Forest Interior Bird Habitat Relationships in the Pennsylvania Wilds

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Abstract

The Pennsylvania Wilds region, located in the state's northern tier, holds the largest intact forests in the state and contains the largest remaining strongholds of forest interior bird populations in Pennsylvania. Migratory breeding species like Swainson's thrush, black-throated blue warbler, and scarlet tanager are among the species threatened by forest fragmentation within the region. Many of the largest tracts of forest are managed by state and federal agencies with an interest in bird habitat conservation, and this study was designed to inform forest managers about the densities of forest interior bird species in these forests. During the 2015 breeding season, we surveyed forest birds across seven agency-defined forest types within conifer, oak, and northern hardwoods forest groups and conducted simultaneous forest community rapid assessments, validating community classifications and measuring forest structure. We estimated detection-corrected densities for 34 bird species using R package 'detect' and identified significant associations with forest community types for management applications. We used boosted regression trees (BRT) to evaluate the response of detection-corrected densities of 22 bird species to 45 habitat attributes. Among the 21 forest attributes selected in the best species models, only forest community type was included for all 22 bird species, and it was the most important variable in models for all but scarlet tanager with 42-98% contribution. Aspect, elevation, tall and short shrub cover, snags and basal area (ft^2/ac) were also among the most influential features. By demonstrating that forest interior bird densities are influenced by agency-used forest community classifications and structural attributes, we can provide forest managers with information to help them better manage habitats for forest interior birds.

Objective

The objective of this study was to document the patterns of occurrence and densities of interior forest bird species away from roads in the Pennsylvania Wilds region. By quantifying relationships between bird densities and forest community types, forest structural features, and other site characteristics, this study provides information to forest managers about which bird species occur in different forest types, and which habitat characteristics are most important to these bird species.

Justification

The twelve county Pennsylvania Wilds region of north-central Pennsylvania (http://pawilds.com/) contains the largest remaining strongholds of forest bird populations in Pennsylvania (Wilson et al. 2012). Between 2010 and 2013 the National Audubon Society conducted an analysis of the largest remaining forests in the Atlantic Flyway, and this resulted in a series of new Important Bird Areas (IBAs) being adopted for Pennsylvania in May 2014. The three largest of these new Forest Block IBAs all lie within the Pennsylvania Wilds, reflecting the significance of the region for forest birds at the continental scale. This region is especially important for bird species with northern distributions for which Pennsylvania is at or near the southern geographic limit of their breeding range, such as Canada warbler (*Cardellina canadensis*).

At the same time, the large, relatively intact forests within the Pennsylvania Wilds which these birds rely on are under threat from a variety of causes. Fragmentation resulting from shale gas drilling and associated infrastructure development is the largest current threat. For example, in Tioga County between 2004 and 2010, 310 km of edges were created as a result of energy development, and the number of forest patches increased from 3,079 to 3,292 (Slonecker et al. 2013). This pattern is expected to continue in the future as shale gas development progresses north and west through the Wilds (Johnson et al. 2010), although there has been a recent decrease in the rate of shale gas development. The increase in edge and decline in core forest area are likely to result in changes in forest bird communities as has been shown for conventional gas development (Brittingham and Goodrich 2010). Thomas et al. (2014) recently showed that high densities of shallow oil and gas wells result in the homogenization of forest bird communities as edge associated ("synanthropic") bird species become common in highly fragmented forests.

Audubon Pennsylvania (APA) and Western Pennsylvania Conservancy (WPC) proposed to conduct surveys for forest birds at sites in the Pennsylvania Wilds region to assess avian community composition, provide baselines for evaluating development and fragmentation impacts, determine the relationships between richness and densities of forest interior birds and current forest community classifications used to manage state and federal forest lands, and to identify landscape features associated with higher densities of interior forest bird species. We used an off-road avian point count protocol that WPC had implemented over the previous two years to establish baselines of abundance and diversity for forest birds at sites of high ecological value. This protocol is similar to protocols employed by other researchers in the region which may enable our data to be aggregated with other studies, including the recent Second Pennsylvania Breeding Bird Atlas (Wilson et al. 2012); all data will be made available to other statewide efforts. These surveys are specifically intended to support future management decisions and conservation strategies of the Pennsylvania Department of Conservation and Natural Resources (DCNR) and the Pennsylvania Game Commission (PGC), as well as private forest managers, to maintain and enhance forest quality in Pennsylvania as forest bird habitat. Linking forest bird densities to current forest stand types will yield a new way to manage forests and activities that can directly benefit interior forest birds and other birds of conservation concern. We hope that our results will be incorporated into management tools like the PA Game Lands Management Tool, SILVAH, and other similar land management planning tools.

Materials and Methods

Bird Surveys

Within the PA Wilds region, bird survey sites were selected from within WPC areas of high ecological value (highest 10% in physiographic section) from a GIS Ecological Value Analysis (EVA) and Audubon PA Forest Block Important Bird Areas (IBA). Points were selected from within seven forest community types and stratified by elevation and ecoregion. The focus for surveys were forest interior species of birds – those which require large, intact forest patches to maintain healthy populations. Within forest communities, forest interior patches from the TNC/WPC analysis of Pennsylvania forest patches (2011) were selected to ensure all points were placed inside core forest. Using these forest interior patches, all survey points were placed at least 100 m from the forest edge. The Geospatial Modeling Environment (GME) suite of tools was used with R statistical software and ArcGIS to generate non-overlapping survey points spaced at a minimum of 250 m to adequately cover each interior forest patch selected as a survey site (Ralph et al. 1993, Ralph et al. 1995, Hamel et al. 1996, Martin et al. 1997, Heckscher 2000, Forcey et al. 2006). Manual adjustments were made as needed to maximize sample size. We surveyed 711 points at 39 sites (Figure 1).

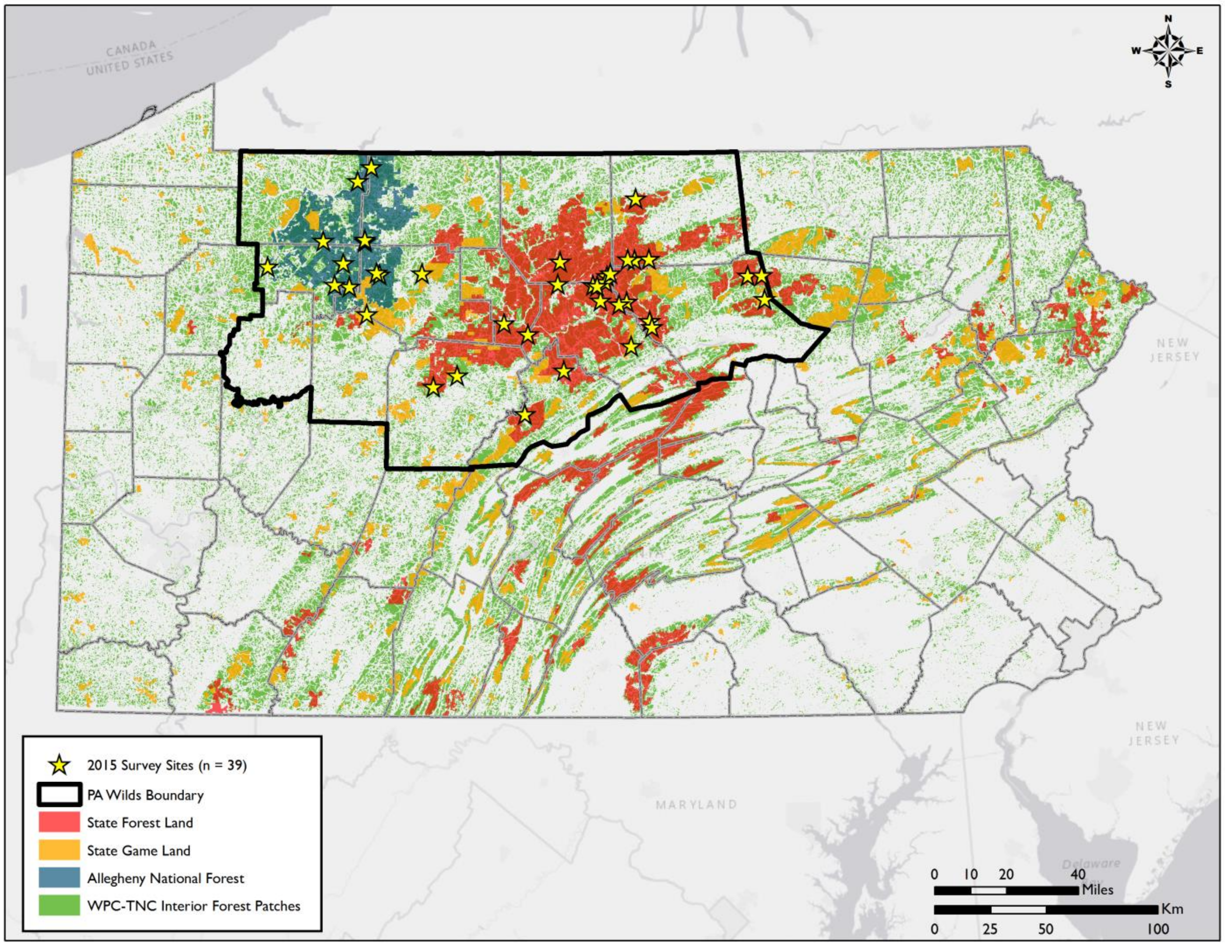

Figure 1. Selected survey sites (stars) are shown within the Wilds region of Pennsylvania.

Point count surveys were conducted during the height of the avian breeding season in Pennsylvania forests, between late May and mid-July (Wilson et al. 2012) of 2015. Each point count location was surveyed twice during the season to account for intra-season variation and variation in bird detectability through time. Each round occurred during the following periods: 25 May – 18 June (early season) and 19 June – 17 July (late season). Surveys were completed during the first five hours after sunrise when detection rates are most stable, generally between 0500 and 1000 EST (Ralph et al. 1993, Ralph et al. 1995, Wilson et al. 2012). Weather and wind conditions were recorded during each count following the Beaufort scale and standard weather codes, and no surveys were conducted during high wind conditions (>12 mph), dense fog, steady drizzle, snow, or prolonged rain (Martin et al. 1997).

Surveys at each point location were 5 minutes in duration, with counts split between an initial 3-minute period and the following 2-minute period. All birds seen or heard within a 50 meter radius of each point were counted (Buskirk and McDonald 1995, Ralph et al. 1993, Ralph et al. 1995, Martin et al. 1997, Dettmers et al. 1999, Heckscher 2000), and birds were recorded in two subsequent distance bands 50-100m, and beyond 100m to enable density estimates to be made. Birds observed flying above the canopy or through the habitat and new species encountered between points were recorded separately (Ralph et al. 1995). Detections were recorded as singing, calling or visual. We recorded weather and wind conditions at each point following the Beaufort scale and standard weather codes, and no surveys were conducted during high wind conditions (>12 mph), dense fog, steady drizzle, snow, or prolonged rain (Martin et al. 1997).

This protocol enabled the completion of 15-20 points per morning, depending on travel (walking) time between points as dictated by the navigability of the forest terrain.

Rapid Vegetation Assessments

We conducted rapid vegetation assessments at each point count location following modifications of Hamel et al. (1996) and Martin et al. (1997). These habitat evaluations were conducted concurrently with point count bird surveys. Vegetation estimates were made for a 25m radius plot and disturbance was assessed for a 50m radius plot, both centered on the point count location.

At the center of each point count location, elevation, aspect and slope were measured using LiDAR derived GIS layers. Vegetation cover was classified according NatureServe categories: leaf type (broad-leaf, semi-broad-leaf, semi-needle-leaf, needle-leaf, broad-leaf herbaceous, graminoid, pteridophyte), leaf phenology (deciduous, semi-deciduous, evergreen, perennial, annual) and physiognomic type (forest, woodland, sparse woodland, scrub thicket, shrubland, dwarf shrubland, dwarf scrub thicket, sparse dwarf shrubland, herbaceous, non-vascular, sparsely vegetated). Forest community types were determined according to Fike et al. (1999). Each of the following were visually estimated for overstory canopy (>15m), midstory (5-15m), tall shrub (2-5m), short shrub (0.5-2m), herbaceous, non-vascular, and vine: categorical percent cover (Rare = 0-<1%, 1=1-5%, 2-=6-12%, 2+=13-25%, 3=26-50%, 4=51-75%, 5=76-100%), height (1=<0.5m, 2=0.5-1m, 3=1-2m, 4=2-5m, 5=5-10m, 6=10-15m, 7=15-20m, 8=20-35m, 9=35-50m, 10=>50m), and dominant plant species (≥ 40% cover) in each strata. We visually estimated percent ground cover for bedrock, large rocks, small rocks, sand, litter/duff, wood, water, bare soil, and bryophytes. Cowardin system was recorded, indicating upland versus palustrine, lacustrine, or riverine wetlands and their subtypes. Similarly we noted soil texture and drainage type. Standing snags and live cavity trees were each counted within the 25m plot, along with the presence of water within 50m. The presence of invasive plant species was recorded, and if present, dominant invasive species were determined along with the estimation of percent cover.

One final standard element of our vegetation assessment was a rapid evaluation of disturbance. We recorded disturbance type and intensity within the 50m plot. Categorical percent cover (Rare = 0-<1%, 1=1-5%, 2-=6-12%, 2+=13-25%, 3=26-50%, 4=51-75%, 5=76-100%) was estimated for infrastructure (paved roads, unpaved roads, power lines, paved trails), ground disturbance (large ditch, small ditch, grading, equipment tracks), vegetation alteration (pine plantation, recent clearcut, logging within past

30 years, mowing, grazing, understory removal, deer browse), garbage, and natural disturbance (recent fire, blow downs, tree disease, tree pest, landslide).

Density Estimates

Point count surveys are one of the most common methods for counting terrestrial birds (Bart, 2005). As such there are a number of methods used to estimate density from these counts. To estimate density we relied upon a formulation of removal models and distance sampling models developed by Solymos et al. (2013). These models allowed us to calculate detection corrected species' density at the level of an individual point count location. Point count data were analyzed using the R (R Core Development Team 2014) extension package 'detect' (Solymos et al. 2013). The package is used to estimate two components of detection probability, availability and perceptibility, as well as the area sampled by your point count by determining the effective detection radius. Availability is the probability that a bird provides a visual or auditory cue during sampling and is thus available to be detected, and perceptibility is a conditional probability that birds available for detection are actually detected. The area sampled is a function of the effective detection radius which is the distance at which you are as equally likely to detect an individual as for an individual to go undetected. These three factors (two detection components and area sampled) are then used as offsets in a linear model framework to estimate density.

Availability was estimated by first stratifying the individual 5 minute point count observations into 2 time periods. The first time period encompassed the first 3 minutes at a point and a secondary time period consisted of the final two minutes at the point. Counts for each species were collapsed across distance categories within each time period, with each individual being counted only once during a time period such that individuals were 'removed' once detected. To determine the removal model structure that best estimates the availability offset from the species' specific counts a series of loglinear removal models were built by constructing all possible model forms that included the visit-level covariates Julian calendar date, time since local sunrise (tslr), wind speed, temperature, cloud cover and the quadratic terms for calendar data and tslr. These models were compared to each other using Akaike's Information Criterion (AIC). The model with the highest AIC weight was viewed as the best model and the availability offset calculated from this model was then applied to the density estimation.

Because we used an unlimited detection radius on our point counts we can assume that perceptibility is always equal to one (see Solymos et al. 2013). Thus for all species we applied an offset value of one during the density estimation. To calculate our final offset used in the estimation of density, effective area sampled, we began by breaking down species counts by point and survey into 3 distance bins consisting of observations ranging from 0 to 50 meters, 50 to 100 meters and distances greater than 100 meters. To determine the distance model structure that best estimates the effective detection radius from the species' specific counts a series of loglinear distance models, assuming a half normal detection function, were built by constructing all possible model forms that included the survey-level covariates forest type, forest group, surveyor and wind speed. These models were compared to each other using Akaike's Information Criterion (AIC). The model with the highest AIC weight was viewed as the best model and the effective detection radius offset calculated from this model was then applied to the density estimation.

Using the species' specific offsets calculated previously we then modeled the log of population density as a function of the covariates forest group, forest community and site:

$$\log(D_i) = X_i B,$$

Where *B* is a vector of the regression parameters corresponding to a column in the covariate matrix X. After species' density estimates were obtained we then compared across the 3 different forest groups (i.e. Conifer, Northern Hardwood and Oak Forests) and the 7 different forest types (i.e., Dry Oak –Mixed Hardwood, Dry Oak – Heath, Red Oak – Mixed Hardwood, Northern Hardwood, Black Cherry – Northern Hardwood, Red Maple, Hemlock – White Pine).

Boosted regression trees

In order to gain a better understanding of the habitat characteristics that relate to species density patterns we built a series of boosted regression tree models using 45 habitat covariates, the species count data from across the PA Wilds region and the species' specific offsets calculated during the previous density estimation.

For each species we began by simplifying the data set by removing habitat predictors that either displayed no variation or had only missing values at the sampled locations. We then proceeded to begin the process of tuning three BRT model parameters (learning rate*,* bag fraction and tree complexity) that would allow us to optimize the model for predictive purposes while avoiding overfitting the model to the data. We started this process by arbitrarily setting the bag fraction and tree complexity to 0.5 and 1 respectively. We then began the process of tuning the learning rate that allowed us to obtain a model containing at least 1000 trees while minimizing model deviance and/or the coefficient of variation (i.e. measures of loss). In the instance that the measures disagreed we went with the model deviance as our preferred measure of loss. Once this was achieved we then moved on to the bag fraction which typically is set between 0.5 and 0.75 (Elith el al. 2008). Beginning at 0.5 the bag fraction was increased by increments of 0.05 with model loss being compared between the current model run and the one that preceded it. If the model loss of the current model run was less than that of the previous run the bag fraction was increased again 0.05. Conversely, if the model loss of the current model run was greater than the previous run then the bag fraction of the previous run was chosen as the correct bag fraction moving forward. Once model loss was minimized for both the learning rate and the bag fraction parameters, tree complexity was tuned by increasing tree complexity by increments of 1. The tree complexity that minimized loss while maintaining at least 1000 trees in the model allowed us to then determine our best model.

An additional step in this process was then to remove any additional covariates from the best model that seemed to explain little model deviance. This was done using R package 'dismo' (Hijmans et al. 2015), which performs k-fold cross validation and automatically drops the lowest performing predictors from the model. The model that remains after this simplification step is then re-run and the model can be summarized. For the significant predictors we obtained confidence intervals about their predicted effect on density by performing 100 bootstrap samples. For the bootstrap samples we used representative values of the focal predictor and held all others at their mean value, using the mean offset for each level of the focal predictor.

Products delivered in addition to this final report

- Presentation at winter staff meeting of the DCNR Bureau of Forestry, January 2016, by Sarah Sargent (preliminary results)
- Abstract submitted and accepted for the North American Ornithological Congress (NAOC) VI, held August 16-20, 2016 in Washington, DC: **Forest Interior Bird Habitat Relationships in the Pennsylvania Wilds,** David Yeany, Sarah Sargent, Ephraim Zimmerman, and Nicole Michel.
- Oral presentation given at NAOC VI by David Yeany.
- Presentation to the Todd Bird Club, May 16, 2016 by David Yeany.
- Presentation to the Presque Isle Audubon Society, February 18, 2017 by Sarah Sargent
- Manuscript in preparation for publication in peer-reviewed journal.
- Series of seven "Forest Interior Birds of (Forest Type)" tables designed as quick references for forest managers working within The Wilds region. See Appendix 1.

Results and Conclusions

Rapid vegetation assessment – Based on our field assessment of vegetation composition and structure we determined there were 16 different PA Community Types (Table 1; Fike 1999) across all point locations sampled versus the seven agency GIS-based forest types. There were marked differences between the forest plant community types determined in the field survey data and those created by the agency aerial photo interpretation methods. These were most likely due to scale issues related to the photo interpretation methods. Differences were apparent across all forest types studied, with the greatest difference noted among conifer and northern hardwoods groups. Oak forest communities, as a broader type were not confused with northern hardwood or conifer forest types; however, agency data failed to recognize the *woodland* type Dry Oak – Heath, which differs from the *forest* type Dry Oak – Heath only by having tree canopy cover less than 40%.

Density estimates – We estimated breeding density for 34 bird species recorded throughout the PA Wilds region. These 34 species included 21 forest interior species, six forest generalists, three young forest species, and three edge habitat species (see Table 3). Twenty-one species, including 15 forest interior species, showed significant differences among the forest groups, i.e., conifer, northern hardwood, and oak (Figure 1a-c). Thirteen bird species had their highest densities in conifer forest with nine having significantly higher densities than one or both of the other forest groups (Figure 1a). Eleven species had their highest densities in each of northern hardwood and oak forest groups with five and seven species respectively with significantly higher densities at the 0.05 level (Figure 1b-c).

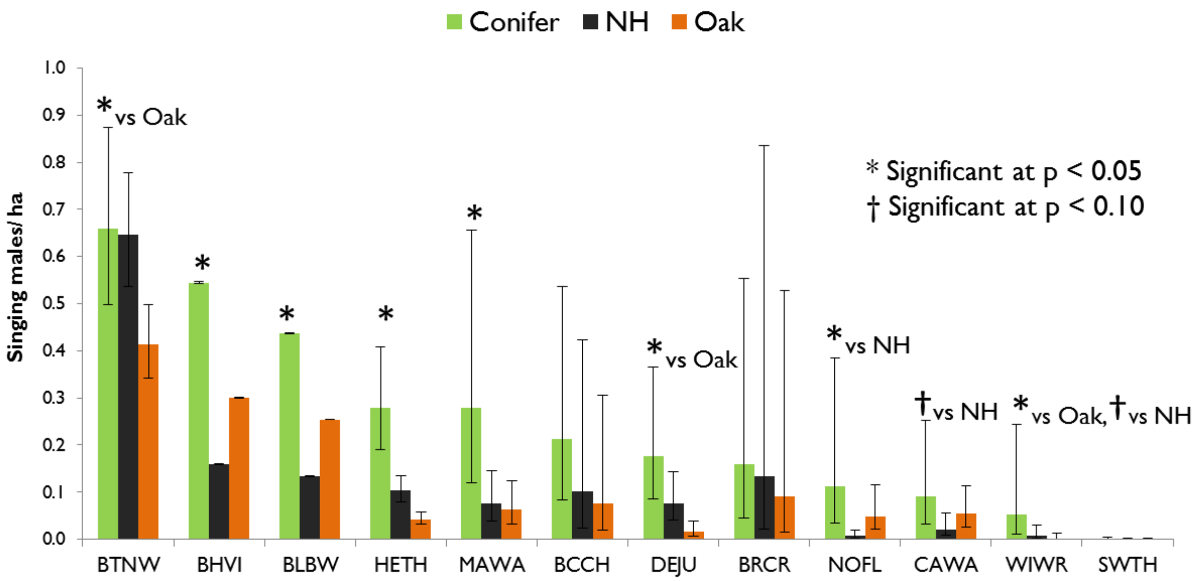

Figure 2a. Detection-corrected densities of bird species with 95% confidence intervals, ranked from highest to lowest density in Conifer forest stands.

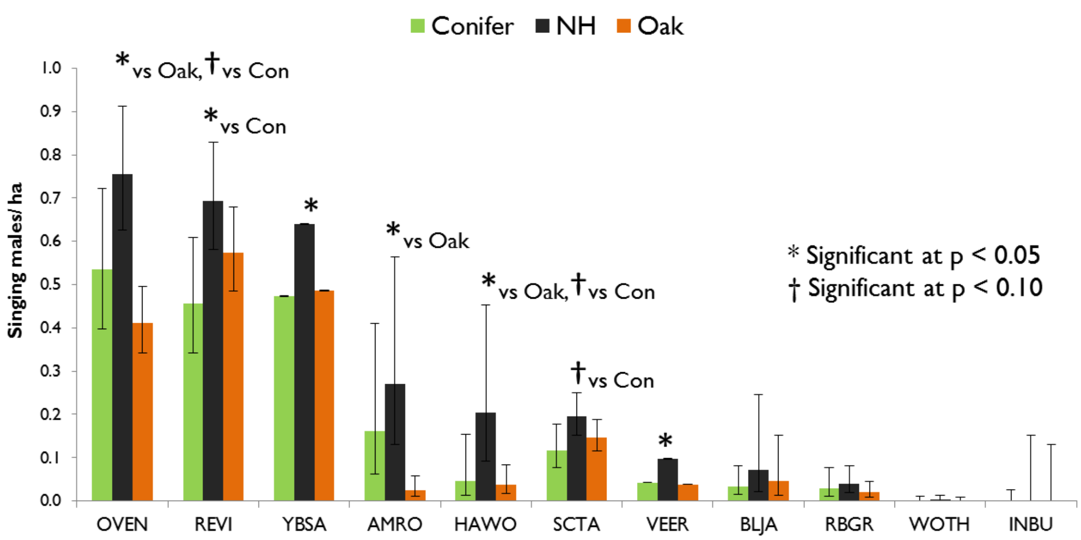

Figure 2b. Detection-corrected densities of bird species with 95% confidence intervals, ranked from highest to lowest density in Northern Hardwood forest stands.

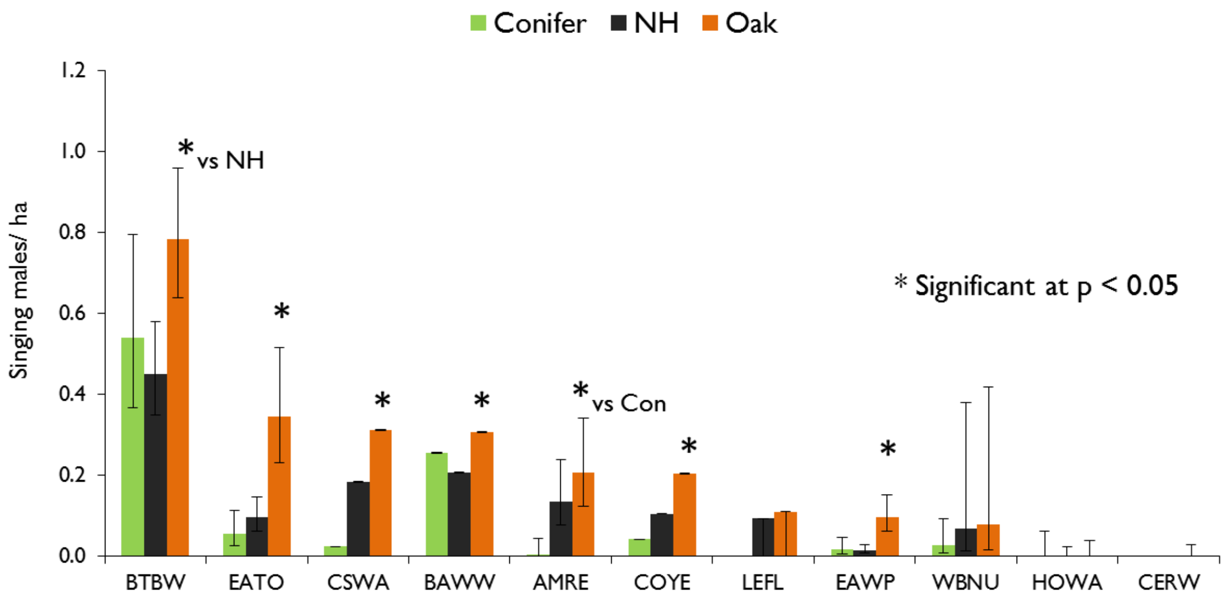

Figure 2c. Detection-corrected densities of bird species with 95% confidence intervals, ranked from highest to lowest density in Oak forest stands.

We found 19 species, including 11 forest interior species, with significant differences in pairwise comparisons across the seven agency forest types, and all but one of these, hairy woodpecker (*Leuconotopicus villosus*), had significantly higher density within the forest community type where the species had its highest overall density (see Table 2, Table 3). More bird species (13) had their highest density within the Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwood type than any of the other seven types, including six species with significantly higher densities: blue-headed vireo, black-throated green warbler, Blackburnian warbler, dark-eyed junco, hermit thrush and magnolia warbler. Swainson's thrush was also found exclusively within this forest type.

Results of this study indicated the importance of forest type to different forest interior bird species in the PA Wilds, as densities differed within the dominant northern hardwood and oak forest communities. Red Oak – Mixed Hardwood and Black Cherry – Northern Hardwood each had six different species with their highest densities (Table 4). American redstart, black-throated blue warbler, eastern wood-pewee and yellow-bellied sapsucker showed strong associations with Red Oak – Mixed Hardwood having significantly higher densities in this type while only ovenbird and red-eyed vireo had significantly higher densities in Black Cherry – Northern Hardwood. Dry Oak – Heath supported significantly higher densities of all three young forest bird species compared across all forest types. Dry Oak – Mixed Hardwood supported the highest density of just one species, cerulean warbler. Each of the three edge habitat species had their highest densities in the three northern hardwood types (Table 4), with American robin having a significantly higher density in Red Maple.

Boosted regression trees

– Boosted regression tree models converged for 22 of the 34 species in the study. Overall we identified 21 habitat variables that influenced bird densities (Table 5). The variable "PA Community Type" was as an important predictor of density for all 22 species and was the most important variable for 21 of the 22 species (see Table 5). Only scarlet tanager (*Piranga olivacea*) had a different variable, elevation, contribute more to its model than PA Community Type. The most prevalent landscape attributes in final models were aspect (16 species) and elevation (11 species), while three structural attributes were most influential: shrub cover (7 species), snags (5 species) and basal area (4 species).

Deviance explained by the modeled covariates ranged between <0.01% and 64.6% with a mean of 23.1% across all 22 species (Table 5). Some of the rarest habitat specialists, like Swainson's thrush fared better with high performing models while others like Canada warbler, did not (Table 5). Still, only six species, including Canada warbler, had deviance explained values below 13% and these comprised widespread forest interior species with more generalized habitat requirements like red-eyed vireo, wood thrush and scarlet tanager.

Discussion and Management Recommendations

Forest bird species within The Wilds region of Pennsylvania showed strong associations with forest community types, and many of them also showed significant density responses to particular features of their habitat. With more than a third (13 of 34) of our study species identified as Species of Greatest Conservation Need (SGCN) in the Pennsylvania Wildlife Action Plan (PGC-PFBC 2015) and all but one of these SGCN being forest interior birds, our study could not be more timely for providing information that can be applied to a significant number of conservation priority birds.

We have shown that forest birds in the largest intact forests in Pennsylvania respond to forest community type (and forest group) with significantly different densities across sampled agency forest types. Additional habitat variables with significant influence on forest bird densities were aspect, elevation, shrub cover, snags, and basal area. While landscape attributes like elevation and slope are not readily changeable, structural attributes and forest type associations can be used by land managers to make appropriate forest management decisions to benefit priority bird species where the birds can benefit the most. With this information managers could target specific forest types with appropriate landscape attributes for target species and assess site characteristics that lead to higher densities of priority birds.

As noted, both forest group and forest type played a major role determining where we observed the highest densities of forest interior species. Of the 21 forest interior birds with statistically significant differences in density between forest groups, more than 60% (13 species) had their highest density in conifer forest. Eleven of these birds are also SGCN. Our conifer forest group, which was also the same as the Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwood PA Community Type, is distinguished from our other northern hardwood types by the fact that it was the only forest with >25% conifer cover. Essentially this is a "mixed" (conifer-deciduous) hardwood forest. Eastern hemlock (*Tsuga canadensis*) is of particularly high value to many of these bird species, and some of the areas we sampled represent the few old growth forest tracts remaining in Pennsylvania. Despite just one year of data collection, our study underscores the conservation value of the keystone state's hemlock and hemlock northern hardwood forests. The recent expansion of the hemlock woolly adelgid into the region is cause for great concern and could have severe effects on the species we found occurring at their highest densities in conifer forests.

For some species (e.g. Canada Warbler, Wood Thrush) our boosted regression tree models were unable to explain a large portion of the model deviance as it relates to density. For these species it is likely that small sample sizes limited our ability to make inferences. Sample size has been shown to affect the performance of boosted regression trees during both the fitting and prediction phase of modeling (Elith et al., 2008). Sample size has been shown to influence the optimal settings used for each of the three boosted regression tuning parameters (i.e. learning rate, bag fraction and tree complexity) used during model fitting. Additionally, predictive performance is mostly strongly affected by sample size, with larger sample sizes leading to lower predictive error.

For forest interior bird species, we recommend a continued focus on off-road surveys combined with high quality vegetation assessments to better focus bird and habitat management in the PA Wilds region for conservation priority species. Furthermore, while this study has revealed a number of important habitat relationships for forest interior birds, it has shown that there is still much to be learned about the habitat needs of this suite of birds if we are to positively impact populations. Ultimately, our results provide guidance for bird conservation and management on forest lands with accurate community typing, like our state and national forests, as well as state game lands. We identified high quality core forest conditions that offer direction for habitat conservation and improvements across forest communities encompassed by the largest remaining tracts in Pennsylvania. With our focus on SGCN and forest interior bird densities, rather than mere presence, our study can help match conservation efforts for priority birds and suites of species to the forest communities where their populations will benefit the most. Ongoing outreach to forest land managers, conveying the results of this study in ways that enable integration into existing tools, will be critical to successful application of our results. Moving forward it will be important to combine the information gained from this study with further studies of habitat associations and species density to effectively conserve forest interior birds and those of greatest conservation need.

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Table 1. Forest community typing results based on rapid vegetation assessments in the field using Fike 1999. Forest Groups are: CON=Conifer, NH=Northern Hardwoods, OAK= Oak Forest

PA Community Type	# of Points	% Total	Forest Group
Dry White Pine (Hemlock) - Oak Forest	28	4%	CON
Hemlock - Mixed Hardwood Palustrine Forest	9	1%	CON
Hemlock (White Pine) - Northern Hardwood Forest	57	8%	CON
Hemlock (White Pine) - Red Oak - Mixed Hardwood Forest	9	1%	CON
Hemlock (White Pine) Forest	6	1%	CON
Pitch Pine - Mixed Hardwood Woodland	2	0%	CON
Pitch Pine - Mixed Oak Forest	2	0%	CON
Black Cherry - Northern Hardwood Forest	120	17%	NH
Northern Hardwood Forest	46	7%	NH
Red Maple (Terrestrial) Forest	110	16%	NH
Sugar Maple - Basswood Forest	1	0%	NH
Tuliptree - Beech - Maple Forest	10	1%	NH
Dry Oak - Heath Forest	113	16%	OAK
Dry Oak - Heath Woodland	71	10%	OAK
Dry Oak - Mixed Hardwood Forest	42	6%	OAK
Red Oak - Mixed Hardwood Forest	71	10%	OAK

Table 2. Significance of forest type in explaining density for each of the 34 bird species, using pairwise comparisons among the 7 forest types. * (+) indicates a significant difference at the p=0.05 level and (-) indicates no significant differences between forest types. FI = Forest Interior, FG = Forest Generalist, EDGE = Forest Edge, YF = Young Forest.

Species (Common Name)	Species Code	Habitat Association	Significant*
American Redstart	AMRE	FI	+
Blackburnian Warbler	BLBW	FI	+
Black-throated Blue Warbler	BTBW	FI	+
Black-throated Green Warbler	BTNW	FI	+
Blue-headed Vireo	BHVI	FI	+
Brown Creeper	BRCR	FI	-
Canada Warbler	CAWA	FI	-
Cerulean Warbler	CERW	FI	-
Eastern Wood Pewee	EAWP	FI	+
Hermit Thrush	HETH	FI	+
Hooded Warbler	HOWA	FI	-
Least Flycatcher	LEFL	FI	+
Magnolia Warbler	MAWA	FI	+
Ovenbird	OVEN	FI	+
Red-eyed Vireo	REVI	FI	+
Rose-breasted Grosbeak	RBGR	FI	-
Scarlet Tanager	SCTA	FI	-
Swainson's Thrush	SWTH	FI	-
Veery	VEER	FI	-
Winter Wren	WIWR	FI	-
Wood Thrush	WOTH	FI	-
Black-and-white Warbler	BAWW	FG	+
Black-capped Chickadee	BCCH	FG	-
Dark-eyed Junco	DEJU	FG	+
Hairy Woodpecker	HAWO	FG	+
Northern Flicker	NOFL	FG	-
White breasted Nuthatch	WBNU	FG	-
Yellow-bellied Sapsucker	YBSA	FG	+
American Robin	AMRO	EDGE	+
Blue Jay	BLJA	EDGE	-
Indigo Bunting	INBU	EDGE	-
Chestnut-sided Warbler	CSWA	YF	+
Common Yellowthroat	COYE	YF	+
Eastern Towhee	EATO	YF	+

Table 3. Mean density and 95% confidence interval [in brackets] in each of the seven forest types for each bird species for which sufficient data was collected. The forest type where the species had its highest density is noted in the rightmost column. The seven forest types include Dry Oak – Mixed Hardwood (AD), Dry Oak – Heath (AH), Red Oak – Mixed Hardwood (AR), Northern Hardwood (BB), Black Cherry – Northern Hardwood (BC), Red Maple (CC), Hemlock – Northern Hardwood (FB).

Species	AD	AH	AR	BB	BC	CC	FB	Highest Density
AMRO	0.16[0.02-1.10]	0.07[0.01-0.81]	1.28[0.24-6.81]	1.38[0.48-3.96]	0.17[0.04-0.85]	4.21[1.35-13.11]	0.11[0.03-0.39]	AR
BAWW	0.61[0.35-1.08]	0.65[0.38-1.11]	0.33[0.15-0.73]	0.29[0.15-0.56]	0.05[0.01-0.16]	0.22[0.11-0.46]	0.16[0.07-0.36]	CC
BCCH	0.11[0.04-0.32]	0.13[0.03-0.62]	0.09[0.02-0.51]	0.10[0.02-0.55]	0.23[0.05-1.18]	0.02[0.00-0.16]	0.22[0.04-1.20]	AH
BLJA	0.02[0.01-0.06]	0.06[0.01-0.26]	0.03[0.01-0.20]	0.08[0.02-0.41]	0.10[0.02-0.51]	0.04[0.01-0.21]	0.05[0.01-0.26]	FB
DEJU	0.03[0.01-0.09]	0.01[0.00-0.05]	0.03[0.01-0.09]	0.05[0.02-0.12]	0.19[0.09-0.39]	0.05[0.02-0.12]	0.21[0.10-0.41]	FB
HAWO	0.06[0.02-0.20]	0.03[0.01-0.12]	0.20[0.06-0.60]	0.06[0.02-0.18]	0.09[0.03-0.27]	0.06[0.01-0.30]	0.08[0.02-0.29]	FB
NOFL	0.06[0.01-0.26]	0.02[0.00-0.12]	0.05[0.01-0.22]	0.00[0.00-0.03]	0.02[0.00-0.07]	0.01[0.00-0.04]	0.07[0.01-0.39]	BB
WBNU	0.12[0.07-0.21]	0.02[0.01-0.07]	0.08[0.04-0.16]	0.08[0.04-0.16]	0.13[0.07-0.24]	0.03[0.01-0.09]	0.07[0.03-0.15]	FB
YBSA	0.18[0.06-0.54]	0.06[0.01-0.29]	1.82[0.64-5.16]	0.45[0.15-1.38]	0.98[0.32-2.95]	0.64[0.21-1.93]	0.88[0.26-2.90]	AR
AMRE	0.14[0.06-0.33]	0.13[0.05-0.35]	0.55[0.26-1.16]	0.11[0.04-0.30]	0.07[0.02-0.23]	0.11[0.04-0.30]	0.01[0.00-0.07]	FB
BHVI	0.45[0.45-0.46]	0.10[0.10-0.10]	0.35[0.35-0.35]	0.25[0.25-0.26]	0.17[0.17-0.17]	0.13[0.13-0.13]	0.81[0.80-0.81]	AD
BLBW	0.27[0.15-0.49]	0.34[0.19-0.61]	0.26[0.13-0.50]	0.06[0.02-0.16]	0.08[0.03-0.21]	0.20[0.10-0.42]	0.83[0.41-1.67]	AH
BRCR	0.18[0.06-0.55]	0.07[0.01-0.40]	0.05[0.01-0.46]	0.14[0.02-0.94]	0.16[0.02-1.10]	0.13[0.02-0.95]	0.21[0.03-1.49]	AH
BTBW	0.71[0.51-1.0]	0.72[0.53-0.98]	1.01[0.73-1.40]	0.46[0.31-0.68]	0.54[0.37-0.81]	0.35[0.23-0.53]	0.56[0.37-0.85]	FB
CAWA	0.06[0.02-0.22]	0.06[0.02-0.18]	0.04[0.01-0.15]	0.03[0.01-0.12]	0.03[0.01-0.12]	0.01[0.00-0.07]	0.10[0.03-0.35]	AH
CERW	0.00[0.00-0.07]	0.00[0.00-0.00]	0.00[0.00-0.05]	0.00[0.00-0.82]	0.00[0.00-0.00]	0.00[0.00-0.00]	0.00[0.00-0.00]	AR
EAWP	0.09[0.05-0.17]	0.09[0.05-0.17]	0.14[0.07-0.28]	0.02[0.01-0.05]	0.02[0.01-0.05]	0.01[0.00-0.03]	0.01[0.00-0.05]	AR
HETH	0.06[0.04-0.09]	0.05[0.03-0.08]	0.04[0.02-0.06]	0.06[0.04-0.09]	0.15[0.10-0.22]	0.11[0.08-0.15]	0.28[0.19-0.42]	FB
HOWA	0.01[0.00-0.08]	0.00[0.00-0.00]	0.04[0.01-0.22]	0.01[0.09-0.09]	0.01[0.00-0.06]	0.00[0.00-0.00]	0.01[0.00-0.14]	AR
LEFL	0.28[0.10-0.81]	0.05[0.01-0.36]	0.21[0.04-1.25]	0.09[0.01-0.63]	0.03[0.00-0.31]	0.28[0.05-1.66]	0.00[0.00-0.00]	BC
MAWA	0.08[0.03-0.20]	0.06[0.02-0.16]	0.07[0.02-0.20]	0.05[0.02-0.13]	0.11[0.04-0.28]	0.05[0.02-0.16]	0.50[0.22-1.13]	CC
OVEN	0.51[0.38-0.67]	0.48[0.37-0.62]	0.29[0.20-0.40]	0.74[0.57-0.94]	0.80[0.60-1.06]	0.76[0.60-0.98]	0.49[0.35-0.67]	FB
RBGR	0.05[0.02-0.14]	0.02[0.01-0.05]	0.06[0.02-0.17]	0.02[0.01-0.05]	0.07[0.02-0.18]	0.01[0.00-0.05]	0.02[0.01-0.07]	FB
REVI	0.60[0.46-0.78]	0.45[0.35-0.58]	0.68[0.51-0.91]	0.67[0.52-0.86]	0.83[0.62-1.11]	0.70[0.54-0.89]	0.41[0.29-0.56]	BC
SCTA	0.21[0.15-0.31]	0.11[0.07-0.16]	0.13[0.09-0.20]	0.19[0.13-0.27]	0.23[0.15-0.34]	0.17[0.12-0.26]	0.13[0.08-0.19]	BC

Table 3. Cont'd.

Species	AD	AH	AR	BB	BC	CC	FB	Highest Density
SWTH	0.00[0.00-0.06]	0.00[0.00-0.05]	0.00[0.00-0.00]	0.00[0.00-0.00]	0.00[0.00-0.00]	0.00[0.00-0.00]	0.01[0.00-0.15]	BC
VEER	0.03[0.01-0.08]	0.03[0.01-0.06]	0.06[0.02-0.17]	0.10[0.04-0.24]	0.08[0.03-0.25]	0.09[0.04-0.22]	0.05[0.02-0.13]	BC
WIWR	0.01[0.00-0.05]	0.00[0.00-0.00]	0.01[0.00-0.06]	0.01[0.00-0.05]	0.01[0.00-0.06]	0.00[0.00-0.00]	0.10[0.03-0.31]	FB
WOTH	0.00[0.00-0.01]	0.00[0.00-0.01]	0.01[0.00-0.02]	0.00[0.00-0.02]	0.00[0.00-0.02]	0.00[0.00-0.00]	0.01[0.00-0.05]	BB
COYE	0.06[0.06-0.06]	0.59[0.58-0.59]	0.25[0.24-0.25]	0.03[0.03-0.03]	0.24[0.24-0.25]	0.11[0.11-0.11]	0.02[0.02-0.02]	BC
CSWA	0.13[0.05-0.34]	0.80[0.39-1.66]	0.35[0.15-0.86]	0.15[0.06-0.39]	0.19[0.06-0.59]	0.16[0.06-0.40]	0.01[0.00-0.03]	FB
EATO	0.21[0.10-0.42]	0.65[0.37-1.15]	0.54[0.27-1.08]	0.04[0.02-0.10]	0.10[0.04-0.25]	0.09[0.05-0.19]	0.04[0.01-0.10]	FB
INBU	0.01[0.00-0.14]	0.01[0.00-0.11]	0.02[0.00-0.27]	0.00[0.00-0.00]	0.06[0.01-0.42]	0.01[0.00-0.16]	0.01[0.00-0.27]	AR

Table 4. Relative variable importance results of boosted regression tree analysis. For each species only the variables that remained in the simplified final model are shown here. Dashed lines indicate that variable did not appear in the final model for that species. In addition to the relative importance of each variable we also include a count of the total number of detections for each species (# Obs), model deviance explained (DevExp), and a measure of correlation between observed and predicted values as measured by spatially stratified cross validation (CV Corr). Twenty-one covariates used in models included: PA Community Type, Aspect, Small Rocks (% cover), Elevation (ft), Tree Canopy Height, Short Shrub Height, Sub-canopy Cover, Tall Shrub Cover, Short Shrub Cover, Herbaceous Cover, Non-vascular Plant Height, Non-vascular Plant Cover, Basal Area (ft^2/ac), Bryophyte Cover, Woody Debris Cover, Number of Snags, Topographic Position, Logging in the last 30 years, Leaf Phenology, and Slope (%).

Species	Guild	# Obs	DevExp	CV Corr	PA Comm Type	Aspect	Small Rocks	Elev (ft)	Tree Canopy Height
AMRE	FIDS	110	19.7%	0.156	62.7	15	22.3	--	--
BAWW	FIDS	249	37.5%	0.265	53.8	17.4	--	9.9	--
BHVI	FIDS	179	13.1%	0.123	49.9	13.2	16.3	7.8	--
BLBW	FIDS	252	33.9%	0.272	60.1	15.2	--	14.0	--
BTBW	FIDS	451	21.5%	0.321	44.2	18.9	--	14.0	--
BTNW	FIDS	705	18.4%	0.334	48.8	12.7	--	--	10.5
CAWA	FIDS	51	0.0%	0.133	41.6	29.8	--	--	--
CSWA	YF	232	33.3%	0.308	47.9	11.0	--	18.0	--
DEJU	FIDS	90	26.8%	0.221	64.8	--	--	--	--
EATO	YF	378	40.5%	0.303	48.5	14.7	--	--	--
EAWP	FG	160	37.5%	0.439	63.6	12.7	--	--	--
HAWO	FIDS	60	0.2%	0.015	62.5	18.5	--	--	--
HETH	FIDS	382	13.7%	0.218	68.3	5.8	--	--	--
HOWA	FIDS	102	45.6%	0.199	48.3	8.3	--	--	--
MAWA	FIDS	118	36.1%	0.266	51.5	--	--	11.0	--
OVEN	FIDS	1069	15.4%	0.252	68.6	9.0	--	--	--
REVI	FIDS	1092	11.2%	0.213	63.6	15.8	--	12.0	--
SCTA	FIDS	326	2.4%	0.043	46.6	--	--	53.0	--
SWTH	FIDS	39	64.6%	0.266	58.7	--	--	--	22.9
WIWR	FIDS	48	24.0%	0.134	97.7	--	--	2.3	--
WOTH	FIDS	92	3.2%	0.112	63.9	--	--	36	--
YBSA	FG	166	9.1%	0.026	59.0	13.6	--	17	--

Table 4. Cont'd.

Species	Short Shrub Height	Tree Canopy Cover	SubCan Cover	Tall Shrub Cover	Short Shrub Cover	Herb Cover	Non-vasc Plant Height	Non-vasc Plant Cover
AMRE		--	--	--	--	--	--	--
BAWW	--	--	--	--	5.9	--	--	--
BHVI	--	--	--	--	--	--	--	--
BLBW	--	--	--	--	--	--	--	--
BTBW	--	--	--	12.3	10.2	--	--	--
BTNW	--	--	--	--	--	--	--	--
CAWA	--	1.9	--	11.0	--	--	--	--
CSWA	--	--	--	--	12.6	--	--	--
DEJU	--	--	--	--	--	--	--	35.2
EATO	--	--	17.5	--	--	--	--	--
EAWP	--	--	--	--	--	--	--	--
HAWO	--	--	--	--	--	--	--	--
HETH	--	--	--	--	--	--	--	--
HOWA	--	--	--	--	--	--	31.6	--
MAWA	--	--	--	6.8	--	--	--	--
OVEN	14.6	--	--	--	--	7.8	--	--
REVI	--	--	--	8.3	--	--	--	--
SCTA	--	--	--	--	--	--	--	--
SWTH	--	--	--	--	--	--	--	--
WIWR	--	--	--	--	--	--	--	--
WOTH	--	--	--	--	--	--	--	--
YBSA	--	--	--	--	--	--	--	--

Table 4. Cont'd.

Species	Basal Area (ft^2/ac)	Bryo Cover	Woody Debris	Snags	Topo Position	Logging < 30yrs	Leaf Pheno	Slope (%)
AMRE	--	--	--	--	--	--	--	--
BAWW	--	--	--	5.8	7.2	--	--	--
BHVI	12.8	--	--	--	--	--	--	--
BLBW	--	--	--	--	--	--	--	10.8
BTBW	--	--	--	--	--	--	--	--
BTNW	--	--	--	--	15.8	12.3	--	--
CAWA	12.9	2.7	--	--	--	--	--	--
CSWA	11.0	--	--	--	--	--	--	--
DEJU	--	--	--	--	--	--	--	--
EATO	--	--	--	--	--	19.3	--	--
EAWP	--	--	10.7	5.3	--	--	--	7.7
HAWO	12.6	--	--	6.5	--	--	--	--
HETH	--	--	--	--	--	--	--	25.9
HOWA	--	--	--	11.8	--	--	--	--
MAWA	--	--	19.0	--	--	--	11.4	--
OVEN	--	--			--	--	--	--
REVI	--	--	--	--	--	--	--	--
SCTA	--	--	--	--	--	--	--	--
SWTH	--	--	18.4	--	--	--	--	--
WIWR	--	--	--	--	--	--	--	--
WOTH	--	--	--	--	--	--	--	--
YBSA	--	--	--	6.0	4.7	--	--	--

Appendix 1.

Summary of Habitat Results for 22 Bird Species, By Guild

Forest Interior Bird Species

American Redstart

- Highest density in Red Oak – Mixed Hardwood Forest
- Increased density where small rock cover was >5%

Black-and-white Warbler

- Highest density in Dry Oak-Heath, Red Oak – Mixed Hardwood Forest
- Prefers lower elevations; density decreases as elevation increases from 1400ft to 2000ft
- Density increases with increasing short shrub cover beginning at 6-12% cover
- Higher snag counts negatively influence density

Blue-headed Vireo

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Density increases with higher basal area from 80^2ft/ac to 170^2ft/ac
- Somewhat decreasing density as elevation increases

Blackburnian Warbler

- Highest density in Dry White Pine (Hemlock) - Oak Forest, Hemlock (White Pine) - Red Oak - Mixed Hardwood Forest, Hemlock - Mixed Hardwood Palustrine Forest
- Density decrease above about 2000ft (600m)

Black-throated Blue Warbler

- Highest density in Red Oak – Mixed Hardwood Forest, followed by Dry Oak-Heath/Dry Oak – Mixed Hardwood Forest
- Density increases with Short Shrub Cover (<1m) when greater than 50%
- Density increases with Tall Shrub Cover (1-5m) when greater than 50%
- Highest density above 2,000ft (600m) in elevation

Black-throated Green Warbler

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Low Level and Midslope topo position positively influenced density
- Highest density when Tree Canopy Height is above 15-20m
- Highest density on NE/E Aspects
- Density negatively influenced by area logged in past 30 years

Canada Warbler

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Density responded positively to basal areas of $75\text{-}120^2$ft/ac
- BRT model was very poor and should be re-run with additional data

Dark-eyed Junco

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest, followed by Black Cherry Northern Hardwood Forest
- Bryophyte cover >12% had positive relationship with increasing density

Hairy Woodpecker

- Highest density in Red Oak – Mixed Hardwood Forest, but higher in Northern Hardwoods group, indicating forest generalist
- BRT model was very poor and should be re-run with additional data
- Highest positive influence on density with > 10 snags per plot

Hermit Thrush

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Increasing slope negatively influenced density, especially at slopes >15%

Hooded Warbler

- Highest density in Red Oak – Mixed Hardwood Forest
- BRT model needs additional investigation

Magnolia Warbler

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Density was positively influenced by Evergreen cover, but even more strongly influenced by Mixed Evergreen-Cold Deciduous cover
- Density was positively influenced by Tall Shrub Cover > 13-25%
- Density was positively influenced by Woody Debris Cover > 20% and up to 40%

Ovenbird

- Highest density in Black Cherry Northern Hardwood Forest, but similar across Northern Hardwoods Group
- Density was weakly negatively influenced by Short Shrub Height up to a maximum of 0.5-1m
- Density was positively influenced by increasing Herbaceous Cover above 26-50%

Red-eyed Vireo

- Highest density in Black Cherry Northern Hardwood Forest. Similar density other Northern Hardwoods types and Red Oak – Mixed Hardwood Forest
- Density was negatively influenced by increasing Tall Shrub Cover

Scarlet Tanager

- Highest density in Black Cherry Northern Hardwood Forest, followed closely by Dry Oak – Mixed Hardwood Forest
- BRT model was very poor

Swainson's Thrush

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Density was strongly increased with Tree Canopy Height above 20-35m
- Density was positively influenced by Woody Debris Cover > 20% and up to 40%

Winter Wren

- Highest density in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- Density was negatively influenced by increasing elevation above 1300 ft (400m)
- PA Community Type's contribution was overwhelmingly important to this model (97.7%)

Wood Thrush

- Density was similar across all three forest groups, but was highest in Hemlock (White Pine)/Hemlock (White Pine) Northern Hardwoods Forest
- BRT model was very poor

Forest Generalist Bird Species

Eastern Wood-Pewee

- Highest density in Red Oak – Mixed Hardwood Forest, followed by Dry Oak-Heath/Dry Oak – Mixed Hardwood Forest
- Density was positively influenced by > 5 Snags per plot up to about 10 snags
- Density was positively influenced by steep slopes above 58%

Yellow-bellied Sapsucker

- Highest density in Red Oak – Mixed Hardwood Forest
- Density was positively influenced with the presence of 1-7 Snags per plot
- Density was positively influenced by elevation from 1500 ft (425 m) to just over 2000 ft (600 m)

Young Forest Bird Species

Chestnut-sided Warbler

- Highest density in Dry Oak - Mixed Hardwood Forest, Dry Oak-Heath Forest
- Density decreases with increasing basal area, declines precipitously between 60^2ft/ac to 140^2ft/ac
- Density increases with increasing short shrub cover above 26-50%

Eastern Towhee

- Highest density in Dry Oak-Heath, Red Oak – Mixed Hardwood Forest
- Increased area logged increases density
- Sub-canopy cover above 5% sharply decreases density

Appendix 2.

Summary of Habitat Results for Forest Interior Birds, By Forest Type

Each of the following matrices summarizes habitat relationships for forest interior birds with densities of at least one singing male per hectare within each of the seven agency forest types evaluated. Each matrix can be used as a guide for forest managers to obtain a snapshot of which species have the strongest associations with each forest type and the conditions that contribute to higher densities of those species.

Forest Interior Birds of Hemlock (White Pine) Page 1

Species	Code	Singing Males /20 acres	Elevation	Tree Canopy Height	Short Shrub (<2 m)	Tall Shrub (2-5m)	Snags	Topo Position	Herb. Cover	Small Rocks (<10cm)	Basal Area	Slope	Recent Logging	Woody Debris	Leaf Pheno	Highest Density
Blackburnian Warbler	BLBW	6.73	Density decrease above 2000'									Prefers steeper slopes				Hemlock-white pine--oak or other hardwoods w/ Hemlock
Blue-headed Vireo	BHVI	6.54	Some decrease as elevation increases							Denser with cover >3%	Density increases from 80 sqft/ac to 170 sqft/ac					Hemlock-white pine & Northern Hardwoods
Black-throated Green Warbler	BTNW	5.66		Highest density above 15-20m				Low level & Midslope position + influences density					Negatively influenced by logging in last 30 years			Hemlock-white pine
Black-throated Blue Warbler	BTBW	4.55	Denser above 2000'		Density increases when >50%	Density increases >50%										Red Oak-Mixed Hardwood
Magnolia Warbler	MAWA	4.03	Denser above 1400'			Densest at >13-25% cover								Denser with >20% cover	Denser with evergreen, mixed evergreen-cold deciduous cover	Hemlock/white pine
Ovenbird	OVEN	3.92			Weak negative influence w/ height up to max 0.5-1m				Denser w/increases above 26-50%							Black Cherry Northern Hardwood but similar across all types

Forest Interior Birds of Hemlock (White Pine) Page 2

Species	Code	Singing Males /20 acres	Elevation	Tree Canopy Height	Short Shrub (<2 m)	Tall Shrub (2-5m)	Snags	Topo Position	Herb. Cover	Small Rocks (<10c m)	Basal Area	Slope	Recent Logging	Woody Debris	Leaf Pheno	Highest Density
Red-eyed Vireo	REVI	3.28	Denser below 1800'			Lower density with more cover										Black Cherry Norther Hardwood
Hermit Thrush	HETH	2.28										Slope >15% negatively influenced density				Hemlock/white pine
Dark-eyed Junco	DEJU	1.63												Denser with bryophyte cover >12%		Hemlock/White pine
Black-and-white Warbler	BAWW	1.29	Density decreases as elevation increases 1400' to 2000'		Density increases beginning w/ 6-12% short shrub cover		High snag count negatively influences density	Prefers mid-slope								Dry Oak-Heath & Mixed Hardwood
Scarlet Tanager	SCTA	1.01	Slightly denser below 1400'													Black Cherry Northern Hardwoods w/ Dry Oak Mixed close behind

Forest Interior Birds of Northern Hardwood													
Species	Code	Singing Males /20 acres	Elevation	Tree Canopy Height	Short Shrub (<2 m)	Tall Shrub (2-5m)	Snags	Topo Position	Herb. Cover	Small Rocks (<10cm)	Basal Area	Recent Logging	Highest Density
Ovenbird	OVEN	5.95			Weak negative influence w/ height up to max 0.5-1m				Denser w/increases above 26-50%				Highest density in Black Cherry Northern Hardwood but similar across all hardwood types
Red-eyed Vireo	REVI	5.4	Denser below 1800'			Negatively influenced by increased tall shrubs							Highest density in Black Cherry Norther Hardwood
Black-throated Green Warbler	BTNW	5.29		Highest density above 15-20m				Denser with Low level & Midslope position				Negatively influenced by logging in last 30 years	Hemlock-white pine
Black-throated Blue Warbler	BTBW	3.7	Denser above 2000'		Density increases (<1m) when >50%	Density increases (1-5m) >50%							Red Oak-Mixed Hardwood
Black-and-white Warbler	BAWW	2.33	Density decreases as elevation increases 1400' to 2000'		Density increases beginning w/ 6-12% short shrub cover		High snag count negatively influences density	Prefers mid-slope					Dry Oak-Heath & Mixed Hardwood
Blue-headed Vireo	BHVI	2.05	Some decrease as elevation increases							Denser with cover >3%	Density increases from 80 sqft/ac to 170 sqft/ac		Hemlock-white pine & Northern Hardwoods
Scarlet Tanager	SCTA	1.53	Slightly denser below 1400'										Black Cherry Northern Hardwoods w/ Dry Oak Mixed following close behind

Forest Interior Birds of Black Cherry- Northern Hardwood														
Species	**Code**	**Singing Males /20 acres**	**Elevation**	**Tree Canopy Height**	**Short Shrub (<2 m)**	**Tall Shrub (2-5m)**	**Topo Position**	**Herb. Cover**	**Small Rocks (<10cm)**	**Basal Area**	**Slope**	**Recent Logging**	**Non vascular plant cover**	**Highest Density**
Red-eyed Vireo	REVI	6.69	Denser below 1800'			Negatively influenced by increased tall shrubs								Black Cherry Norther Hardwood
Ovenbird	OVEN	6.47			Weak negative influence w/ height up to max 0.5-1m			Denser w/increases above 26-50%						Black Cherry Northern Hardwood but similar across all hardwood types
Black-throated Green Warbler	BTNW	5.26		Highest density above 15-20m			Denser with Low level & Midslope position					Negatively influenced by logging in last 30 years		Hemlock-white pine
Black-throated Blue Warbler	BTBW	4.4	Denser above 2000'		Density increases (<1m) when >50%	Density increases (1-5m) >50%								Red Oak-Mixed Hardwood
Scarlet Tanager	SCTA	1.82	Slightly denser below 1400'											Black Cherry Northern Hardwoods w/ Dry Oak Mixed close behind
Dark-eyed Junco	DEJU	1.53											Denser with >12% bryophyte cover	Hemlock/White pine
Blue-headed Vireo	BHVI	1.35	Some decrease as elevation increases						Denser with cover >3%	Density increases from 80 sqft/ac to 170 sqft/ac				Highest Density in Hemlock-white pine & Northern Hardwoods
Hermit Thrush	HETH	1.22									Slope >15% negatively influenced density			Hemlock/white pine

Forest Interior Birds of Red Maple (Terrestrial)														
Species	**Code**	**Singing Males /20 acres**	**Elevation**	**Tree Canopy Height**	**Short Shrub (<2 m)**	**Tall Shrub (2-5m)**	**Snags**	**Topo Position**	**Herb. Cover**	**Small Rocks (<10cm)**	**Basal Area**	**Slope**	**Recent Logging**	**Highest Density**
Ovenbird	OVEN	6.18			Weak negative influence w/ height up to max 0.5-1m				Denser w/increases above 26-50%					Black Cherry Northern Hardwood but similar across all hardwood types
Red-eyed Vireo	REVI	5.62	Denser below 1800'			Negatively influenced by increased tall shrubs								Black Cherry Norther Hardwood
Black-throated Green Warbler	BTNW	5.29		Highest density above 15-20m				Denser with Low level & Midslope position					Negatively influenced by logging in last 30 years	Hemlock-white pine
Black-throated Blue Warbler	BTBW	2.81	Denser above 2000'		Density increases (<1m) when >50%	Density increases (1-5m) >50%								Red Oak-Mixed Hardwood
Black-and-white Warbler	BAWW	1.8	Density decreases as elevation increases 1400' to 2000'		Density increases beginning w/ 6-12% short shrub cover		High snag count negatively influences density	Prefers mid-slope						Dry Oak-Heath & Mixed Hardwood
Blackburnian Warbler	BLBW	1.64	Density decrease above 2000'									Prefers steeper slopes		Hemlock-white pine--oak or other hardwoods w/ Hemlock
Scarlet Tanager	SCTA	1.42	Slightly denser below 1400'											Black Cherry Northern Hardwoods w/ Dry Oak Mixed close behind
Blue-headed Vireo	BHVI	1.07	Some decrease as elevation increases							Denser with cover >3%	Density increases from 80 sqft/ac to 170 sqft/ac			Hemlock-white pine & Northern Hardwoods

Forest Interior Birds of Dry Oak - Heath											
Species	**Code**	**Singing Males /20 acres**	**Elevation**	**Short Shrub (<2 m)**	**Tall Shrub (2-5m)**	**Snags**	**Topo Position**	**Herb. Cover**	**Small Rocks (<10cm)**	**Slope**	**Highest Density**
Black-throated Blue Warbler	BTBW	5.83	Denser above 2000'	Density increases (<1m) when >50%	Density increases (1-5m) >50%						Red Oak Mixed; Second highest in Dry Oak-Heath
Black-and-white Warbler	BAWW	5.25	Prefers lower elevation (Density decreases as elevation increases 1400' to 2000')	Density increases beginning w/ 6-12% short shrub cover		High snag count negatively influences density	Prefers mid-slope				Dry Oak-Heath & Mixed Hardwood
Ovenbird	OVEN	3.87		Weak negative influence w/ height up to max 0.5-1m				Denser w/increases above 26-50%			Black Cherry Northern Hardwood but similar across all hardwood types
Red-eyed Vireo	REVI	3.63	Denser below 1800'		Negatively influenced by increased tall shrubs						Black Cherry Norther Hardwood
Blackburnian Warbler	BLBW	2.78	Density decrease above 2000'							Prefers steeper slopes	Hemlock-white pine--oak or other hardwoods w/ Hemlock
American Redstart	AMRE	1.08							Increase with >5% cover		Red Oak-Mixed Hardwood

Forest Interior Birds of Dry Oak - Mixed Hardwood														
Species	**Code**	**Singing Males /20 Acres**	**Elevation**	**Tree Canopy Height**	**Short Shrub (<2 m)**	**Tall Shrub (2-5m)**	**Snags**	**Topo Position**	**Herb. Cover**	**Small Rocks (<10cm)**	**Basal Area**	**Slope**	**Recent Logging**	**Notes**
Black-throated Blue Warbler	BTBW	5.77	Denser above 2000'		Density increases (<1m) when >50%	Density increases (1-5m) >50%								Red Oak-Mixed Hardwood
Black-and-white Warbler	BAWW	4.96	Density decreases as elevation increases 1400' to 2000'		Density increases beginning w/ 6-12% short shrub cover		High snag count negatively influences density	Prefers mid-slope						Dry Oak-Heath & Mixed Hardwood
Red-eyed Vireo	REVI	4.86	Denser below 1800'			Negatively influenced by increased tall shrubs								Black Cherry Northern Hardwood
Ovenbird	OVEN	4.11			Weak negative influence w/ height up to max 0.5-1m				Denser w/increases above 26-50%					Black Cherry Northern Hardwood but similar across all hardwood types
Blue-headed Vireo	BHVI	3.67	Some decrease as elevation increases							Denser with cover >3%	Density increases from 80 sqft/ac to 170 sqft/ac			Hemlock-white pine & Northern Hardwoods
Black-throated Green Warbler	BTNW	3.36		Highest density above 15-20m				Denser with Low level & Midslope position					Negatively influenced by logging in last 30 years	Hemlock-white pine
Blackburninan Warbler	BLBW	2.19	Density decrease above 2000'									Prefers steeper slopes		Hemlock-white pine--oak or other hardwoods w/ Hemlock
Scarlet Tanager	SCTA	1.73	Slightly denser below 1400'											Black Cherry Northern Hardwoods w/ Dry Oak Mixed close behind
American Redstart	AMRE	1.17								Increase with >5% cover				Red Oak-Mixed Hardwood

Forest Interior Birds of Red Oak - Mixed Hardwood												
Species	**Code**	**Singing Males /20 acres**	**Elevation**	**Short Shrub (<2 m)**	**Tall Shrub (2-5m)**	**Herb. Cover**	**Snags**	**Topo Position**	**Basal Area**	**Small Rocks (<10cm)**	**Slope**	**Highest Density**
American Redstart	AMRE	4.48								Increase with >5% cover		Red Oak - Mixed Hardwood
Black-and-white Warbler	BAWW	2.70	Density decreases as elevation increases 1400' to 2000'	Density increases beginning w/ 6-12% short shrub cover			High snag count negatively influences density	Prefers mid-slope				Dry Oak-Heath & Mixed Hardwood
Blue-headed Vireo	BHVI	2.82	Some decrease as elevation increases						Density increases from 80 sqft/ac to 170 sqft/ac	Denser with cover >3%		Hemlock-white pine & Northern Hardwoods
Blackburnian Warbler	BLBW	2.07	Density decrease above 2000'								Prefers steeper slopes	Hemlock-white pine--oak or other hardwoods w/ Hemlock
Black-throated Blue Warbler	BTBW	8.18	Denser above 2000'	Density increases when >50%	Density increases >50%							Red Oak-Mixed Hardwood
Hairy Woodpecker	HAWO	1.58					Denser with >10 snags/ac					Red Oak-Mixed Hardwood
Ovenbird	OVEN	2.33		Weak negative influence w/ height up to max 0.5-1m		Denser w/increases above 26-50%						Black Cherry Northern Hardwood but similar across all types
Red-eyed Vireo	REVI	5.48	Denser below 1800'		Lower density with more cover							Black Cherry Norther Hardwood
Scarlet Tanager	SCTA	1.06	Slightly denser below 1400'									Black Cherry Northern Hardwoods w/ Dry Oak Mixed close behind