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Songbird Responses to Land Preservation Within Southern New England Cluster Subdivisions

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Abstract

Cluster subdivisions were designed to protect open space in response to rapid rates of conventional development. One of the proclaimed benefits of preserving open space within cluster subdivisions is the provision of habitat for native wildlife, but this has rarely been evaluated. This study examined songbird response to the amount of land protected within cluster subdivisions in Rhode Island (USA). We selected 11 sites along a gradient based on the relative amount of land protected within a site (% land under a conservation easement; %CE). We used nonparametric multivariate statistics to compare songbird communities between protected and developed areas within subdivisions and regression analyses to relate bird abundance and community metrics to %CE. Songbird communities differed significantly between protected and developed areas within cluster subdivisions. Songbird richness and diversity both peaked between 73-74 %CE, while densities of forest interior and human intolerant species increased with increasing %CE. Ovenbird, Veery, and Pine Warbler most typified high %CE sites and were found most often in protected areas far from development edges. This study demonstrates that cluster subdivisions need to preserve approximately 70-75% of the original undeveloped parcel of land in order to maximize songbird diversity. A higher percentage should be preserved in large contiguous blocks to further benefit forest interior species. This suggests that proposed regulations that require Rhode Island subdivisions to protect at least 50% of a parcel's buildable land may not be adequate to enhance bird diversity or preserve species that depend on large contiguous blocks of forest interior habitat.

Keywords: songbirds, cluster subdivisions, New England, habitat value, diversity, conservation easements

1. Introduction

A defining characteristic of the changing United States landscape is the rapid and ongoing loss of natural and agricultural habitats to residential and urban development. The area of developed lands increased by approximately 14.2 million ha (48%) between 1982 and 2003 (White, Morzillo, & Alig, 2009) and as of 2007 comprised 6% of the landmass of the conterminous United States (United States Department of Agriculture [USDA], 2009). Although estimates vary, similar rates of development are expected to continue. For example, Stein et al. (2005) estimated that approximately 18 million ha of additional land will be developed by 2030, while White et al. (2009) projected that 22 million ha of land will be developed between 2003 and 2030. Much of this development has occurred (and will occur) in exurban areas, or areas beyond urban centers and their suburbs, through the conversion of natural and agricultural habitats into residential housing (Brown, Johnson, Loveland, & Theobald, 2005; Radeloff, Hammer, & Stewart, 2005; Theobald, 2005). This exorbitant growth has many negative ecological implications, including the loss and fragmentation of natural habitats (Ritters et al., 2002; Radeloff et al., 2005; Drummond & Loveland, 2010), reduced air and water quality (Tu, Xia, Clark, & Grei, 2007; Duh, Shandas, Chang, & George, 2008; Stone, 2008), declines and extinctions of native and rare species (Czech, Krausman, & Devers, 2000; Marzluff, 2001; McKinney, 2006), introduction and expansion of non-native and invasive species (Riley et al., 2005; McKinney, 2006), and disruption of natural ecological processes (e.g., fire regimes) (Syphard et al., 2007).

Much of the loss of exurban habitats is due to the proliferation and sprawl of conventional or tract subdivisions resulting from suburban zoning and subdivision ordinances. These kinds of residential developments were typically comprised of large housing lots with little or no preservation of natural habitats as open space (Arendt, 1994; Flinker, 2003). The concept of cluster subdivisions was developed in response to growing concern over the rapid loss of natural habitats from conventional development practices. Cluster subdivisions are designed specifically to allow a similar number of housing units as conventional developments in a given area, but by reducing the individual lot size (typically less than 1 acre) and grouping houses together, a portion of the original buildable parcel is protected as open space. The potential benefits of cluster subdivisions include the retention of some of the original character of the landscape, a more aesthetically pleasing landscape, increased property tax revenues, and the provision of open space and habitat for both human residents and native plants and wildlife (Brabec, 1994; Flinker, 2003; Odell, Theobald, & Knight, 2003). In practice, however, not all of these benefits are realized and the value of cluster subdivisions remains debatable (Arendt, 1996; Brabec, 2001; Lenth, Knight, & Gilbert, 2006; Freeman & Bell, 2011).

The idea that native wildlife will benefit when natural habitats are protected within cluster subdivisions is often cited (Arendt, 1996; Theobald, Miller, & Hobbs, 1997; Odell et al., 2003). On a larger scale, it is clear that remnant or protected fragments of natural habitats within urbanizing landscapes can provide important habitat for native and other human-intolerant species (Donnelly & Marzluff, 2004; Fernández-Juricic, 2004; Chace & Walsh, 2006; Mason, Moorman, Hess, & Sinclair, 2007; Oliver et al., 2011). However, the same may not be true at the scale of individual cluster subdivisions, although published case studies are severely lacking. In the sole study of which we are aware that directly quantified the value of cluster subdivisions for wildlife, Lenth et al. (2006) found that in developments in mixed-grass prairie ecosystems in Colorado, plants, birds, and mammals were generally similar between cluster and conventional subdivisions. While their findings call into question the general wildlife-benefit assumption associated with cluster subdivisions, it is clear that further studies are needed to provide reliable information about the ecological effects of development alternatives.

Rhode Island is a microcosm of the patterns that are occurring nationally in terms of urbanization and the construction of cluster subdivisions without fully understanding their ecological effects. As of 1997, 33% of non-federal rural land in Rhode Island was developed, placing it second only to New Jersey (White et al., 2009). Developed lands in Rhode Island increased by 43% between 1970 and 1995 with most of this development occurring in rural and exurban areas (Rhode Island Statewide Planning Program [RISPP], 2006). Suburban sprawl and residential housing development in Rhode Island have increased the amount of impervious surfaces and led to forest fragmentation and loss (Novak & Wang, 2004; Zhou & Wang, 2007). In an attempt to help slow urban and suburban sprawl and the loss of natural and agricultural areas, 19 of Rhode Island's 39 towns had passed ordinances to allow cluster subdivisions (or similar alternative development types) by 1990 (RISPP, 2001). This increased to 28 towns by 2000, five of which mandated that new subdivisions must follow cluster subdivision guidelines (RISPP, 2001). In suburban North Kingstown RI, for example, 37 cluster subdivisions, comprising 976 hectares (approximately 6.5% of the entire town), had been built as of 2008 (Town of North Kingstown, unpublished data). However, the economic, ecological and aesthetic effects of cluster subdivisions in Rhode Island have not been quantified and, specifically, the value of open space that is protected within cluster subdivisions for wildlife remains unknown.

The overall goal of this study was to quantify the value of protected open space within Rhode Island cluster subdivisions for songbird populations and communities. More specifically, this study 1) directly compared songbirds between developed and protected areas within cluster subdivisions, and 2) examined songbird species, guild, and community metrics along a gradient based on the relative amount of land that was conserved within cluster subdivisions. The former goal will help quantify the value of natural habitats that are protected within cluster subdivisions for songbirds. The latter goal will help determine the proportion of the original undeveloped parcel of land that should be protected to provide the most benefit for songbirds.

2. Methods

2.1 Study Sites

This study was conducted at eleven sites that represent a gradient based on the relative amount of land that is protected with conservation easements (%CE; percent land under a conservation easement). Nine of the sites were cluster subdivisions with varying amounts of %CE. These were augmented with one conventional development site (0 %CE) and one undeveloped state forest (100 %CE), which represent the two endpoints along the %CE gradient. Cluster sites were selected from a pool of 37 cluster subdivisions comprising 976 hectares based on comparable size, accessibility of conservation easement areas, and proximity to one another (to minimize variability in regional bird species assemblages), and then targeted to ensure spread along the %CE gradient (Table 1). All of the subdivisions and the state forest were located within the town of North Kingstown, RI, but due to a lack of appropriate sites, the conventional development site was located within the neighboring town of Narragansett, RI. However, both towns are classified as suburban (RISPP, 1999) and all sites were located within 17 km of each other (Figure 1). All sites were selected from suburban areas in order to control for any potentially confounding effects from different surrounding matrix types. Percent CE was calculated by dividing the area of conserved land within the original undeveloped parcel by total parcel size (Table 1; Figure 2). The density of edges between conservation easement and developed areas at each site was calculated by dividing the total length of these types of edges by the total area of the site (Table 1). Based on 2003/2004 land use/land cover data from the Rhode Island Geographic Information System (RIGIS, 2007), conservation easement lands within the nine subdivisions were dominated by deciduous and mixed forests (90.0%), followed by residential development (3.5%), wetlands and water (3.3%), power line easements (1.6%), pasture (1.1%), and other minor habitat types (0.4%).

Table 1. Characteristics of the eleven sites included in this study. %CE for each site is the area protected within conservation easements divided by the area of the entire site multiplied by 100. Edge density for each site is the length of edge between easement and non-easement areas divided by total site area

Site Name	Site code	Type	Age	Total area (ha)	Conservation Easement (ha)	%CE	Edge density (m ha^{-1})
Candy Apple	CAA	Cluster	1996	41.95	31.89	76.0	69.05
Carriage Hill	CAH	Cluster	1981	33.55	21.39	63.8	82.79
Cocumcussoc	COC	State Forest	n/a	n/a [a]	n/a [a]	100.0	n/a
Cole Drive	COD	Cluster	1985	26.08	17.16	65.8	148.70
Laurel Ridge	LAR	Cluster	1988	33.68	13.62	40.4	157.67
Mettatuxet	MET	Conventional	variable	n/a [b]	0.00	0.0	n/a
Misty Meadows	MIM	Cluster	1999	42.23	35.43	83.9	53.75
Pride's Crossing	PRC	Cluster	2000	22.93	16.65	72.6	51.19
Shady Lea	SHL	Cluster	1994-96	40.84	30.58	74.9	57.82
Signal Rock	SIR	Cluster	1993	42.97	29.42	68.5	132.87
Orchard Woods	ORE	Cluster	2001	25.04	14.93	59.6	79.92

[a] The total size of COC is 158 ha; we selected stations within a central area of 34 ha, which represents the mean size of the nine cluster subdivisions.

[b] MET is a large conventional development that does not have distinct boundaries; we selected stations within a central area of 34 acres, which represents the mean size of the nine cluster subdivisions.

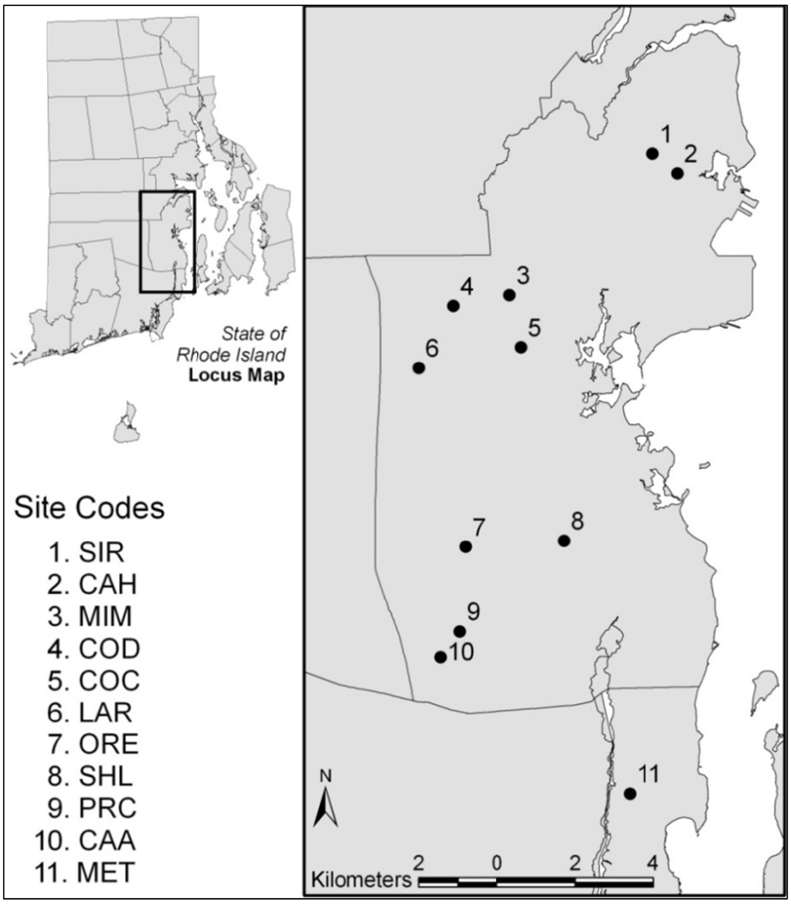

Figure 1. Locations and three-letter codes of the 11 sites included in this study (refer to Table 1 for all site codes and names)

Note: All sites are located in North Kingstown, RI except Metatuxet (MET; Site 11), which is in Narragansett, RI. Lines represent boundaries between towns.

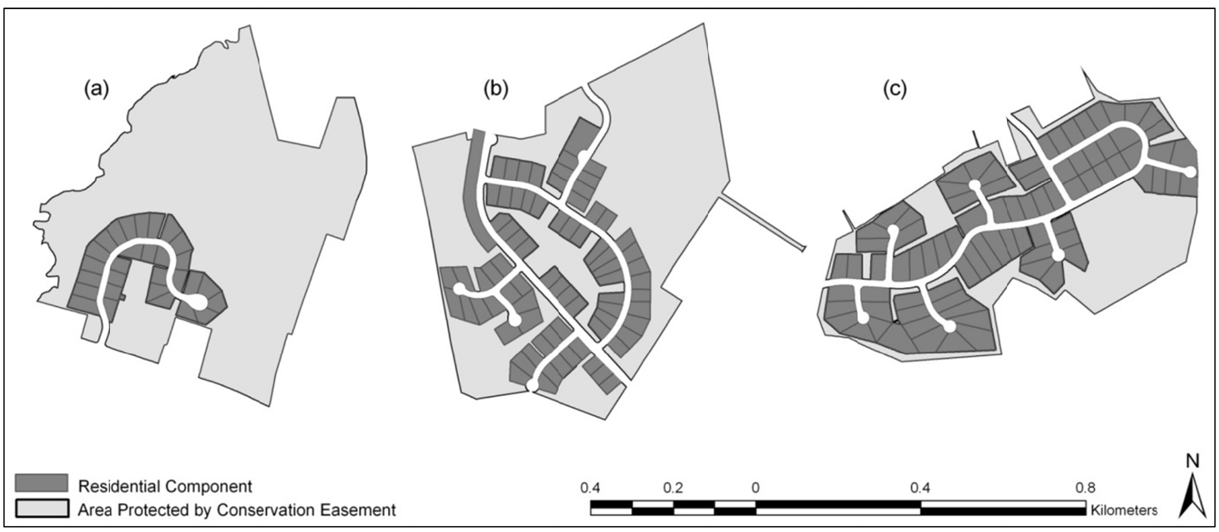

Figure 2. Three examples of cluster subdivisions with varying amounts of %CE

Note: A=Misty Meadows (MIM; 84 %CE); B=Signal Rock (SIR; 69 %CE); C=Laurel Ridge (LAR; 40 %CE). These figures were created with the parcels dataset provided by the Town of North Kingstown, RI and with the municipal and NGO conservation lands coverage available from the Rhode Island Geographic Information System (RIGIS, 2011).

2.2 Data Collection

We randomly selected 7-8 sampling stations within each of the 11 sites. All stations were selected using ARCGIS (v. 10) prior to initiating field sampling. Stations were spaced a minimum of 200 m away from each other to avoid overlap of 100-m point count radii around each station. Eight stations were established at all sites except PRC, which was too small; only seven stations were established at this site. Stations were then classified as either being in conservation easement or developed areas.

All songbirds seen or heard within a 100-m radius of each sampling station were recorded using the dependent observer method. This method uses survey teams that consist of a primary observer who identified and quantified bird species and abundance, and a second observer who recorded data and helped identify and count any individuals missed by the primary observer (Nichols et al., 2000; Forcey, Anderson, Ammer, & Whitmore, 2006). Two teams of two people conducted all of the bird sampling during this study. Songbirds were sampled once from every station at each site between May 19 and June 22, 2009. At each station, the sampling effort lasted 10 minutes, and all sampling occurred between 0500 and 0900 each day when weather conditions were favorable (e.g., no rain, light winds).

2.3 Statistical Analyses

Pre-treatment data handling varied depending on the analysis performed and is summarized here for clarity. All community metrics used in regression analyses were calculated using raw bird abundance data. However, abundances at the level of individual species and bird guilds were standardized (for each sample, by subtracting the sample mean from each data point and then dividing by the standard deviation) prior to regression analysis to account for differences in abundance that might occur between field survey teams. Similarly, all data were standardized prior to all multivariate PRIMER analyses (see below). However, PRIMER standardizes data by dividing raw abundance data in a sample by the total abundance for that sample, resulting in relative abundance data. As recommended for biological community data, this was done to address factors that might affect total abundance counts, such as differences in sample size or among survey teams (Clarke & Gorley, 2006).

We used multidimensional scaling (MDS), analysis of similarity (ANOSIM) and similarity percentages (SIMPER) to compare bird communities between stations located in conservation easements and stations located in developed areas. This was done under the assumption that if there is no value in protecting land within cluster subdivisions then there will be no difference in bird communities between the two groups of stations. MDS was used to visualize patterns of similarity among stations in two-dimensional space, while ANOSIM (two-way nested model with station type nested within sites) was used to statistically compare bird communities between the two types of stations. SIMPER was used to identify the species that typify both groups of stations and species that most contribute to any dissimilarity between the station groups. Only data from the nine cluster subdivisions were used in these analyses; data from the COC and MET sites were not used here. Prior to each of these analyses, raw data were standardized as described above and square-root transformed to give less weight to common and ubiquitous species. Each of these analyses was conducted using PRIMER version 6.1.2 (Clarke & Gorley, 2006).

We used a series of regression analyses to determine the proportion of protected land within cluster subdivisions that maximizes songbird diversity. We included the conventional subdivision and the undeveloped state forest as endpoints around the nine cluster subdivisions to examine patterns along a broader gradient of land protection. Because guidance for cluster and conservation subdivisions (the more refined successor to cluster subdivisions) in Rhode Island and elsewhere are often based on a percentage of the land being set aside using conservation easements, we used best-fit linear and nonlinear regression analyses to relate bird metrics at three scales (individual species, guilds, and communities) against cluster subdivision %CE. At the community level, bird species richness and diversity were calculated at each site using raw abundance data and the Margalef and Shannon-Weiner indices, respectively. Mean standardized abundances of species in migratory (short-distance, permanent resident, or neotropical), human-tolerance (tolerant or intolerant), and habitat (forest, edge, or non-forest) guilds were calculated for each site and related to %CE. Mean standardized abundances of individual species were also calculated for each site and related to %CE. Regressions were run for all species that contributed to 90% of total bird abundance (Table 2). All regression analyses were conducted in SigmaPlot version 12 and SigmaStat version 3.5 software packages.

Table 2. Summary of abundance metrics and guild affiliations for all bird species observed during this study

Species	Common name	Alpha code	Total # observed	Relative abundance (%)	Cumulative (%)	Guilds		
						Migration	Tolerance	Habitat
Turdus migratorius	American Robin	AMRO	232	17.4	17.4	SD	tolerant	edge
Baeolophus bicolor	Tufted Titmouse	TUTI	116	8.7	26.1	PR	tolerant	edge
Quiscalus quiscula	Common Grackle	COGR	105	7.9	33.9	SD	tolerant	non-forest
Dumetella carolinensis	Gray Catbird	GRCA	91	6.8	40.7	NT	tolerant	edge
Cardinalis cardinalis	Northern Cardinal	NOCA	68	5.1	45.8	PR	tolerant	edge
Cyanocitta cristata	Blue Jay	BLJA	56	4.2	50.0	SD	tolerant	edge
Spinus tristis	American Goldfinch	AMGO	49	3.7	53.7	SD	tolerant	edge
Melospiza melodia	Song Sparrow	SOSP	40	3.0	56.7	SD	tolerant	non-forest
Poecile atricapillus	Black-capped Chickadee	BCCH	39	2.9	59.6	PR	tolerant	edge
Troglodytes aedon	House Wren	HOWR	39	2.9	62.5	NT/SD	tolerant	edge
Spizella passerine	Chipping Sparrow	CHSP	36	2.7	65.2	NT	tolerant	edge
Pipilo erythrophthalmus	Eastern Towhee	EATO	33	2.5	67.7	NT	intolerant	forest/edge
Zenaida macroura	Mourning Dove	MODO	33	2.5	70.2	SD	tolerant	non-forest
Bombycilla cedrorum	Cedar Waxwing	CEDW	31	2.3	72.5	SD	intolerant	edge
Agelaius phoeniceus	Red-winged Blackbird	RWBL	31	2.3	74.8	SD/NT	tolerant	non-forest
Seiurus aurocapilla	Ovenbird	OVEN	27	2.0	76.9	NT	intolerant	forest
Melanerpes carolinus	Red-bellied Woodpecker	RBWO	27	2.0	78.9	PR	tolerant	edge
Corvus brachyrhynchos	American Crow	AMCR	23	1.7	80.6	SD	tolerant	edge
Aves	Unidentified Bird	UNBI	23	1.7	82.3			
Molothrus ater	Brown-headed Cowbird	BHCO	20	1.5	83.8	SD	intolerant	non-forest
Catharus fuscescens	Veery	VEER	18	1.3	85.2	NT	intolerant	forest
Vireo olivaceus	Red-eyed Vireo	REVI	17	1.3	86.4	NT	intolerant	forest
Sitta carolinensis	White-breasted Nuthatch	WBNU	16	1.2	87.6	PR	intolerant	edge
Setophaga petechia	Yellow Warbler	YEWA	16	1.2	88.8	NT	tolerant	edge
Passer domesticus	House Sparrow	HOSP	14	1.0	89.9	SD	tolerant	non-forest
Thryothorus ludovicianus	Carolina Wren	CARW	13	1.0	90.9	PR	tolerant	edge
Setophaga pinus	Pine Warbler	PIWA	13	1.0		SD	intolerant	forest
Picoides pubescens	Downy Woodpecker	DOWO	12	0.9		PR	tolerant	edge
Geothlypis trichas	Common Yellowthroat	COYE	11	0.8		NT	intolerant	edge
Contopus virens	Eastern Wood-Pewee	EAPW	11	0.8		NT	intolerant	forest/edge
Myiarchus crinitus	Great Crested Flycatcher	GCFL	11	0.8		NT	tolerant	edge
Hylocichla mustelina	Wood Thrush	WOTH	10	0.7		NT	intolerant	forest

Table 2. Summary of abundance metrics and guild affiliations for all bird species observed during this study (continued)

Species	Common name	Alpha code	Total # observed	Relative abundance (%)	Cumulative (%)	Guilds		
						Migration	Tolerance	Habitat
Carpodacus mexicanus	House Finch	HOFI	6	0.4		SD	tolerant	edge
Sayornis phoebe	Eastern Phoebe	EAPH	5	0.4		SD	tolerant	non-forest
Spizella pusilla	Field Sparrow	FISP	5	0.4		SD	intolerant	edge
Mniotilta varia	Black-and-white Warbler	BAWW	4	0.3		NT	intolerant	forest
Picoides villosus	Hairy Woodpecker	HAWO	4	0.3		PR	tolerant	edge
Colaptes auratus	Northern Flicker	NOFL	4	0.3		SD	intolerant	edge
Mimus polyglottos	Northern Mockingbird	NOMO	4	0.3		PR	tolerant	non-forest
Setophaga discolor	Prairie Warbler	PRAW	4	0.3		NT	intolerant	edge
Archilochus colubris	Ruby-throated Hummingbird	RTHU	3	0.2		NT	tolerant	edge
Setophaga ruticilla	American Redstart	AMRE	2	0.1		NT	intolerant	edge
Sturnus vulgaris	European Starling	EUST	2	0.1		SD	tolerant	non-forest
Tachycineta bicolor	Tree Swallow	TRES	2	0.1		NT	intolerant	non-forest
Parulidae	Unidentified Warbler	UNWA	2	0.1				
Empidonax traillii	Willow Flycatcher	WIFL	2	0.1		NT	intolerant	edge
Vermivora cyanoptera	Blue-winged Warbler	BWWA	1	0.1		NT	intolerant	edge
Pheucticus ludovicianus	Rose-breasted Grosbeak	RBGR	1	0.1		NT	intolerant	edge
Piranga olivacea	Scarlet Tanager	SCTA	1	0.1		NT	intolerant	forest
Emberizidae	Unidentified Sparrow	UNSP	1	0.1				
Setophaga coronata	Yellow-rumped Warbler	YRWA	1	0.1		NT	intolerant	forest

Note: Alpha codes were derived from Pyle and DeSante (2011). Guild information was compiled from Ehrlich, Dobkin, & Wheye (1988), Lussier et al. (2006), Pidgeon et al. (2007), and personal experience.

Finally, we used ARCGIS to calculate the mean distance that each species (and select guilds) was found from the nearest development edge to provide further insight into species' responses to cluster subdivision design. For each species, these distances were calculated by multiplying the number of individuals found at each station by the distance from the center of that station to the nearest development edge, and then summing these across all stations and dividing by the total abundance of that species.

3. Results

3.1 Bird Community Composition

Forty-eight songbird species (not including birds classified as unidentified, unidentified sparrows or unidentified warblers) and 1335 individuals were recorded during this study. Twenty-six species comprised over 90% of all observations (Table 2). The American Robin was by far the most abundant species (it comprised 17% of the entire community), followed by Tufted Titmouse (9%), Common Grackle (8%), Gray Catbird (7%), and Northern Cardinal (5%). In contrast, 24 species each comprised less than 1% of the entire songbird community. At the guild level, the bird community was dominated by short-distance migrants (47% of the migratory guild), neotropical migrants (23%) and permanent residents (22%). It was dominated by edge species (71% of the habitat guild), followed by non-forest (19%), forest-interior (7%), and forest/edge habitat (3%) species. Human tolerant species were far more abundant (81% of the community) than were human-intolerant species (18%).

3.2 Conservation Easement Versus Developed Stations

An MDS plot of all stations from the nine cluster subdivisions shows that the conservation easement stations and the developed stations generally grouped apart from each other, but that there was some overlap; a number of conservation easement stations clearly intermix with the developed stations (Figure 3). A statistically significant difference was found between bird communities at stations protected by conservation easements and those that were developed (ANOSIM; global $R = 0.32$; $p = 0.001$). Based on SIMPER, 30 species contributed to over 90% of the dissimilarity between the two station groups (Table 3), but most of these species were ubiquitously found through the study area (e.g., Tufted Titmouse, Northern Cardinal, American Robin and Gray Catbird). Many of these same species also typified both conservation easement and developed stations, but some species were only identified by SIMPER as typifying one set of stations or the other. Species that only typified conservation easement stations include Eastern Towhee (contributed 4.4% to overall similarity of easement stations), Black-capped Chickadee (2.4%), Ovenbird (2.4%), Red-winged Blackbird (1.8%), White-breasted Nuthatch (1.7%), and Red-eyed Vireo (1.2%) (Table 3). In contrast, species that only typified developed stations include the Common Grackle (contributed 12.9% to overall similarity of these stations), Song Sparrow (7.0%), American Goldfinch (5.2%), and Brown-headed Cowbird (1.7%).

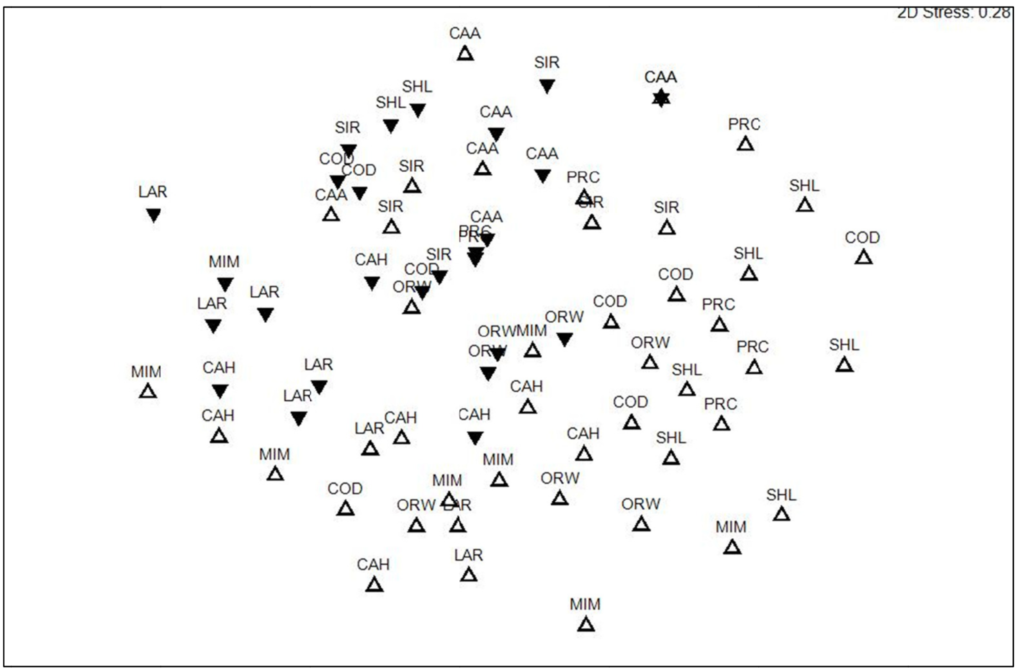

Figure 3. Two-dimensional multidimensional scaling (MDS) plot of individual bird survey stations

Note: Each station is labeled with its three-letter site code. Symbols indicate whether the station is within a conservation easement (△) or a developed (▼) area

Table 3. Results from SIMPER analyses comparing conservation easement (CE) and developed (Dev) stations

Species code	Rel. Abun.		% Contribution		
	CE	Dev	CE similarity	Dev similarity	CE/Dev dissimilarity
COGR	0.54	2.66		12.91	6.70
TUTI	2.73	1.98	16.17	8.31	5.93
NOCA	1.86	1.49	9.02	4.91	4.91
AMRO	3.75	4.25	30.25	29.32	4.85
GRCA	2.24	2.19	13.63	11.62	4.71
AMGO	0.58	1.67		5.16	4.46
SOSP	0.44	1.59		6.99	4.10
BLJA	1.24	1.01	4.26	1.99	4.06
CHSP	0.56	1.43	0.98	4.80	3.65
EATO	1.26	0.45	4.42		3.54
BCCH	0.94	0.87	2.39		3.37
RBWO	0.71	0.85	1.43	2.00	2.83
RWBB	0.98	0.24	1.75		2.82
UNBI	0.24	0.95			2.82
HOWR	0.46	0.89			2.82
MODO	0.53	0.80	0.87	1.75	2.70
OVEN	0.91	0.14	2.37		2.51
BHCO	0.17	0.93		1.72	2.50
AMCR	0.45	0.75			2.41
WBNU	0.75	0.23	1.67		2.30
REVI	0.68	0.29	1.23		2.17
YEWA	0.49	0.42			2.03
CEWA	0.36	0.48			1.92
CAWR	0.50	0.18			1.56
COYE	0.49	0.14			1.47
VEER	0.54	0.08			1.47
HOSP	0.07	0.51			1.47
DOWO	0.37	0.25			1.40
EWPE	0.47	0.08			1.31
WOTH	0.48	0.00			1.26

Note: Abundance is a relative number and was calculated using standardized and square-root transformed data in PRIMER. For each species, when applicable, its percent contribution to bird community similarity within CE stations, similarity within Dev stations, and dissimilarity between CE and Dev stations is shown.

3.3 Bird Relationships With Subdivision %CE

Eight bird species exhibited statistically significant relationships with %CE (Table 4). Abundances of American Robin, Common Grackle, House Wren, Mourning Dove, and Song Sparrow all declined linearly with increasing %CE. Abundances of American Goldfinch and Black-capped Chickadee peaked at 70 and 63 %CE, respectively, and Ovenbird abundance increased exponentially with increasing %CE. Similarly, five bird guilds were statistically related to %CE. Short-distance migrants, human tolerant birds, and non-forest habitat birds all decreased linearly with increasing %CE, while human intolerant birds increased linearly and forest interior birds increased exponentially with increasing %CE (Table 4). At the bird community level, species richness and diversity both exhibited statistically significant nonlinear relationships with %CE; distinct peaks were found for richness at 73 %CE and for diversity at 74 %CE (Table 4; Figure 4). No significant relationship were found for any other species or bird guilds that were examined, or for total bird abundance (p > 0.05 in each case).

Table 4. A summary of significant relationships found between bird species, guild, and community variables and %CE using linear and nonlinear regression analyses

	Independent Variable	Model type	Trend	F	P	R^2
Species	AMGO	Peak	Peak at 70 %CL	67.04	<0.0001	0.93
	AMRO	Linear	Decrease	5.23	0.048	0.37
	BCCH	Peak	Peak at 63 %CE	5.91	0.027	0.60
	COGR	Linear	Decrease	36.65	0.000	0.78
	HOWR	Linear	Decrease	5.63	0.042	0.38
	MODO	Linear	Decrease	8.51	0.017	0.49
	OVEN	Exponential	Increase	11.83	0.004	0.75
	SOSP	Linear	Decrease	31.59	0.000	0.78
Guild	Short-distance migrant	Linear	Decrease	15.42	0.004	0.63
	Human tolerant	Linear	Decrease	8.52	0.017	0.49
	Human intolerant	Linear	Increase	10.84	0.009	0.55
	Forest interior	Exponential	Increase	18.41	0.002	0.67
	Non-forest	Linear	Decrease	29.52	<0.001	0.77
Community	Species diversity	Peak	Peak at 74 %CE	10.57	0.005	0.82
	Species richness	Peak	Peak at 73 %CE	16.45	0.002	0.88

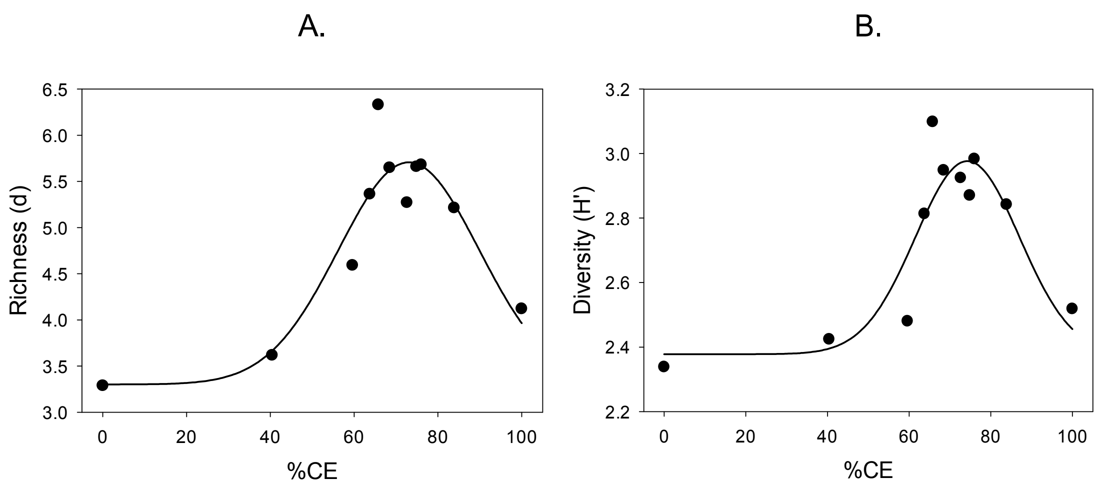

Figure 4. Relationships between Margalef species richness (A) and Shannon-Weiner diversity (B) and cluster subdivision %CE

Note: Both indices were significantly related to %CE based on non-linear regression; richness peaked at 73 %CE; diversity peaked at 74 %CE

3.4 Distance to Development Edges

At the habitat guild level, forest interior species were found at a mean distance of 148 m from the nearest development edge. In contrast, human-associated, non-forest species were found in close proximity to development edges (mean of 15 m); edge species were predictably found at intermediate distances (mean of 49 m). Seven of the ten species found at the greatest mean distance from a development edge were forest interior species (ranging from Red-eyed Vireo at 117 m to Pine Warbler at 222 m; Figure 5).

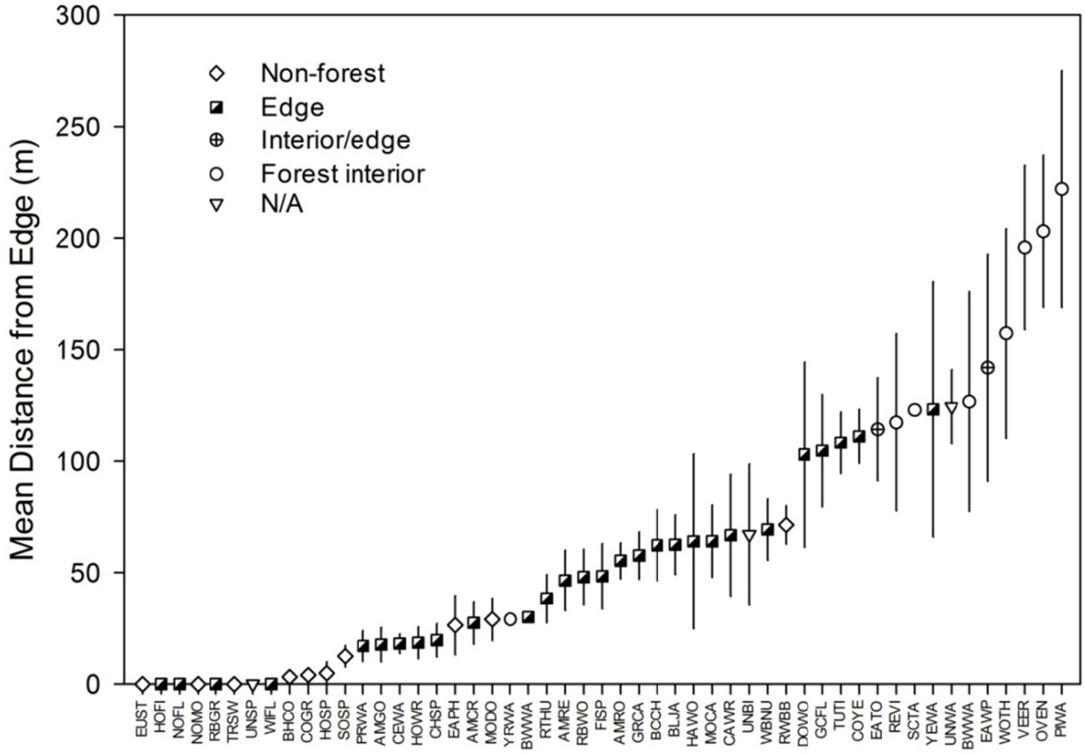

Figure 5. Mean distance each bird species was found from the nearest residential development edge. Birds are symbolized based on habitat guild; error bars represent ± 1SE

4. Discussion

Debate between planners and natural resource managers continues (at least in Rhode Island) in regards to the value of cluster subdivisions for wildlife. This is likely facilitated by a shortage of published studies addressing this issue. Our study helps fill this gap and provides evidence that well-designed cluster subdivisions can provide valuable habitat for songbird communities and bird species of concern. Specifically, we found significant differences in songbird community composition between developed and protected areas within cluster subdivisions. This difference, and the fact that it was largely due to the retention of some forest interior species in conservation easement areas, demonstrates that protected habitat within cluster developments can provide value for these species and are not completely subsumed by nearby developed areas. Conversely, Lenth et al. (2006) found that bird community composition and the number of bird nests in cluster subdivisions were more similar to conventional dispersed developments than undeveloped areas. The contrasting results from these two studies suggest that the value of cluster subdivisions for songbirds may not be universal and instead may depend on geographic region, dominant local habitat types, and study design and methods. Unfortunately, these are the only studies to date that have directly quantified bird use of cluster subdivisions and more case studies are clearly needed.

Our study shows that conservation easement areas within cluster subdivisions enhance songbird diversity, yet are clearly impacted by proximate and/or regional human development. Ubiquitous suburban species such as American Robin, Tufted Titmouse, Northern Cardinal, Gray Catbird, and Blue Jay were dominant throughout most study sites regardless of habitat. This is another clear example of biotic homogenization, which is a well-documented phenomenon where native species become replaced by a small number of ubiquitous, abundant, and synanthropic species (McKinney, 2006; Devictor, Julliard, Couvet, Lee, & Jiguet, 2007; van Rensburg, Peacock, & Robertson, 2009). Despite this, our SIMPER analyses show that bird communities in conservation easement areas were still typified and defined in part by less abundant, forest affiliated species such as Eastern Towhee, Ovenbird, and Red-eyed Vireo. This agrees with van Rensburg et al. (2009) who found that suburban areas in South Africa provided important habitat for native bird species even though communities were also dominated by a ubiquitous non-native species (Common Myna *Acridotheres tristis*). In cases such as these, it may be necessary to use analytical techniques (e.g., transformations to downweight dominant species were used here) that dampen the potentially masking effects of dominant species in order to elucidate responses by less abundant species that may be of conservation concern.

In our study, songbird occurrence in protected land within cluster subdivisions depended on the bird metrics that were used and the relative amount of land that was protected. This in turn shows that determining the appropriate amount of land to protect depends on *a priori* conservation goals. For example, if the goal is to maximize songbird biodiversity, then approximately 70-75% of the land should be protected. This finding is an example of intermediate levels of disturbance leading to enhanced biodiversity, which occurs when the influx of new species into a community from disturbance (e.g., residential development) is faster than the loss of disturbance-sensitive species (Blair, 1996; McKinney, 2002; Crooks, Suarez, & Bolger, 2004; McKinney, 2006). In our study, biodiversity began to decrease when development exceeded approximately 25-30% of the parcel. However, one issue with using enhanced local biodiversity as a conservation goal is that richness and diversity indices are both indiscriminate; they incorporate synanthropic, urban adaptable species that benefit from expanding residential development and that are not generally of conservation concern.

Conversely, an even higher percentage of land should be protected within subdivisions if human intolerant, forest interior birds (e.g., Ovenbird, Pine Warbler, and Veery) are of primary concern. Bird species in these guilds are negatively impacted by increasing residential development (Kluza, Griffin, & DeGraaf, 2000), are generally declining (Robbins, Sauer, Greenberg, & Droege, 1989; Jones, McCann, & McConville, 2001; Blodget, Dettmers, & Scanlon, 2009), and may be a more appropriate focus of conservation efforts associated with cluster subdivisions than songbird biodiversity (Lenth et al., 2006). Our data show that abundances of birds classified within human intolerant and forest interior guilds increase linearly and exponentially with increasing %CE, respectively. Unfortunately, it is difficult to quantify or recommend a specific relative or absolute amount of land that should be protected for these species. One issue is that the amount of required land is species-specific (Robbins et al., 1989), but estimates also vary among regions and studies. For example, a threshold of 12% residential development was quantified for human-intolerant species in Rhode Island riparian habitats by Lussier, Enser, Dasilva and Charpentier (2006). In other regions, Donnelly and Marzluff (2004) found that most forest interior species required at least 42 ha of protected habitat near Seattle, WA and Fernández-Juricic (2004) determined that forest specialists needed 20-90 ha of protected habitat in Madrid, Spain, depending on species.

If the preservation of forest interior species is a conservation goal, then protected land within cluster subdivisions should be placed into large contiguous blocks that maximize the amount of forest away from the influence of residential development edges. Our data show that forest interior birds were found at a mean distance of 148 m away from the nearest residential development edge, but edge effects vary by species and among studies. For example, Jones et al. (2001) define forest interior as 300 ft (91 m) away from adjacent habitats such as residential development, while Mason et al. (2007) found some forest interior bird species only when greenways were wider than 100 m; other species (e.g., Ovenbird) were only found when greenways were at least 300 m wide. The required distance away from development edges for forest-interior species is clearly variable and species-specific. Further, even if most of the land is protected within a well-designed cluster subdivision in Rhode Island, it will be difficult to protect forest-interior habitats because parcel sizes are relatively small (the mean size was 34 ha among our study sites). This emphasizes that it is critical to consider all existing and potential future habitat types that exist in abutting parcels in the surrounding matrix to try to create the largest possible blocks of habitat across multiple protected parcels (i.e., greenways). This further highlights the need to move beyond standard cluster subdivisions and towards conservation subdivisions, which have stricter land preservation requirements and a higher potential for creating open space greenways by connecting multiple protected parcels (Flinker, 2003; Arendt, 2004; Freeman & Bell, 2011).

The results of our study should be interpreted carefully because the use of only structural data such as abundance or density can be misleading (Van Horn, 1983). For example, Porneluzi, Bednarz, Goodrich, Zawada, & Hoover (1993) found that Ovenbird abundance in large (> 100 ha) forest fragments in eastern Pennsylvania were similar to a larger unfragmented forest, but fragments of approximately 180 ha were still not big enough to support successfully breeding Ovenbirds based on nesting success (a functional measure). In their study, the smaller protected habitats were serving as sinks for individuals or breeding pairs emigrating from nearby larger source forests. Ovenbirds and other forest-interior species were generally common in conservation easement areas in our study, but it is possible that these areas were also merely sinks for non-breeding birds that emigrated from much larger protected forests in nearby western Rhode Island. Unfortunately, information on the functional responses of songbirds to the protection of habitats within cluster subdivisions in the eastern United States does not exist. Without these data, land protection efforts associated with cluster subdivisions must rely on the best available structural assessments to determine how much land needs to be protected to achieve the desired conservation goals.

The results of our study should be interpreted carefully for a few additional reasons. First, our study was purposefully conducted only in a suburban landscape/matrix and the results may differ if the setting was either more urbanized or more rural or exurban. Many studies clearly show that the surrounding matrix can have a strong effect on bird habitat use (reviewed by Prevedello & Vieira, 2010) and a study such as ours should be conducted in matrix settings that are both more urbanized and more natural to provide a better understanding of how songbirds respond to cluster subdivisions in Rhode Island and southern New England. Second, our results may not apply across different dominant habitat types. In our study, forest comprised 90% of the land protected within cluster subdivisions. In other areas of the United States, however, cluster subdivisions are built on land that is dominated by farmland, ranchland, prairie, and other, non-forested habitat types (Brabec, 2001; Lenth et al., 2006). While some of our results may translate across habitats, the specific responses of birds to land protection within cluster subdivisions should be evaluated across a variety of different habitats. Finally, we utilized a gradient approach by including data from one conventional development and one state forest. A follow-up study could build upon this by quantifying birds from replicated conventional development and protected forest sites. This would produce a database of songbird metrics from large protected southern New England forests that in turn could provide quantifiable reference targets to help assess the effectiveness of future land preservation efforts in cluster developments.

Based on our results, an ideal cluster or conservation development in suburban Rhode Island would protect at least 70-75% of the original undeveloped parcel of land, and it would maximize the amount of forest away from residential development edges to benefit bird community metrics and forest interior species (our data suggest a conservative, minimum distance of approximately 150 m). Based on these recommendations, a site such as Misty Meadows provides a good example to follow. It protects 84% of the entire parcel of land as open space, has a low edge density, and most of the protected land lies within one large contiguous block, 33% of which is at least 150 m from the nearest development edge (although this would drop to only 10% if two abutting parcels that are currently unprotected were to be developed; this again illustrates the need to consider both current and future land uses when designing cluster subdivisions). Its protected lands also directly abut an additional 65 ha of cluster subdivision protected land, thus creating a protected greenway of over 100 ha. At the same time, this site still contains 29 housing units with a median value that is 88% higher than the median value of the entire Town of North Kingstown (www.zillow.com; accessed April 2012). Thus, a well-designed cluster subdivision can develop a neighborhood of relatively valuable houses while simultaneously protecting large contiguous blocks of forested open space that minimize development edges and benefit sensitive songbirds.

5. Conclusion

In conclusion, our study shows that cluster subdivisions can enhance songbird biodiversity and provide habitat for species of concern, depending on the amount and configuration of the land that is protected. Currently, the State of Rhode Island does not recommend or require that cluster subdivisions protect a certain percentage of land. At the time of this writing, however, a bill had been introduced into the State legislature that would require the protection of a minimum of 50% of the buildable land within a parcel that is to be developed as a conservation subdivision. This measure of land protection differs from the percent of the entire parcel of land (%CE) that we used in our study, but our results are still relevant for planning purposes in Rhode Island. If it is accepted that at least 70-75% of the entire parcel should be protected, then the proposed conservation subdivision requirement is only adequate when a parcel is at least 50% unbuildable (e.g., due to wetland, groundwater, or slope issues, etc.); anything less than this and the proposed requirement will not necessarily protect the 70-75% target. To address this, language could be changed to require the protection of at least 50% of the buildable land or 75% of the entire parcel, whichever is greater. Regardless of how well a new cluster or conservation subdivision is designed, it will alter the composition of the songbird community that was present in the original undeveloped parcel of land. Results from our study can be used to help guide the planning and design of future subdivisions in suburban Rhode Island and elsewhere to help achieve desired wildlife conservation goals.

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