04	C	C
Vireo olivaceus	Red-eyed Vireo	0.88	C	C
Oreothlypis ruficapilla	Nashville Warbler	0.33	G	G, C
Setophaga petechia	Yellow Warbler	0.25	C	B, C
Setophaga pensylvanica	Chestnut-sided Warbler	0.42	C	C
Setophaga magnolia	Magnolia Warbler	0.04	C	B
Setophaga caerulescens	Black-throated Blue Warbler	0.21	C	C
Setophaga coronata	Yellow-rumped Warbler	0.17	C	C
Setophaga virens	Black-throated Green Warbler	0.38	C	B, C
Setophaga pinus	Pine Warbler	0.46	C	B, C
Mniotilta varia	Black-and-white Warbler	0.17	G	B
Setophaga ruticilla	American Redstart	0.29	C	C
Seiurus aurocapilla	Ovenbird	0.75	G	G
Geothlypis philadelphia	Mourning Warbler	0.38	G	G, C
Piranga olivacea	Scarlet Tanager	0.38	C	C
Cardinalis cardinalis	Northern Cardinal	0.50	C	G
Pheucticus ludovicianus	Rose-breasted Grosbeak	0.42	C	B, C
Passerina cyanea	Indigo Bunting	0.04	C	G, C
Pipilo erythrophthalmus	Eastern Towhee	0.08	G	G, C
Spizella passerina	Chipping Sparrow	0.38	C	G, C
Melospiza melodia	Song Sparrow	0.38	G	G, C
Zonotrichia albicollis	White-throated Sparrow	0.17	G	G, C
Molothrus ater	Brown-headed Cowbird	0.29	C	G
Carduelis tristis	American Goldfinch	0.92	C	G, C

Nesting strata are classified as C (canopy), G (ground), and V (cavity). Foraging strata are classified as B (bark), C (canopy), G (ground), or O (other)

Merenlender 2008; Remacha et al. 2011; Wolf et al. 2013), the seasonality of use (e.g., Gutzwiller et al. 1994), the timing of access (van der Zande et al. 1984), or permitted recreation types (e.g., Banks and Bryant 2007; Miller et al. 2001). Management options in non-staffed protected areas are more limited, but in most cases, land managers could design a trail network that would minimize impacts on resident wildlife, while still providing recreational opportunities for visitors. In this study, the area of forest free from trail-related disturbances had a significant influence on the density of forest birds (Fig. 1b), and ground-foraging birds particularly (Fig. 1d), even though the influence of overall habitat area was non-significant. Land managers can best ensure that sensitive species are retained within their protected areas by managing their property to maintain trail-free refuge habitat. As trail density did not relate to impacts to breeding bird communities, the need for land managers to limit the presence of trails themselves is not as important as the need to minimize the extent to which they fragment habitat. Thus, protected area managers may be able to balance the demand for trails, with habitat needs, by maximizing the amount of trail-free habitat they manage, either by ensuring that trails stay as close as possible to habitat edges (rather than bisecting core areas), or by focusing trail development in less sensitive areas, leaving more diverse and productive habitats as refuge areas. A number of ways of designing trail-free refuge habitat have been proposed, based on establishing buffers around recreational trails whose width would be equal to mean values of flight initiation distance or alert distance, or based on the distance within which a set percentage of birds would be expected to respond to trail users (Fernández-Juricic et al. 2005). For some protected areas, sufficient published research on behavioral responses to trail use is available for use in buffer design (Fernández-Juricic et al. 2004, 2005); in other cases the demonstrated relationship between flight initiation distance and body size can be used when such data is unavailable (Fernández-Juricic et al. 2004; Blumstein et al. 2005). Most studies documenting alert distances or flight initiation distances were conducted in Spain (e.g., Fernández-Juricic et al. 2001), South America (e.g., Fernández-Juricic et al. 2004, 2005), or western North America (e.g., Gutzwiller et al. 1998; Miller et al. 2001). This study took a simple approach of defining refuge areas as those areas in the forest that were beyond the most commonly reported flight initiation distances in songbirds in this study area (Campbell 2011). Actual flight initiation distances may vary between sites however, related to factors such as vegetation structure (Fernández-Juricic et al. 2001, 2004, Campbell 2011; Wolf et al. 2013), distance to refuge habitat (Fernández-Juricic et al. 2001), food availability (Gill 2007), and with trail-use group size (Remacha et al. 2011) and behavior (Campbell 2011; Stankowich and Blumstein 2005). A greater range of studies documenting species-specific flight initiation and alert distances would permit more refined trail planning however (Fernández-Juricic et al. 2005). To support this need, field biologists should record observations of these sorts of behaviors while doing nest monitoring projects (Whitfield et al. 2008). Ultimately, however, buffer widths established based on studies of this sort are based on estimates of behavioral changes in birds resulting from the presence of trails. In some cases, impacts of trails on reproductive success have been observed at much greater distances from trails (Miller et al. 1998). These impacts can vary among natural areas however, perhaps as a result of differences in the local predator community (Miller and Hobbs 2000). While it was beyond the scope of this study to determine appropriate buffer widths to protect forest-dwelling birds from trail impacts, that remains an important question to be examined for the forests of eastern North America.

In order to assess the effectiveness of the design of trail networks, protected area managers should monitor the response of bird populations over time. Bryce et al. (2002) proposed a breeding bird-based Index of Biotic Integrity for monitoring forest-dwelling birds in eastern North America, based on the proportion of birds in disturbance-sensitive functional guilds, including both ground-nesting and ground-foraging species. The response of these functional guilds to disturbance associated with trail presence evident in this study supports their proposed index as a tool to monitor the impacts of recreation on forest birds. Furthermore, given the non-significant response of forest type evident in this study, a guild-based metric such as this one appears to be suitable for both coniferous and deciduous forests.

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Compliance with Ethical Standards All applicable international, national, and/or institutional guidelines for the care and use of animals were followed

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