A Bird Community Index for the

Mid-Atlantic Piedmont and Coastal Plain

Final Report
Submitted to:

U. S. Environmental Protection Agency – NCERQA
401 M. Street, SW (8723R)
Washington, DC 20460

Report No. 2003-02
Penn State Cooperative Wetlands Center
April 2003

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United States Environmental Protection Agency

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April 2003

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Executive Summary

At the Penn State Cooperative Wetlands Center, we are pursuing several projects aimed at developing large-scale ecological assessment tools that feature the ecological characteristics of breeding songbird assemblages as the primary indicator. Based on earlier research that produced a bird community-based indicator of ecological condition in the Appalachians, we expanded to the Mid-Atlantic Piedmont and Coastal Plain physiographic provinces in 2001. We sampled 81 sites with point counts along 1-km transects across a broad study region from eastern Pennsylvania to coastal North Carolina and inland to the Ridge-and-Valley physiographic province. We selected sample sites to represent a gradient of condition from urban or industrial land cover, to intensive crop production, to low density residential development, to managed forest for timber and pulpwood, and mature forest. We recognize two distinct states of "natural" condition at landscape scales in uplands of the study region: a mature, mesic, broadleafed or mixed forest that is infrequently disturbed by natural forces, and a pine and oak savanna maintained by frequent low-intensity fires. Like our previous research in the Appalachians, we found traditional community measures such as richness and Shannon diversity to be unreliable indicators of anthropogenic disturbances. In contrast, life history groups such as "ground nesting forest birds" exhibit statistical relationships to varying degrees of landscape level disturbance. We chronicle herein the development of a new Piedmont/Coastal Plain Bird Community Index that uses proportions of nine guilds to assess overall ecological condition.

A Bird Community Index for the Mid-Atlantic Piedmont and Coastal Plain

Introduction

Natural resource managers, agency representatives, and others interested in characterizing the health or condition of a given area frequently rely on ecological indicators to provide efficient and reliable information on the system under study. Many indicators have been developed to date, and these range in scale of response from site-specific indicators of stream water quality (e.g., benthic macroinvertebrates, Karr 1991, 1993; Fore et al. 1996) to landscape scale indicators of entire ecoregions (e.g., Jones et al. 1997).

The Bird Community Index (BCI) was one of the early attempts to produce a biological indicator that operates at an ecoregion scale (O'Connell et al. 1998). The BCI is a multi-metric index that ranks relative proportions of 16 songbird life history guilds on a scale of ecological condition. Because the BCI was initially modeled on a series of sites at which multiple taxa (e.g., herbaceous plants, mammals, amphibians) had been assessed, BCI scores are intended to convey information on overall ecological condition, rather than just on the condition of the songbird assemblage. Because BCI scores are significantly associated with elements of land cover, the BCI summarizes biological information at landscape scales and calibrates thresholds of land cover change with significant biological changes in bird communities (O'Connell et al. 2000).

Ecological indicators that feature data on songbird assemblages are well suited for generalized assessments of upland condition at large scales for several reasons. First, with a few noteworthy exceptions (e.g., salt flats, high peaks), there is a relatively species rich songbird assemblage occurring in every upland environment of temperate North America. Many species' distributions are affected by habitat fragmentation or other habitat structure parameters (Askins and Philbrick 1987, Freemark and Collins 1992, Murray and Stauffer 1995, Wilson et al. 1995, Schmiegelow et al. 1997). Also, birds commonly occupy high trophic levels and may integrate functional disturbance at lower levels (Cody 1981, Sample et al. 1993, Pettersson et al. 1995, Rodewald and James 1996). Bird community composition reflects interspecific dynamics and population trends (Cody 1981). Thus, a detailed community account of a breeding songbird assemblage conveys information relating to ecosystem structure, function, and composition that are relevant to discussions of ecological health or integrity (Noss 1990, Karr and Chu 1999).

Birds assemblages are also attractive as ecological indicators because, relative to other taxa, songbird survey techniques have been well studied, and millions of people are skilled in techniques to sample birds. Also, several large scale monitoring projects are established across the United States and Canada that are volunteer supported, publicly available, and potentially a source of data to which songbird indicators could be applied. At least one such program, the North American Breeding Bird Survey, has shown potential as source data for the BCI (O'Connell et al. 2002). Thus, the implementation of bird-based models of ecological condition could be rapidly, cheaply, and efficiently administered across all U. S. ecoregions.

It is important to note, however, that the manner in which bird assemblage data are compiled bears on the utility of those data to accurately reflect ecological condition. Simple measures of species richness or Shannon-Weiner diversity can yield confounding results when these calculations peak at levels of intermediate disturbance. To eliminate this ambiguous interpretation, we designed the BCI to feature relative proportions of life history guilds on which breeding bird assemblages are sorted and ranked (e.g., Verner 1984, Szaro 1986, Brooks and Croonquist 1990). A bird community that indicates high integrity is dominated by guilds dependent on native system attributes. This guild-based approach to evaluating biotic integrity results in high BCI scores for bird communities in which specialists are well represented relative to generalists (O'Connell et al. 1998, 2000). Because each species belongs simultaneously to several guild categories, we can iteratively analyze bird species data to create a multi-metric index. Based on guilds, the index can be calibrated for many different regions and be relevant regardless of species composition.

A network of bird-based indicators, modeled after the BCI, could be developed and applied across all ecoregions of the coterminous United States and contribute to efforts to produce national assessments of ecological health and condition. The number of BCIs required to achieve full coverage for the coterminous U.S. is a function of large scale potential vegetation cover and major shifts in the breeding bird fauna. For example, the area to which we are confident in applying the original BCI encompasses the following ecoregions as identified in Ricketts et al. (1999): Appalachian/Blue Ridge Forests, Appalachian Mixed Mesophytic Forests, Central U.S. Hardwood Forests, Allegheny Highlands Forests, Southern Great Lakes Forests, and Eastern Great Lakes Forests (Figure 1). Throughout all of these ecoregions, broadleaf and mixed forest types predominate where anthropogenic disturbance is light, and songbird communities are typified by warblers, vireos, thrushes, and woodpeckers. In contrast, areas disturbed by urban or agricultural development are characterized by a dearth of warblers, and conspicuous corvids, blackbirds, and exotic species (O'Connell et al. 2000).

To the south and east of the original "Appalachian" BCI area, a significant shift in climate and geomorphology creates conditions in which a more xeric oak/pine forest or fire-influenced pine savanna characterizes areas receiving little anthropogenic disturbance. This area is identified in Ricketts et al. (1999) as including the Northeastern Coastal Forests, Atlantic Coastal Pine Barrens, Southeastern Mixed Forests, Middle Atlantic Coastal Forests, and Southeastern Conifer Forests ecoregions. We refer to this area as the “Piedmont/Coastal Plain,” a title that is inclusive of both Atlantic and Gulf coastal areas (Figure 1).

Corresponding with differences in potential natural vegetation between Appalachian and Piedmont/Coastal Plain areas, there is also an important shift in potential bird fauna. At least 22 species of small land birds, including nine species of warblers, breed in the Appalachian area but not in the Piedmont/Coastal Plain area. Approximately six species breed in the Piedmont/Coastal Plain but not in the Appalachian area. Thus, due to differences in potential vegetation and potential breeding bird fauna, we conclude that the original “Appalachian” BCI is inappropriate in the Piedmont/Coastal Plain area, and development of a new BCI for the Piedmont/Coastal Plain is warranted.

Objectives. Our objective in this research was to develop a new Bird Community Index specific to the Piedmont/Coastal Plain. The intent was not to produce a model for application at a local scale that would result in a bird-based rating of ecological health at any given site, e.g., a suburban backyard. Rather, the BCI is a model that is applied to data from multiple spatially explicit locations for an assessment of the entire region. Thus, we cannot provide an accurate assessment of ecological health in the Piedmont/Coastal Plain with the model described herein; the assessment is a second step featuring the application of our model to other data (e.g., Breeding Bird Survey) from the region.

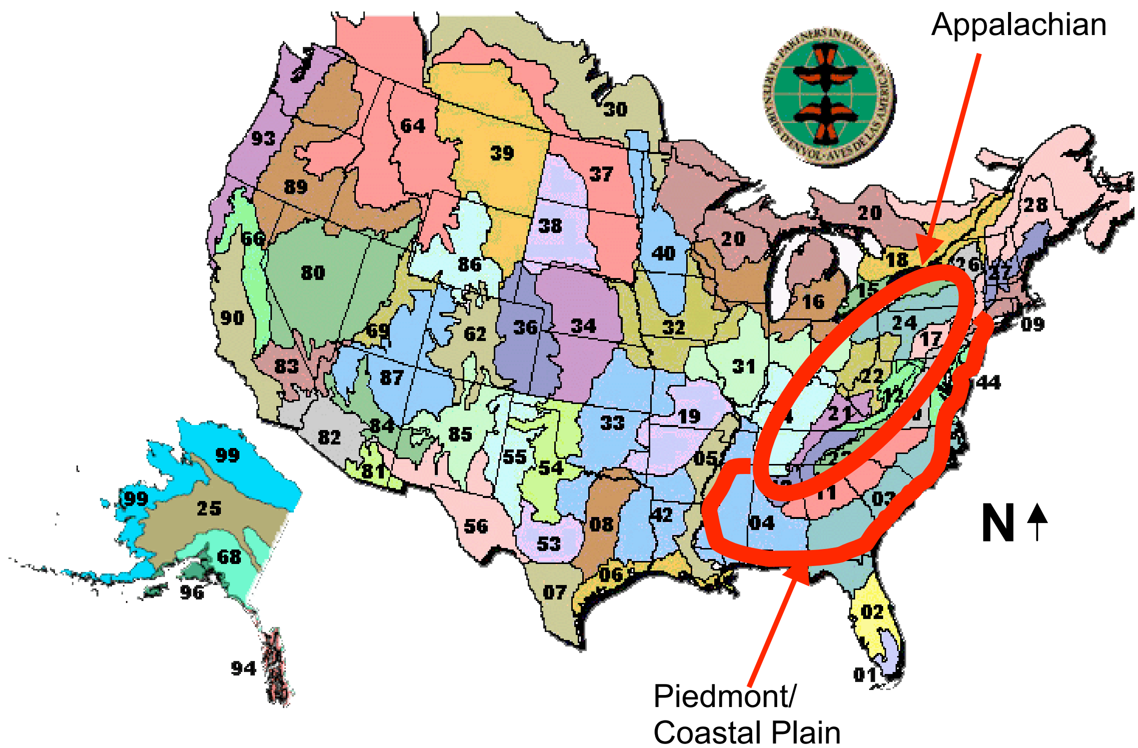

Figure 1. Approximate regions of application for the “Appalachian” and the proposed “Piedmont/Coastal Plain” Bird Community Index overlaid on a map of Partners in Flight physiographic management areas. Map courtesy of Partners in Flight (www.blm.gov/wildlife/pifplans.htm).

Methods

Study Area. We conducted field work within upland environments of the Mid-Atlantic Piedmont and Coastal Plain physiographic provinces of Pennsylvania, Maryland, Delaware, Virginia, North Carolina, and the District of Columbia. This region contains examples of habitats, natural disturbance regimes, environmental stressors, and potential avifauna representative of the entire Piedmont/Coastal Plain area. We developed the BCI with data from 81 sites in this region intended to reflect a gradient of ecological condition from near pristine to severely degraded (Figure 2).

We attempted to sample breeding bird assemblages from a gradient of condition in the region. Thus, we visited older growth broadleaf forest, fire-maintained pine savanna, regenerating forests, agricultural lands, residential developments, and highly urbanized areas. Again, the goal was not for the proportion of sites to be representative of the region, but rather to sample from the complete range of upland conditions in the region.

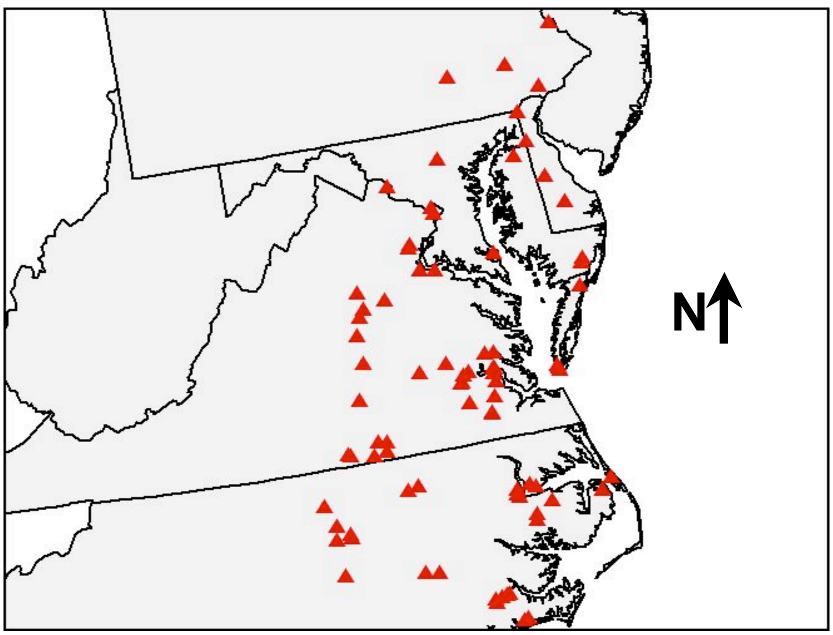

Figure 2. Approximate sample locations of 81 sites used in the development of the Piedmont/Coastal Plain Bird Community Index.

Ecological Condition in the Region. We made the *a priori* decision to recognize two distinct types of habitats that would indicate high ecological integrity, i.e., best attainable ecological condition in the region. A mature, 2nd growth broadleaf forest type, dominated by oaks, beech, hickories, and tuliptree occurs in scattered parks and natural areas in patches big enough to acquire certain older growth characteristics (e.g., abundant downed wood, large diameter trees, pit-and-mound topography). Some examples include Calvert Cliffs State Park in Calvert County, MD, the College Woods on the campus of the College of William and Mary in Williamsburg, VA, and Medoc Mountain State Park in Halifax County, NC.

We identified a fire-influenced pine savanna habitat as a second type indicative of high ecological integrity in the study region. In these habitats, isolated stands of mature pines are embedded in a matrix of grasses. Oaks (*Quercus*), sweetgum (*Liquidambar*) and *Rubus* thickets may also be represented in these habitats. In the southern U.S., the dominant pine in savannas is often longleaf pine (*Pinus palustris*); in our Mid-Atlantic study area loblolly pine (*Pinus taeda*) serves as the dominant pine species. While pine savannas historically occurred across much of the Piedmont and Coastal Plain, they typically occur today only where specific management (i.e., prescribed fire) has been introduced to mimic a natural disturbance regime, or on military bases where explosion of live ordnance creates frequent low intensity fires in certain areas. The Blackwater Ecological Preserve in Virginia's Isle of Wight County and the Croatan National Forest in Carteret County, NC provide well developed examples of Southeastern pine savanna.

The Mid-Atlantic study area is experiencing rapid growth in commercial and residential development, and includes several large metropolitan centers, e.g., Philadelphia, PA, Washington, DC, Virginia Beach, VA, and Raleigh-Durham, NC. In addition to the pressures of urban sprawl in the region, intensive agricultural development for both crop and livestock production is widespread, and forests frequently persist as small patches relative to the Appalachian region. Forest management practices that replace mature hardwood stands to short rotation pulp and paper production also significantly degrade the quality of the apparent forest habitat revealed by satellite imagery.

Sampling. At each site, we established a 1-km sampling transect with five sample plots located every 200m along the transect. Where access was granted by land owners, we established off-road transects through forests, fields, or clearcuts. We also sampled along roads, utility rights-of-way, or walking paths where we were prohibited from following an off-road transect (e.g., residential subdivisions) or where there would be no apparent benefit to leaving the path (e.g., state parks).

At each plot along a transect, we sampled birds with a 10-minute, unlimited-radius point count between sunrise and 10:00 hrs EDT (Hutto et al. 1986, Manuwal and Carey 1991, Ralph et al. 1993). We divided detection times into the first three, first five, and last five minutes of the count period to facilitate comparisons to other sampling methods. We timed bird sampling to coincide with the peak number of breeding songbirds in the region and minimize the number of transients in the data. Thus we restricted bird sampling to the period between 23 May and 3 July, 2001. We initiated field work earlier in the southern portions of the study area, and concluded in July in the northern portion of the study area.

While we recorded all individuals of any species that we encountered during point counts, we restricted analysis to a subset of the total species pool that is efficiently sampled by our methods. Thus, the subjects of this research include all breeding members of the Passeriformes, Columbiformes, Apodiformes, Piciformes, Cuculiformes, and the Common Bobwhite (*Colinus virginianus*).

At each bird sampling plot, we also sampled a suite of vegetation variables to characterize ground-level habitat. We recorded the percentage cover of graminoids, forbs, mosses, ferns, leaf litter, downed wood, rock, and impervious surfaces in three, 5-m radius, circular subplots located 25m from plot center at 120, 240, and 360°. Also in the subplots, we recorded the percentage cover of shrubs from 0.00-0.50m, 0.51-2.00m, and 2.01-5.00m, and identified all shrubs to genus. Because we stressed vertical structure over taxonomic affinity in our vegetation sampling, we applied the term "shrub" liberally, and considered any leaf cover less than 5m in height to be a component of the "shrub layer." We recorded in the 5m subplots the number of downed trees at least 50cm in diameter, the number of exposed root masses from fallen trees, the number of trees with fire scars, and applied an Anderson Land Use Code (Anderson et al. 1976). For sampling overstory trees, we established 11.3m-radius tree plots on the same center points as the 5m subplots. All live trees within these plots were identified to species and the dbh was recorded for trees and snags. We used a clinometer to determine canopy height and slope, and a compass to assign aspect to each tree plot. We determined plot elevation from USGS 7.5-minute topographic maps. All estimates of percentage cover were made via ocular estimation with direct comparison to a percentage cover template design.

Because we relied on multiple observers to collect data in the field, we conducted training sessions for all observers prior to the field season. All observers demonstrated at least 85% agreement in assessments of percent cover, tree heights, slope measurements, auditory bird species identification, and abundance of bird species before any data were collected. We also ran a “spot-check” on bird sampling later in the field season (22 June) in which all observers conducted simultaneous point counts from the same location.

For each sample site, we identified the coordinates for the center point of the 1-km transect on USGS topographic maps using MapTech Terrain Navigator topographic software (MapTech 2001). We are confident that all center points we mapped in this way were accurate to within 10m of the actual transect center point. With center points located, we quantified land cover in the local landscape contained within a circular area of 500m radius centered on the transect center point. The resulting area is approximately 79ha on the ground. O’Connell et al. (2000) demonstrated a high correlation between land cover at this local scale and condition of the breeding songbird community.

Land cover data that were used in this study were produced as part of a cooperative project between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (USEPA) to produce a consistent, land cover data layer for the conterminous U.S. based on Landsat thematic mapper (TM) data. National Land Cover Data (NLCD) were developed from TM data acquired by the Multi-resolution Land Characterization (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies that produce or use land cover data (Loveland & Shaw 1996). Spatial resolution is 30m on a side (900 m^2) and the images were preprocessed to correct for electronic problems and geographic referencing by the MRLC. Images for the mid-Atlantic region were acquired from dates ranging from 1989 to 1994.

To quantify land cover around our sample sites, we plotted center point locations in ArcView on the NLCD layer, and clipped out the 79-ha circular area around the points. We used the program spatial analyst in ArcView to calculate land cover metrics.

Bird Communities in the Study Area. We summarized bird data for each site by pooling data collected at each of the five point counts. We used abundance data from the transects to calculate richness and diversity and to sort sites by dominant species.

We used species occurrence data only to calculate proportions of life history guilds in each species assemblage.

We assigned birds to 33 life history guilds based on a literature review (Harrison 1975, Blake 1983, DeGraaf et al. 1985, Roberts 1987, Ehrlich et al. 1988, Freemark and Collins 1992, Curson et al. 1994, Byers et al. 1995, Rising 1996, Baicich and Harrison 1997, Gough et al. 1998, O'Connell 1999, Chadwick 2003) (Appendix A). To construct the Piedmont/Coastal Plain BCI, we iteratively reduced the number of guilds that could serve as potential metrics in the BCI, aiming for 8-12 metrics in the finished model (Karr and Chu 1999). We considered several factors (e.g., high correlation with other guilds, predictable response to land cover change) in determining the final list of guilds to be included in BCI development.

Because we selected guilds specifically to reflect different aspects of each species' life history traits, species belong simultaneously to several guilds. Also, guild assignments apply only to breeding season life history traits. If a species subsists on fruit during the winter but is insectivorous during the breeding season, we included that species with the insectivores. Also, guild assignments were specific to the Piedmont/Coastal Region, so we considered American Robin (*Turdus migratorius*) to be a resident even though this species is highly migratory in more northern portions of its breeding range.

We categorized individual guilds as “specialist” or “generalist” based on each guild’s relationship to specific elements of ecosystem structure, function, and composition. With this interpretation, a high proportion of a “specialist” guild or a low proportion of a “generalist” guild at a site both result in high ranks for those guilds at those sites. The ultimate BCI score is a compilation of individual guild ranks, based on our interpretation of guild proportions. Because the guilds we used are really life history traits, a single species may be assigned to both specialist and generalist guilds simultaneously.

To illustrate the interpretation, the Nest Placement guilds relate directly to the availability of appropriate nesting substrate (a structural element). In our study, obligate tree-canopy nesters (specialists) indicate high integrity because they are largely restricted to mature forests native to the region, while shrub nesters (generalists) also encounter appropriate nesting substrate in regenerating forests, agricultural hedgerows, and suburban areas (Brauning 1992).

Analysis. To describe the variability in species occurrence and abundance, we applied a detrended correspondence analysis (DCA) to the raw abundance data from all 81 sites. We then identified regions of ordination plot that shared similar land cover proportions.

With species assigned to guilds, we summarized the proportional species richness of each guild at each site to construct a bird community profile. For example, if two of the species at a site containing a total of 10 species are single-brooded, then the bird assemblage at the site would be summarized with a “0.20” for the single-brooded guild. We grouped sites according to their similarity in bird community profiles through cluster analysis, and confirmed statistically separable differences in individual guild proportions among groups with one way analysis of variance (ANOVA) and Tukey’s multiple comparisons procedure (Neter et al. 1990).

Prior to analyses, we tested all variables for normality (Anderson-Darling test) and homogeneity of variance (Levene’s test). Variables that did not meet our assumptions of normality or homogeneity of variance for parametric statistics were transformed or omitted from analyses (Neter et al. 1990). All statistical analyses were performed with the Minitab 10.5 Xtra for the Power MacIntosh statistical software package (Minitab 1995) or Canoco for Windows ordination software.

Steps in Development of the Piedmont/Coastal Plain BCI. With a basic idea of community structure in the region and a guild profile available for every site, we began the process of testing guild proportions as potential metrics in the BCI. Again, the process is iterative, and subsequent steps are based on the results of preceding steps:

1. Because we were dealing exclusively with proportional data and we desired to use normally distributed data for multivariate applications, we ran arcsin transformations on all guild proportions (Neter et al. 1990).

2. To minimize the potential for multicollinearity to influence multivariate analyses, we examined correlation matrices to identify a smaller number of guilds that would not be correlated with any other guild at $r > 0.60$. Through the analysis of correlation matrices, transformations, and tests for normality, we reduced the number of guilds that could be used for multivariate analysis from 33 to 8.

3. We applied cluster analysis to the 81 sites, grouping sites according to arcsin-transformed proportions of: interior forest birds, forest edge birds, cavity nesters, shrub nesters, temperate migrants, Partners in Flight (PIF) open country priority species for the Southeastern U. S., insectivores that primarily forage below 5m, and aerial sallying insectivores. We used Ward's linkage and Euclidean distance to produce this cluster.

4. To determine the maximum number of clusters (i.e., the number of bird communities in the region), we used ANOVA to identify statistically separable categories of guild proportions in the groups of sites that clustered together. For example, if the cluster analysis revealed three distinct groups of sites, we would test individual guild

proportions for differences among those clusters using cluster number as the factor level in the ANOVA model.

5. With five clusters identified, we first tested individual guilds for normality and homoscedasticity among the five clusters/factor levels. Diversity, richness, and 19 guilds met the requirements of the ANOVA model. While no single guild occurred in proportions that were mutually statistically distinct among all categories, the ANOVA results for 18 of 19 guilds provided redundant, statistically significant support for an interpretation that five bird communities occur in the study area.

6. We next applied ranks (based on the specialist/generalist interpretation) to relative proportions of 18 guilds at the 81 sites. Because no single guild occurred in five mutually distinct proportions, even though our analysis pointed to five distinct communities, we could only rank guilds from one to four. Thus for each of 18 guilds, a site received a rank of 1-4.

7. To determine a preliminary BCI score for each site, we summed all ranks, divided by 18, and then divided by 4. The division steps normalize BCI scores on a theoretical absolute scale from 0.25 – 1.00.

8. Next we clustered (Ward, Euclidean) sites by two variables: BCI score and rank of BCI score over all 81 sites. The point of this step was to determine the number of categories of ecological condition that occur in the study area, based on BCI.

9. With the number of clusters again serving as ANOVA factor levels, we tested for differences in BCI scores among clusters. Strictly applied, there is circularity in testing for BCI score differences when BCI scores were used to build the cluster. Our intent, however, was to apply the ANOVA only to shed light on the cluster results and determine the number of distinct categories of sites supporting similar BCI scores. This step confirmed four categories of sites in the region in different states of ecological condition.

10. To reduce the number of guilds to be included in the final model from 18 to 8-12, we decided to select three structural, three compositional, and three functional guilds that exhibited a strong dose response curve (Karr and Chu 1999) on a gradient of percent forest in the local landscape.

11. To determine if the Bird Community Index relates to actual land cover at local scales, we used regression and ANOVA to characterize the relationship.

Results and Discussion

Birds of the Piedmont/Coastal Plain. We documented 120 species at the 81 sample sites during point counts in the 2001 breeding season. Species richness ranged from 10 to 49 (mean 27), mean Shannon-Weiner diversity was 17.41. Of the 120 total species recorded, 30 were species not reliably sampled with our point count methods (e.g, raptors, herons, shorebirds), and these were omitted from further analysis. The remaining 90 passerines and allies occurred across a large gradient of abundance and distribution. For example 12 species were recorded in abundances less than 0.1% of the total number of individuals sampled. In contrast, nearly 15% (1954) of all individuals detected were European Starling (*Sturnus vulgaris*). The top five most abundant species, amounting to nearly 35% of all 13,204 individuals detected were starling, Common Grackle, American Crow, Barn Swallow, and Northern Cardinal.

Regarding distribution of 90 breeding songbirds and near passerines, eight species were detected at a single site, while we recorded American Crow at 84% of sample sites. Seven species (American Crow, Northern Cardinal, Carolina Wren, Mourning Dove, Brown-headed Cowbird, Red-eyed Vireo, Tufted Titmouse, and Downy Woodpecker) occurred at 66% (at least 53) of the 81 sites. Despite the great abundance of European Starling in the study area, this species was limited in distribution to just 32 (40%) of sample sites.

A Detrended Correspondence Analysis of abundance data (Figure 3) reveals a major gradient with at least two diverging community types at one end. Figure 4 illustrates a hierarchical cluster dendrogram based on proportions of eight arcsin-transformed life history guilds at 81 sample sites. Cluster analysis suggested that there are five distinct bird communities embedded in the sample. Table 1 presents results of one-way ANOVAs on guild proportions using cluster identifiers as ANOVA factor levels.

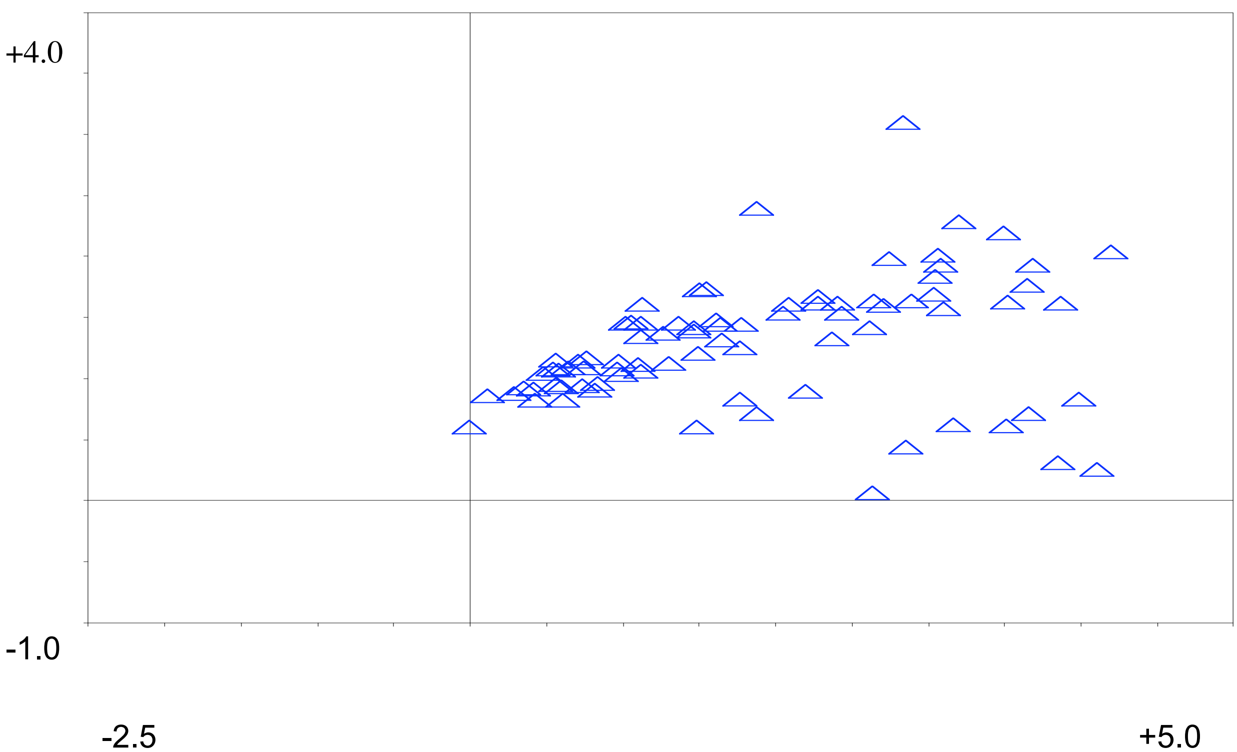

Figure 3. Detrended Correspondence Analysis based on raw abundance of 90 passerines and allies at 81 sites in the Mid-Atlantic Piedmont and Coastal Plain.

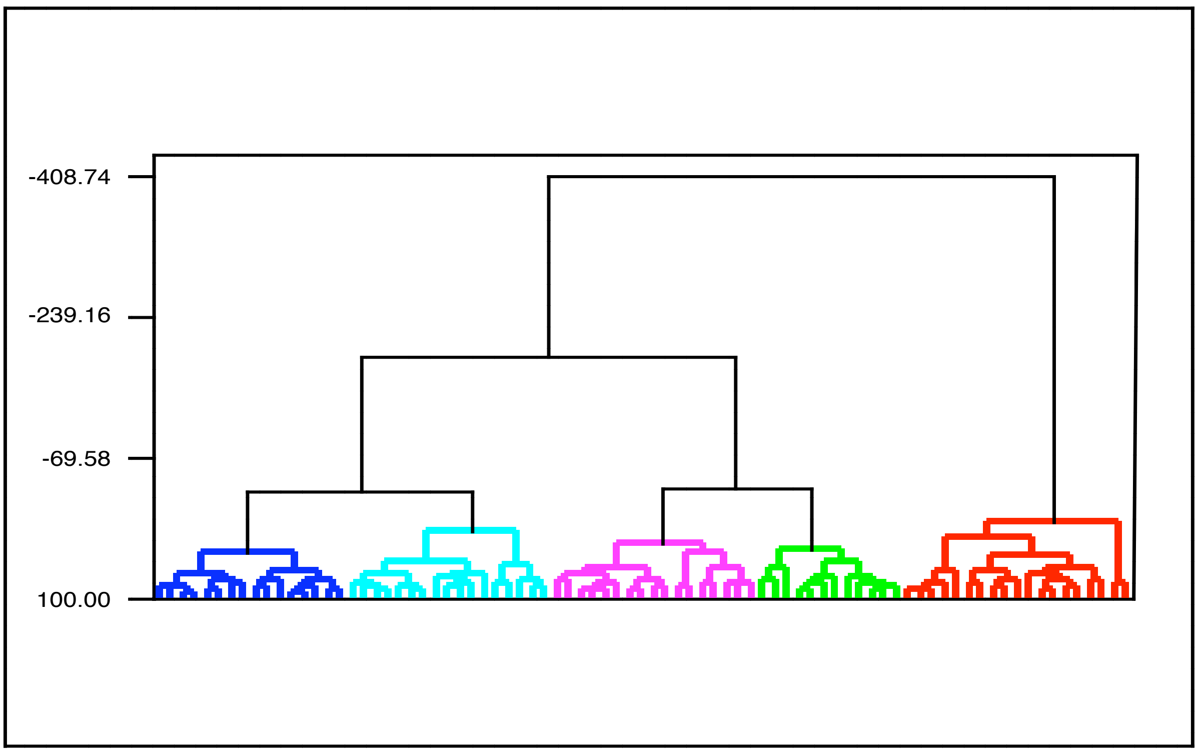

Figure 4. Hierarchical cluster (Ward's linkage, Euclidean distance) of 81 sites by proportions of eight life history guilds. Five clusters are indicated.

Table 1. One-way ANOVA results (4,80 df) using cluster memberships from Figure 4 as factor levels in the ANOVA model. Statistical differences (alpha = 0.05) among clusters were determined using Tukey's procedure for multiple comparisons. Letters indicate statistical significance in mean guild proportions among groups.

Guild	**F**	P	**Cl. 1**	**Cl. 2**	**Cl. 3**	**Cl. 4**	**Cl. 5**
Forest Generalist	18.90	<0.001	A	AB	BC	CD	D
Forest Edge	9.33	<0.001	AB	BC	C	C	A
Wetland/Riparian	0.34	0.853	6.6	6.4	7.1	7.9	6.6
Savanna/Oldfield	17.61	<0.001	A	AB	C	C	BC
Cavity Nester	15.36	<0.001	A	B	BC	BC	C
Shrub Nester	32.49	<0.001	A	B	C	BC	B
Tree Canopy nester	7.86	<0.001	A	AB	AB	C	BC
Resident	7.49	<0.001	A	AB	A	BC	C
Temperate Migrant	16.50	<0.001	A	A	B	B	A
Tropical Migrant	24.73	<0.001	A	A	A	B	B
Single Brooded	40.49	<0.001	A	B	B	C	C
Multi-Brooded	17.29	<0.001	A	B	BC	C	BC
PIF Priority	6.54	<0.001	A	AB	C	BC	ABC
Insectivore	41.21	<0.001	A	B	B	C	C
Bark Prober	45.25	<0.001	A	B	C	D	D
Ground Gleaner	29.52	<0.001	A	B	B	C	C
Upper Canopy Insectivore	18.74	<0.001	A	AB	BC	CD	D
Lower Canopy Insectivore	14.95	<0.001	A	A	B	A	C
Aerial Sallier	10.56	<0.001	A	A	A	B	B
Diversity	9.63	<0.001	A	A	A	AB	B
Richness	4.43	0.003	A	AB	B	B	A

BCI Development. When we ranked relative guild proportions and summed the ranks to calculate a preliminary BCI score, we were only able to discriminate four categories of scores within the five community types. A second cluster analysis, this time clustering on BCI score and rank of the BCI score, confirmed four categories of ecological condition in the study area (Figure 5). Figure 6 illustrates the distribution of BCI scores across the four clusters.

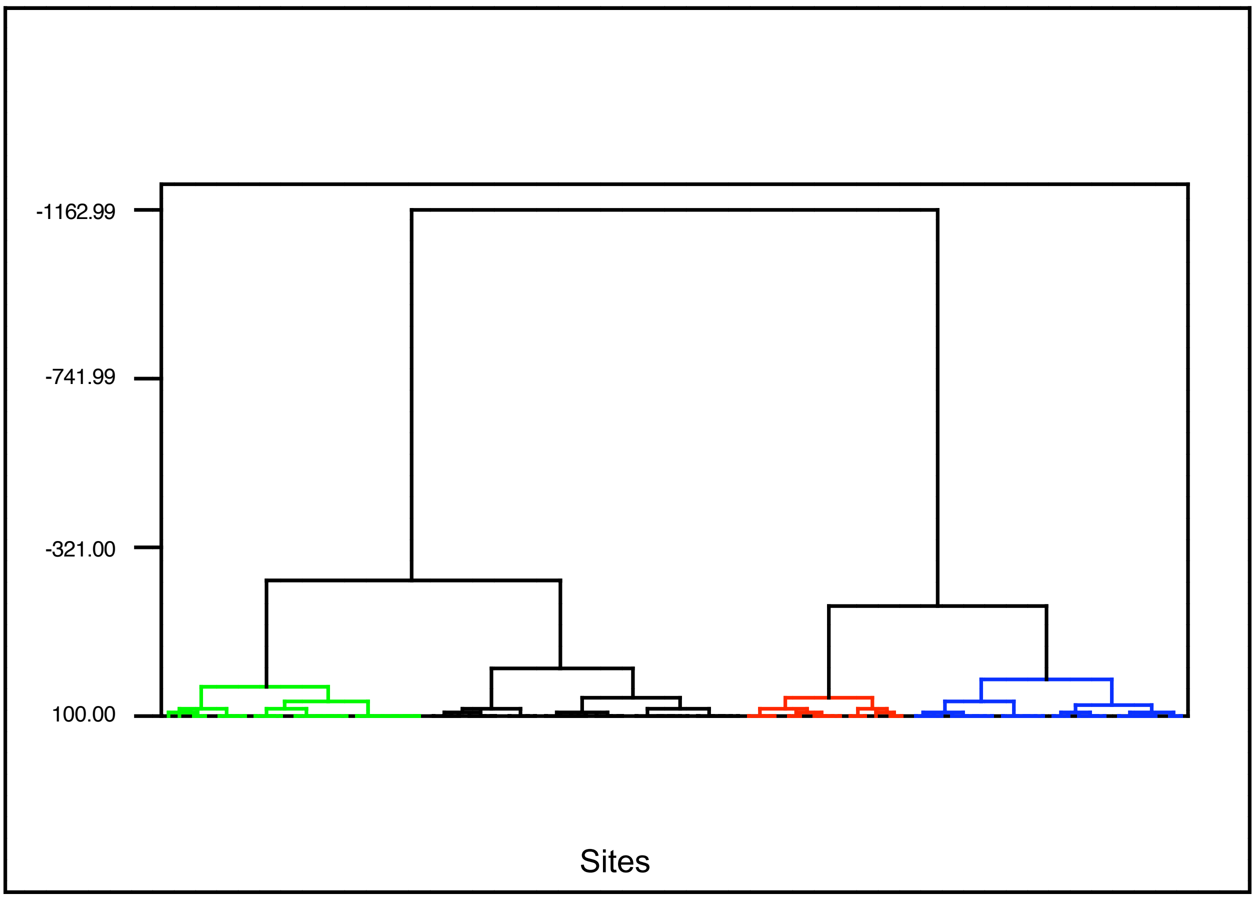

Figure 5. Hierarchical cluster (Ward's linkage, Euclidean distance) of 81 sites by preliminary BCI score and rank of BCI score among all sites.

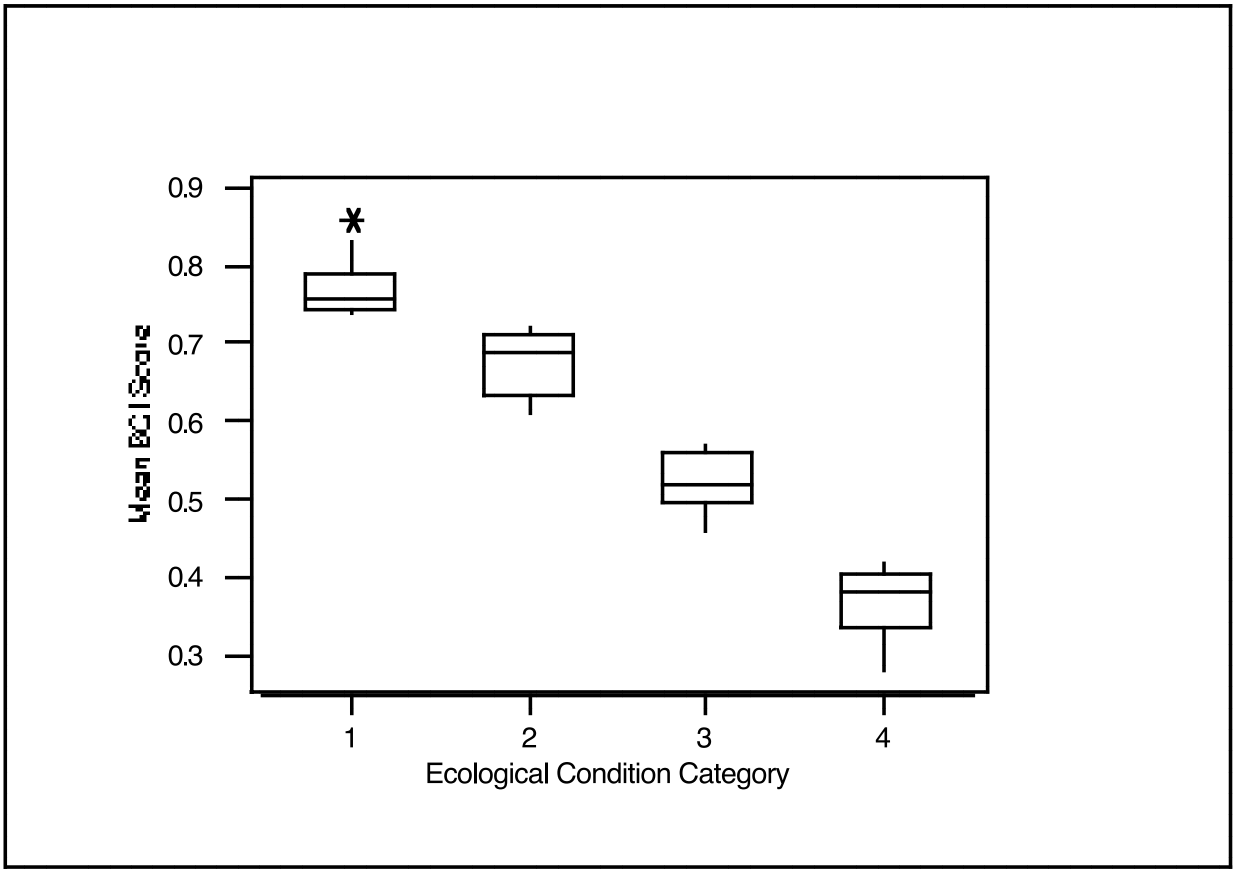

Figure 6. Mean BCI score in four categories of ecological condition identified in the cluster analysis illustrated in Figure 5. Values in each category are statistically distinct ($F_{3, 80}$ = 347.12, P < 0.001; Tukey C.I.s do not include zero) from adjacent categories.

Land Cover Sampling. We sampled sites that ranged from 0 to at least 90% land cover of forest, pasture, row crop, and urban types in the 79-ha circles around the transect center points (Table 2). Thus, we sampled from a broad spectrum of ecological condition in the region. The distributions, however, are highly skewed as evidenced by the difference between mean and median percent forest. Figure 7 illustrates representative land cover circles of various configurations.

Table 2. Descriptive statistics for proportions of five main cover types in 79-ha landscape circles around sample transect center points.

Cover Type	n	minimum	maximum	median	mean	SE
Forest	81	0	100	82.40	62.91	4.36
Pasture	81	0	96	0.69	13.12	2.54
Row Crops	81	0	100	0.46	12.28	2.36
Urban	81	0	91	0.00	4.65	1.82
Suburban	81	0	59	0.00	3.20	1.14

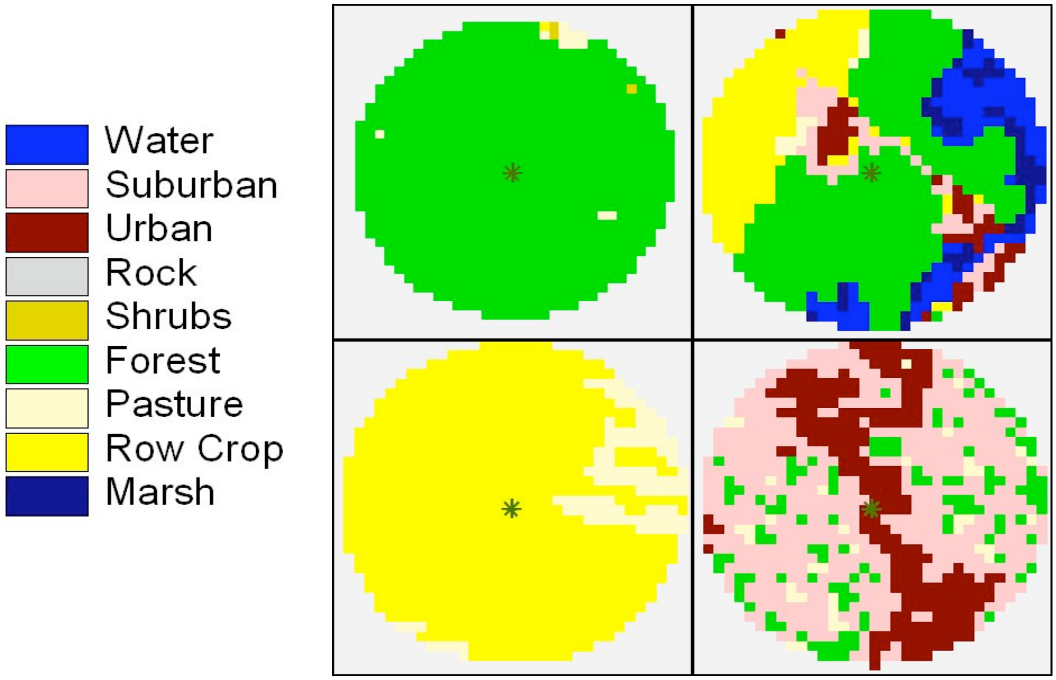

Figure 7. Representative land cover circles (79-ha) of the varied land cover configurations sampled in the Piedmont/Coastal Plain study area.

Land Cover Association with BCI. We found that local land cover, especially a simple measure of percent forest, in 79-ha circles, was strongly associated with songbird assemblage attributes. Figure 8 identifies regions of the DCA in Figure 3 where sites with similar land cover configurations are clumped. Figure 9 illustrates the fitted line plot for a highly significant regression between percent forest and BCI score. Finally, Figure 10 provides the distribution of percent forest in the four categories of ecological condition identified by clustering BCI scores (from Figure 5).

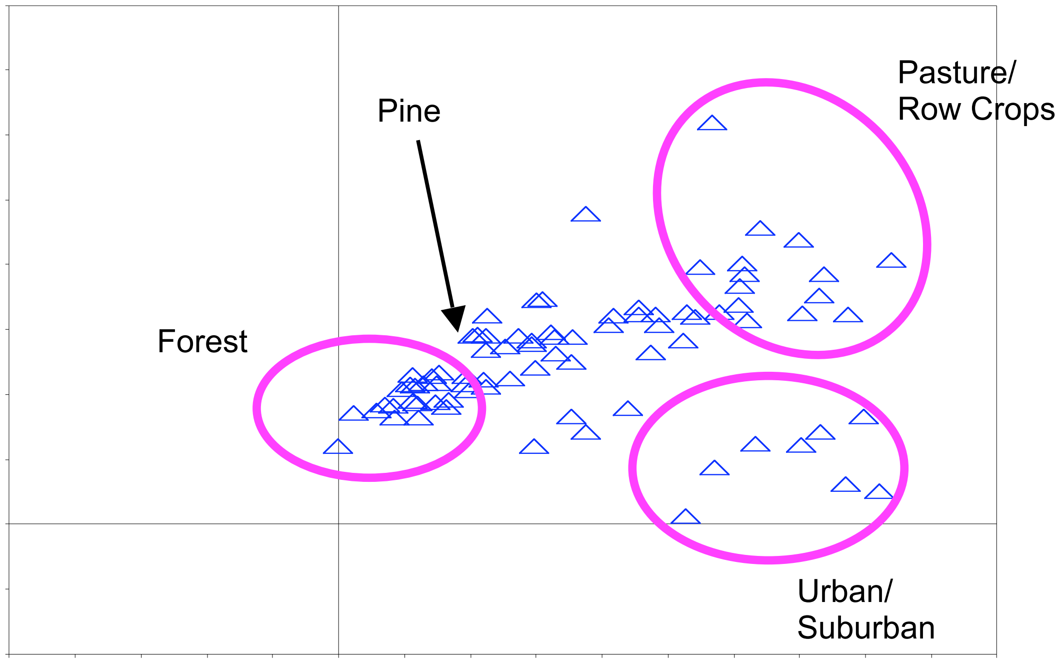

Figure 8. Regions of a DCA on raw species abundance where sites share common land cover attributes. The dominant land cover type within each ellipse is indicated. Note that sites where open pine savannas are managed with prescribed fire are grouped with sites supporting large blocks of closed canopy, mature, broadleaf forest.

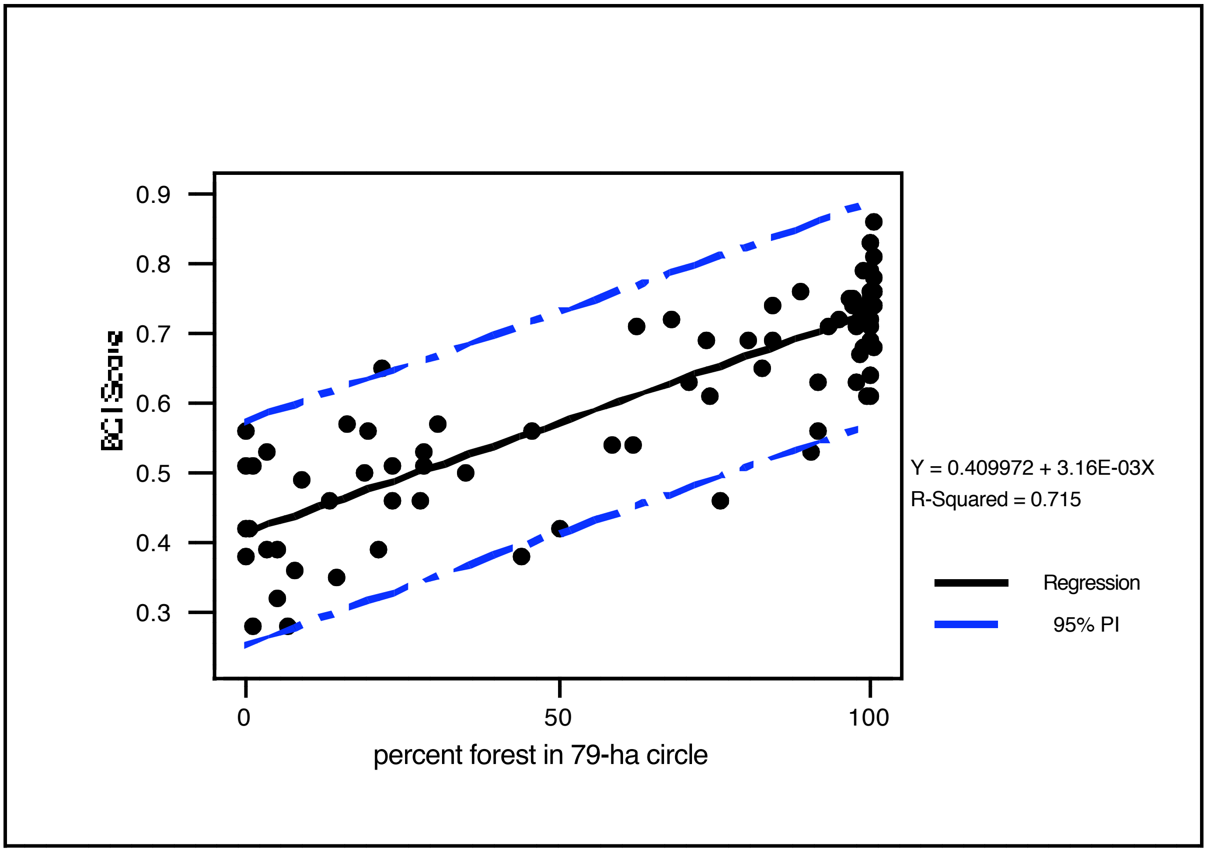

Figure 9. Fitted line regression of BCI score by percent forest (P< 0.001).

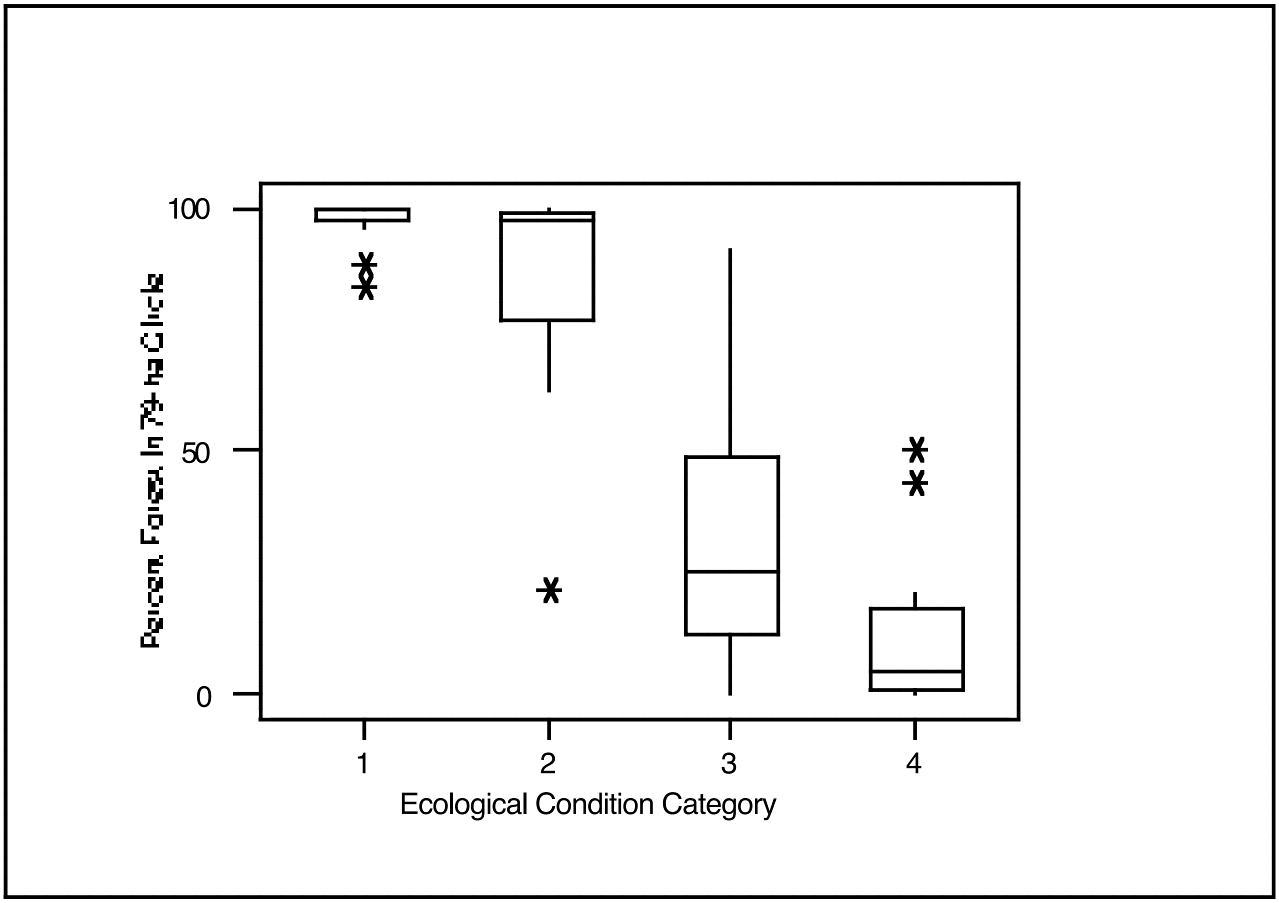

Figure 10. Mean percent forest in four categories of ecological condition identified with the BCI ($F_{3, 80}$ = 88.57, P < 0.001; categories 1 and 2 not significantly different).

Piedmont/Coastal Plain BCI. To produce a final version of the Piedmont/Coastal Plain BCI, we plotted proportions of 18 guilds in Table 1 against percent forest to describe a dose/response curve. From this exercise, we selected nine guilds that represented the strongest curves. Figures 11-13 illustrate the proportions of these guilds in four categories of ecological condition identified with the BCI. Table 3 lists the ranks for specific guild proportions.

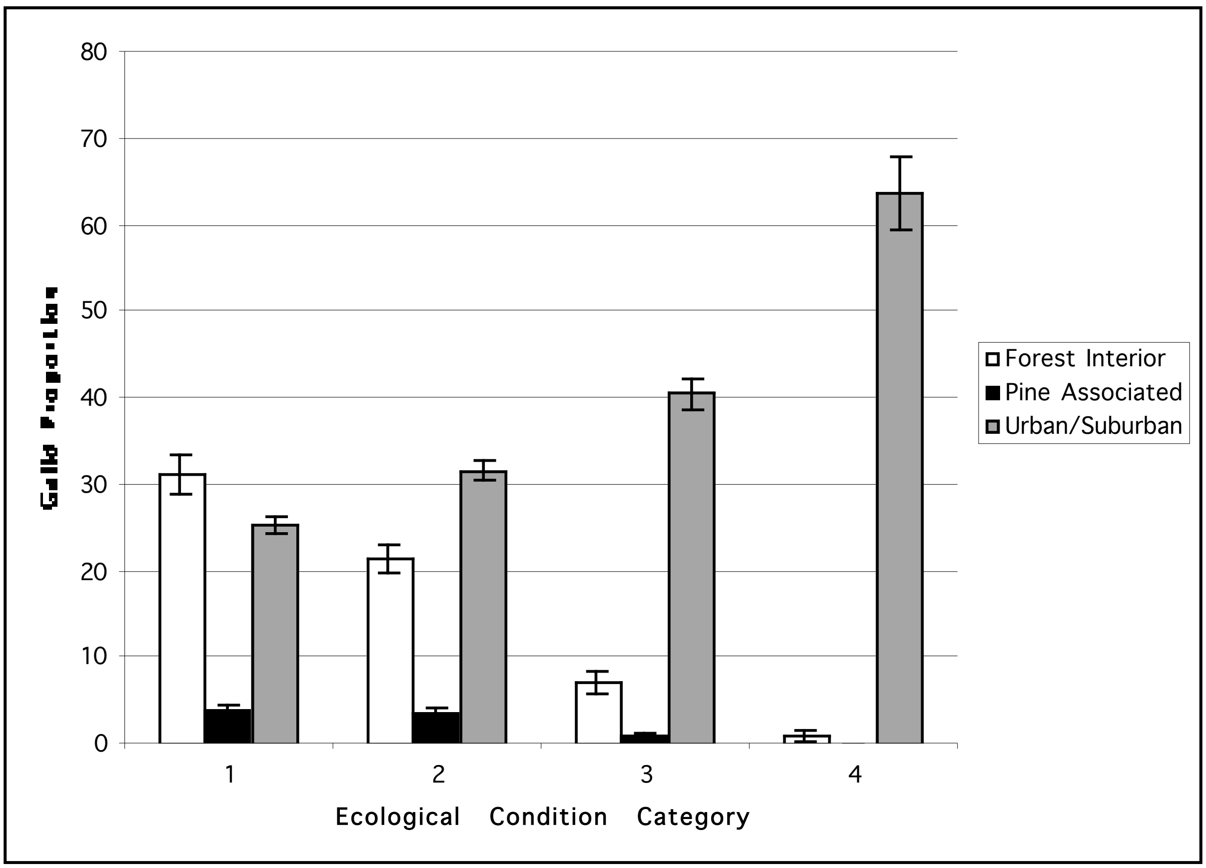

Figure 11. Proportions of three structural guilds among four categories of ecological condition identified with the Bird Community Index.

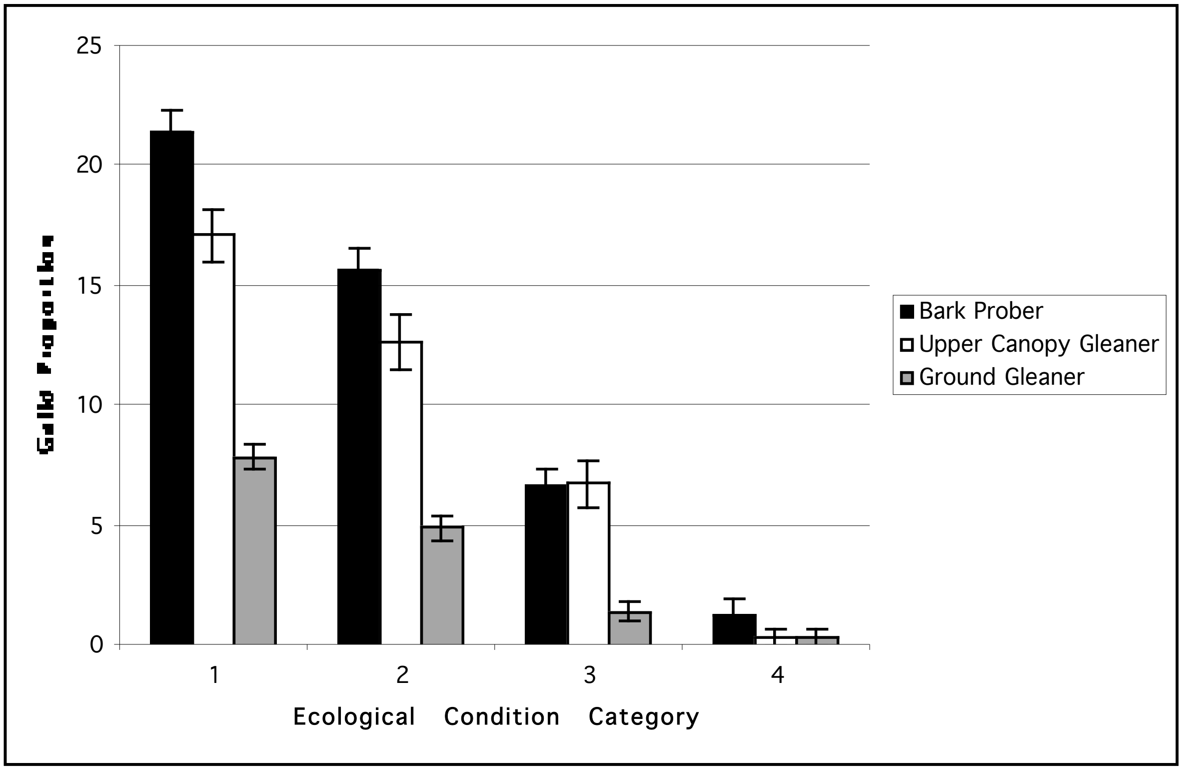

Figure 12. Proportions of three functional guilds among four categories of ecological condition identified with the Bird Community Index.

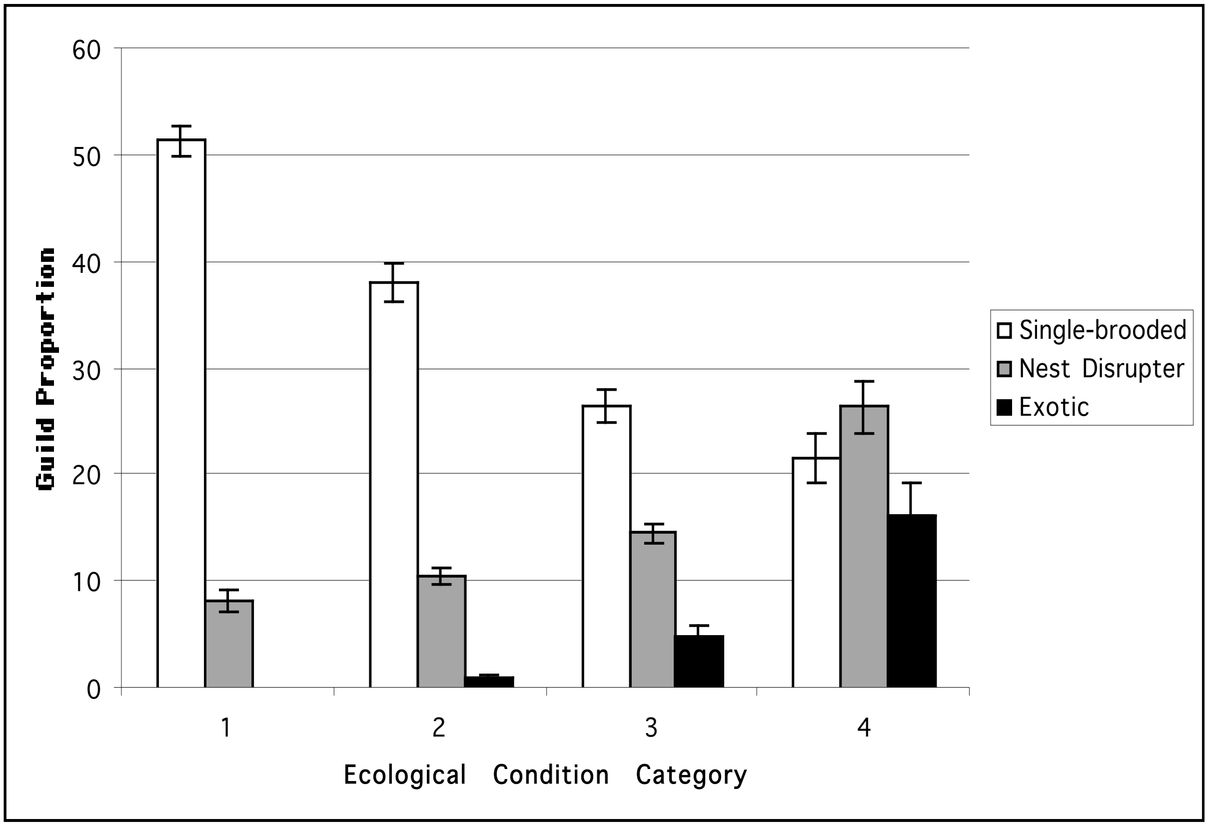

Figure 13. Proportions of three compositional guilds among four categories of ecological condition identified with the Bird Community Index.

Table 3. Ranks for specific guild proportions of nine guilds in the Piedmont/Coastal Plain BCI.

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

Thus the Piedmont/Coastal Plain BCI is calculated as follows:

V1 = ∑ Structural Guild Ranks/4

V2 = ∑ Functional Guild Ranks/4

V2 = ∑ Compositional Guild Ranks/4

BCI score = ∑ (V1-V3)/9

We recommend the following thresholds of total BCI scores for interpretation of ecological condition: humanistic (0.250-0.460), moderately disturbed (0.461-0.600), largely intact (0.601-0.730), and naturalistic (0.731-1.00).

Discussion. With the development of a new BCI for the Piedmont/Coastal Plain study area described herein, we now have a tool for assessing overall ecological condition across upland environments from southern New England, south along the Atlantic Coast, and inland to the Mississippi River floodplain. Together with the original Appalachian BCI, we have assessment tools capable of summarizing biological information at landscape scales across most of the eastern United States.

To produce an assessment of ecological condition for the Piedmont/Coastal Plain, the BCI would need to be applied to spatially explicit data on bird communities from the region. Those data could be derived from the Breeding Bird Survey, state breeding bird atlases, or a new sample of sites collected from a probability sampling grid.

The Piedmont/Coastal Plain BCI points to forest cover in the local landscape as crucial to maintenance of ecological integrity. We recognize that many rare or unusual habitat types of high conservation value are not forested, and may not score as high as expected with the BCI. Bird Community Indices are developed and intended for use across entire reporting regions, i.e., the proportion of sites in a region that fall into different categories of condition defines the utility of the BCI. The BCI is not intended to be used as a site specific, local scale tool for prioritizing conservation.

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Appendix A. Life history guilds used in development of the Piedmont/Coastal Plain BCI.

STRUCTURAL								
HABITAT ASSOCIATION								
forgen	**pine**	**forint**	**foredg**	**wetrip**	**grass**	**savold**	**agric**	**urbsub**
YBCU	RCWO	HAWO	RBWO	ACFL	GRSP	PUMA	BHCO	AMCR
RBWO	BHNU	PIWO	BBCU	SWWA	HESP	TRSW	AMCR	RODO
EAPH	PIWA	EWPE	RTHU	LOWA	VESP	NRWS	RODO	MODO
BLJA	BASP	ACFL	RHWO	EAPH	BOBO	BANS	MODO	HOSP
AMCR		WBNU	DOWO	YTWA	EAME	COYE	HOLA	EUST
BCCH		VEER	NOFL	PROW		RWBL	BARS	PUMA
CACH		WOTH	WIFL	PUMA		BTGR	FICR	NOMO
TUTI		YTVI	GCFL	TRSW		PRAW	EABL	AMGO
BGGN		NOPA	CARW	NRWS		PABU	HOSP	RBWO
WAVI		BTNW	HOWR	BANS		BASP	EUST	RTHU
REVI		BAWW	AMRO	MAWR		NOBO		DOWO
YTWA		CERW	GRCA	COYE		EAKI		CARW
PROW		AMRE	BRTH	SWSP		CLSW		AMRO
		SWWA	CEDW	RWBL		NOMO		GRCA
		LOWA	WEVI	BTGR		LOSH		CEDW
		WEWA	YEWA			YBCH		NOCA
		OVEN	PRAW			FISP		CHSP
		HOWA	SUTA			OROR		SOSP
		KEWA	NOCA			AMGO		COGR
		SCTA	BLGR			BEWR		BLJA
		RBGR	INBU					ECDO
		EATO	PABU					CHSW
			CHSP					HOFI
			SOSP					
			COGR					
			BHCO					
			BAOR					

NEST LOCATION						
forgro	opegro	graree	cavity	shbnes	trenes	shelfn
SWWA	BASP	RWBL	HOSP	NOMO	CEDW	ECDO
LOWA	HOLA	FISP	EUST	AMGO	BLJA	AMRO
VEER	NOBO	MAWR	PUMA	GRCA	ECDO	HOSP
WOTH	GRSP	SWSP	RBWO	CEDW	PRAW	HOFI
BAWW	HESP		DOWO	NOCA	EAKI	EUST
WEWA	VESP		CARW	CHSP	YEWA	PUMA
OVEN	BOBO		EABL	SOSP	BLGR	EABL
KEWA	EAME		TRSW	BLJA	YTVI	TRSW
EATO			PROW	ECDO	AMRE	RODO
			RHWO	HOFI	WOTH	CHSW
			NOFL	COYE	AMCR	BARS
			GCFL	BTGR	MODO	NRWS
			HOWR	PRAW	RTHU	BANS
			HAWO	PABU	AMRO	CLSW
			PIWO	EAKI	COGR	EAPH
			WBNU	LOSH	FICR	
			RCWO	YBCH	ACFL	
			BHNU	OROR	YTWA	
			BCCH	BBCU	SUTA	
			CACH	WIFL	BAOR	
			TUTI	BRTH	EWPE	
			BEWR	WEVI	NOPA	
				YEWA	BTNW	
				BLGR	CERW	
				INBU	SCTA	
				YTVI	RBGR	
				AMRE	PIWA	
				HOWA	BGGN	
				YBCU	WAVI	
				REVI		

COMPOSITIONAL							
MIGRATORY			**NUMBER BROODS**				**LIMITING**
resid	**tempmg**	**tropmi**	**single**	**multi**			**prepar**
ECDO	TRSW	PUMA	PUMA	BARS	HOLA		LOSH
AMRO	EAPH	CHSW	CHSW	BANS	RWBL		HOSP
HOSP	GRCA	BARS	NRWS	CLSW	FISP		EUST
HOFI	COYE	NRWS	PRAW	BLGR	SWSP		BLJA
EUST	BRTH	BANS	EAKI	RTHU	NOBO		AMCR
EABL	MAWR	CLSW	YEWA	RBGR	GRSP		BTGR
RODO	HESP	PRAW	YTVI	BGGN	EAME		RBWO
CEDW	VESP	EAKI	AMRE	WAVI	EATO		RHWO
BLJA	BEWR	YEWA	WOTH	PABU	BHCO		COGR
AMCR		BLGR	ACFL	YBCH	BEWR		FICR
MODO		YTVI	YTWA	WEVI			
COGR		AMRE	SUTA	INBU		**ORIGIN**	
FICR		WOTH	BAOR	HOWA		**exotic**	
PIWA		RTHU	EWPE	PROW		HOSP	
NOMO		ACFL	NOPA	EAPH		EUST	
AMGO		YTWA	BTNW	GRCA		ECDO	
NOCA		SUTA	CERW	COYE		HOFI	
CHSP		BAOR	SCTA	MAWR		RODO	
SOSP		EWPE	OROR	HESP			
BTGR		NOPA	BBCU	VESP			
LOSH		BTNW	WIFL	ECDO			
RBWO		CERW	YBCU	AMRO		**CONSERVATION PRIORITY**	
DOWO		SCTA	REVI	HOSP		**confor**	**conopn**
CARW		RBGR	GCFL	HOFI		CERW	PRAW
RHWO		BGGN	BOBO	EUST		WOTH	FISP
NOFL		WAVI	SWWA	EABL		LOWA	NOBO
HOWR		PABU	LOWA	RODO		KEWA	BEWR
HAWO		YBCH	VEER	CEDW		WEWA	PABU
PIWO		OROR	BAWW	BLJA		SWWA	OROR
WBNU		BBCU	WEWA	AMCR		PROW	HESP
RCWO		WIFL	OVEN	MODO		ACFL	GRSP
BHNU		WEVI	KEWA	PIWA		BTNW	RCWO
BCCH		INBU	TRSW	NOMO		HOWA	BASP
CACH		HOWA	BRTH	AMGO		NOPA	BHNU
TUTI		YBCU	COGR	NOCA			
BASP		REVI	FICR	CHSP			
HOLA		PROW	NOFL	SOSP			
RWBL		GCFL	HAWO	BTGR			
FISP		BOBO	PIWO	LOSH			
SWSP		SWWA	WBNU	RBWO			
NOBO		LOWA	RCWO	DOWO			
GRSP		VEER	BHNU	CARW			
EAME		BAWW	BCCH	RHWO			
EATO		WEWA	CACH	HOWR			

BHCO		OVEN			TUTI			
		KEWA			BASP			

FUNCTIONAL								
TROPHIC LEVEL			**FORAGING SUBSTRATE**					
insvor		**omnvor**	**barkp**	**grogle**	**uppcan**	**lowcan**	**airscr**	**airsal**
BARS	BAWW	PABU	PIWA	SWWA	RBGR	BLGR	BARS	EAPH
BANS	WEWA	YBCH	DOWO	LOWA	BGGN	RTHU	BANS	EABL
CLSW	OVEN	INBU	TUTI	OVEN	WAVI	WEVI	CLSW	LOSH
BLGR	KEWA	GRCA	YTWA	KEWA	YTVI	HOWA	PUMA	EAKI
RTHU	TRSW	HESP	BAWW	NOFL	SUTA	PROW	CHSW	ACFL
RBGR	NOFL	VESP	HAWO		BAOR	COYE	NRWS	EWPE
BGGN	HAWO	ECDO	PIWO		NOPA	MAWR	TRSW	WIFL
WAVI	PIWO	AMRO	WBNU		BTNW	CARW		GCFL
WEVI	WBNU	HOSP	RCWO		CERW	HOWR		
HOWA	RCWO	HOFI	BCCH		SCTA	PRAW		
PROW	BCCH	EUST	CACH		YBCU	YEWA		
EAPH	CACH	RODO			REVI	AMRE		
COYE	BEWR	CEDW				OROR		
MAWR		BLJA				BBCU		
EABL		AMCR				WEWA		
PIWA		MODO				BEWR		
LOSH		NOMO						
DOWO		AMGO						
CARW		NOCA						
HOWR		CHSP						
TUTI		SOSP						
PUMA		BTGR						
CHSW		RBWO						
NRWS		RHWO						
PRAW		BASP						
EAKI		HOLA						
YEWA		RWBL						
YTVI		FISP						
AMRE		SWSP						
ACFL		NOBO						
YTWA		GRSP						
SUTA		EAME						
BAOR		EATO						
EWPE		BHCO						
NOPA		WOTH						
BTNW		BOBO						
CERW		VEER						
SCTA		BRTH						
OROR		COGR						
BBCU		FICR						

WIFL		BHNU						
YBCU								
REVI								
GCFL								
SWWA								
LOWA								

Structural Guilds

Forgen (generalist): occurs in forests, but not area sensitive

Pine (specialist): occurs only in pines

Forint (specialist): interior forest obligate

Foredge (generalist): uses forest edges and shrubby habitats

Wetrip (specialist): wetland and/or riparian species

Grass (specialist): occurs only in grassy fields

Savold (specialist): occurs in early-mid successional fields

Agric (generalist): abundant in farmland

Urbsub (generalist): occurs in human dominated habitats

Forgro (specialist): nests on ground in forests

Opegro (specialist): nests on ground in open fields

Graree (specialist): nests above ground in tall grass or reeds

Cavity (specialist): nests in cavities

Shbnes (generalist): nests in shrubs

Trenes (specialists): nests in high tree canopies

Shelfn (generalist): nests on human structures

Compositional

Resid (generalist): non-migratory in the study region

Tempmig (generalist): leaves breeding ground in autumn, but winters north of 30º

Tropmig (specialist): winters south of 30º

Single (specialist): typically raises one brood/breeding season

Multi (generalist): routinely raises two broods/season

Prepar (generalist): nest predators and brood parasites.

Confor (specialist): Partners in Flight forest priority for the Southeast

Conopn (specialist): Partners in Flight open priority for the Southeast

Exotic (generalist): non-native to the study region

Functional

Insvor (specialist): obligate insectivore

Omnvor (generalist): will take animal or plant material during the breeding season

Barkp (specialist): bark probing insectivore

Grogle (specialist): gleans invertebrates from the ground

Uppcan (specialist): forages for insects in tall canopy trees

Lowcan (specialist): forages for insects generally below 5m

Airscre (specialist): aerial insectivore

Airsal (specialist): flycatches

Appendix B. Species names and codes.

Code	Common Name	Scientific Name
ACFL	Acadian Flycatcher	*Empidonax virescens*
AMCR	American Crow	*Corvus brachyrhynchos*
AMGO	American Goldfinch	*Carduelis tristis*
AMRE	American Redstart	*Setophaga ruticilla*
AMRO	American Robin	*Turdus migratorius*
BAOR	Baltimore Oriole	*Icterus galbula*
BARS	Barn Swallow	*Hirundo rustica*
BASP	Bachman's Sparrow	*Aimophila aestivalis*
BAWW	Black-and-white Warbler	*Mniotilta varia*
BCCH	Black-capped Chickadee	*Poecile atricapillus*
BGGN	Blue-gray Gnatcatcher	*Polioptila caerulea*
BHCO	Brown-headed Cowbird	*Molothrus ater*
BHNU	Brown -headed Nuthatch	*Sitts pusilla*
BHVI	Blue-headed Vireo	*Vireo solitarius*
BLGR	Blue Grosbeak	*Guiraca caerulea*
BLJA	Blue Jay	*Cyanocitta cristata*
BRTH	Brown Thrasher	*Toxostoma rufum*
BTGR	Boat-tailed Grackle	*Quiscalua major*
BTNW	Black-throated Green Warbler	*Dendroica virens*
CACH	Carolina Chickadee	*Pocile carolinensis*
CARW	Carolina Wren	*Thryothorus ludovicianus*
CEDW	Cedar Waxwing	*Bombycilla cedrorum*
CERW	Cerulean Warbler	*Dendroica cerulea*
CHSP	Chipping Sparrow	*Spizella passerina*
CHSW	Chimney Swift	*Chaetura pelagica*
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*
COGR	Common Grackle	*Quiscalus quiscula*
COYE	Common Yellowthroat	*Geothlypis trichas*
DOWO	Downy Woodpecker	*Picoides pubescens*
EABL	Eastern Bluebird	*Sialia sialis*
EAKI	Eastern Kingbird	*Tyrannus tyrannus*
EAME	Eastern Meadowlark	*Sturnella magna*
EAPH	Eastern Phoebe	*Sayornis phoebe*
EATO	Eastern Towhee	*Pipilo erythrophthalmus*
EUST	European Starling	*Sturnus vulgaris*
EWPE	Eastern Wood-Pewee	*Contopus virens*
FICR	Fish Crow	*Corvus ossifragus*
FISP	Field Sparrow	*Spizella pusilla*
GCFL	Great Crested Flycatcher	*Myiarchus crinitus*
GRCA	Gray Catbird	*Dumetella carolinensis*
GRSP	Grasshopper Sparrow	*Ammodramus savannarum*
HAWO	Hairy Woodpecker	*Picoides villosus*
HOFI	House Finch	*Carpodacus mexicanus*
HOLA	Horned Lark	*Eremophila alpestris*
HOSP	House Sparrow	*Passer domesticus*
HOWA	Hooded Warbler	*Wilsonia citrina*
HOWR	House Wren	*Troglodytes aedon*

INBU	Indigo Bunting	*Passerina cyanea*
KEWA	Kentucky Warbler	*Oporornis formosus*
LOSH	Loggerhead Shrike	*Lanius ludovicianus*
Code	Common Name	Scientific Name
LOWA	Louisiana Waterthrush	*Seiurus motacilla*
MODO	Mourning Dove	*Zenaida macroura*
NOBO	Northern Bobwhite	*Colinus virginianus*
NOCA	Northern Cardinal	*Cardinalis cardinalis*
NOFL	Northern Flicker	*Colaptes auratus*
NOMO	Northern Mockingbird	*Mimus polyglottos*
NOPA	Northern Parula	*Parula americana*
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
OROR	Orchard Oriole	*Icterus spurius*
OVEN	Ovenbird	*Seiurus aurocapillus*
PIWA	Pine Warbler	*Dendroica pinus*
PIWO	Pileated Woodpecker	*Dryocopus pileatus*
PRAW	Prairie Warbler	*Dendroica discolor*
PROW	Prothonotary Warbler	*Protonaria citrea*
PUMA	Purple Martin	*Progne subis*
RBWO	Red-bellied Woodpecker	*Melanerpes carolinus*
RCWO	Red-cockaded Woodpecker	*Picoides borealis*
REVI	Red-eyed Vireo	*Vireo olivaceus*
RHWO	Red-headed Woodpecker	*Melanerpes erythrocephalus*
RODO	Rock Dove	*Columba livia*
RTHU	Ruby-throated Hummingbird	*Archilocus colubris*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
SCTA	Scarlet Tanager	*Piranga olivacea*
SOSP	Song Sparrow	*Melospiza melodia*
SUTA	Summer Tanager	*Piranga rubra*
SWWA	Swainson's Warbler	*Limnothlypis swainsonii*
TRSW	Tree Swallow	*Tachycineta bicolor*
TUTI	Tufted Titmouse	*Baeolophus bicolor*
VEER	Veery	*Catharus fuscenscens*
VESP	Vesper Sparrow	*Pooecetes gramineus*
WAVI	Warbling Vireo	*Vireo gilvus*
WBNU	White-breasted Nuthatch	*Sitta carolinensis*
WEVI	White-eyed vireo	*Vireo griseus*
WEWA	Worm-eating Warbler	*Helmitheros vermivorus*
WOTH	Wood Thrush	*Hylocichla mustelina*
YBCH	Yellow-breasted Chat	*Icteria virens*
YBCU	Yellow-billed Cuckoo	*Coccyzus americanus*
YEWA	Yellow Warbler	*Dendroica petechia*
YTVI	Yellow-throated Vireo	*Vireo flavifrons*
YTWA	Yellow-throated Warbler	*Dendroica dominica*