Winter 2018

SITE-SPECIFIC AND LANDSCAPE FEATURES ASSOCIATED WITH SHRUBLAND BIRD OCCURENCE IN ANTHROPOGENIC SHRUBLANDS IN THE NORTHEASTERN UNITED STATES

Randy Shoe
University of New Hampshire, Durham

Recommended Citation

Shoe, Randy, "SITE-SPECIFIC AND LANDSCAPE FEATURES ASSOCIATED WITH SHRUBLAND BIRD OCCURENCE IN ANTHROPOGENIC SHRUBLANDS IN THE NORTHEASTERN UNITED STATES" (2018). *Master's Theses and Capstones*. 1250.
https://scholars.unh.edu/thesis/1250

SITE-SPECIFIC AND LANDSCAPE FEATURES ASSOCIATED WITH SHRUBLAND BIRD OCCURENCE IN ANTHROPOGENIC SHRUBLANDS IN THE NORTHEASTERN UNITED STATES

BY

RANDY SHOE

Wildlife Conservation and Biology BS, University of New Hampshire, 2015

THESIS

Submitted to the University of New Hampshire
in Partial Fulfillment of
the Requirements for the Degree of

Master of Science
in
Natural Resources:
Wildlife and Conservation Biology

December 2018

This thesis has been examined and approved in partial fulfillment of the requirements for the degree of Master of Science in Natural Resources: Wildlife and Conservation Biology by:

Thesis Director, John Litvaitis, Ph.D., Professor Emeritus

Thomas Lee, Ph.D., Associate Professor, Natural Resources & The Environment

Matthew Tarr, Ph.D., Extension Professor, UNH Cooperative Extension

Mariko Yamasaki, U.S. Forest Service, Research Wildlife Biologist

Don Keirstead, Natural Resources Conservation Service, State Resource Conservationist

On 29 November 2018

Original approval signatures are on file with the University of New Hampshire Graduate School.

ACKNOWLEDGEMENTS

I would like to thank the Nuttall Ornithological Club, the Natural Resources Conservation Service, the New Hampshire Fish and Game Department, and the University of New Hampshire for their generous financial support. I would like to acknowledge my committee and the following people who made this possible: Jack and Kamron Hernandez, Erin Smith, Kyle Crafts, Jennifer Gibson, Ryan Brown, Elizabeth Godin, Mike Doherty, Casey Coupe, Cooper Bryer, Brittany Taylor, Rory Carroll, Avery Shoe-Ricker, Amir Kirata, Beau Garcia, and Shane Bradt. Some special thanks go to my right-hand support and friend, Erica Holm. I would like to express my thanks and love to my daughters, Stacy and Stefanie, and my wife Shirley for their support and love during this project; for my success would be nothing without them.

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

SITE-SPECIFIC AND LANDSCAPE FEATURES ASSOCIATED WITH SHRUBLAND BIRD OCCURRENCE IN ANTHROPOGENIC SHRUBLANDS IN THE NORTHEASTERN UNITED STATES

By

Randy Shoe

University of New Hampshire, December 2018

Habitats dominated by low-growing trees and shrubs are becoming increasingly uncommon in the northeastern U.S. Human development, altered natural-disturbance regimes, and forest succession have reduced the quantity and quality of these shrublands. As a result, over half of the shrubland-dependent songbirds in the region have experienced long-term population declines. Anthropogenic shrublands, including regenerating clearcuts, sand and gravel mines, old fields, and transmission line rights-of-way may provide nesting habitat for most shrubland birds; but differences in size, site-specific features, and landscape composition may affect bird use. To assess the features that may influence shrubland bird occurrence in anthropogenic shrublands, I conducted presence/absence surveys of 8 species [alder flycatcher (*Empidonax alnorum*), brown thrasher (*Toxostoma rufum*), blue-winged warbler (*Vermivora cyanoptera*), chestnut-sided warbler (*Setophaga pensylvanica*), eastern towhee (*Pipilo erythrophthalmus*), field sparrow (*Spizella pusilla*), indigo bunting (*Passerina cyanea*), and prairie warbler (*Setophaga discolor*)] in 101 sites in southeastern New Hampshire during the 2015 and 2016 nesting seasons. For each shrubland, I measured area, site-specific features (e.g., vegetation height, density, and coverage), and characteristics of surrounding landscape features within different buffer zones. Overall, 67% of the variables in the best models predicting bird occurrence were landscape features and 33% were site-specific features. Bird occurrence at a site was positively associated with the proportion of shrublands in the surrounding landscape, particularly within a 500 m buffer. Occurrence of all species except blue-winged warblers and indigo buntings was negatively associated with the proportion of urban development in the surrounding landscape. Shrubland bird species richness increased with vegetation density until vegetation density became too dense for brown thrashers, field sparrows, and prairie warblers. Occurrence of all species except blue-winged warblers increased with shrubland size. These results provide opportunities to enhance existing anthropogenic habitats to benefit populations of declining shrubland birds.

TABLE OF CONTENTS

1. INTRODUCTION

Habitats dominated by low-growing trees and shrubs are becoming increasingly uncommon in the northeastern United States (Hunter et al. 2001, Motzkin and Foster 2002) where human developments, altered disturbance regimes, and forest succession have reduced the quantity and quality of shrublands that are important to many wildlife species (Litvaitis 1993, Askins 2001, Thompson and DeGraaf 2001). As a result, shrubland-dependent wildlife, including 29 of 41 shrubland-dependent birds have experienced long-term population declines (Rosenberg et al. 2016). In response to these declines, federal and state natural resource agencies, in partnership with public and private landowners, are working to create and maintain shrublands (Oehler et al. 2006). The largest and most recent of these efforts in New England and eastern New York involves clearcutting large (> 5 ha) blocks of second growth forest near existing anthropogenic shrublands such as sand and gravel mines, transmission line rights-of-way (ROW), and shrubby old fields, to restore populations of New England cottontails (*Sylvilagus transitionalis*) (Fuller and Tur 2012). While this effort is focused on establishing a network of shrublands that support cottontail breeding and dispersal, these habitats and their arrangement are expected to provide similar benefits to declining shrubland birds.

Throughout New England, populations of many shrubland bird species, including prairie warblers (*Setophaga discolor*), blue-winged warblers (*Vermivora cyanoptera*), chestnut-sided warblers (*Setophaga pensylvanica*), brown thrashers (*Toxostoma, rufum*), eastern towhees (*Pipilo erythrophthalmus*), field sparrows (*Spizella pusilla*), and indigo buntings (*Passerina cyanea*) rely on anthropogenic shrublands as their primary breeding habitat wherever natural xeric shrublands such as pine barrens are absent (Dettmers 2003, Gifford et al. 2010). Here, shrubby old fields, shrubby ROWs, active and idle sand and gravel mines, and regenerating clearcuts are the most common anthropogenic habitats these birds use for breeding (Confer and Pascoe 2003, Schlossberg and King 2007, King et al. 2009*a*). Although there is overlap in the bird species expected to use each of these shrubland types (Rodewald and Vitz 2005, Bulluck and Buehler 2006, Schlossberg and King 2007), differences in growing conditions, vegetation structure, and plant species composition may lead to distinct bird communities among shrublands (Skowno and Bond 2003, Bulluck and Buehler 2006, Schlossberg and King 2007). Further, the extent to which shrubland size and shape, and landscape composition surrounding such shrublands interact to influence habitat selection by shrubland birds has received limited study (Askins et al. 2007, Chandler et al. 2009*a*, Roberts and King 2017). Understanding how these factors influence habitat selection by shrubland birds is critical for determining the amount of habitat currently available for these species and for guiding habitat management and conservation efforts aimed at maintaining functioning bird populations.

Vegetation structure can have an important influence on bird community assemblages (Karr and Roth 1971) and shrubland birds are recognized as habitat specialists that require or prefer specific vegetation structure or composition for nesting and feeding (Schlossberg and King 2007, King et al. 2009*b*, Schlossberg et al. 2010). As a result, differences in vegetation structure and composition between anthropogenic shrublands may result in each bird species occurring in different abundances among different shrubland types or being completely absent from shrublands lacking required conditions (DeGraaf and Yamasaki 2003, Schlossberg and King 2007). Composition of bird communities in these habitats should also change as vegetation structure changes (Schlossberg 2009). For example, by 10-15 years after cutting a stand of northern hardwoods, woody vegetation has typically grown beyond the shrub stage required by nesting shrubland birds and management is required to return the site to a shrubby condition

(DeGraaf and Yamasaki 2003, Dettmers 2003). Further, many ROWs in New England are maintained in a shrubby condition by mowing with a brontosaurus-style forestry mower (a large flailing-head mower attached to an excavator used to grind up shrubs and young trees) every 3-4 years to cut tree saplings that will grow tall enough to intercept the transmission lines (K. Nelson, Eversource, personal communication). Immediately following mowing, the vegetation along a ROW is typically dense herbaceous cover interspersed with low, scattered shrubs that quickly succeed to very tall and dense shrubs and tree saplings during the 3-4 years between mowing events. This succession of vegetation can result in wide variation in the composition and density of the shrubland bird community within a ROW throughout a mowing cycle (Kroodsma 1982, King and Byers 2002, Askins et al. 2012). Understanding how differences in shrubland vegetation structure influences the occurrence of different shrubland bird species is an important step toward determining how different anthropogenic shrublands function as habitat.

Although vegetation structure is generally considered more important than plant species composition when birds select habitats (MacArthur et al. 1962, James 1971, Karr and Roth 1971), shrub species composition may influence habitat use and selection by shrubland birds (Willson 1974, Rotenberry 1985, Schlossberg et al. 2010). For example, preference for nesting in non-native invasive shrubs vs. native shrubs varies among areas (Stoleson and Finch 2001, Heckscher 2004, Schlossberg and King 2010). Differences in food resources, particularly insects (Burghardt et al. 2010, Pendleton et al. 2011, Fickenscher et al. 2014) and fruits (Howe and Estabrook 1977, Herrera 1982, Smith et al. 2013) can also vary between habitats dominated by non-native vs. native plants and contribute to differences in the bird community among habitats (Burghardt et al. 2009, Tarr 2017, E. Holm, University of New Hampshire, unpublished data). Understanding whether shrubland birds select for or avoid anthropogenic shrublands containing non-native shrubs is important for understanding differences in bird distribution among shrublands and for guiding habitat management decisions regarding if and when non-native shrubs should be controlled to benefit birds.

Factors other than vegetation structure and composition may also have an important influence on shrubland bird use of anthropogenic shrublands. Specifically, the size and shape of shrublands may be especially important because most shrubland birds are considered to be area sensitive (Rodewald and Vitz 2005, Lehnen and Rodewald 2009*a*, Shake et al. 2012) and absent from openings below some minimum size (Taylor and Taylor 1979, Costello et al. 2000, Askins et al. 2007). For example, Askins et al. (2007) suggested a minimum shrubland size of 0.6 ha for shrubland birds and Costello et al. (2000) found clearcuts < 0.8 ha were too small to support most shrubland bird species in northern New Hampshire. Larger shrublands are likely to support greater shrubland bird richness due, in part, to the greater diversity of microhabitats they contain compared to smaller openings (Rudnicky and Hunter 1993), but shrubland openings < 1.1 ha can provide habitat for some shrubland birds if those openings contain required microhabitats (Roberts and King 2017). Similarly, wide ROWs tend to support a greater diversity of shrubland birds than narrow ROWs (Anderson et al. 1977, Confer and Pascoe 2003, Askins et al. 2012). This area sensitivity may also be the result of shrubland birds preferring to nest away from habitat edges where predation risk can be greater than within shrubland interiors (Shake et al. 2011). As a result, long and narrow shrublands (i.e., ROWs) may support a lower diversity and abundance of shrubland birds than large and comparatively wider openings such as clearcuts (Anderson et al. 1977, Schlossberg and King 2007, Askins et al. 2012), so differences in shrubland size and shape may influence shrubland bird occurrence among anthropogenic shrubland types.

Finally, bird habitat selection may also be influenced by the composition of the landscape surrounding a site (Hinsley et al. 1995, Askins et al. 2012). Few studies have investigated the importance of landscape composition to predict shrubland bird occurrence (e.g., Askins et al. 2007, Chandler et al. 2009*b*, Shake et al. 2012) and the results of these studies seem equivocal. For example, in landscapes composed predominately by forest, wetlands, or shrublands (i.e., not human-developed landscapes), Hagan and Meehan (2002) found that landscape composition within 1 km of shrublands explained the presence/absence of only 2 out of 20 bird species and Chandler (2006) found shrubland bird occurrences in wildlife openings was better predicted by microhabitat variables within openings than by the proportion of shrublands in the surrounding landscape. These results may be due, in part, to shrubland birds evolving stronger associations to specific vegetation conditions within shrublands rather than to the composition of the matrix landscape that was historically composed predominantly of mature forest (Askins et al. 2007). However, in predominately developed landscapes, the dominant landcover may be especially important for predicting shrubland bird occurrence in remnant shrublands (Roberts and King 2017), with the importance of the surrounding landscape composition extending beyond 100 m from study shrublands (Hostetler and Knowles-Yanez 2003). As suburban development increases in many areas of New England, understanding how landscape habitat composition influences shrubland bird distribution among shrublands is important for planning landscape-level habitat management and conservation to benefit declining bird species.

To examine the role of site-specific features (e.g., vegetation composition and shrubland size) and surrounding landscape composition, I examined the occurrence of common shrubland birds in four types of anthropogenic shrublands; clearcuts, sand and gravel mines, old fields, and ROWs. I predicted that site-specific features would have a greater influence on shrubland bird occurrences than surrounding landscape features, that surrounding landscape features within 500 m of a shrubland would have a greater influence on bird occurrences than features farther away, and that bird occurrences would be associated positively with the proportion of shrubland and negatively with the proportion of urban development within the surrounding landscape.

2. METHODS

2.1. Study Area and Shrubland Selection

I conducted this study in seacoast of southeastern New Hampshire, in Rockingham and Strafford counties (Fig 1). The study area (2873 km^2) contains approximately 70% Forest, 14% Urban Development, 7% Fields/Pastures (i.e., habitats composed predominantly of herbaceous vegetation < 1m tall), 4% Open Water, 4% Shrubland (i.e., habitats composed of thickets of shrubs and young trees mixed with scattered grasses and wildflowers), 0.2% Tidal Vegetation (i.e., habitats composed of grasses and herbaceous vegetation influenced by salt water influx) and 0.2% Agricultural (i.e., lands managed for crops). The dominant forest type in this area is eastern hemlock (*Tsuga canadensis*) – American beech (*Fagus grandifolia*) - oak (*Quercus spp*.) - white pine (*Pinus strobus*) forest (Sperduto and Nichols 2012). There is more urbanization, open water, and tidal vegetation near the coast leading into a more forested landscape as the distance increases inland. Fields/Pastures and Agricultural landscape features are scattered throughout the landscape as soil conditions permit.

The seacoast area of New Hampshire has unique anthropogenic shrublands, such as sand and gravel mines, clearcuts, and ROW due to geological conditions (Sperduto and Nichols 2012), New England cottontail habitat management (Fuller and Tur 2012), and urbanization respectively. Old fields are less abundant due to forest succession (Litvaitis 1993). A total of 101 shrublands were selected as study sites: 26 clearcuts, 25 sand and gravel mines, 25 old fields, and 25 ROWs. Each shrubland was ≥ 0.8 ha and at least 250 m from the next nearest shrubland surveyed. All ROWs were > 50 m wide and characterized by extensive shrub and sapling hardwood growth that varied in density and vertical structure depending on time since it was mowed. All ROWs were mowed with a brontosaurus-style forestry mower within the previous 1-4 years and all vegetation was < 5 m tall. Study sites within ROWs varied from 1.1 to 26.5 ha and each was considered a continuous shrubland until it was bisected by a road, parking lot, housing development, agricultural field, or by a water feature that observers could not cross. All silviculture openings (patch cuts, clearcuts, group selection cuts) were considered clearcuts and were within 1-15 years of complete post-timber harvest and ranged from 1.1 to 23.7 ha. All clearcuts had few standing trees, a hard forest/shrubland edge, and contained shrubs, regenerating trees, and woody debris resulting in extensive vertical and horizontal diversity. Old fields varied from 1.1 to 21.6 ha and were last mowed or grazed > 2 years prior to the study, creating a variable vertical structure (0.2 to < 3 m tall) of dense grasses interspersed with shrubs and small saplings. Sand and gravel mines varied in size from 1.7 to 90.9 ha and contained extensive areas of overturned soils in a xeric environment, with pockets of shrubs, grasses and saplings, and ponds of variable sizes created by mining activities. Active sand and gravel mines (n = 11) were composed of a perimeter of shrubby habitat interspersed among areas where gravel was being extracted. Idle sand and gravel mines (n = 14) were composed of a perimeter of taller shrubs and small trees, and shrubby interiors interspersed with areas of bare ground.

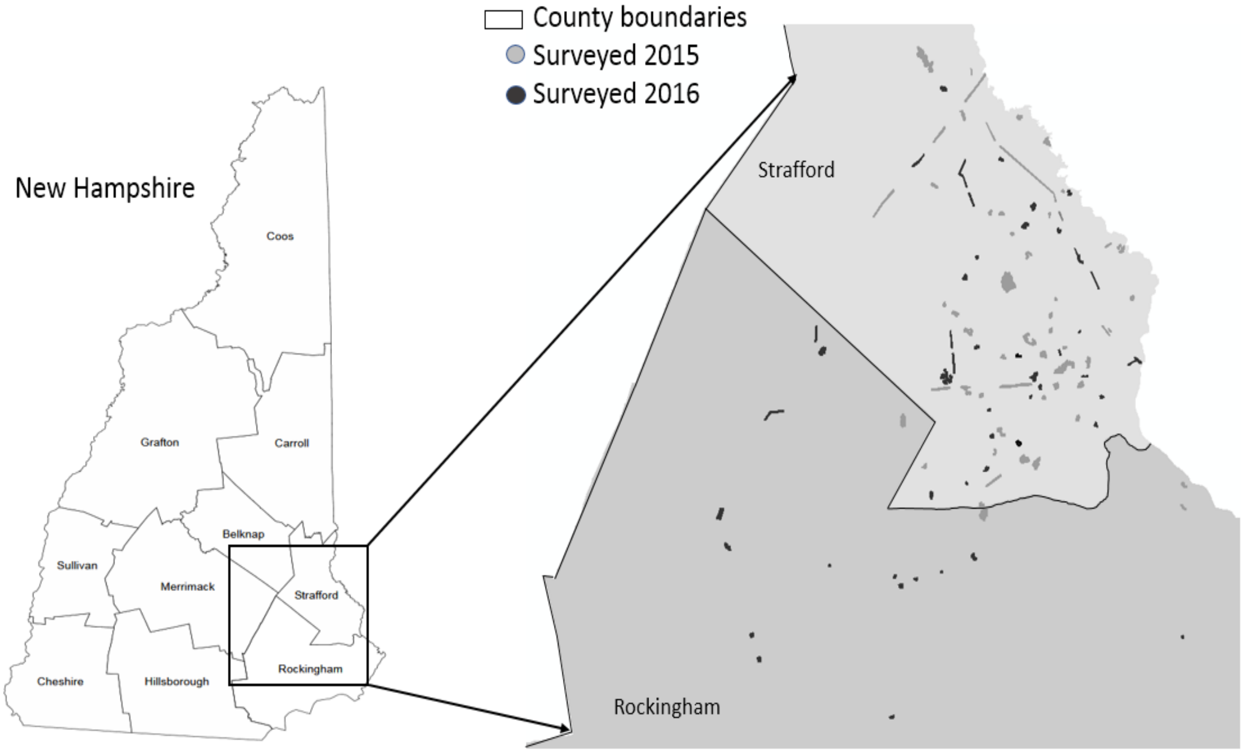


FIGURE 1. Distribution of 101 anthropogenic shrublands surveyed for shrubland birds in southeastern New Hampshire, 2015-2016.

2.2. Focal Species

Eight shrubland bird species were the focal species of this study: alder flycatchers, brown thrashers, blue-winged warblers, chestnut-sided warblers, eastern towhees, field sparrows, indigo buntings, and prairie warblers. These species are identified as "Stewardship Species of Continental Importance" for the U.S. and Canada (Rosenberg et al. 2016), as "Species of Greatest Conservation Need" in one or more New England state wildlife action plans, and they require shrublands as their primary breeding habitat (Schlossberg and King 2007). Collectively, these species require or prefer a range of shrubland habitat conditions (e.g., mesic, xeric, exposed soils, dense/sparse shrub and tree cover, minimum required shrubland size) and they all have experienced population declines in New England over the last 50 years (U.S. Fish and Wildlife Service 2008, Rosenberg et al. 2016).

2.3. Field Methods

I conducted three presence/absence surveys for focal bird species in each shrubland between May and August, with approximately half of the shrublands surveyed in 2015 and the other half in 2016. Consecutive surveys at each shrubland were separated by ≥ 2 weeks. Each survey consisted of a surveyor using a handheld speaker to broadcast the breeding songs of each focal bird species throughout the entire shrubland to ensure complete coverage. Each focal species was recorded as either present (detected by sight or sound) or absent (not detected) during each survey. Once a species was detected, no further breeding song was broadcast for that species during that survey. A species occurred at a site if it was present during at least one survey. Surveys were conducted in the morning between sunrise and 1200 and they were not conducted during rain, excessive wind (> 4 in Beaufort scale), fog (visibility < 200 m), or excessive heat index (> 32 C).

2.3.1. Site-Specific Features

Eleven site-specific features were used to describe structural characteristics of sites inventoried for breeding birds (Appendix A). Size and perimeter were determined for clearcuts, sand and gravel mines, and old fields by walking the perimeter of the area with a handheld GPS unit and calculating area in ArcGIS 10.2.2. I estimated size for ROWs from digital aerial photographs in ArcGIS 10.2.2. *Bare Ground Cover* (the litter layer, rocks, and tree stumps), area of *Open Water*, and the height, and percent cover of six vegetation classes (grasses, ferns, forbs, native shrubs, non-native shrubs and trees) were estimated at 30 sampling points located randomly within each shrubland. A mil-acre plot was established at each point using a 1.13 m long rope attached to a pole held vertically at the center of the point, with the pole marked at 0.2 m intervals. The height of each vegetation class was estimated as the tallest specimen representing each class (nearest 0.2 m, continuously from 0 to > 3 m). Any class missing or < 0.2 m tall was recorded as zero. Woody plants < 7.0 cm in diameter at breast height were considered shrubs and those larger as trees. Visual estimates of the percent cover were made for bare ground, water, and each vegetation class by looking directly down upon the plot. Cover estimates were averaged from estimates collected simultaneously by ≥ 2 observers trained at the beginning of each study season and weekly thereafter, to ensure consistent estimates among observers. Because vegetation height correlated with percent cover for each vegetation class (r > 0.7), it was not included as a model variable. *Vegetation Density* (all vegetation classes combined) in each plot was measured with a density comparison gauge (5.1 cm x 7.6 cm x 10.2 cm down spout adapter with 9 equidistant sections created by wire on the rectangular section). The density comparison gauge was held directly against the eye 1 m above the ground and any portion of a section containing vegetation within the 1 mil acre plot was recorded. Using the density comparison gauge, scores for density were recorded as follows: 0 = no section with vegetation, 1 = 1 – 3 vegetated sections, 2 = 4 – 6 vegetated sections and 3 = 7 – 9 vegetated sections. Density readings were taken at cardinal headings and averaged for each plot. *Vegetation Density* is based on a combination of average percent cover or all vegetation types and the average height of vegetation at 1 meter and categorized as: *Sparse Vegetation* (≥ 60% bare ground with limited shrub, grass, and forb cover that seldom exceed 1 m in height); *Dense Short Vegetation* (60 - 80% shrub cover interspersed with grasses, forbs, and shrubs all occasionally exceeding 1 meter in height with ≤ 40% bare ground and some small saplings < 3 m tall); *Very Dense Vegetation* (> 80% shrub cover with most grasses, forbs, shrubs, and saplings exceeding 1 meter in height, with ≤ 20% bare ground and some small trees > 3m tall); and *All Vegetation Very Dense & Tall* (>

80% shrub cover with all vegetation types averaging > 1m tall, some trees > 3m tall , and minimal to no bare ground).

2.3.2. Landscape Features

To estimate the landscape composition surrounding each shrubland, six buffer distances (50 m, 250 m, 500 m, 1 km, 5 km, and 10 km) were establish around each shrubland using ArcGIS 10.2.2. The 28 LANDFIRE 2014 Existing Vegetation Height (30 m pixels) (LANDFIRE 2014) data land categories were combined into seven surrounding landscape features and then estimated within each buffer distance (Appendix B). Specifically, I estimated the proportion of the landscape that was *Agriculture*, *Field/Pasture*, *Open Water*, *Shrubland*, *Tidal Vegetation*, *Forest*, and *Urban Development* within each buffer. Although the larger buffer landscape features incorporated all subsequent smaller buffer landscape features, all surrounding landscape features within each buffer were retained in the analyses regardless of correlation strength due to buffer overlap. Variability in the percentages of surrounding landscape features decreases as buffer distances decrease around the shrublands.

I was unable to examine all vegetation types in every buffer distance and categorizing LANDFIRE data into surrounding landscape features had its challenges. Growth of vegetation over time, misinterpreted vegetation types within LANDFIRE, and the combining of LANDFIRE into only seven types of surrounding landscape features may affect the responses of the shrubland birds. I found most representations of LANDFIRE data did match the vegetation at the surveyed sites after two years or was within the appropriate categories I selected as surrounding landscape features.

TABLE 1. LANDFIRE 2014 Existing Vegetation Height (30 m pixels) categories grouped into seven surrounding landscape features with reasons for grouping.

LANDFIRE 2014 category	Surrounding landscape feature category	Reason
Barren	Shrubland	Sparse shrub vegetation
Developed-Roads	Urban Development	Urban development
Developed-Upland Deciduous Forest	Trees	Trees in developed areas
Developed-Upland Evergreen Forest	Trees	Trees in rural and developed areas
Developed-Upland Herbaceous	Fields, Pastures	Golf courses/fields: mowed often
Developed-Upland Mixed Forest	Trees	Tree pockets in developed areas
Developed-Upland Shrubland	Urban Development	Small backyards by rural roads
Developed-High Intensity	Urban Development	Urban development
Developed-Medium Intensity	Urban Development	Urban development
Developed-Low Intensity	Urban Development	Urban development
Forest Height 0 to 5 meters	Forest	Forest
Forest Height 5 to 10 meters	Forest	Forest
Forest Height 10 to 25 meters	Forest	Forest
Forest Height 25 to 50 meters	Forest	Forest
Herb Height 0 to 0.5 meters	Tidal	Areas next to rivers, ponds, lakes
Herb Height 0.5 to 1.0 meters	Fields, Pastures	Most are fields, and pastures
Herb Height > 1.0 meters	Fields, Pastures	Most are fields, and pastures
NASS-Close Grown Crop	Agriculture	Agriculture
NASS-Row Crop	Agriculture	Agriculture
NASS-Row Crop-Close Grown Crop	Agriculture	Agriculture
NASS-Vineyard	Agriculture	Agriculture
NASS-Wheat	Agriculture	Agriculture
Open Water	Open water	Open water
Quarries-Strip Mines-Gravel Pits	Shrubland	Sparse shrub vegetation
Shrub Height 0 to 0.5 meters	Shrubland	Shrubland
Shrub Height 0.5 to 1.0 meters	Shrubland	Shrubland
Shrub Height > 3.0 meters	Shrubland	Shrubland
Sparse Vegetation Height	Shrubland	Shrubland

2.4. Statistical Analysis

2.4.1. Bird Occurrence

Differences in detection likelihood among shrubland types were analyzed in JMP Pro 13.0.0 (SAS Institute, Cary, NC) for each species using Kruskal-Wallis followed by Wilcoxon tests among all pairs with a test for false discovery rate for significance.

2.4.2 Site-Specific and Landscape Features Affecting Occurrence

Shrubland bird associations between the species occurrence and local and landscape features were analyzed using non-metric multidimensional scaling (NMDS) in PC-ORD v.6.19 (MjM Software Gleneden Beach, OR). Ordination was performed with the Sorensen distance measure in the Autopilot Slow and Thorough mode (McCune and Grace 2002), with 250 runs using both real and randomized data. NMDS supports presence/absence, categorical, and continuous data allowing for unconstrained analysis. The secondary matrix of shrubland and surrounding landscape features was generally relativized to sum of squares ($P = 1$) to standardize to the norm for Sorensen distance measure. In NMDS, goodness-of-fit is measured by a stress value used to determine the number of dimensions that adequately represent sample units in ordination space and to indicate how well the configuration matches the data (Kruskal 1964). The starting configuration was optimized in previous ordinations to achieve the lowest final stress (8.813) and both 2 and 3-dimensionalities were assessed. I selected the programs default joint plot cutoff ($R^2 = 0.20$) representing the minimum value identifying a strong relationship between the environmental variables and shrubland bird occurrences.

Focal species likelihood of occurrence in shrublands was assessed with nonparametric multiplicative regression (NPMR) using Hyperniche v.2.30 (MjM Software, Gleneden Beach, OR) because I expected birds would have a complex, non-linear or even an asymmetrical response to variables. NPMR creates a multidimensional environmental space unconstrained by linear responses and uses multiplicity of the variables to model species responses (McCune and Mefford 2009). Specifically, it uses all the variables, and combinations of all variables, to target the best location in multidimensional space identifying successively important variables that best explain the likelihood of a species occurring (McCune and Mefford 2009). Shrubland types were combined to determine focal species occurrence associated with surrounding landscape features. Model form was set to Local Mean – Gaussian to center the probability density function on the target point achieving full weighting for an observation with the same environment as the target point. This allows a diminishing weight in observations with increasing distance from the target point. All other settings for Free Search were set to defaults. I assessed model quality by using the maximum cross-validated coefficient of determination R^2 (xR^2) from the best fit models (McCune and Mefford 2009) and conducted sensitivity analyses. Sensitivity is expressed as a proportion of the range of the response variable within each model (values are only compared to each other within the model) and higher values have more influence and indicate the species is more sensitive to the model (McCune and Mefford 2009). The minimum average neighborhood size for acceptable model, and minimum neighborhood size for estimate, were set at automatic and the response curves overfitting controls were set at medium. In the predicted occurrence percent change, I considered a response to be negligible if the response achieved < 20% change over the range of the variable.

To determine whether a species responded more to site-specific or surrounding landscape features I totaled the number of features comprising each species' best NPMR model and calculated a percentage of the total composed by each category of features to determine which was greater.

3. RESULTS

3.1. Shrubland Bird Detection and Shrubland Types

All but one of the eight focal species were detected at least once in every shrubland type; brown thrashers were detected in all shrubland types except clearcuts (Fig 2). P-values are derived from Kruskal-Wallis followed by Wilcoxon tests among all pairs with a test for false discovery rate for significance. Brown thrashers were more likely ($P < 0.008$) to be detected in sand and gravel mines than in the other shrubland types. Prairie warblers and field sparrows were more likely ($P < 0.009$ for both) to be detected in ROWs and sand and gravel mines than in clearcuts or old fields. Eastern towhee detections were greatest in ROWs and sand and gravel mines, and the proportion of detections in ROWs was greater ($P < 0.004$) than that in clearcuts and old fields. Chestnut-sided warbler detections were greatest in ROWs and clearcuts, and the proportion of detections in ROWs was greater ($P < 0.006$) than those in old fields and sand and gravel mines. Indigo bunting detections were greatest in sand and gravel mines and ROWs; the proportion of indigo bunting detections in sand and gravel mines was greater ($P < 0.002$) than those in clearcuts and those in old fields ($P < 0.007$); those in ROWs were greater ($P < 0.019$) than in clearcuts. There was no difference in detections among shrubland types for alder flycatchers or blue-winged warblers.

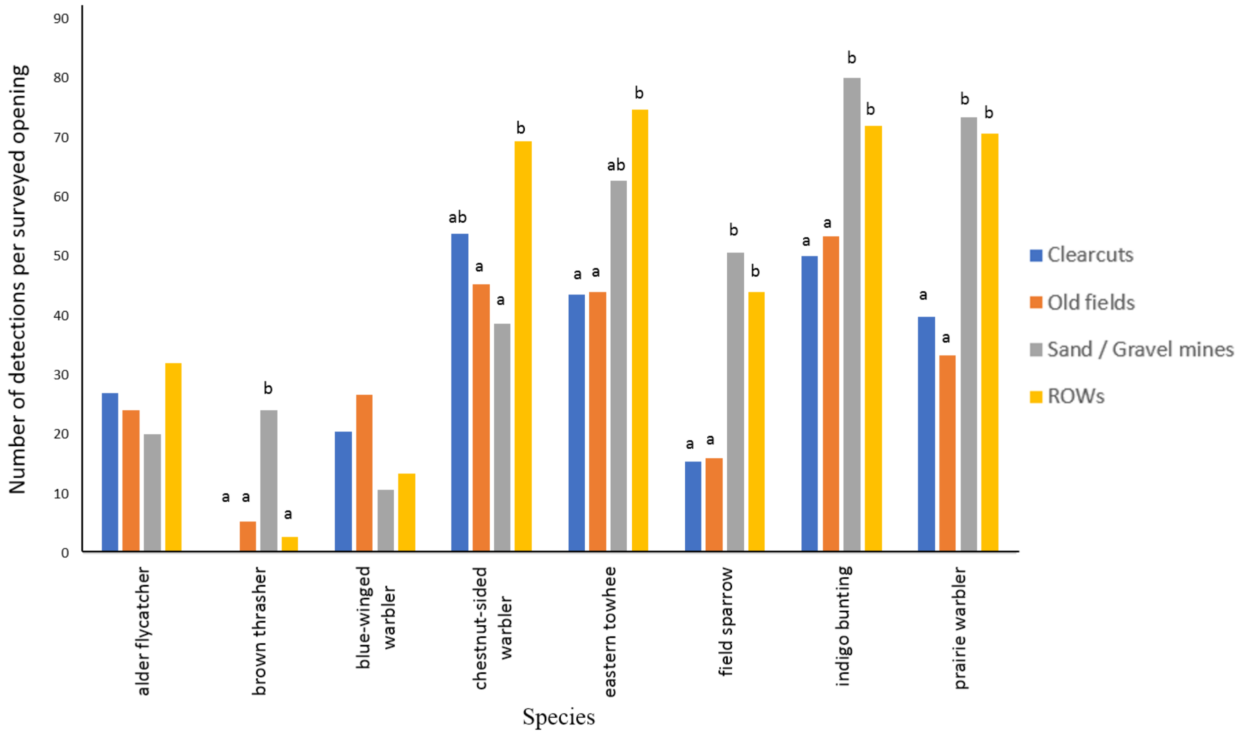


FIGURE 2. Comparing the likelihood that each of eight focal shrubland bird species was detected within each of four anthropogenic shrubland types occurring in Rockingham and Strafford Counties, New Hampshire May-August 2015 and 2016. Differences in detections analyzed using Kruskal-Wallis followed by Wilcoxon tests among pairs with a false discovery rate for significance. Bars with different letters differ ($P < 0.05$).

3.2. Bird Responses to Site-Specific and Landscape Features

Site-specific features for shrublands combined had averages for *Size* (9.7 ha), *Perimeter* (1.9 km), *Vegetation Density* (1.5), *Species Richness* (4.8), *Open Water cover* (0.2%), *Bare Ground cover* (35.6%), *Grass cover* (34%), *Fern cover* (9.4%), *Native Shrub cover* (33.3%), *Non-native Shrub cover* (7%), *Tree cover* (7.4%) and *Forb cover* (33.1%). All shrubland site-specific features with ranges and averages for sand and gravel mines (S&GM), transmission line rights-of-way (ROW), old fields (OF), and clearcuts (CC) are in Appendix A.

Overall, *Urban development* and *Field/Pasture* increase in the surrounding landscape out to 500 meters and then decrease from 1 km to 10 km. Surrounding *Shrubland* in the landscape decreases as distance increases from the shrubland and there is less than a 3% change of *Forest* in the surrounding landscape at all buffer distances (Appendix B). All shrubland surrounding landscape feature ranges and averages for sand and gravel mines (S&GM), transmission line rights-of-way (ROW), old fields (OF), and clearcuts (CC) are in Appendix B.

The best-fit NPMR models included site-specific and landscape features (Fig 3). Three birds (alder flycatcher, brown thrasher, chestnut-sided warbler) were positively associated with surrounding *Shrubland*. Five birds (brown thrasher, prairie warbler, eastern towhee, alder flycatcher, field sparrow) were negatively associated with surrounding *Field/Pasture* and the blue-winged warbler was positively associated with *Field/Pasture*. Two birds (chestnut-sided warbler, indigo bunting) were negatively associated with surrounding *Urban Development*. Two birds (field sparrow, blue-winged warbler) were positively associated with *Tidal Vegetation* and two birds (indigo bunting, prairie warbler) were negatively associated with *Tidal Vegetation.* Two birds (brown thrasher, field sparrow) were negatively associated with *Open Water* and the prairie warbler was positively associated with *Open Water*. The alder flycatcher was positively associated with *Agriculture* and the blue-winged warbler was negatively associated with *Agriculture*. Two birds (indigo bunting, chestnut-sided warbler) were positively associated with *Vegetation Density* and the brown thrasher was negatively associated with *Vegetation Density*. Two birds (eastern towhee, field sparrow) were associated positively with *Shrubland Size*. The blue-winged warbler was positively associated with *Non-native* shrubs. The alder flycatcher was negatively associated with *Bare Ground Cover* and the eastern towhee was positively associated with *Bare Ground Cover*. The chestnut-sided warbler was negatively associated with *Tree Cover*. The prairie warbler was negatively associated with *Grass Cover*.

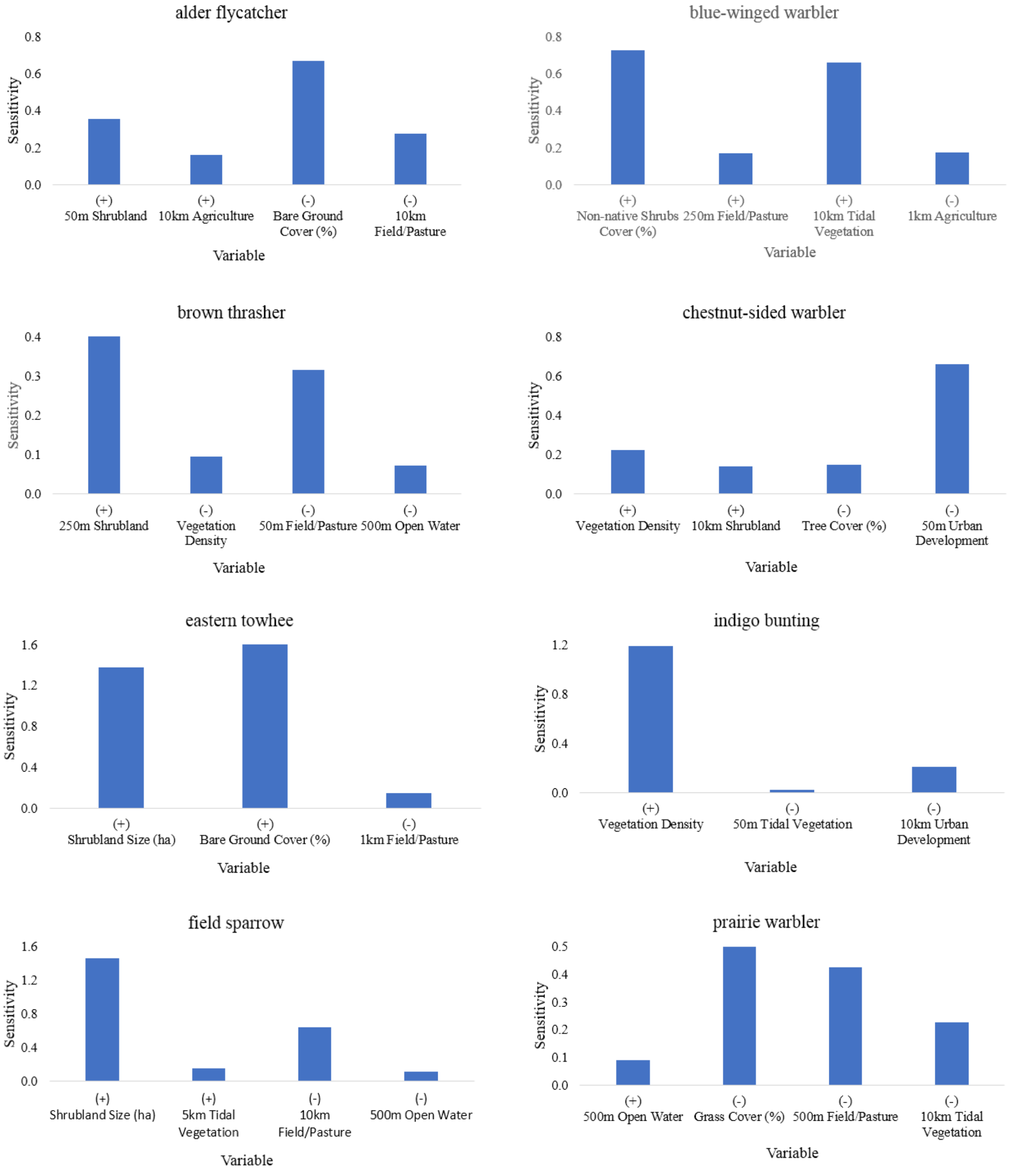


FIGURE 3. Best NPMR models predicting focal bird occurrence and bird sensitivity to an increasing proportion of site-specific and surrounding landscape features. Positive (+) and negative (-) signs indicate the direction of association of the species to the variable. Higher sensitivity values indicate the predicted occurrence of the species changes readily (positive/negative) in response to changes in the variable.

The importance of site-specific and surrounding landscape features as predictors of focal bird occurrence differed among the species (Fig 4). Specifically, surrounding landscape features comprised 75% of the feature types associated with alder flycatchers, brown thrashers, blue-winged warblers, field sparrows, and prairie warblers and 67% of the feature types associated with indigo buntings. Comparatively, the site-specific features comprised 67% of the feature types associated with eastern towhees. The site-specific and surrounding landscape features each comprised 50% of the feature types associated with chestnut-sided warblers (Fig 4). These results were derived from the best models that explained the occurrences of each focal species (Fig 3).

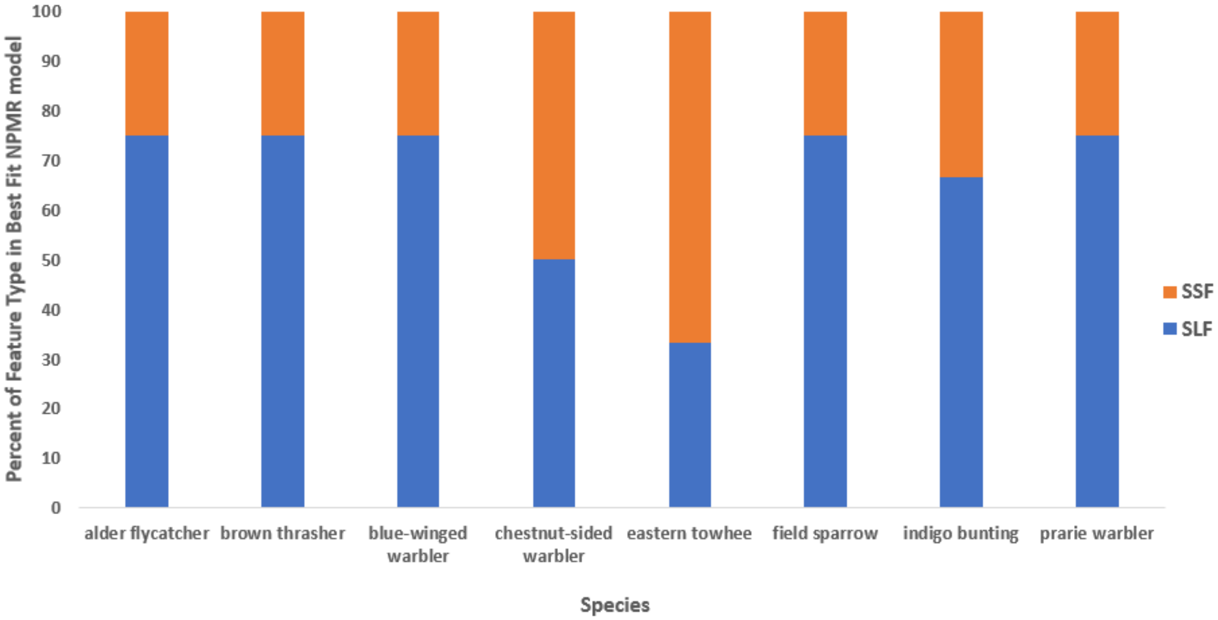


FIGURE 4. The proportion of the site-specific features (SSF) and surrounding landscape features (SLF) comprising the best fit NPMR models predicting focal species occurrence in 101 anthropogenic shrublands in southeastern New Hampshire 2015-2016.

Combined, *Shrubland*, *Field/Pasture*, and *Urban Development* account for 55% of surrounding landscape features identified in the best fit models predicting the occurrence for all species. The average percent change in predicted occurrence of all species was associated positively with increasing *Shrubland* and variable, by species, with increasing *Field/Pasture* and

Urban Development across all buffer distances (Fig 5). Specifically, alder flycatchers, blue-winged warblers and chestnut-sided warblers responded positively, and all other species responded negatively, to *Field/Pasture*. Blue-winged warblers and indigo buntings responded positively, and all other species responded negatively, to *Urban Development*.

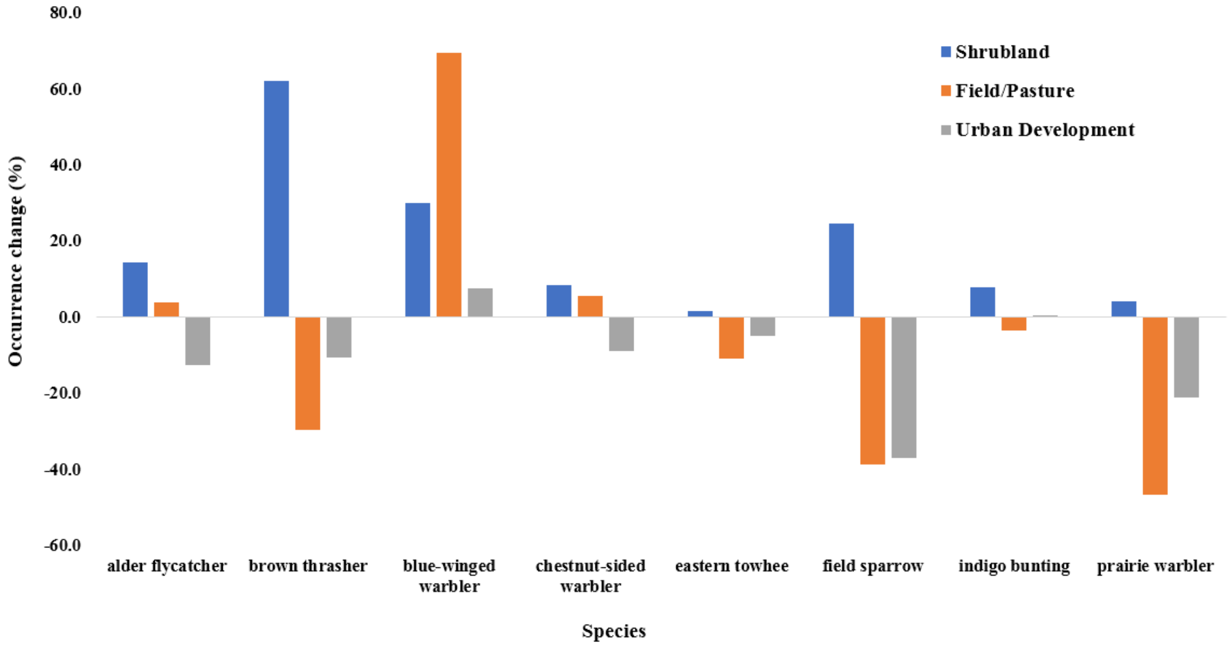


FIGURE 5. Average percent change in predicted occurrence for eight focal shrubland bird species in response to increasing proportions of *Shrubland*, *Field/Pasture*, and *Urban Development* in the surrounding landscape (50 m – 10 km) from the best fit NPMR models. Positive value indicates an increase in average predicted occurrence and negative value indicates a decrease in average predicted occurrence.

A convergent three-dimensional solution was reached by NMDS comparing site-specific and surrounding landscape features to shrubland bird occurrence (Fig 6). The three axes captured a total of 91.8% of the variance in the model (axis 1: 44.8%, axis 2: 33.4%, axis 3: 13.5%). Axes 1 and 2 had the highest coefficients of determination and explained 78.2% of the shrubland bird occurrence in relation to the site-specific and surrounding landscape feature data. *Species richness* ($R^2 = 0.320$) and *Field/Pasture* within 1 km ($R^2 = 0.211$) met the minimum association of $R^2 \geq 0.2$ and had the strongest relationship between the site-specific and surrounding landscape features to the ordination scores in ordination space. Specifically, the chestnut-sided warblers and blue-winged warblers had positive associations with *Field/Pasture* within 1 km as it increased from axis 1, and *Species richness* increased as *Vegetation density* increased (Fig 6).

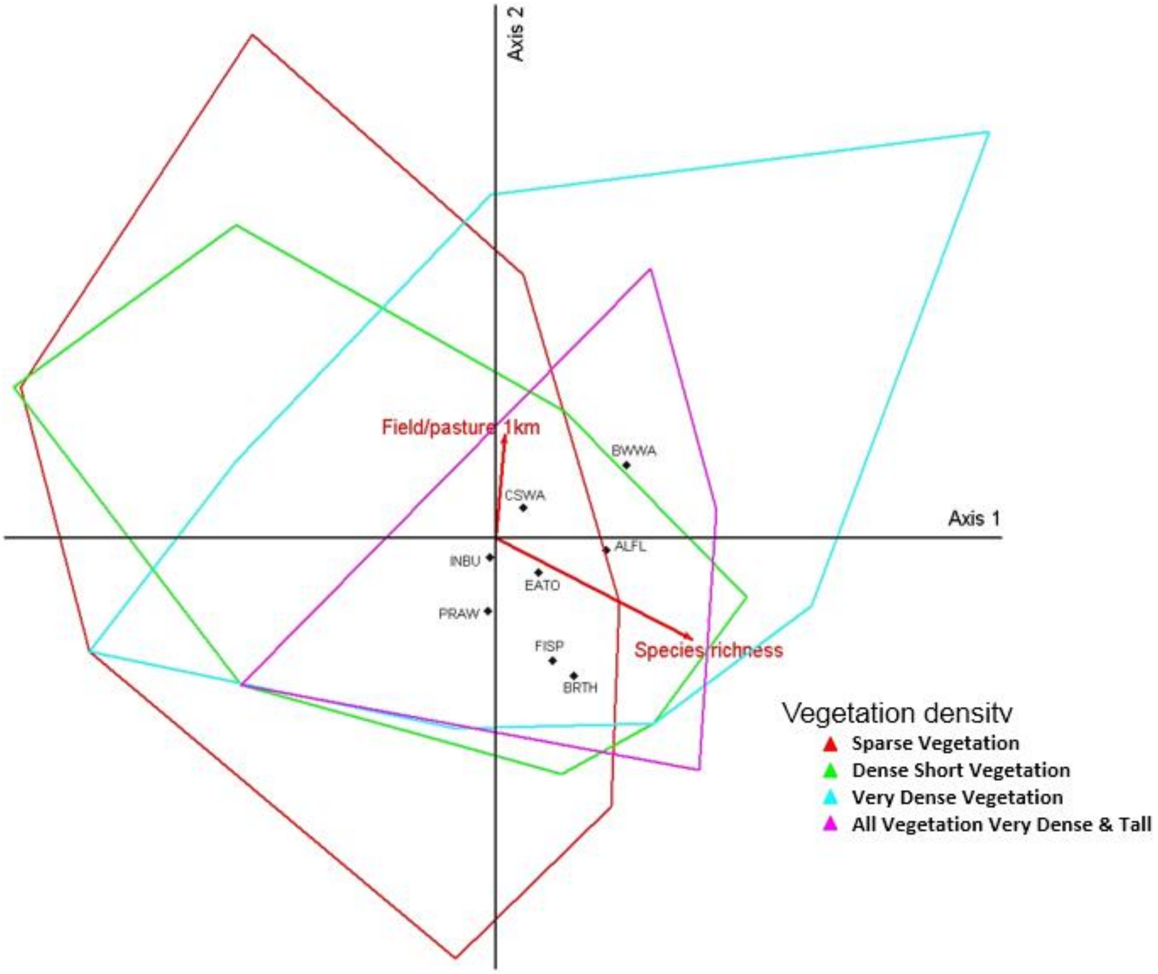


FIGURE 6. Nonmetric multidimensional scaling (NMDS) of eight focal shrubland bird species in a community structure of 101 anthropogenic shrublands in southeastern New Hampshire, USA, 2015-2016. Field/Pasture within 1 km and Species richness vectors are oriented toward the direction of greatest increase and vector lengths are proportional to R^2 with the ordination. The angle between vectors indicates the correlation between variables. Convex hulls indicate *Vegetation Density* categories and are defined in METHODS 2.3.1.

Based on the related strength of *Species Richness* to *Vegetation Density* a separate analysis was conducted comparing *Species Richness* to *Vegetation Density*. All eight focal species were associated with *Dense Short Vegetation* (n = 27) and *Very Dense Vegetation* (n = 38), which, combined had the most shrublands associated with them. *Species Richness* in *Sparse Vegetation Density* (n = 22) was limited to seven of the focal species with blue-winged warbler absent and *Species Richness* in *All Vegetation Very Dense and Tall* (n = 14) was limited to five species with the brown thrasher, prairie warbler and field sparrow absent.

The NPMR indicated either a positive or negative percent change in predicted occurrence to increasing *Vegetation Density* (Fig 7). The alder flycatchers, blue-winged warblers, indigo buntings, chestnut-sided warblers and eastern towhees had an overall positive predicted occurrence as *Vegetation Density* increased. The brown thrashers, field sparrows, and prairie warblers had and overall negative predicted occurrence as *Vegetation Density* increased.

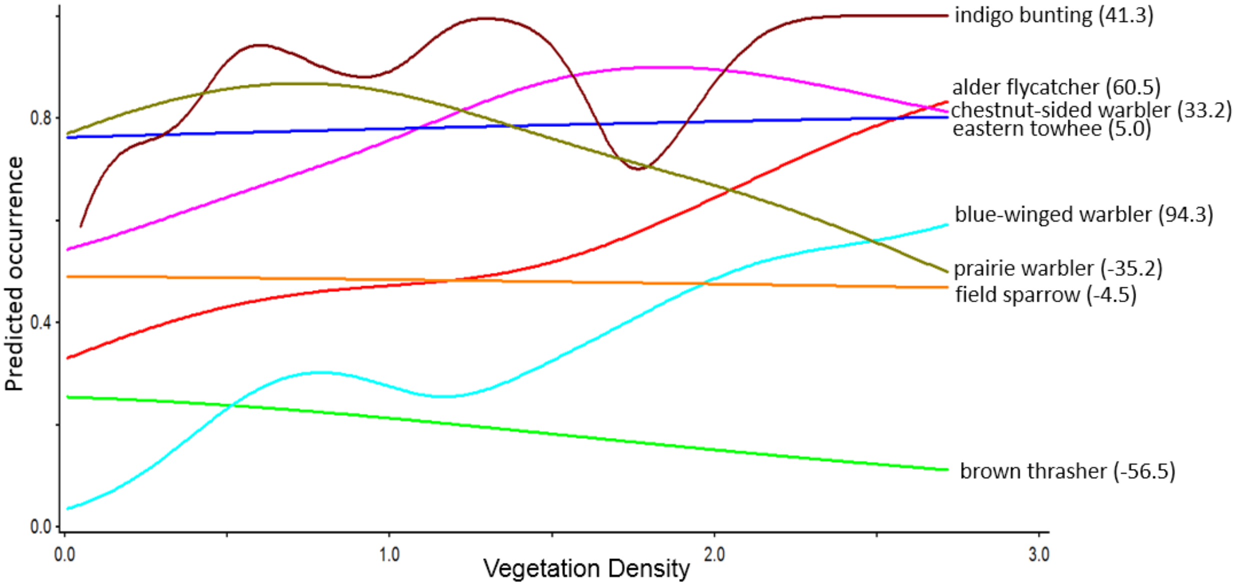


FIGURE 7. NPMR comparing predicted occurrence of eight focal shrubland bird species in response to increasing Vegetation Density estimated in 101 anthropogenic shrublands in Strafford and Rockingham Counties New Hampshire 2015-2016. Percent increase/decrease in predicted occurrence is indicated in parentheses. Alder flycatchers, brown thrashers, blue-winged warblers, chestnut-sided warblers, indigo buntings, and prairie warblers have significant (>20% change) predicted occurrence responses.

3.3. Bird Responses to Shrubland Size

The NPMR model indicated either a positive or negative percent change (% change) in predicted occurrence of the eight focal shrubland bird species in response to increasing *Shrubland Size* and the association was generally positive (Fig 8). For alder flycatchers (% change = 43.0), brown thrashers (% change = 44.2), eastern towhees (% change = 31.1), field sparrows (% change = 53.1), prairie warblers (% change = 27.4), and indigo buntings (% change = 9.2) the predicted percent change in response to increasing *Shrubland Size* was clearly and consistently positive. Blue-winged warblers (% change = -4.3) had a minimal negative response to increasing *Shrubland Size*. Chestnut-sided warblers (% change = 1.1) had a positive response to increasing *Shrubland Size* that peaked around 7.8 ha in *Shrubland Size,* then the response was negative as *Shrubland Size* increased. In the NPMR model (Fig 8), the response lines for the indigo buntings and brown thrashers are longer because a greater number of predicted occurrence responses in sand and gravel mines met the minimum neighborhood size for inclusion in the analysis.

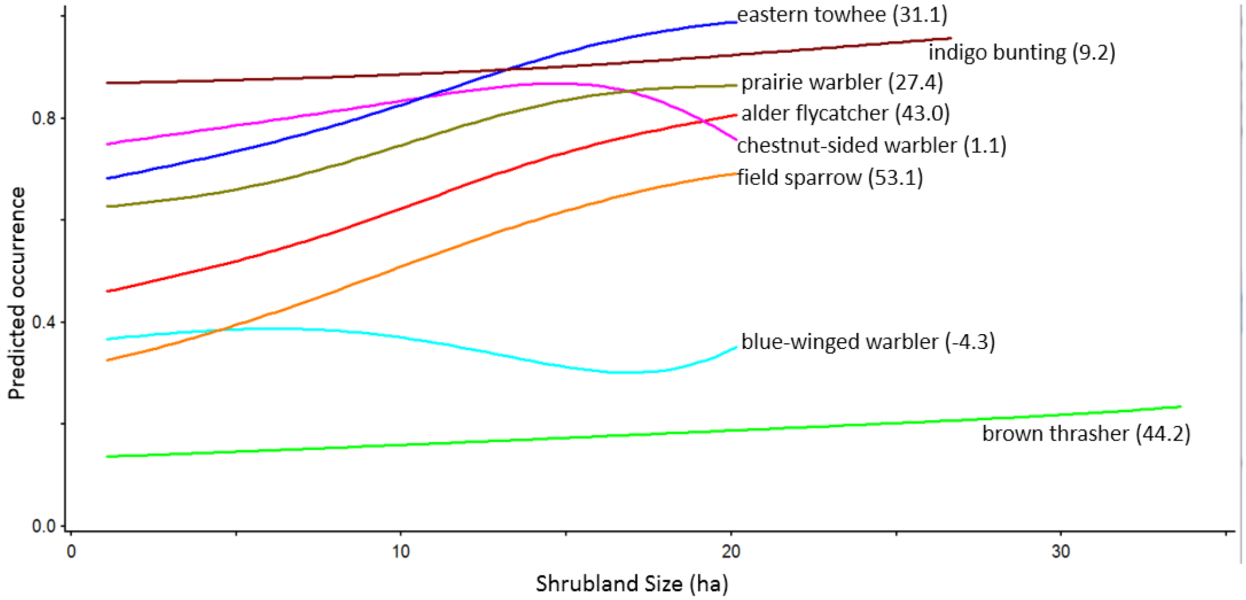


FIGURE 8. NPMR comparing predicted occurrence of eight focal shrubland bird species in response to increasing *Shrubland Size* (ha) estimated in 101 anthropogenic shrublands in Strafford and Rockingham Counties New Hampshire 2015-2016. Percent increase/decrease in predicted occurrence is indicated in parentheses.

4. DISCUSSION

Contrary to previous studies (Bulluck and Buehler 2006, Chandler 2006, Shake et al. 2012), I found that shrubland bird occurrence was better predicted by the composition of the surrounding landscape than by habitat features measured within shrublands. But similar to those and other studies (King et al. 2009*b*, Bauer 2018), shrubland bird occurrence and species richness were associated positively with vegetation density within shrublands and shrubland size. Specifically, shrubland birds as a group were more commonly present in shrublands situated in landscapes where the surrounding 500 m was composed of a greater proportion of shrublands than of fields or urban development, in shrublands > 12 ha, and in shrublands with *Dense Short Vegetation* or

Very Dense Vegetation. These results can serve as a basic guide for identifying, managing and conserving shrublands that are likely to support the greatest diversity of shrubland birds within contemporary landscapes. However, species-specific preferences for specific microhabitats (e.g., sparse/dense/short/tall vegetation, amount of bare ground, mesic/xeric soils) indicates each bird species will occur most predictability in shrublands that support its preferred microhabitats, and local landscapes composed of multiple shrubland types (e.g., ROW, clearcuts, old fields, sand and gravel mines, pine barrens, beaver meadows) occurring across a range of growing conditions (e.g., mesic, xeric), should support the greatest diversity and abundance of shrubland birds (Chandler et al. 2009*b*, King et al. 2009*a*, Gifford et al. 2010). Overall, sand and gravel mines and ROW were the largest shrublands in my study and they supported both the greatest diversity of microhabitats and the greatest species richness of shrubland birds (Fig 2).

4.1. Importance of Landscape Composition to Breeding Shrubland Birds

Occurrence of all species was associated positively with increasing proportions of *Shrublands* in the surrounding landscape. All species except the blue-winged warbler, chestnut-sided warbler, and alder flycatcher were associated negatively with increasing proportions of *Field/Pasture* and the indigo bunting and blue-winged warbler were associated positively to increasing proportions of *Urban Development* in the surrounding landscape (Fig 5). The positive response I observed for blue-winged warblers to *Urban Development* and *Fields/Pasture* (Fig 5) is likely because these land uses were more common within 500 m around old fields, where blue-winged warbler occurrence was greatest (Fig 2), than around the other shrubland types in my study area. The negative response and sensitively of most focal birds to greater proportions of *Field/Pasture* and *Urban Development* may be associated with attributes of these habitats that can have negative consequences to breeding bird fitness. For example, fragmentation by human development and agriculture can decrease nesting success due to increased nest predation (Rudnicky and Hunter 1993, Rodewald and Yahner 2001) and/or by parasitism by brown-headed cowbirds (Burhans and Thompson III 2006, Askins et al. 2012). *Urban Development* may further reduce nesting success in shrublands due to elevated noise and light levels (Oneal and Rotenberry 2009) and/or reduced food and cover resources compared to when the adjacent habitat is mature forest (King and DeGraaf 2004, Oneal and Rotenberry 2009, Shake et al. 2012).

Shrubland bird fitness should be greatest in landscapes where multiple shrublands are clustered in close proximity within a matrix composed primarily of forest and wetlands and a low proportion of fields, pasture, agricultural crops or urban development (Roberts and King 2017). Specifically, shrubland birds are known to increase their fitness by readily moving among adjacent habitat patches during a breeding season to seek extra-pair copulations (Nolan 1978, Byers et al. 2004, Akresh et al. 2015), to relocate following nest failure (Best 1977, Nolan 1978), and possibly to scout and assess other potential habitats (Nolan 1978, Whitaker and Warkentin 2010). Also, this large-scale habitat selection may also indicate shrubland birds may have more movement during the breeding season (Lehnen and Rodewald 2009*b*) than previously examined. However, the ideal distance shrublands must be from one another to facilitate these bird movements requires further study. Roberts and King (2017) determined that small (0.02 -1.3 ha) shrublands were more likely to be occupied by shrubland birds when those shrublands occurred within < 100 m of larger shrublands, and Lehnen and Rodewald (2009*a*) recommended clustering shrublands within 1 km of one another to facilitate bird movements.

During my study, I observed individual color-banded prairie warblers, field sparrows, and eastern towhees movements averaging 6.7 km, and as much as 29 km, within multiple shrublands during the same nesting season (R. Shoe, University of New Hampshire, unpublished data). Although these birds used multiple shrublands juxtaposed across a large local landscape, I found shrubland bird occurrence was best predicted by the proportion of shrublands within 500 m of my study sites, likely because the proportion of shrublands in the landscape around my sites decreased as distance from sites increased. It is possible that shrubland bird occurrence within 500 m of my sites may be due to neighborhood fidelity, whereas a bird has fidelity to multiple sites within a radius that supports its habitat preference. More study is needed on the possible neighborhood fidelity of shrubland birds. My results suggest clustering shrublands within 500 m of one another may be best for encouraging shrubland bird occurrence in anthropogenic shrublands within a suburban landscape and may possibly support neighborhood fidelity.

Unlike the other focal species, occurrence of chestnut-sided warblers was predicted equally by site-specific and surrounding landscape features (Fig 4). The chestnut-sided warbler is strongly influenced by microhabitat and landscape-level variables (Hagan and Meehan 2002, Chandler 2006) and its positive response to *Vegetation Density* and negative response to *Tree Cover* (Fig 3) are consistent with other studies (Askins et al. 2007, 2012). Movement by chestnut-sided warblers during the breeding season can be limited by *Urban Development* (Byers et al. 2004), and this may explain the negative predicted occurrence I observed for chestnut-sided warblers in response to *Urban Development* within 50 m (Fig 3). An explanation of why the chestnut-sided warbler had a positive response to a decreasing proportion of *Shrublands* out to 10 km (Fig 3) may be as the amount of surrounding Shrublands decrease from the occupied habitat and the amount of Forest increases, it may be chestnut-sided warblers are responding to its preference of an increasing proportion of understory stems < 1m tall (Hagan and Meehan 2002), provided that the forest has limited canopy cover and sufficient understory. Similar to my other focal species, shrublands located in a landscape with minimum *Urban Development* are those most likely to benefit chestnut-sided warblers. Managers can further attract chestnut-sided warblers to shrublands by encouraging microhabitats composed of dense to very dense vegetation surrounded by forest with an understory growth.

The eastern towhee was the only focal species for which site-specific features better predicted occurrence than the surrounding landscape features (Fig 4) and towhees were most sensitive (positively) to *Bare Ground Cover* and *Shrubland Size* (Fig 3). Increased sensitivity to *Bare Ground Cover* may be explained by the habit of eastern towhees to forage and nest on the ground in habitats with leaf litter and dense grasses, forbs and ferns. Towhees are reported to use shrublands that span a range of sizes (0.02 - 21 ha: Askins et al. 2007, Roberts and King 2017), and in my study area, they seem to use shrubland openings of any size as long as the shrubland supports their foraging and nesting habits. Towhee sensitivity to *Shrubland size* is likely because they occurred most predictably in large ROW and sand and gravel mines; these large openings supported a variety of microhabitat conditions, including areas of *Bare Ground Cover, Dense Short Shrubs*, and *Very Dense Shrubs* that satisfy multiple towhee habitat preferences. Managers can make shrublands more suitable for eastern towhees by ensuring a site has dense to very dense vegetation for nesting and bare ground with leaf litter for foraging.

4.2. Vegetation Structure, not Species Composition, Predicted Shrubland Bird Occurrence

Vegetation Density within shrublands had an overall positive influence on focal bird richness and shrublands composed of *Dense Short Vegetation* and *Very Dense Vegetation* were those most likely to be occupied by all eight focal species. However, bird response to *Vegetation Density* was species-specific. As expected, brown thrashers, prairie warblers and field sparrows were most likely to occur in shrublands with *Sparse, Dense Short, and Very Dense Vegetation* and they were least likely to occur in shrublands with *All Vegetation Very Dense and Tall*.

Comparatively, blue-winged warblers and alder flycatchers were more likely to occur in shrublands with *All Vegetation Very Dense & Tall*, and they were less common in shrublands composed of *Sparse Vegetation* or *Dense Short Vegetation*. Chestnut-sided warblers were most predictable in shrublands composed of *Dense Short Vegetation* or *Very Dense Vegetation* and they were least likely to occur in *All Vegetation Very Dense & Tall* shrublands. Indigo buntings and eastern towhees were present in all shrublands sampled and among all species, their occurrence seemed the least influenced by vegetation density.

Because bird responses to vegetation density was species-specific, large shrublands composed of a variety of microhabitats that support vegetation conditions ranging from *Sparse Shrub Vegetation* to *All Vegetation Very Dense & Tall* are those shrublands most likely to support the greatest shrubland bird richness. In my study, sand and gravel mines and ROW's were the largest shrublands I surveyed, and they supported both the greatest diversity of microhabitats and the greatest shrubland bird richness (5.4 and 5.2 respectively). Specifically, sand and gravel mines contained microhabitats consisting of mesic and xeric areas, low-growing and tall-growing shrubs, and extensive bare ground, and they were also the shrublands with the greatest proportion of other shrublands in the surrounding landscape; combined, these characteristics of sand and gravel mines likely explain why they had the highest species richness of all shrubland types surveyed. In some landscapes, sand and gravel mines may functions as the most stable and predictable habitats for shrubland birds due to their harsh growing conditions that naturally keep them in a shrubby condition longer than other anthropogenic shrublands such as clearcuts and old fields where shrubby conditions are more ephemeral (Borgegard 1990, Bulluck and Buehler 2006). Regular maintenance of ROW by utility companies creates an additional source of diverse and predictable shrubland habitat supporting a variety of shrubland bird species (King and Byers

2002, King et al. 2009*a*, Askins et al. 2012, this study) resulting from the diverse vegetation conditions within the length of most ROW. My study indicates sand and gravel mines and transmission ROW should be considered important habitats that can contribute to the long-term conservation of declining shrubland birds in suburban New England landscapes.

I suspect the type of shrubland may also affect species richness with vegetation density, especially in sand and gravel mines and ROW. Although sand and gravel mines have the highest species richness and four of the highest detections for the species, I believe their size and the features in the surrounding landscape may be what affects species richness more than vegetation density. Sand and gravel mines, with less shrubs than old fields, clearcuts and ROW, have the most shrublands surrounding them out to 500 m more than any other shrubland type. More shrublands surround sand and gravel mines than any other shrubland type, and the value of shrublands is important to all the species studied (Fig 5). Active sand and gravel mines and ROW, ranging from *Sparse* to *Very Dense Vegetation*, are the only two anthropogenic habitats I studied maintained in a shrubby condition. Habitats maintained in a shrubby condition have indicated over a three-year mark and recapture study (2014 – 2016) that 85% of the yearly re-sighted or re-captured prairie warblers, field sparrow, and eastern towhees have shown site fidelity to active sand and gravel mines and ROW (R. Shoe, University of New Hampshire, unpublished data). ROW’s are also well connected and have varying mowing schedules and likely offer safer or easier species movement and habitat selection of desirable vegetation densities, thereby increasing species richness.

Managers can attempt to make each shrubland suitable for a variety of shrubland bird species by managing for a diversity of vegetation densities that are most suited for the growing conditions of each shrubland. It may not be possible or feasible to increase vegetation diversity in a shrubland composed of homogenous growing conditions; here, the best option for increasing vegetation diversity is to identify opportunities within the surrounding 500 m landscape where additional shrublands can be created or maintained on sites that can support different and complimentary vegetation conditions.

Except for blue-winged warblers, vegetation species composition did not predict the occurrence of focal shrubland birds (Fig 3). In my study area, shrubland bird richness has been shown to increase as the proportion of invasive shrubs (e.g., *Frangula alnus*, *Eleagnus umbellata*, *Lonicera* spp.) in a shrubland increases from zero to about 55% of the total shrub cover (Tarr 2017, Bauer 2018). My study did not indicate this response for the shrubland bird species, likely because I measured the percent cover of native and invasive shrubs as a proportion of total vegetation cover (including grasses, forbs, ferns, trees, bare ground, and open water), and both Bauer (2018) and Tarr (2017) measured native/invasive shrub cover as a proportion of total shrub cover only. As a result, my sites averaged 7% *Non-native shrub cover* and 33% *Native shrub cover* which may explain why *Species Richness* increased with vegetation structure and not vegetation species composition. Blue-winged warblers responded positively to increasing proportions of *Non-native shrub cover* (Fig 3), but because non-native shrubs were most abundant in old fields, the shrubland type where blue-winged warblers were most predictable, I cannot conclude whether they were responding specifically to *Non-native shrub* cover or the high vegetation densities of old fields, coinciding with King et al. (2009b). Overall, my results indicate that vegetation density and height was more important for influencing shrubland bird distribution than was the native/non-native shrub composition in shrublands.

4.3. Shrubland Birds Occur More Predictably in Larger Shrublands

Most bird species occurred with increasing predictability as shrubland size increased above 0.8 ha (Fig 8). I predicted bird occurrence would increase with shrubland size because larger shrublands should provide birds with a lower risk of edge effects such as nest predation (King and Byers 2002, DeGraaf and Yamasaki 2003), and compared to smaller shrublands, they are more likely to support a greater variety of microhabitats that support shrubland birds (Rodewald and Vitz 2005, Chandler et al. 2009*b*, Singer et al. 2012). Chestnut-sided warblers and blue-winged warblers were the exceptions to the pattern of greater predictability in response to larger shrubland size (Fig 8). Chestnut-sided warbler occurrence became less predictable when shrubland size exceeded 7.8 ha (Fig 8), likely explained by the fact that most shrublands larger than 7.8 ha in my study were sand and gravel mines where the microhabitats preferred by chestnut sided-warblers were uncommon. Similarly, blue-winged warbler occurrence was largely unresponsive to differences in shrubland size, likely because they occurred most predictably in old fields (Fig 2) characterized by *All Vegetation Very Dense and Tall*, a microhabitat type that was uncommon in the larger ROW and sand and gravel mines in my study. Although, by not limiting the shrubland size during my study to a maximum value, the sand and gravel mines, averaging 17.3 ha may have swayed the predicted occurrence of the blue-winged warbler and chestnut-sided warbler, since the sand and gravel mines were significantly larger than all other shrubland types except ROW's. Managing for large shrublands has long been a conservation strategy to increase shrubland bird species richness (DeGraaf and Yamasaki 2003, Shake et al. 2012, Roberts and King 2017) and my findings agree with this strategy.

5. CONCLUSION AND MANAGEMENT RECOMMENDATIONS

My study was done in the southeastern seacoast of New Hampshire and my results may not be applicable to northern or southern areas based on forest types, soil composition and because this area is the northernmost range of the blue-winged warblers, eastern towhees, and prairie warblers (Dunn and Alderfer 2011). The presence and absence of the blue-winged warblers, eastern towhees, and prairie warblers may have been affected by their availability earlier or later in the breeding season in this northernmost range of their habitat. No shrubland bird in my study had a modeled response to *Forest* in the surrounding landscape and only the chestnut-sided warbler had a response to site-specific *Tree cover* (negative). I suspect in heavily forested areas the shrubland bird occurrences would be less, as found in other studies (Costello et al. 2000, Chandler 2006), than the shrubland bird occurrences in the seacoast of New Hampshire, possibly based on the extent of the surrounding forest, size and type of opening, and a lack of alternate shrublands within the surrounding landscape.

Increased shrubland size and increasing vegetation density should be considered during the planning stages of conservation site selection for shrubland birds, as most of the shrubland birds responded positively to an increase in *Size* and *Vegetation Density*. Because shrubland *Size* did not correlate to *Vegetation Density,* the predicted occurrence of the shrubland birds to shrubland *Size* are based on the species habitat preferences to other site-specific and surrounding landscape features. Most species predicted occurrence were in response to surrounding landscape features (Fig 4) yet evaluating an appropriate size for shrubland bird conservation based on surrounding landscape features of up to 10 km is unreasonable for most applications. Focusing on the site-specific features (*Size* and *Vegetation Density*) and adjacent surrounding landscape features (*Shrublands, Urban Development, Field/Pasture*) that best predicted most species occurrences may be best when making a conservation decision regarding shrubland birds. Also, the trend of increasing *Urban Development* and *Field/Pastures* as *Shrubland* decreases in the adjacent surrounding landscape needs to be examined more closely. By combining the site-specific and adjacent surrounding landscape features the birds are responding to, managers may be able to determine if the size of a shrubland can be ‘extended’ with limited consideration to local surrounding landscape features to increase the shrubland.

More study is also needed for shrubland bird conservation within sand and gravel mines and ROW’s which seem to have high value to shrubland birds. Incorporating anthropogenic shrublands maintained in a shrubby condition, such as ROW, or slow growing for an extended time, such as sand and gravel mines (Rehounková and Prach 2006), should be considered as primary conservation areas for shrubland birds. Generally, increasing shrub (native or exotic) density within the shrubland habitat increases the predicted occupancy of most of the shrubland bird species we studied.

LITERATURE CITED

Akresh, M. E., D. I. King, and R. T. Brooks. 2015. Demographic response of a shrubland bird to habitat creation, succession, and disturbance in a dynamic landscape. Forest Ecology and Management 336:72–80.

Anderson, S. H., K. Mann, and H. H. Shugart. 1977. Effect of transmission-line corridors on bird populations. American Midland Naturalist 97:216–221.

Askins, R. A. 2001. Sustaining biological diversity in early successional communities: The challange of managing unpopular habitats. Wildlife Society Bulletin 29:407–412.

Askins, R. A., C. M. Folsom-O’Keefe, and M. C. Hardy. 2012. Effects of vegetation, corridor width and regional land use on early successional birds on powerline corridors. PloS one 7:e31520. <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3282771&tool=pmcentrez&rendertype=abstract>. Accessed 2 Feb 2014.

Askins, R. A., B. Zuckerberg, and L. Novak. 2007. Do the size and landscape context of forest openings influence the abundance and breeding success of shrubland songbirds in southern New England? Forest Ecology and Management 250:137–147.

Bauer, M. L. 2018. Assessing the effects of habitat restoration on shrubland specialists: Case study on the New England cottontail and shrubland birds. Thesis, University of New Hampshire, Durham, New Hampshire.

Best, L. B. 1977. Territory quality and mating success in the field sparrow (*Spizella pusilla*). American Ornithological Society 79:192–204.

Borgegard, S. 1990. Vegetation development in abandoned gravel pits: Effects of surrounding vegetation, substrate, and regionality. Journal of Vegetation Science 1:675–682.

Bulluck, L. P., and D. A. Buehler. 2006. Avian use of early successional habitats: Are regenerating forests, utility right-of-ways and reclaimed surface mines the same? Forest Ecology and Management 236:76–84.

Burghardt, K. T., D. W. Tallamy, and W. Gregory Shriver. 2009. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. Conservation Biology 23:219–224.

Burghardt, K. T., D. W. Tallamy, C. Philips, and K. J. Shropshire. 2010. Non-native plants reduce abundance, richness, and host specialization in lepidopteran communities. Ecosphere 1:art11.

Burhans, D. E., and F. R. Thompson III. 2006. Songbird abundance and parasitism differ between urban and rural shrublands. Ecological Society of America 16:394–405.

Byers, B. E., H. L. Mays, and D. F. Westneat. 2004. Extrapair paternity increases variability in male reproductive success in the chestnut-sided warbler (*Dendroica pensylvanica*), a socially monogamous songbird. The Auk 121:788–795.

Chandler, R. B. 2006. Early-successional shrubland bird abundance and nesting success in managed shrublands on the White Mountain National Forest. Thesis, University of Massachusetts. Amherst, MA.

Chandler, R. B., D. I. King, and C. C. Chandler. 2009*a*. Effects of management regime on the abundance and nest survival of shrubland birds in wildlife openings in northern New England, USA. Forest Ecology and Management 258:1669–1676.

Chandler, R. B., D. I. King, and S. Destefano. 2009*b*. Scrub–shrub bird habitat associations at multiple spatial scales in beaver meadows in Massachusetts. The Auk 126:186–197.

Confer, J. L., and S. M. Pascoe. 2003. Avian communities on utility rights-of-ways and other managed shrublands in the northeastern United States. Forest Ecology and Management 185:193–205.

Costello, C. A., M. Yamasaki, P. J. Pekins, W. B. Leak, and C. D. Neefus. 2000. Songbird response to group selection harvests and clearcuts in a New Hampshire northern hardwood forest. Forest Ecology and Management 127:41–54.

DeGraaf, R. M., and M. Yamasaki. 2003. Options for managing early-successional forest and shrubland bird habitats in the northeastern United States. Forest Ecology and Management 185:179–191.

Dettmers, R. 2003. Status and conservation of shrubland birds in the northeastern US. Forest Ecology and Management 185:81–93.

Dunn, J. L., and J. Alderfer. 2011. National Geographic field guide to birds of North America. 6th edition. National Geographic Society, Washington D.C.

Fickenscher, J. L., J. A. Litvaitis, T. D. Lee, and P. C. Johnson. 2014. Insect responses to invasive shrubs: Implications to managing thicket habitats in the northeastern United States. Forest Ecology and Management 322:127–135.

Fuller, S., and A. Tur. 2012. Conservation strategy for the New England cottontail (*Sylvilagus transitionalis*). <https://newenglandcottontail.org/sites/default/files/research_documents/conservation_strategy_final_12-3-12.pdf>. Accessed 13 Nov 2018.

Gifford, N. A., J. M. Deppen, and J. T. Bried. 2010. Importance of an urban pine barrens for the conservation of early-successional shrubland birds. Landscape and Urban Planning 94:54–62.

Hagan, J. M., and A. L. Meehan. 2002. The effectiveness of stand-level and landscape-level variables for explaining bird occurrence in an industrial forest. Forest Science 48:231–242.

Heckscher, C. M. 2004. Veery nest sites in a Mid-Atlantic piedmont forest: Vegetative physiognomy and use of alien shrubs. The American Midland Naturalist 151:326–337.

Herrera, C. M. 1982. Seasonal variation in the quality of fruits and diffuse coevolution between plants and avian dispersers. Ecology 63:773–785.

Hinsley, S. A., P. E. Bellamy, I. Newton, and T. H. Sparks. 1995. Habitat and landscape factors influencing the presence of individual breeding bird species in woodland fragments. Journal of Avian Biology 26:94–104.

Hostetler, M., and K. Knowles-Yanez. 2003. Land use, scale, and bird distributions in the Phoenix metropolitain area. Landscape And Urban Planning 62:55–68.

Howe, H. F., and G. F. Estabrook. 1977. On intraspecific competition for avian dispersers in tropical trees. The American Naturalist 111:817–832.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440–455.

James, F. C. 1971. Ordinations of habitat relationships among breeding birds. The Wilson Bulletin 83:215–236.

Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. The American Naturalist 105:423–435.

King, D. I., and B. E. Byers. 2002. An evaluation of powerline rights-of-way as habitat for early-successional shrubland birds. Wildlife Society Bulletin 30:868–874.

King, D. I., R. B. Chandler, J. M. Collins, W. R. Petersen, and T. E. Lautzenheiser. 2009*a*. Effects of width, edge and habitat on the abundance and nesting success of scrub-shrub birds in powerline corridors. Biological Conservation 142:2672–2680.

King, D. I., R. B. Chandler, S. Schlossberg, and C. C. Chandler. 2009*b*. Habitat use and nest success of scrub-shrub birds in wildlife and silvicultural openings in western Massachusetts, USA. Forest Ecology and Management 257:421–426.

King, D. I., and R. M. DeGraaf. 2004. Effects of group-selection opening size on the distribution and reproductive success of an early-successional shrubland bird. Forest Ecology and Management 190:179–185.

Kroodsma, R. L. 1982. Bird community ecology on power-line corridors in east Tennessee. Biological Conservation 23:79–94.

Kruskal, J. B. 1964. Nonmetric Multidimensional Scaling: A Numerical Method. Psychometrika 29:115–129.

LANDFIRE. 2014. CONUS LANDFIRE Existing vegetation height. LANDFIRE v1.4.0. <https://www.landfire.gov/evh.php>. Accessed 7 Feb 2015.

Lehnen, S. E., and A. D. Rodewald. 2009*a*. Investigating area-sensitivity in shrubland birds: Responses to patch size in a forested landscape. Forest Ecology and Management 257:2308–2316.

Lehnen, S. E., and A. D. Rodewald. 2009*b*. Dispersal , interpatch movements, and survival in a shrubland breeding bird community. Journal of Field Ornithology 80:242–252.

Litvaitis, J. A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7:866–873.

MacArthur, R. H., J. W. MacArthur, and J. Preer. 1962. On bird species diversity II. Prediction of bird census from habitat measurements. American Naturalist 96:167–174.

McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, Oregon, USA.

McCune, B., and M. J. Mefford. 2009. Hyperniche: Multiplicative Habitat Modeling. MjM Software Design, Gleneden Beach, Oregon, USA.

Motzkin, G., and D. R. Foster. 2002. Grasslands, heathlands and shrublands in coastal New England: Historical interpretations and approaches to conservation. Journal of Biogeography 29:1569–1590.

Nolan, V. 1978. The ecology and behavior of the prairie warbler (*Dendroica discolor*). First edition. The American Ornithologists Union, Lawrence, KS.

Oehler, J. D., D. F. Covell, S. Capel, and B. Long. 2006. Managing grasslands, shrublands and young forests for wildlife. A guide for the Northeast. The Northeast Upland Habitat Technical Committee, Westboro, MA.

Oneal, A. S., and J. T. Rotenberry. 2009. Scale-dependent habitat relations of birds in riparian corridors in an urbanizing landscape. Landscape and Urban Planning 92:264–275.

Pendleton, R. L., B. K. Pendleton, and D. Finch. 2011. Displacement of native riparian shrubs by woody exotics: Effects on arthropod and pollinator community composition. Natural Resources and Environmental Issues 16:197–208.

Rehounková, K., and K. Prach. 2006. Spontaneous vegetation succession in disused gravel-sand pits: Role of local site and landscape factors. Journal of Vegetation Science 17:583–590.

Roberts, H. P., and D. I. King. 2017. Area requirements and landscape-level factors influencing shrubland birds. Journal of Wildlife Management 81:1298–1307.

Rodewald, A. D., and A. C. Vitz. 2005. Edge and area sensitivity of shrubland birds. The Journal of Wildlife Management 69:681–688.

Rodewald, A. D., and R. H. Yahner. 2001. Influence of landscape composition on avian community. Ecology 82:3493–3504.

Rosenberg, K. V., J. A. Kennedy, R. Dettmers, R. P. Ford, D. Reynolds, J. D. Alexander, C. J. Beardmore, P. J. Blancher, R. E. Bogart, G. S. Butcher, A. F. Camfield, A. Couturier, D. W. Demarest, W. E. Easton, J. J. Giocomo, R. H. Keller, A. E. Mini, A. O. Panjabi, D. N. Pashley, T. D. Rich, J. M. Ruth, H. Stabins, J. Stanton, and T. Will. 2016. Partners in Flight Landbird Conservation Plan: 2016 Revision for Canada and Continental United States. Partners in Flight Science Committee 119 pp.

Rotenberry, J. T. 1985. The role of habitat in avian community composition: physiognomy or floristics? Oecologia 67:213–217.

Rudnicky, T. C., and M. L. Hunter. 1993. Reversing the fragmentation perspective: Effects of clearcut size on bird species richness in Maine. Ecological Applications 3:357–366.

Schlossberg, S. 2009. Site fidelity of shrubland and forest birds. The Condor 111:238–246.

Schlossberg, S., and D. I. King. 2007. Ecology and management of scrubshrub birds in New England: A comprehensive review. USDA Natural Resources Conservation Service Resource Inventory and Assessment Division. Amherst, MA.

Schlossberg, S., and D. I. King. 2010. Effects of invasive woody plants on avian nest site selection and nesting success in shrublands. Animal Conservation 13:286–293.

Schlossberg, S., D. I. King, R. B. Chandler, and B. A. Mazzei. 2010. Regional synthesis of habitat relationships in shrubland birds. Journal of Wildlife Management 74:1513–1522.

Shake, C. S., C. E. Moorman, and M. R. Burchell. 2011. Cropland edge, forest succession, and landscape affect shrubland bird nest predation. Journal of Wildlife Management 75:825–835.

Shake, C. S., C. E. Moorman, J. D. Riddle, and M. R. Burchell II. 2012. Influence of Patch Size and Shape on Occupancy by Shrubland Birds. The Condor 114:268–278.

Singer, M. S., T. E. Farkas, C. M. Skorik, and K. A. Mooney. 2012. Tritrophic interactions at a community level: Effects of host plant species quality on bird predation of caterpillars. American Society of Naturalists 179:363–374.

Skowno, A. L., and W. J. Bond. 2003. Bird community composition in an actively managed savanna reserve importance of vegetation structure and vegetation composition. Biodiversity and Conservation 12:2279–2294.

Smith, S. B., S. A. DeSando, and T. Pagano. 2013. The value of native and invasive fruit-bearing shrubs for migrating songbirds. Northeastern Naturalist 20:171–184.

Sperduto, D. D., and W. F. Nichols. 2012. Natural communities of New Hampshire. 2nd edition. NH Natural Heritage Bureau, Concord, NH. Pub. UNH Cooperative Extension, Durham, NH.

Stoleson, S. H., and D. M. Finch. 2001. Breeding bird use of and nesting success in exotic Russian olive in New Mexico. The Wilson Bulletin 113:452–455.

Tarr, M. D. 2017. Effects of alien shrubs on caterpillars and shrubland-dependent passerines within three transmission line rights-of-way in southeastern New Hampshire. Dissertation, University of New Hampshire, Durham, NH.

Taylor, C. M., and W. E. Taylor. 1979. Birds of upland openings. Management of north central and northeastern forests for nongame birds, workshop proceedings, 21-25 January 1979, Minneapolis, MN. USDA Forest Service General Technical Report NC-51 Costello.

Thompson, F. R., and R. M. DeGraaf. 2001. Conservation approaches for woody, early successional communities in the eastern United States. Wildlife Society bulletin 29:483–494.

U.S. Fish and Wildlife Service. 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management. Arlington, Virginia. 85 pp.

Whitaker, D. M., and I. G. Warkentin. 2010. Spatial ecology of migratory passerines on temperate and boreal forest breeding grounds. The Auk 127:471–484.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017–1029.

APPENDIX A

Shrubland site-specific features for sand and gravel mines (S&GM), transmission line rights-of-way (ROW), old fields (OF), and clearcuts (CC). Size range (ha) and Species Richness are included and are not considered site-specific features.

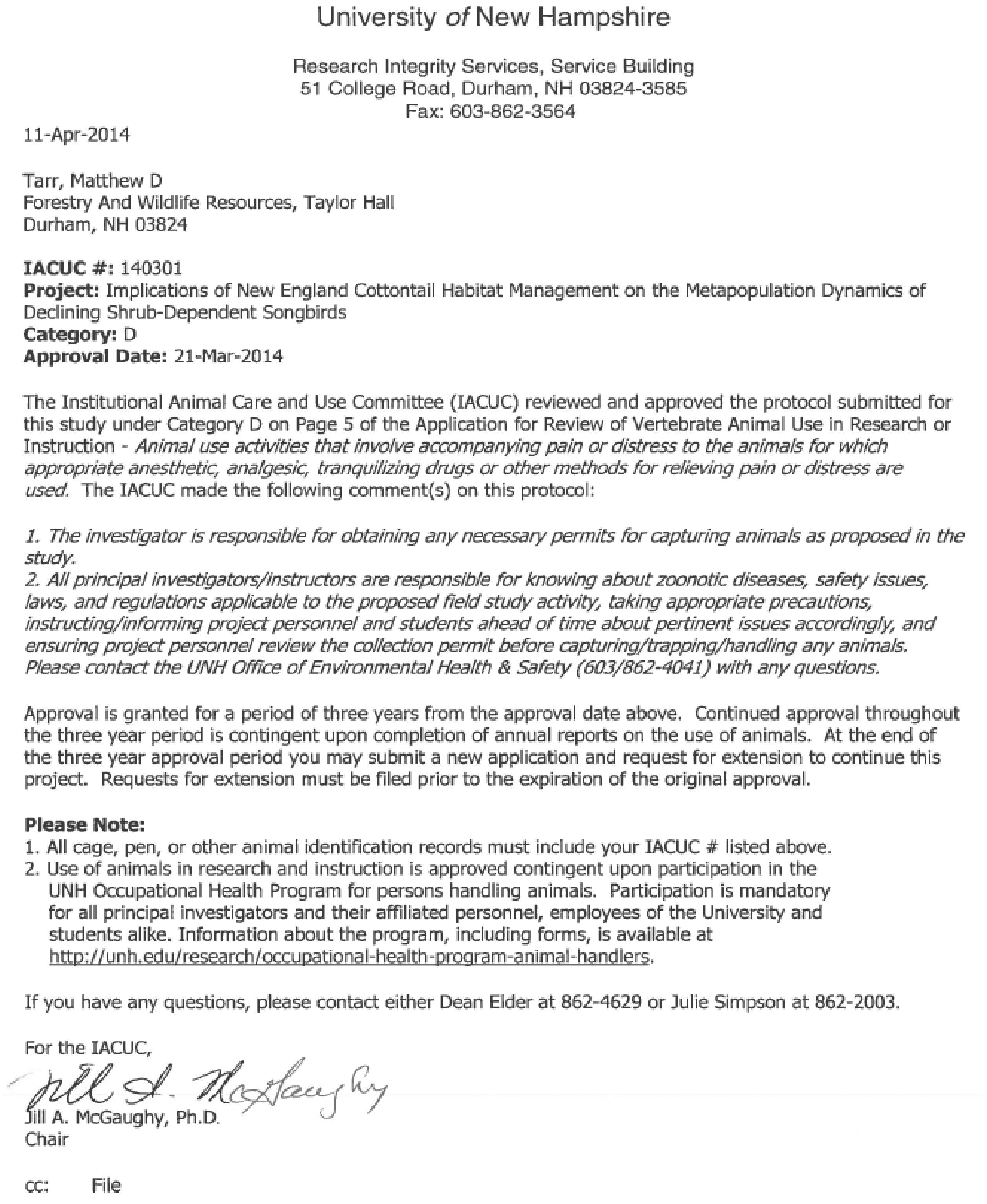
Variable	Range	S&GM Average	ROW Average	OF Average	CC Average	Overall Average
Size (ha)	1-91	17.3	7.77	6.87	6.66	9.7
Size range (ha)		2-91	1-26	1-22	1-24	9.7
Perimeter (km)	0.4-12	2.2	3.1	1.4	1.3	1.9
Vegetation density	0-3	0.82	1.78	1.79	1.54	1.5
Open Water cover (%)	0-4	0	0.3	0.3	0.2	0.2
Bare Ground cover (%)	2-85	59.6	26.6	20.9	35.3	35.6
Grass cover (%)	1-91	24.2	25.6	55.7	30.5	34
Fern cover (%)	0-48	1.2	20.2	7.2	8.8	9.4
Native Shrub cover (%)	1-82	23.8	45	27.2	37.3	33.3
Non-native shrub cover (%)	0-43	2.4	8.7	8.2	8.7	7
Tree cover (%)	0-38	7.5	4.4	5.7	11.9	7.4
Forb cover (%)	1-68	25.8	30.1	44.5	32	33.1
Species Richness	1-8	5.4	5.2	4.4	4.1	4.8

APPENDIX B

Shrubland surrounding landscape features, ranges and averages for sand and gravel mines (S&GM), transmission line rights-of-way (ROW), old fields (OF), and clearcuts (CC).

Variable	Range (%)	S&GM Averages (%)	ROW Averages (%)	OF Averages (%)	CC Averages (%)	Overall Average (%)
50m agriculture	0-1	0.00	0.11	0.06	0.00	0.04
50m field/pasture	0-62	3.70	7.06	17.86	4.24	8.21
50m open water	0-4	0.26	0.20	0.10	0.06	0.16
50m shrubs	0-71	28.79	8.02	12.77	4.68	13.57
50m tidal vegetation	0-5	0.07	0.10	0.07	0.49	0.18
50m forest	9-100	55.82	66.46	47.08	81.63	62.75
50m urban development	0-72	11.38	18.04	22.06	8.90	15.09
250m agriculture	0-1	0.01	0.13	0.05	0.02	0.05
250m field/pasture	0-44	6.14	8.04	14.33	8.98	9.37
250m open water	0-13	0.57	1.07	0.76	0.20	0.65
250m shrubs	0-38	15.84	4.68	7.44	6.59	8.64
250m tidal vegetation	0-2	0.12	0.11	0.08	0.16	0.12
250m forest	6-99	65.21	63.17	52.72	70.29	62.85
250m urban development	0-81	12.11	22.79	24.63	13.76	18.32
500m agriculture	0-3	0.01	0.13	0.25	0.03	0.11
500m field/pasture	1-37	6.03	8.85	11.86	12.06	9.70
500m open water	0-20	0.36	1.66	1.17	0.52	0.93
500m shrubs	0-33	11.14	4.58	6.08	6.17	6.99
500m tidal vegetation	0-1	0.10	0.06	0.06	0.13	0.09
500m forest	10-92	68.12	59.78	54.78	65.04	61.93
500m urban development	0-73	14.23	24.93	25.80	16.05	20.25
1km agriculture	0-4	0.13	0.10	0.34	0.13	0.17
1km field/pasture	1-36	6.92	9.66	10.52	12.87	9.99
1km open water	0-20	0.42	2.34	1.07	1.41	1.31
1km shrubs	1-20	8.85	5.15	5.57	5.43	6.25
1km tidal vegetation	0-2	0.25	0.13	0.06	0.16	0.15
1km forest	10-91	70.29	57.19	57.01	63.61	62.03
1km urban development	3-77	13.15	25.43	25.44	16.38	20.10
5km agriculture	0	0.14	0.15	0.22	0.20	0.18
5km field/pasture	3-15	7.66	9.05	11.08	10.12	9.48
5km open water	0-18	2.22	2.90	2.33	3.47	2.73
5km shrubs	3-8	5.70	5.18	5.73	5.20	5.45
5km tidal vegetation	0-1	0.16	0.20	0.17	0.22	0.19
5km forest	32-89	71.27	61.88	58.44	62.92	63.63
5km urban development	4-42	12.85	20.64	22.03	17.87	18.35
10km agriculture	0	0.16	0.16	0.18	0.18	0.17
10km field/pasture	3-13	7.30	8.48	10.18	9.64	8.90
10km open water	1-35	3.92	3.89	4.39	5.27	4.37
10km shrubs	3-6	5.01	5.02	5.35	5.16	5.13
10km tidal vegetation	0-1	0.19	0.24	0.23	0.27	0.23
10km forest	32-85	70.57	67.81	62.27	64.58	66.30
10km urban development	5-21	12.86	14.41	17.39	14.90	14.89

APPENDIX C



University *of* New Hampshire

Research Integrity Services, Service Building
51 College Road, Durham, NH 03824-3585
Fax: 603-862-3564

11-Apr-2014

Tarr, Matthew D
Forestry And Wildlife Resources, Taylor Hall
Durham, NH 03824

IACUC #: 140301
Project: Implications of New England Cottontail Habitat Management on the Metapopulation Dynamics of Declining Shrub-Dependent Songbirds
Category: D
Approval Date: 21-Mar-2014

The Institutional Animal Care and Use Committee (IACUC) reviewed and approved the protocol submitted for this study under Category D on Page 5 of the Application for Review of Vertebrate Animal Use in Research or Instruction - *Animal use activities that involve accompanying pain or distress to the animals for which appropriate anesthetic, analgesic, tranquilizing drugs or other methods for relieving pain or distress are used.* The IACUC made the following comment(s) on this protocol:

1. The investigator is responsible for obtaining any necessary permits for capturing animals as proposed in the study.
2. All principal investigators/instructors are responsible for knowing about zoonotic diseases, safety issues, laws, and regulations applicable to the proposed field study activity, taking appropriate precautions, instructing/informing project personnel and students ahead of time about pertinent issues accordingly, and ensuring project personnel review the collection permit before capturing/trapping/handling any animals. Please contact the UNH Office of Environmental Health & Safety (603/862-4041) with any questions.

Approval is granted for a period of three years from the approval date above. Continued approval throughout the three year period is contingent upon completion of annual reports on the use of animals. At the end of the three year approval period you may submit a new application and request for extension to continue this project. Requests for extension must be filed prior to the expiration of the original approval.

Please Note:

1. All cage, pen, or other animal identification records must include your IACUC # listed above.
2. Use of animals in research and instruction is approved contingent upon participation in the UNH Occupational Health Program for persons handling animals. Participation is mandatory for all principal investigators and their affiliated personnel, employees of the University and students alike. Information about the program, including forms, is available at http://unh.edu/research/occupational-health-program-animal-handlers.

If you have any questions, please contact either Dean Elder at 862-4629 or Julie Simpson at 862-2003.

For the IACUC,

Jill A. McGaughy

Jill A. McGaughy, Ph.D.
Chair

cc: File