Habitat Associations of Birds in Northern Alabama

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the degree of
Master of Science

Auburn, Alabama
December 8, 2012

Keywords: birds, habitat, occupancy, detection, modeling, discriminant function

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Abstract

I examined habitat associations of woodpeckers (Picidae) and warblers (Parulidae) on Redstone Arsenal, Madison County, Alabama. I used maps derived from satellite imagery to construct models of habitats occupied by the Red-headed, Red-bellied, Downy, and Hairy woodpeckers, Northern Flicker, Yellow-bellied Sapsucker, Northern Parula, Pine Warbler, Prothonotary Warbler, Common Yellowthroat, and Yellow-breasted Chat. Of the 17 habitats on Redstone Arsenal, dry-mesic forest was occupied most often by Red-headed, Red-bellied, Hairy, and Downy woodpeckers. Mesophytic forest was used most often by Downy Woodpeckers, Northern Flickers, Yellow-bellied Sapsuckers, Pine Warblers, Prothonotary Warblers, Common Yellowthroats, Northern Parulas, and Yellow-breasted Chats. Southern-Appalachian pine forest was associated with presence of Red-headed Woodpeckers and Yellow-bellied Sapsuckers. Habitats with small-streams and riparian areas often were occupied by Hairy Woodpeckers. I also examined habitat associations of 128 species of birds on Redstone Arsenal using maps derived from satellite imagery in a discriminant-function analysis to determine habitat associations. I focused on 18 species of conservation concern. Anthropogenic successional scrub-shrub was occupied most often by Bachman's Sparrows, American Woodcocks, Kentucky Warblers, Northern Parulas, and Chuck-will's-widows. Habitats comprised of open water were used by Belted Kingfishers, American Bitterns, Yellow-crowned Night-Herons, and Prothonotary Warblers. Habitats with small-streams and riparian areas were associated with Black-crowned Night-Herons, Hairy Woodpeckers, and Downy Woodpeckers. Evergreen

plantations were used by Red-headed Woodpeckers and Whip-poor-wills. Habitats with low-intensity development were associated with Wood Thrushes, dry-mesic forest with Brown-headed Nuthatches, large-floodplain forest with Green Herons, and pasturelands with Loggerhead Shrikes.

Acknowledgments

I thank my parents, Gary and Kathy Ortman. Thanks also to Danny Dunn and Shannon Allen of Redstone Arsenal, to fellow graduate student Chris McClure for help and guidance in modeling, to The Best Lab (Lisa A. McWilliams, Justin A. Dellinger, L. Michelle Gilley, Samuel J. Hirt, and Charles H. Kilgore), The Hill Lab, the crew of undergraduate research assistants (Katy Henderson, Olga Bodrikova, Rebecca Roper, and Frank Cartya), James Grand for suggestions and for trouble-shooting my models, and members of my graduate committee (Geoffrey E. Hill and Gary R. Hepp) for guidance and friendship. A special thanks to Troy L. Best for patience and guidance and for giving me an opportunity to pursue a graduate degree in his lab.

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Chapter 1

HABITAT ASSOCIATIONS OF WOODPECKERS (PICIDAE) IN NORTHERN ALABAMA

ABSTRACT

I examined associations between woodpeckers (Picidae) and habitats on Redstone Arsenal, Madison County, Alabama. I used maps derived from satellite imagery to construct models of habitats occupied by Red-headed, Red-bellied, Downy, and Hairy woodpeckers, Northern Flickers, and Yellow-bellied Sapsuckers. A total of 17 habitats were examined. Red-headed, Red-bellied, Hairy, and Downy woodpeckers most often occupied dry-mesic oak forest. Downy Woodpeckers, Northern Flickers, and Yellow-bellied Sapsuckers were associated with mesophytic forest, Red-headed Woodpeckers and Yellow-bellied Sapsuckers with southern-Appalachian pine forest, and Hairy Woodpeckers selected habitats of small-stream and riparian forests.

INTRODUCTION

The family Picidae includes 216 species of woodpeckers, wrynecks, and piculets, nearly all of which have strong affiliations with forested habitats (Mikusiński 2006). Trees, dead-woody debris, and snags are primary sources of nesting sites, protection, and food for woodpeckers (Winkler et al. 1995). Woodpeckers excavate cavities in trees, both living and dead, and therefore, woodpeckers are considered to be keystone species in some ecological communities (Daily et al. 1993, Jones et al. 1994, Conner et al. 2004, Martin et al. 2004, Ojeda 2004).

Woodpeckers are sensitive to structural and compositional changes in woodland habitats (Hess and King 2002, Lammertink 2004, Uliczka et al. 2004). Several species have experienced declines in populations and contractions of ranges due to loss and degradation of habitat, primarily from activities by humans (Winkler and Christie 2002). Lack of dead or standing snags and mature woodlands often are a result of fragmentation of habitats and some timber-management practices (Lammertink 2004). Diversity of woodpeckers usually is greater in uncut versus cut forests (Conner et al. 1975). Some species are highly selective on specialized resources, they are indicative of naturally dynamic forests, and presence of woodpeckers can be an indicator of diversity of forests (Mikusinski et al. 2001). Identification of critical habitats and landscapes for breeding, migration, and wintering are important areas of research dealing with Neotropical-migrant songbirds and woodpeckers (Donovan et al. 2002).

With the exception of the Red-cockaded Woodpecker (*Picoides borealis*), most species of woodpeckers in Alabama are of little or no conservation concern; however, many species are in decline and may be at risk in the future (Sauer et al. 2011). Deforestation is a major conservation concern facing woodpeckers (Mikusiński et al. 2001). Expansion of agricultural croplands was a primary cause of loss of forests in the United States, particularly in the Southeast (Gill 2007). Examining habitat associations of woodpeckers at the landscape level using maps derived from remote sensing and GIS (Geographical Information System) may be useful in efforts to conserve habitats occupied by woodpeckers.

Lichstein et al. (2002) examined the relationship between abundance of songbirds and habitats at local and landscape scales. Abundances of songbirds in large managed forests were linked to effects of landscape and suggested that abundance in forested landscapes primarily reflected quantity of habitats in the landscape rather than spatial arrangement of those habitats. Mikusiński et al. (2001) suggested that woodpeckers selected patches of forest based on total amount of forested area available (a feature easily identified by remote sensing). Mitchell et al. (2006) evaluated relationships between structure of forests and avian diversity at levels of landscape and individual stands. They reported that models generated for eight of nine guilds of Neotropical songbirds (as opposed to short-distance migrators), indicated a strong relationship between diversity of habitats, availability of habitats, and configuration of features in the landscape.

In the United Kingdom, land-cover maps generated from remote sensing provided an effective way to link birds to habitats (Fuller et al. 2005). Those types of maps may be useful when coupled with GIS to model habitat associations of woodpeckers. In Ohio, Dettmers and Bart (1999) used presence of birds in habitats coupled with GIS to construct models of use of habitats. These models performed better than random in identifying where species occurred and provided useful information in predicting amounts and spatial distributions of suitable habitats. Carter et al. (2006) reported that sources of data in GIS were at too large a scale and were not updated frequently enough to be useful in predicting occupancy of habitats. They used digital orthophotos and a grid-cell classification to develop an efficient technique to quantify variables that could predict habitats occupied by Florida Scrub-jays (*Aphelocoma coerulescens*). GIS also has been useful in predicting habitats occupied by tigers (*Panthera tigris*) in India (Singh et al. 2009) and habitats of birds in the Greater Yellowstone Ecosystem (Saveraid et al. 2001). While data on habitats that are generated by imagery obtained from satellites may be adequate for modeling more generalist species, it may be inadequate to model relations of habitats of species that key on characteristics of microhabitats. Current methods are improving and technologies such as light-detection and ranging (LIDAR) may improve usefulness of maps derived from remote sensing in modeling habitat associations of wildlife. Satellite-based, remote sensing could be used for evaluation and modeling of habitats, for monitoring programs, and to achieve conservation and management objectives. This is true especially for remote regions of the world (Gottschalk et al. 2005). Models based on aerial imagery can predict avian habitats at some spatial scales (Osborne et al. 2001), but more research is needed to determine how to use this technology at a broader scale. I used maps derived from satellite imagery to build models of habitats occupied by woodpeckers for use in making conservation and management decisions regarding these species.

MATERIALS AND METHODS

My study area was Redstone Arsenal, a 15,305-ha military installation in southwestern Madison County, Alabama. Redstone Arsenal is in the Tennessee Valley physiographic region and the Tennessee River borders the installation on the south. Redstone Arsenal contains a variety of habitats, including croplands, pasturelands, upland forests, wet mesic forests in the floodplain, and forested palustrine wetlands (Appendix 1).

During 2008-2010, distribution of birds on Redstone Arsenal was assessed using 884 point-count transects following Hamel et al. (1996). Sites to be surveyed were selected using information provided by personnel of the Cultural and Natural Resources Environmental Management Division of Redstone Arsenal. Each site was ≥250 m from all other sites surveyed. Information on habitats was provided as GIS maps and data obtained from the Alabama-GAP Program (http://www.basic.ncsu.edu/segap/). Each site was given an identification number, and global-positioning-system (GPS) coordinates, temperature, wind speed, weather conditions, date, time, and observer were recorded.

Once at a site, the observer waited 5 minutes to begin the survey to allow the area to recover from intrusion. Activity (calls, songs, visual sightings) was recorded using a bulls-eye datasheet over three time intervals (0-3, 3-6, and 6-10 minutes), which resulted in a survey lasting 10 minutes as described by Hamel et al. (1996). Surveys were not conducted on days with inclement weather, such as rain or winds >25 km/hour.

For each site surveyed, GIS was used to determine types and amounts of habitats within a circle that had a radius of 125 m and encompassed a total area of 4.91 ha. A list of *a priori* models for each species was compiled based on published descriptions of habitat associations of the species I investigated and on characteristics of habitats from the Alabama-GAP Program. To determine the most-parsimonious models, I used PRESENCE statistical software (Hines 2006) and compared and ranked models using Akaike's Information Criterion (AIC) and AICc (corrected for small samples; Burnham and Anderson 2002). I constructed sets of best-possible models for each species using variables that were based upon past research using a manual, forward-selection process (King et al. 2009). All covariates believed to be important were added to the first model. Covariates were then removed one at a time based on having the lowest ratio of maximum-likelihood estimator (β) to standard error (*SE*) as described by Arnold (2010). Following Arnold (2010), this process continued until AIC-values of the model increased instead of decreased. Models with ΔAIC = 0 were selected as the best. A parametric bootstrap was used to assess goodness-of-fit of the global model, using 10,000 replicates. Probability of detection (p) and probability of occupancy (ψ) were recorded. Variables such as minutes since sunrise, cloud cover, temperature, and speed of wind, which were believed to affect detections of species, were used in models of detectability. These variables were used in my analysis and were chosen because they were reported to affect detection in other studies (Wintle et al. 2005) and from my observations in the field.

RESULTS

During January 2008-July 2010, three research assistants and I counted 814 woodpeckers at 884 locations in 15 habitats. The variable most affecting detection of woodpeckers was observer and was a factor in all models (Table 1.1). Temperature was the second most-important variable affecting detection of individuals (3 models) and date was important in one model (Table 1.1).

The model of habitats for Red-headed Woodpeckers (*Melanerpes erythrocephalus*; Table 1.1) had positive relationships with southern-Appalachian pine forests (β = 6.11, *SE* = 3.49) and dry-mesic oak forests (β = 1.66, *SE* = 0.49) indicating that occupancy of a site increased as these habitats increased. Of sites containing 100% dry-mesic oak forest, 70% were occupied (Fig. 1.1) and 100% of habitats containing ≥49% of evergreen plantations were occupied by Red-headed Woodpeckers (Fig. 1.2). The number of Red-headed Woodpeckers observed was greater in these two habitats compared to other habitats. Temperature had a negative effect on detection (β = -2.03, *SE* = 0.75). As temperature increased, number of Red-headed Woodpeckers observed decreased. Detection also was effected by observer (observer 1: β = 0.53, *SE* = 0.39; observer 2: β = 1.18, *SE* = 0.40; and observer 3: β = 0.02, *SE* = 0.52), indicating that observer must be considered in the models. Observer 2 was most likely to detect Red-headed woodpeckers and they were least likely to be detected by observer 3.

The model for Red-bellied Woodpeckers (*Melanerpes carolinus*) revealed a positive relationship with dry-mesic forests (β = 3.55, *SE* = 0.96) and occupancy of sites increased with an increase in that habitat. Nearly 100% of sites containing ≥70% dry-oak forest were occupied by Red-bellied Woodpeckers (Fig. 1.3). Detection of this species was related inversely to date and temperature; detections decreased later in seasons and as temperatures increased (β = -1.96, *SE* = 0.79; β = -1.42, *SE* = 0.51, respectively). Detection of Red-bellied Woodpeckers also varied by observer (observer 1: β = 1.29, *SE* = 0.22: observer 2: β = 0.21, *SE* = 0.24; and observer 3: β = 0.22, *SE* = 0.29). Observer 1 was most likely to detect Red-bellied Woodpeckers and they were least likely to be detected by observer 2 and 3, respectively.

The model for Hairy Woodpeckers (*Picoides villosus*) indicated a positive relationship with dry-mesic oak forests (β = 2.14, *SE* = 1.16) and small-stream and riparian habitats (β = 2.91, *SE* = 3.85). Thus, occupancy of sites increased as proportions of these two habitats increased. When sites contained ≥80% dry-mesic oak forest or ≥85% small-stream and riparian habitats, occupancy reached nearly 100% (Figs. 1.4 and 1.6). Occupancy of a site was related inversely to evergreen plantations (β = -1.87, *SE* = 2.00). As the proportion of evergreen plantations increased, occupancy by Hairy Woodpeckers decreased. Sites with 100% evergreen plantations were occupied only 20% of the time by Hairy Woodpeckers. Detectability of these woodpeckers was affected by observer (observer 1: β = -0.95, *SE* = 0.62; observer 2: β = 1.22, *SE* = 0.56; and observer 3: β = 0.57, *SE* = 0.64). Observer 2 was most likely to detect Hairy Woodpeckers and they were least likely to be detected by observer 1.

Occurrence of Downy Woodpeckers (*Picoides pubescens*) was related positively to dry-mesic oak forests (β = 1.12, *SE* = 0 .83; Fig. 1.7) and mesophytic forests (β = 1.77, *SE* = 0.87; Fig. 1.8). Detectability of Downy Woodpeckers was affected by observer (observer 1: β = -3.46, *SE* = 0.52; observer 2: β = -0.04, *SE* = 0.30; and observer 3: β = -0.17, *SE* = 0.36). Downy Woodpeckers were most likely to be detected by observer 2 and they were least likely to be detected by observer 1.

Northern Flickers (*Colaptes chrysoides*) were associated positively with mesophytic forest (β = 5.07, *SE* = 2.28); sites containing ≥50% small-stream and riparian habitats were occupied nearly 100% of the time by this species (Fig. 1.10). The model of detectability was affected by observer (observer 1: β = 1.01, *SE* = 0.49; observer 2: β = -0.07, *SE* = 0.54; and observer 3: β = 0.20, *SE* = 0.61). Observer 1 was most likely to detect Northern Flickers and they were least likely to be detected by observer 2.

Occurrence of the Yellow-bellied Sapsucker (*Sphyrapicus varius*) was related positively to mesophytic forests (β = 2.53, *SE* = 0.33; Fig. 1.11) and southern-Appalachian pine forests (β = 1.79, *SE* = 0.89; Fig. 1.12). Presence of this species increased as proportions of these habitats increased. There was no relationship between detection and observer, but temperature was related inversely to detectability (β = -1.29, *SE* = 0.39); this species was less likely to be detected as temperature increased.

DISCUSSION

Of 17 habitats at Redstone Arsenal (Appendix 1), five were significant in models of habitats for the six species of woodpeckers studied. Evergreen plantations, dry-mesic oak forests, small-stream and riparian habitats, mesophytic forests, and southern-Appalachian pine forests were occupied most often by the six species of woodpeckers I studied. Except for models constructed for the Northern Flicker and Yellow-bellied Sapsucker, dry-mesic oak forests contributed the most to associations between woodpeckers and habitats in all models. Thus, manipulation of dry-mesic forests will affect most woodpeckers within Redstone Arsenal. To maintain appropriate habitats for woodpeckers, care should be taken to preserve dry-mesic oak forests. Establishment of dry-mesic oak forest takes many years; however, regeneration of this habitat should be considered instead of establishing monocultures of pine trees.

Small-stream and riparian habitats were occupied most often by Hairy Woodpeckers, Downy Woodpeckers, and Northern Flickers. Protection of small-stream and riparian areas should be a priority during harvesting of trees and during construction of buildings and other developmental activities. Protection can be accomplished in these areas of Redstone Arsenal by preventing intrusion into these habitats during logging operations. These small-stream and riparian areas should remain as natural and undisturbed as possible (Osborne and Kovacic 1993, Belt and O'Laughlin 1994, Castelle et al. 1994).

Evergreen plantations were associated positively with Hairy Woodpeckers, mesophytic forests were occupied often by Red-headed Woodpeckers, and southern-Appalachian pine forests were important to Yellow-bellied Sapsuckers. Southern-Appalachian pine forests occurred at low frequency on Redstone Arsenal compared to the other 16 habitats. Southern-Appalachian pine forests were on many limestone cliffs and hills and construction and intrusion into this habitat should be minimized as this habitat is scarce on Redstone Arsenal.

The Red-headed Woodpecker is of moderate conservation concern in Alabama (Haggerty et al. 2004), but is not listed as threatened or endangered elsewhere in it range. This species uses nesting cavities in trees, but it also may use cavities in utility poles that have been treated with creosote. Loss of suitable habitat and nesting cavities raises concerns about conservation of Red-headed Woodpeckers because it takes many years for forests to reach a level of maturity in which nesting cavities are available; artificial nesting cavities can be expensive and difficult to install and maintain. However, reforestation in other areas of North America has improved some habitats. Little is known about ecological interactions of Red-headed Woodpeckers and organisms that may rely on nesting cavities that are excavated by these woodpeckers (Smith et al. 2000). Red-headed Woodpeckers are omnivorous, they are excellent fly catchers, and they often occur in deciduous woodlands of oak (*Quercus*) and beech (*Fagus*; Reller 1972) in lowland, upland, river-bottom, and open-woodland habitats (Degraff et al. 1980, Kahl et al. 1985, Hamel 1992). However, in my study area, pine plantations and dry-mesic oak forests were the habitats occupied most often by this species. Results of my analyses are similar to reports by other researchers (Degraff et al. 1980, Kahl et al. 1985, Hamel 1992, Reller 1972) who suggested that Red-headed Woodpeckers prefer deciduous forests. In the Southeast, many hardwood forests are harvested and then converted into pine plantations. Although pine plantations may not be preferred habitats, it likely adds additional habitats to adequately support populations of Red-headed Woodpeckers.

The Red-bellied Woodpecker is not a species of conservation concern in Alabama (Haggerty et al. 2004) or elsewhere within its range. Most concerns relate to conflicts with humans, such as damage to commercial orchards (Breitwisch 1977) and use of pesticides and chemicals by humans (Rumsey 1970). Loss of suitable nesting cavities and competition for those cavities with European Starlings (*Sturnus vulgaris*) also are concerns (Shackelford et al. 2000). This species inhabits mixed-pine (*Pinus*) and hardwood forests in the eastern United

States, it forages for fruits, mast, and arboreal arthropods, and it seldom excavates dead wood for food (Shackelford et al. 2000). Presence of Red-bellied Woodpeckers on my study area increased as amount of dry-mesic oak forests increased (Fig. 1.1). Dry-mesic forests were upland-hardwood forests dominated by oaks (*Quercus*) and hickories (*Carya*) along gentle to steep slopes of various aspects. While populations were relatively stable, continuing fragmentation of mature forests could lead to a significant loss of habitats (Shackelford et al. 2000) and research should focus on possible use of artificial nesting cavities (Ingold 1989) and creating more habitats for nesting. Habitats can be improved by retaining snags during clearcutting and prescribed-burning operations (Dickson et al. 1983).

The Hairy Woodpecker is a species of moderate conservation concern in Alabama (Haggerty et al. 2004). This species is neither threatened nor endangered throughout most of its distribution, but it probably suffers from fragmentation of forested habitats, loss of old-growth forests, and competition with European Starlings (Tate 1986). Hairy Woodpeckers occur in small populations throughout North America and inhabit a variety of forests and woodlands; however, in the southeastern United States, the species primarily occupies pine forests. Hairy Woodpeckers are among the most ecologically variable species in North America, it has been the focus of few studies (Jackson et al. 2002). In my study, presence of Hairy Woodpeckers increased in dry-mesic oak forests (Fig. 1.4), evergreen plantations (Fig. 1.5), and small-stream and riparian habitats (Fig. 1.6). Small-stream and riparian habitats were similar to floodplain forests. However, floodplain forests typically contained trees that were more mature and small-stream and riparian habitats lacked overall development of trees and canopy. Evergreen plantations were characterized by planted pines that typically were even-aged and evenly spaced.

However, small-stream and riparian habitats had the greatest effect on abundance of Hairy Woodpeckers (Fig. 1.6).

The Downy Woodpecker is of moderate conservation concern in Alabama (Haggerty et al. 2004), but this small woodpecker occurs from coast to coast in North America (Jackson and Ouellet 2002). Downy Woodpeckers are not threatened or endangered, but there are concerns about their welfare because of degradation of habitats and conflicts with humans, such as the damage that these birds inflict on wooden sidings of homes and other buildings (Jackson and Ouellet 2002). Downy Woodpeckers inhabit forested habitats from virgin bottomlands to sparse forests along tops of ridges (Schroeder 1983), as well as urban woodlots (Jackson and Ouellet 2002). My assessment suggested that occurrence of Downy Woodpeckers increased slightly in dry-mesic oak forests (Fig. 1.7), but greatly increased in mesophytic forests (Fig. 1.8). In my study area, dry-mesic forests were highly diversified habitats dominated by deciduous trees on deep and enriched soils. Other studies suggested that the number of Downy Woodpeckers increased as bottomland habitats increased (Schroeder 1983); bottomland habitats are similar to mesophytic forests. Clearcutting and thinning forests has helped this species because it occupies early successional and edge habitats (Conner et al. 2004). Downy Woodpeckers are believed to be the only species of woodpeckers to increase populations after a forest is thinned (Raphael et al. 1988). Christmas Bird Counts and Breeding Bird Surveys indicate that this is the most abundant woodpecker in eastern North America (Plaza 1975, 1978, Hess 2000). However, clearing of land for agricultural practices probably has had a negative impact on nesting success because many roosting sites in the 1900s were wooden fence posts that were used in place of naturally occurring roost sites in hollow trees (Sherman 1996).

The Northern Flicker is not of conservation concern in Alabama (Haggerty et al. 2004). This species is common; however, populations have been declining since 1966, possibly caused by loss of habitats resulting in loss of suitable nesting cavities and competition for nesting cavities with European Starlings (Robbins et al. 1986, Erskine 1992). It is a ground-forager and habitat generalist that occurs in many types of woodlands in North America (Wiebe and Moore 2008). Northern Flickers seem to select edges of forests and open woodlands, but they also occur in areas with swamps, ponds constructed by American beavers (*Castor canadensis*), and flooded and recently burned areas with many snags (Bent 1939, Hubbard 1965, Conner and Adkisson 1976, 1977, Aldrich and Coffin 1980, Wiebe and Moore 2008). My model revealed that occupancy of habitats by Northern Flickers was influenced most by small-stream and riparian habitats (Fig. 1.9), which is similar to habitats reported by Wiebe and Moore (2008).

Yellow-bellied Sapsuckers (*Sphyrapicus varius*) are of conservation concern in the Blue Ridge Mountains and southern Appalachian Mountains (Walters et al. 2002). However, this species is not of conservation concern in Alabama (Haggerty et al. 2004). Current populations are larger than in pre-colonial times in many parts of their range, but populations have declined dramatically since the 1950s (Walters et al. 2002). This species creates shallow wells in the bark of trees and feeds on sap that pools there (Walters et al. 2002). Yellow-bellied Sapsuckers play an important ecological role as many organisms use the wells these birds create for food or consume insects that are attracted to the wells (Walters et al. 2002). Yellow-bellied Sapsuckers require early successional species of trees (Eberhardt 1994). Unlike many species of woodpeckers, Yellow-bellied Sapsuckers are less dependent on snags and dead-woody debris (Eberhardt 1994). In areas of the Southeast, such as Mississippi, Yellow-bellied Sapsuckers are in greatest densities in bottomland hardwoods (Wilkins 2001). In northern Alabama, occupancy of habitats by Yellow-bellied Sapsuckers increased as mesophytic forests (Fig. 1.10) and southern-Appalachian pine forests increased (Fig. 1.11). Southern-Appalachian pine forests occur in lower elevations of the Appalachian Mountains and are dominated by short-leaf pines (*Pinus echinata*) and Virginia pines (*Pinus virginiana*).

Knowledge of habitats occupied by a species is a basic ingredient for successful management (Carter et al. 2006). Habitat-association modeling can be a valuable tool for prioritizing conservation of biodiversity and in planning use of land (De Wan et al. 2009). Accuracy in modeling habitats of woodpeckers may increase as imagery from satellites is better able to detect features of landscape, such as types of forests, more accurately. However, associations of birds and landscapes may change in accordance with small-scale changes (Brennan and Schnell 2005). Woodpeckers likely choose habitats based on abundance and availability of specific types of trees such as hardwoods or pines. Type of forest is easier to determine from satellite imagery than features of microhabitats, such as woody debris or depth of leaf litter. Many species of birds select habitats based on microhabitats; however, many species select habitats on a coarser scale (e.g., woodpeckers; MacFaden and Capen 2002). While it may seem obvious that woodpeckers would choose forested habitats, characteristics of microhabitats may not be obvious and they are more difficult to detect using satellite imagery. Thus, while it is informative to use satellite imagery to model habitat associations of birds that are highly associated with forests, little is known about which characteristics of microhabitats within these forests are important to woodpeckers.

In a study of birds in South Carolina, models of landscapes were as predictive as models of microhabitats. Likely, variables modeled at the landscape-scale were co-linear with characteristics of microhabitats that were selected by birds. Predictive models of distribution of birds based on variables derived from maps tend to have limited resolution. Ultimately, a mixing of maps with ground-truth data and information from satellites produce the best models to predict distribution of birds (Seoane et al. 2004); both can be integrated using GIS.

Collection of data on microhabitats can be costly in manpower, time, and money. Maps of vegetation provide data on habitats at a landscape scale that easily is accessible and readily available. However, transformation of satellite imagery to maps suitable for use in modeling of habitat associations of wildlife must be timely, and characteristics of habitats may change before maps are made available. In areas where land is manipulated and changed frequently, this lag in time may complicate modeling or give inferior results. Characteristics of microhabitats may be most important in determining occurrence of a species in a habitat, and these characteristics may not be represented adequately by GIS maps of habitats. However, determining usefulness of satellite images of vegetation in predicting where species of birds and other organisms occur on the landscape is important for conservation of woodpeckers, other wildlife, and their habitats.

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Table 1.1. Species of woodpeckers (Picidae) and corresponding best models (ΔAIC) of detectability. Covariates of detectability and β-values of parameters are presented.

		Parameters		Covariates of Detectability		
Species	Model	Occupancy ψ (*SE*)	Detectability p (*SE*)	Date (*SE*)	Temperature (*SE*)	Observer (*SE*)
Red-headed Woodpecker	ψ(evergreen plantation + dry-mesic oak forest), p(observer + temperature)	-1.30 (0.28)	(1) -1.46 (0.66) (2) -0.56 (0.65) (3) -1.51 (0.66)		-2.03 (0.75)	(1) 0.53 (0.39) (2) 1.18 (0.40) (3) 0.02 (0.52)
Red-bellied Woodpecker	ψ(dry-mesic oak forest), p(observer + temperature + date)	-0.63 (0.21)	(1) 4.33 (0.40) (2) 4.19 (0.41) (3) 4.21 (0.41)	-1.07 (0.79)	-1.42 (0.51)	(1) 1.29 (0.22) (2) 0.21 (0.24) (3) 0.22 (0.29)
Hairy Woodpecker	ψ(dry-mesic oak forest + small- stream and riparian + evergreen plantation), p(observer)	-1.48 (0.52)	-3.21 (0.69)			(1) -0.95 (0.62) (2) 1.22 (0.56) (3) 0.57 (0.64)
Downy Woodpecker	ψ(small-stream and riparian + dry-mesic oak forest) p(observer)	-0.21 (0.48)	(1) -1.44 (0.32) (2) -2.22 (0.35) (3) -1.96 (0.34)			(1) -3.46 (0.52) (2) -0.04 (0.30) (3) -0.17 (0.36)
Northern Flicker	ψ(small-stream and riparian), p(observer)	-0.38 (0.33)	-3.02 (0.51)			(1) 1.01 (0.49) (2) -0.07 (0.54) (3) 0.20 (0.60)
Yellow-bellied Sapsucker	ψ(mesophytic forest + southern-Appalachian pine forest), p(temperature)	-2.51 (0.88)	3.16 (1.79)		-1.29 (0.39)	

TABLE 1.2. Summary of observations of woodpecker (Picidae) by habitat at Redstone Arsenal, Madison County, Alabama.

Species	Large-floodplain forest	Successional grassland-herbaceous	Dry-mesic oak forest	Mesophytic forest	Open water	Evergreen plantation	Small-stream and riparian forest	Clearcut shrub-scrub	Southern-Appalachian pine forest	Developed open space	Number observed
Downy Woodpecker	15	22	16	9	11	16	20	7	0	13	129
Hairy Woodpecker	10	7	13	5	29	12	10	6	0	1	73
Northern Flicker	16	14	18	25	4	12	6	17	2	16	130
Red-bellied Woodpecker	46	53	95	65	18	118	28	31	5	18	447
Red-headed Woodpecker	28	15	28	2	1	101	4	21	4	13	217
Yellow-bellied Sapsucker	0	1	1	0	0	3	0	0	0	1	6

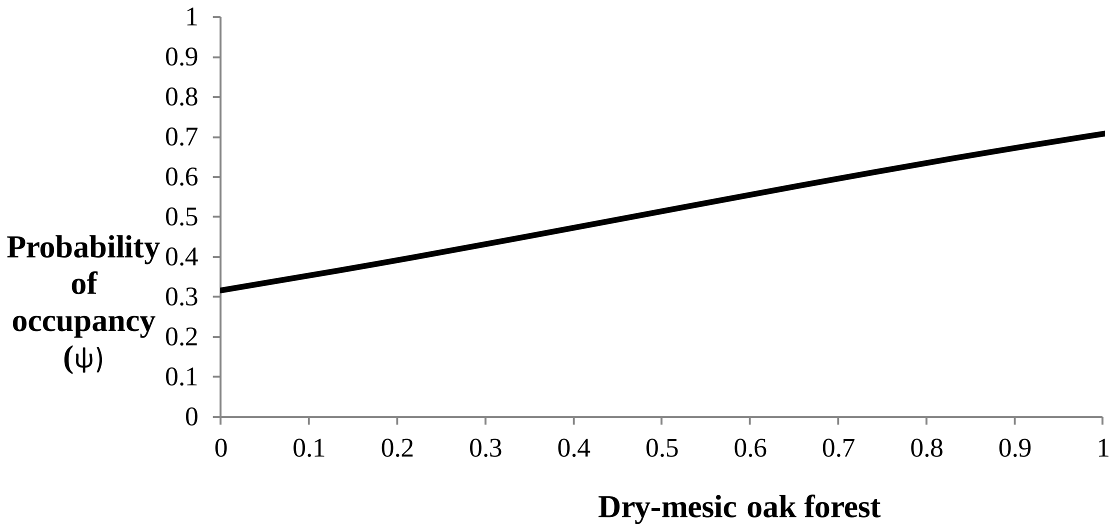

FIG. 1.1. Effect of increasing proportion of mesophytic forest on use and occupancy (ψ) of this habitat by Red-headed Woodpeckers.

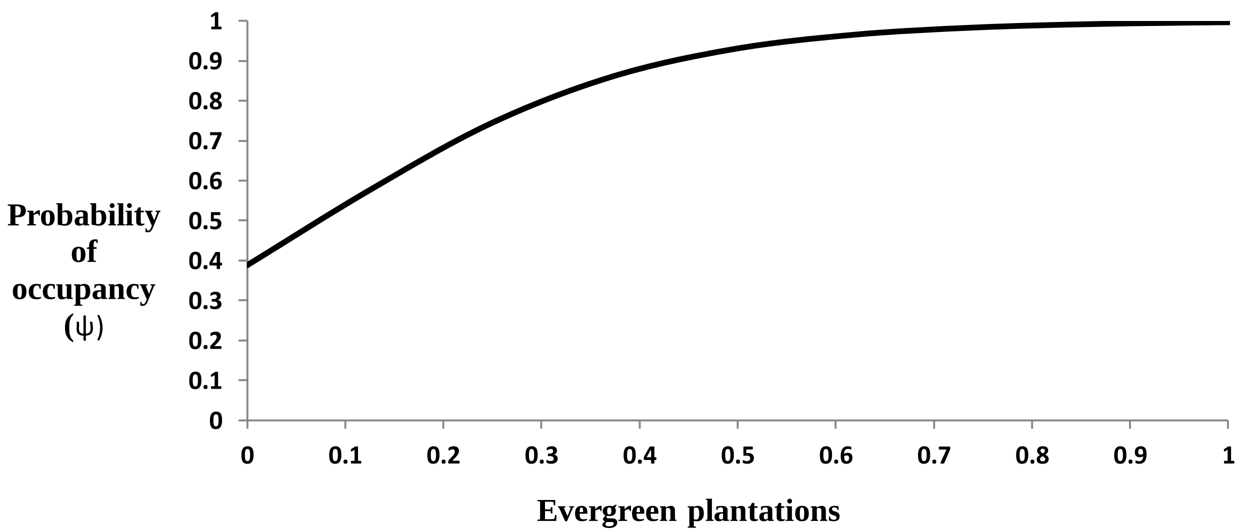

FIG. 1.2. Effect of increasing proportion of evergreen plantations on use and occupancy (ψ) of this habitat by Red-headed Woodpeckers.

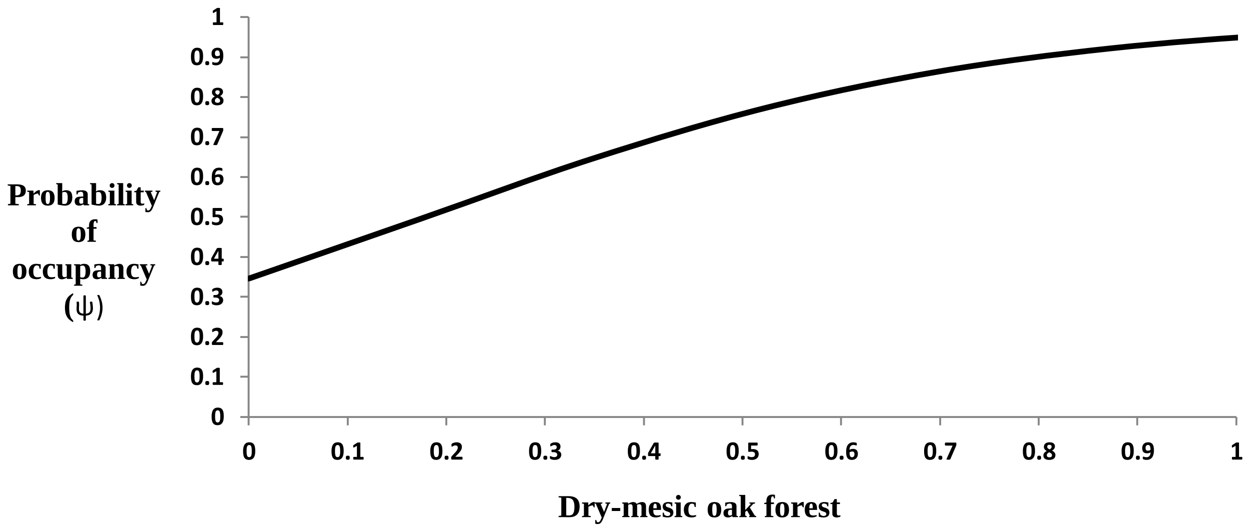

FIG. 1.3. Effect of increasing proportion of dry-mesic oak forest on occupancy (ψ) of this habitat by Red-bellied Woodpeckers.

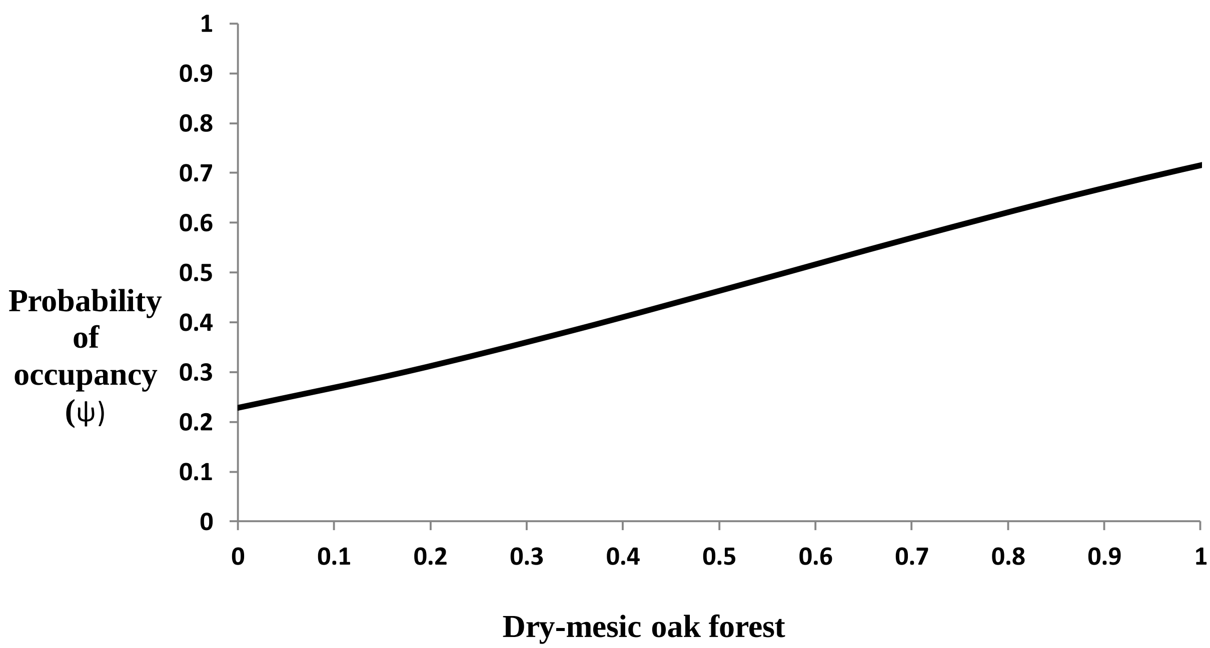

FIG. 1.4. Effect of increasing proportion of dry-mesic oak forest on use and occupancy (ψ) of this habitat by Hairy Woodpeckers.

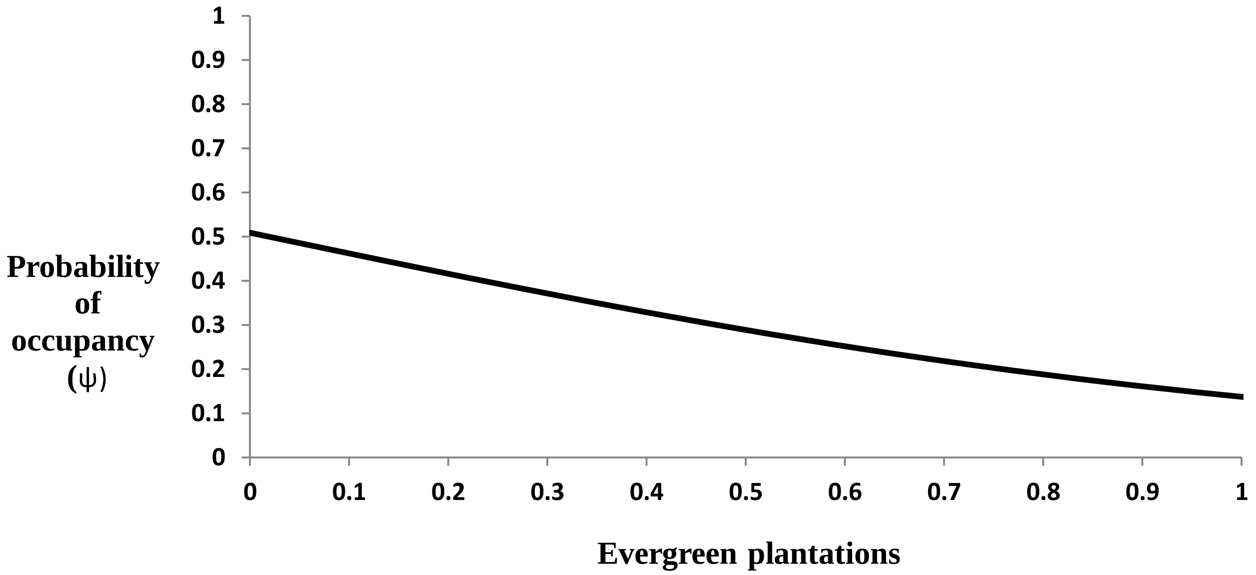

FIG. 1.5. Effect of increasing proportion of evergreen plantations on use and occupancy (ψ) of this habitat by Hairy Woodpeckers.

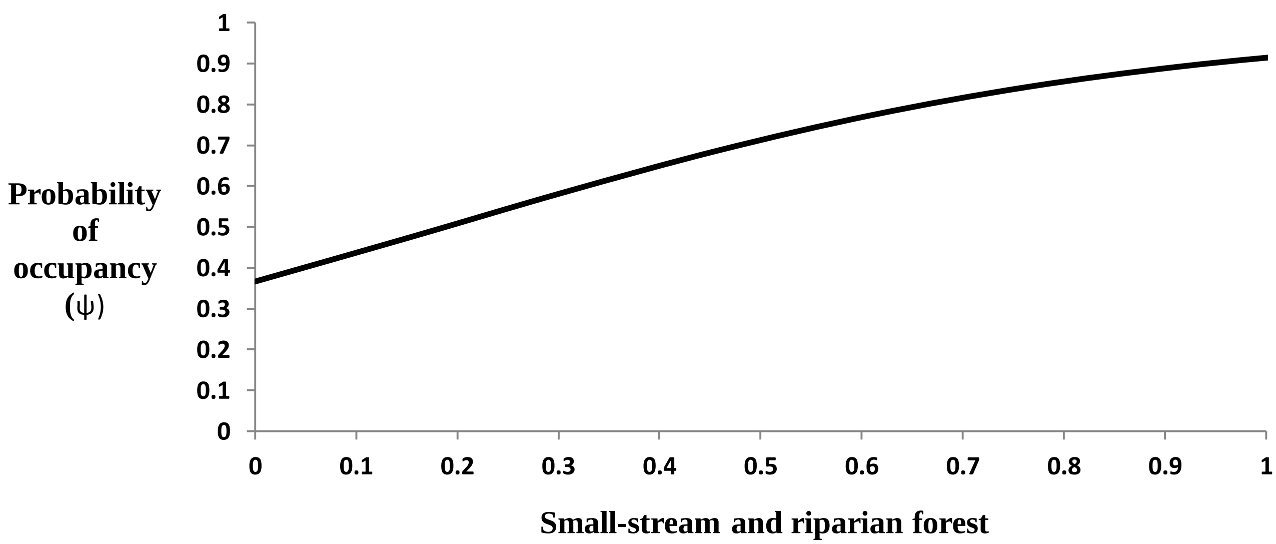

FIG. 1.6. Effect of increasing proportion of small-stream and riparian forest on use and occupancy (ψ) of this habitat by Hairy Woodpeckers.

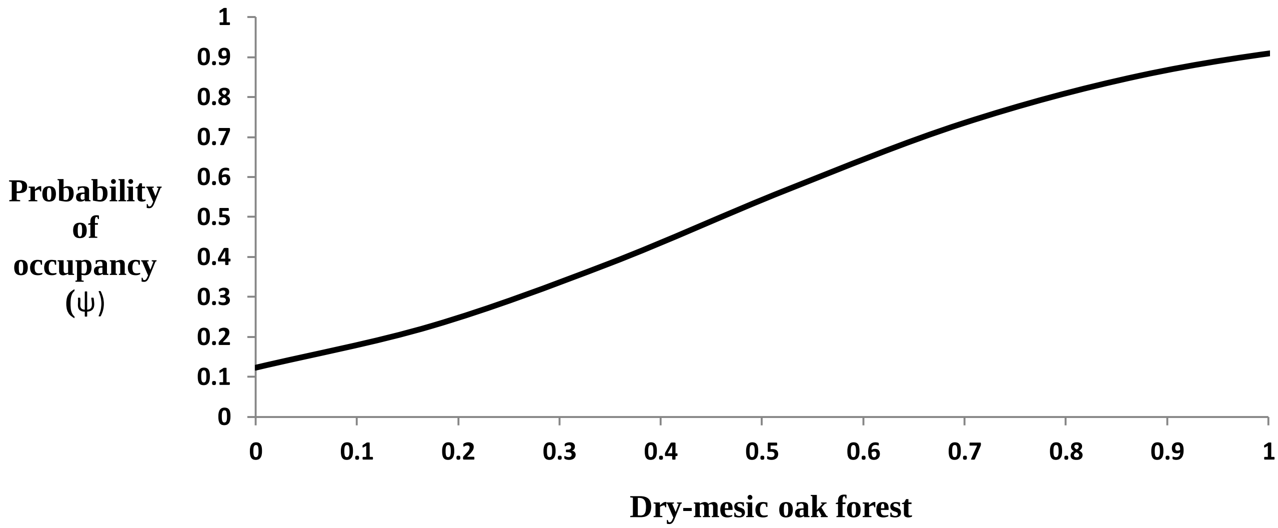

FIG. 1.7. Effect of increasing proportion of dry-mesic oak forests on use and occupancy (ψ) of this habitat by Downy Woodpeckers.

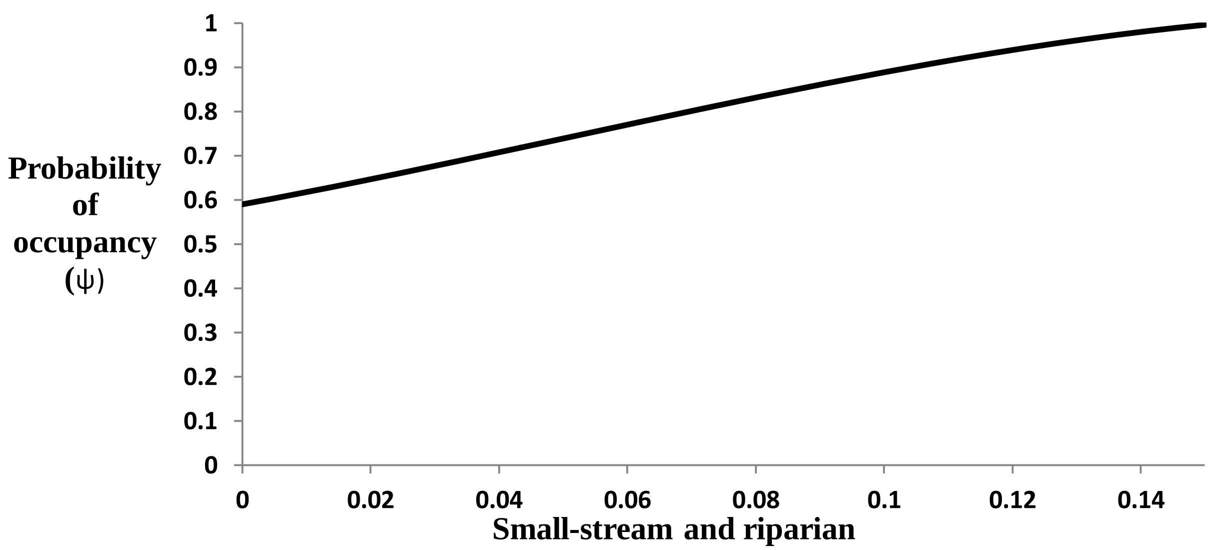

FIG. 1.8. Effect of increasing proportion of small-stream and riparian on use and occupancy (ψ) of this habitat by Downy Woodpeckers.

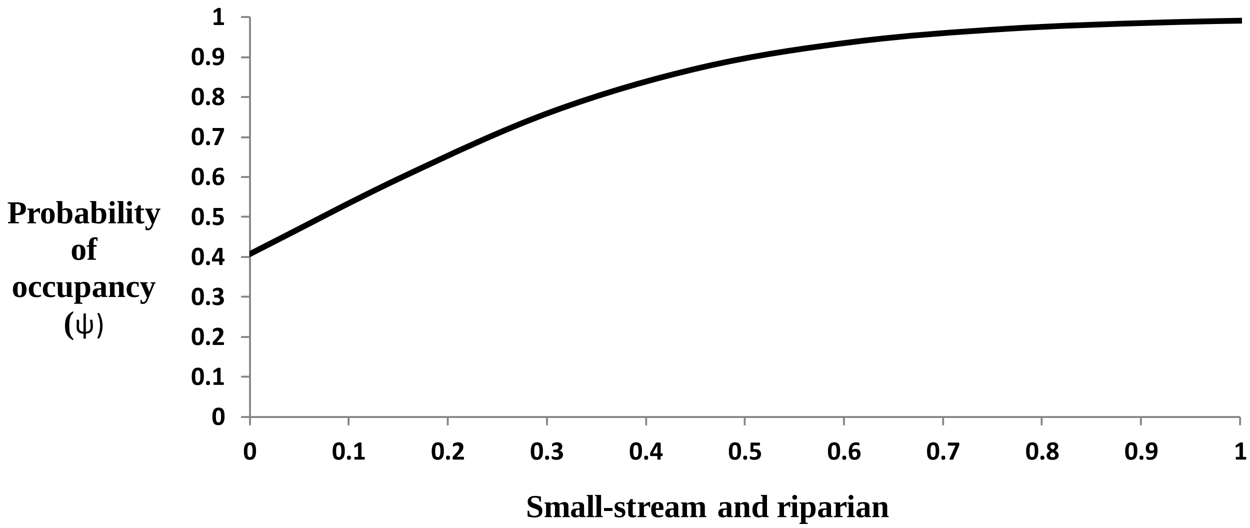

FIG. 1.9. Effect of increasing proportion of small-stream and riparian on use and occupancy (ψ) of this habitat by Northern Flickers.

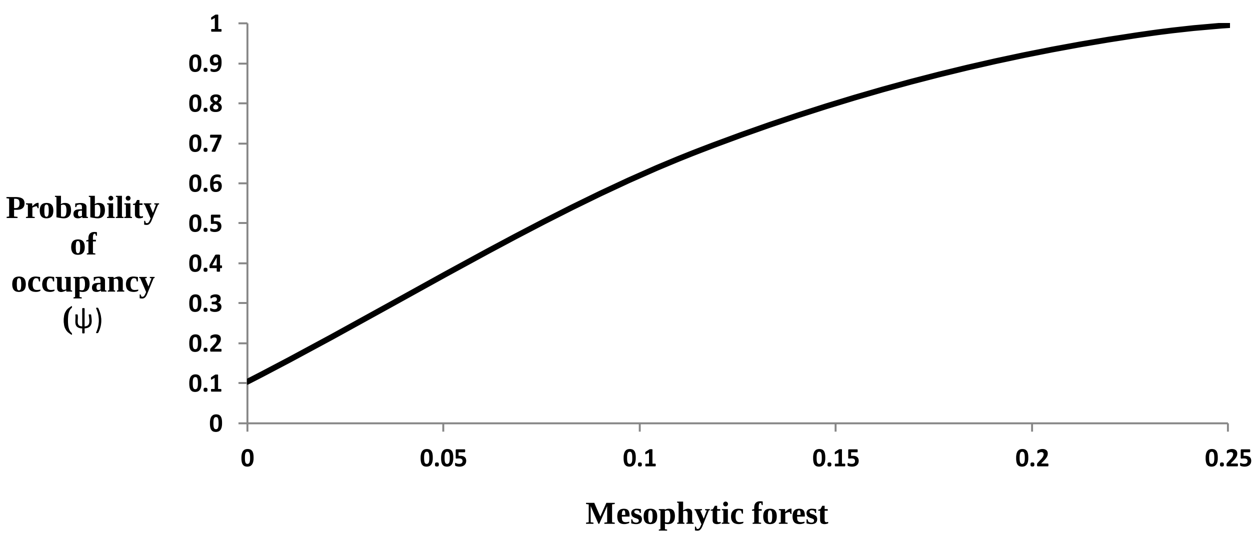

FIG. 1.10. Effect of increasing proportion of mesophytic forests on use and occupancy (ψ) of this habitat by Yellow-bellied Sapsuckers.

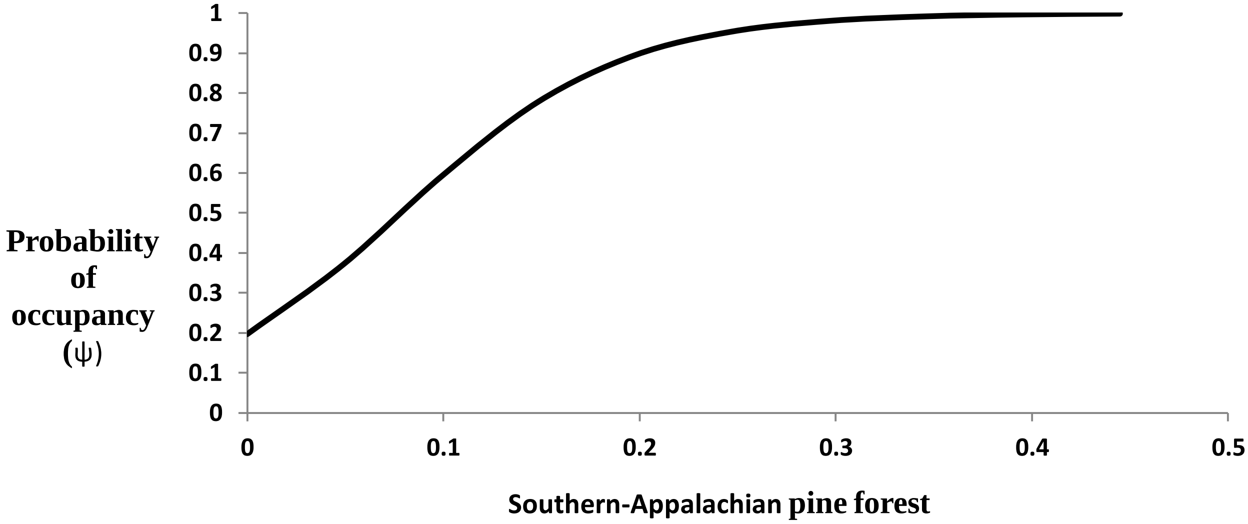

FIG. 1.11. Effect of increasing proportion of southern-Appalachian pine forests on use and occupancy (ψ) of this habitat by Yellow-bellied Sapsucker.

Chapter 2

HABITAT ASSOCIATIONS OF WARBLERS (PARULIDAE) IN NORTHERN ALABAMA

ABSTRACT

I examined associations of warblers (Parulidae) with habitats on Redstone Arsenal, Madison County, Alabama. I used maps of 17 habitats derived from satellite imagery to construct models of habitats occupied by Northern Parulas, Pine Warblers, Prothonotary Warblers, Common Yellowthroats, and Yellow-breasted Chats. My models indicated that habitats comprised of evergreen plantations were occupied most often by Pine Warblers, Common Yellowthroats, and Yellow-breasted Chats. Habitats containing open-water and small-stream and riparian areas were occupied most often by Prothonotary Warblers and large-floodplain forests were occupied most often by Northern Parulas.

INTRODUCTION

Loss of habitat has been the primary cause of declines in populations of many Neotropical-migrant songbirds. Urbanization and production of agricultural crops account for most fragmentation of habitats (Donovan et al. 2002). Knowledge of habitats occupied by a species is a basic element for successful management (Carter et al. 2006). Conservation of habitats is critical; managers are in need of methods and data that will aid them in making appropriate decisions regarding management and conservation (Donovan et al. 2002).

Models of habitat-association can be a valuable tool for prioritizing conservation of biodiversity and in planning use of land (De Wan et al. 2009). In a study of birds in South Carolina, models of overall landscape were as predictive as models of microhabitats. Variables derived from maps used to model distributions of birds tend to have limited resolution. Maps with thematic (ground-truth data) and satellite information produce the best models to predict distribution of birds (Seoane et al. 2004) and these can be integrated using Geographic Information Systems (GIS).

Collecting data from microhabitats can be costly in manpower, time, and money. Maps derived from satellite imagery provide data on habitats at a landscape scale that easily are accessible and readily available. Determining usefulness of these maps in predicting where species of birds and other organisms occur on the landscape is important for conservation of species and their habitats. However, lag-time exists in converting satellite images to ground-cover maps. In certain areas where land cover is manipulated and changed frequently, this lag in time may complicate modeling or give inferior results. Furthermore, variables that focus on microhabitats may be the most important in determining occupancy of a habitat by a given species and these characteristics of microhabitats may not be represented adequately by maps.

However, microhabitats selected by many species may be embedded within maps that depict distribution of vegetation.

Applications of satellite-based remote sensing could be used for evaluation and modeling of habitats, for monitoring programs, and to achieve conservation and management objectives. This is especially true for remote regions of the world that are difficult to access (Gottschalk et al. 2005), such as some tropical areas used by wintering birds. Models based on imagery alone can predict avian habitats at some spatial scales (Osborne et al. 2001), but more research is needed to determine how to use this technology at different spatial scales, especially at the scale of microhabitat that many species may use when selecting habitats.

The family Parulidae includes 116 species representing 25 genera of New World warblers (Lovette and Bermingham 1999). This family displays high levels of adaptive radiation (MacArthur 1958, Mayr 1963, Morse 1989) and each species may have home ranges and territories that overlap with other species of warblers. While many species of birds have radiated due to geographical barriers, many warblers have evolved based on dietary niche (Lovette and Bermingham 1999). They inhabit similar habitats but are partitioned by differences in diet. Worldwide, about 23 species of parulids are threatened. Thus, warblers are an ideal group of birds that could be used to assess relationships between species and the habitats they occupy. I used maps derived from satellite imagery to build models of habitats occupied by warblers for use in conservation and management of these species.

MATERIALS AND METHODS

My study area was Redstone Arsenal, a 15,305-ha military installation in southwestern Madison County, Alabama. Redstone Arsenal is in the Tennessee Valley physiographic region and the Tennessee River borders the installation on the south. Redstone Arsenal contains a variety of habitats, including croplands, pasturelands, upland forests, wet-mesic forests in the floodplain, and forested palustrine wetlands (Appendix 1).

During 2008-2010, distribution of birds on Redstone Arsenal was assessed using 884 point-count transects following Hamel et al. (1996). Sites where surveys were conducted were selected using information provided by personnel of the Cultural and Natural Resources Environmental Management Division of Redstone Arsenal. Each site was ≥250 m from all other sites surveyed. Information on habitats was provided as GIS maps of data obtained from the Alabama-GAP Program (http://www.basic.ncsu.edu/segap/). Each site was given a unique number and global-positioning-system (GPS) coordinates, temperature, wind speed, weather conditions, date, time, and observer were recorded.

Once at a site, the observer waited 5 minutes to begin the survey to allow the area to recover from intrusion. Activity (calls, songs, visual sightings) was recorded using a bulls-eye datasheet during three time intervals (0-3, 3-6, and 6-10 minutes; Hamel et al. 1996). Surveys were not conducted on days with inclement weather, such as rain or winds >25 km/hour.

GIS was used to determine habitats within a circle with a radius of 125 m encompassing a total area of 4.91 ha. A list of *a priori* models for each species was compiled based on published studies of their habitats. Those data were compared to characteristics of habitats from the Alabama-GAP Program to determine a list *of a priori* models for each species of warbler.

Models were analyzed using PRESENCE statistical software (Hines 2006) and compared and ranked using Akaike's Information Criterion (AIC) and AICc (corrected for small samples) to determine the most-parsimonious models (Burnham and Anderson 2002). I constructed sets of best-possible models for each species using only variables that were based upon past ecological research using a manual, forward-selection process as described by King et al. (2009).

All covariates that I believed were important from the published literature were added to the first model. Covariates were removed one at a time based on having the lowest ratio of maximum-likelihood estimator (β) to standard error (*SE)* as described by Arnold (2010). This process continued until AIC-values of the model increased instead of decreased (Arnold 2010). Models with ΔAIC = 0 were selected as the best. A parametric bootstrap was used to assess goodness-of-fit of the global model, using 10,000 replicates. Probabilities of detection (p) or ability to locate an animal or species (MacKenzie et al. 2002) and occupancy (ψ), the probability that a randomly selected site is occupied by a species (MacKenzie et al. 2002), were calculated. Variables, such as minutes since sunrise, cloud cover, temperature, and speed of wind, which were believed to affect detections of species were incorporated into models as suggested by Wintle et al. (2005).

RESULTS

During January 2008-July 2010, three research assistants and I counted 249 warblers representing five species at 884 locations in 11 habitats. The variable most affecting detection of warblers was date, which affected detection of three of the five species of warblers I examined (three of five models); followed by temperature and observer that each affected detection of two of the five species of warblers (two of five models).

The model for the Northern Parula (*Parula americana*) had a positive correlation with large-floodplain habitats (β = 8.75, *SE* = 0.10) and probability of being present at a surveyed site increased as proportion of large-floodplain habitats increased (Fig. 2.1). Detection was effected by observer (observer 1: β = 1.87, *SE* = 0.98; observer 2: β = 1.93, *SE* = 0.87; observer 3: β = -1.04, *SE* = 0.60). Thus, the Northern Parula was more likely to be detected by observers 1 and 2 and less likely to be detected by observer 3.

The model for the Pine Warbler (*Dendroica pinus*) revealed a positive correlation with evergreen plantations (β = 1.77, *SE* = 0.61) and probability of being present at a site increased as proportion of evergreen plantations increased (Fig. 2.2). Detection was effected by date (β = -2.19, *SE* = 0.47); this species was less likely to be detected later than earlier in the survey (i.e., detectability decreased from January to May).

Presence of the Prothonotary Warbler (*Protonotaria citrea*) was correlated positively with open water (β = 1.97, *SE* = 0.54; Fig. 2.4), small-stream and riparian habitats (β = 2.41, *SE* = 0.67; Fig. 2.5), and large-floodplain forest habitats (β = 5.09, SE = 0.26; Fig. 2.3). Occupancy of sites increased as proportions of these three habitats increased. Detection increased as temperature increased (β = 3.13, *SE* = 0.80). Detection also was affected negatively by observers 1 and 3 and positively affected by observer 2 (observer 1: β = -3.54, *SE* = 0.45; observer 2: β = -1.28, *SE* = 0.42; and observer 3: β = -0.80, *SE* = 0.57). Observer 1 was least likely to detect Prothonotary Warblers and they were most likely to be detected by observer 2.

Presence of Common Yellowthroats (*Geothlypis trichas*) was correlated positively with small-stream and riparian habitats (β = 1.27, *SE* = 0.68; Fig. 2.7) and negatively with dry-mesic oak forests (β = -1.78, *SE* = 0.78; Fig. 2.6). Presence of this species at a site increased as proportion of small-stream and riparian habitats increased and decreased as proportion of dry-mesic oak forests increased. Detectability decreased as temperature decreased (β = -6.89, *SE* = 3.08).

Presence of Yellow-breasted Chats was correlated positively with evergreen plantations (β = 1.09, *SE* = 1.04; Fig. 2.8). Encounters with this species increased as proportion of evergreen plantations increased. Incidence of detection increased from January-February to April-May (β = 4.58, *SE* = 1.78).

DISCUSSION

Warblers were recorded in 11 types of habitats on Redstone Arsenal. Of these, five were related significantly to the warblers I studied. Evergreen plantations and small-stream and riparian habitats were the most useful habitats for predicting where the five species of warblers occurred. Large-floodplain forest, open-water, and dry-mesic oak forest habitats were the second-most informative predictors of habitats.

The Northern Parula breeds throughout the eastern United States and southern Canada (Moldenhauer and Regelski 1996). Northern Parulas feed in mid-to-upper canopy of forests, and they selects riparian vegetation in moist deciduous, coniferous, or mixed hardwoods associated with epiphytic growth (Moldenhauer and Regelski 1996) in bottomlands along rivers and creeks. My models also predicted that Northern Parulas occupied large-floodplain forests (Fig. 2.1) that consisted primarily of hardwoods such as *Quercus, Acer, Platanus,* and *Liquidambar* intermixed with shrubs. This habitat typically experiences flooding each year, usually in spring. Northern Parulas have been extirpated as a nesting species in some areas of the northeastern United States (Forbush 1929), supposedly due to reduction in abundance of epiphytes caused by air pollution. Clearcutting forests (Robbins 1990, Brewer et al. 1991, Robbins and Easterla 1992) and draining bogs and moist areas (Bull 1974, Robbins 1990) also are responsible for declines in populations of this species.

In winter, Pine Warblers are abundant in pine (*Pinus*) forests in the southeastern United States (Rodewald et al. 1999). They are unique among most parulids in that their wintering and breeding ranges predominately are within the United States and Canada (Rodewald et al. 1999). Throughout their range, Pine Warblers nest in a variety of habitats ranging from upland deciduous forests intermixed with pines to pine plantations and hardwoods (Schroeder 1985, Degraaf et al. 1991, Hamel 1992, Foss 1994, Stevenson and Anderson 1994, Murray and Stauffer 1995). My assessment predicted a preference for pine plantations (Fig. 2.2). In my study area, pine plantations were even-aged, evenly spaced, and derived from afforestation or reforestation. Pesticides used to control insects in forests are a conservation concern (Sample et al. 1993). Clearcutting (Thompson et al. 1992, Annand and Thompson 1997) and even-aged stands of pines <10 years old (Conner et al. 1979) also negatively impact Pine Warblers.

The Prothonotary Warbler occurs primarily in swampy habitats (Petit 1999). Key habitats are believed to be near water and contain adequate cavity-nesting sites (Petit 1999). These habitats include seasonally flooded hardwood bottomlands and swamps dominated by bald cypress trees (*Taxodium distichum*; Walkinshaw 1953, Blem and Blem 1991). Usually, nests are over water but they also may be over areas that temporarily are flooded (Kleen 1973). Other important habitats are low-elevation, flat terrain, with a shady over-story (Kahl et al. 1985, Robbins et al. 1989). Prothonotary Warblers are tolerant of disturbance by humans (Petit 1999). The most important conservation concern for this species is loss of bottomland habitats from logging and conversion to pastures and croplands (Dickson et al. 1995). Removal of dead and decaying trees also is detrimental to this species (Pashley and Barrow 1993, Dickson et al. 1995). However, degradation of habitats dominated by mangroves (*Rhizophora*) in wintering areas as a result of agricultural practices, construction of roadways, and development of coastal areas may become the greatest threat to Prothonotary Warblers (Terborgh 1989). My analyses predicted that this species was associated with open-water (Fig. 2.4), small-stream and riparian (Fig. 2.5), and large-floodplain forest (Fig. 2.3) habitats. Small-stream and riparian habitats and large-floodplain forests are areas that can be impacted greatly by agricultural and logging operations

(Lockaby et al. 1997). Intrusion into these areas should be minimized and buffers should exist to soften effects of these operations.

The Common Yellowthroat is an inhabitant of thick vegetation, usually in moist areas (Guzy and Ritchison 1999). Habitats other than wetlands include thickets in open pine forests (Burleigh 1958), drainage ditches and hedge rows along agricultural fields, (Bohlen 1989), and other thick, low vegetation associated with moist areas (Stevenson and Anderson 1994). Conservation concerns include large-scale commercial agriculture (Yahner 1995) and lack of disturbance that can cause loss of thick layers of vegetation (Canterbury and Blockstein 1997). My assessment of the Common Yellowthroat demonstrated that this species is associated with small-stream and riparian habitats (Fig. 2.7) and dry-mesic oak forests (Fig. 2.6). This may be a function of amount of edge habitats associated with agricultural fields where my data were collected. Bohlen (1989) determined that Common Yellowthroats were associated with ditches and hedgerows in agricultural fields. There is no report of associations with forests. Habitat associations I detected could be a result of agriculture fields being near small-stream and riparian habitats and dry-mesic oak forests.

The Yellow-breasted Chat inhabits low, dense, deciduous and coniferous forests, early secondary growth, and scrub-shrub habitats (Dennis 1958). Crawford et al. (1981) discovered that densities of populations were related directly to density of shrubs that were 4.5 m tall. My analysis demonstrated that Yellow-breasted Chats were associated with pine plantations (Fig. 2.8). However, the map of habitats derived from satellite imagery provided no indication of density of understory in many categories of forested habitats (Appendix 1). This association may be a reflection of composition of understory and density of understory rather than size and species of trees in each habitat. While maps of vegetation from satellite imagery had some scrub-shrub habitats (Appendix 1), my results did not indicate an association with any scrub-shrub habitat. Saab et al. (1995) noted that conservation efforts should focus on preserving shrub habitats. Burning and chemical manipulation of early successional stands of timber can greatly improve habitats for birds associated with scrub-shrub habitats (King et al. 2009).

Accuracy in modeling habitats of warblers is suspect because satellite imagery is less able to detect features of microhabitats, such as density of understory within forests, depth of leaf litter, and dead woody debris. Also, associations of birds and variables change in accordance with small-scale changes in landscapes (Brennan and Schnell 2005), which may not be detected by remote sensing. Many species of birds, such as warblers, may select habitats based on characteristics of microhabitats; however, many species select habitats on coarser scales (MacFaden and Capen 2002).

Further research is needed to evaluate usefulness of satellite imagery and GIS maps in modeling habitats of birds and other organisms. While data on habitats that are generated by satellite imagery may be adequate for modeling more generalist species, they may be inadequate to model relationships of habitats of species that key on characteristics of microhabitats.

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TABLE 2.1. Species of warblers (Parulidae) and their corresponding best models (ΔAIC) of detectability. Covariates of detectability and β-values of parameters are presented.

		Parameters		Covariates of Detectability		
Species	Model	Occupancy ψ (SE)	Detectability p (SE)	Date (SE)	Temperature (SE)	Observer (SE)
Northern Parula	ψ(large-floodplain forest), p(observer)	-1.48 (3.40)	-2.20 (0.83)			(1) 1.87 (0.98) (2) 1.93 (0.87) (3) -1.04 (0.60)
Pine Warbler	ψ(evergreen plantation), p(date)	-1.18 (3.31)	8.46 (1.20)	-2.19 (0.47)		
Prothonotary Warbler	ψ(open water + small-stream and riparian), p(date + temperature + observer)	-2.32 (0.33)	-1.23 (0.42)	3.02 (0.87)	3.13 (0.80)	(1) -3.13 (0.45) (2) -1.28 (0.42) (3) -0.80 (0.57)
Common Yellow Throat	ψ(small-stream and riparian + dry-mesic oak forest) p(temperature)	-2.22 (0.52)	2.66 (2.11)		-6.89 (3.08)	
Yellow-breasted Chat	ψ(evergreen plantations), p(date)	-2.67 (0.31)	-1.86 (0.47)	4.58 (1.18)		

TABLE 2.2. Summary of observations of warblers (Parulidae) by habitat at Redstone Arsenal, Madison County, Alabama.

Species	Large-floodplain forest	Successional grassland-herbaceous	Dry-mesic oak forest	Mesophytic forest	Open water	Evergreen plantation	Small-stream and riparian forest	Clearcut shrub-scrub	Southern-Appalachian pine forest	Developed open space	Number Observed
Common Yellowthroat	10	5	1	0	10	1	0	2	0	0	29
Northern Parula	1	5	2	1	0	4	1	11	0	1	26
Pine Warbler	1	5	3	0	0	35	3	3	0	4	54
Prothonotary Warbler	21	3	5	7	10	11	13	2	1	0	73
Yellow-breasted Chat	5	6	16	6	1	25	0	9	0	0	68

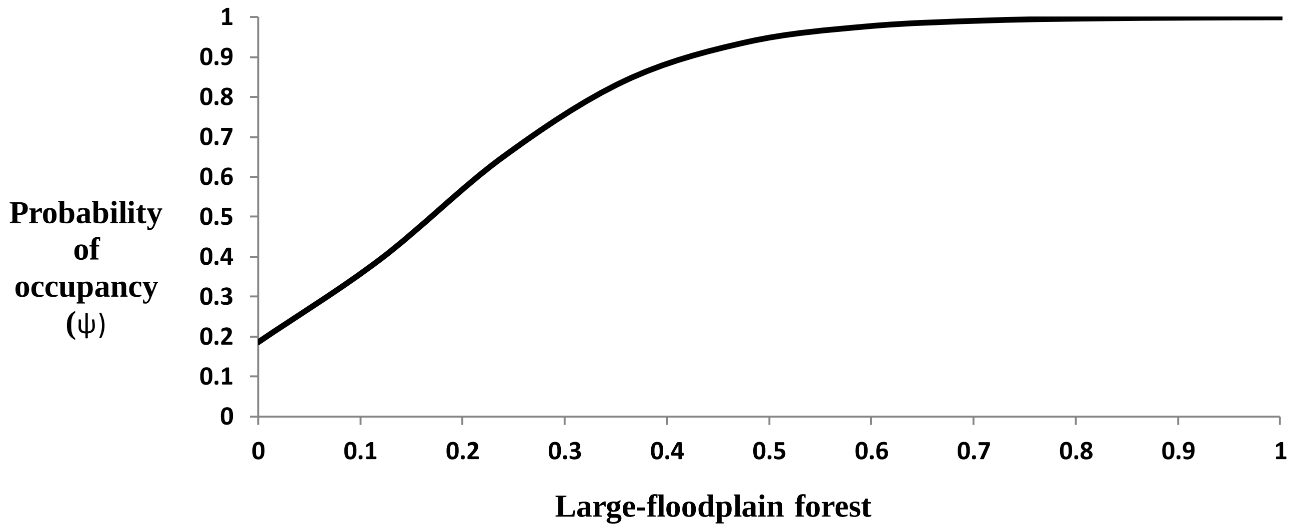

FIG. 2.1. Effect of increasing proportion of large-floodplain forests on use and occupancy (ψ) of this habitat by the Northern Parula.

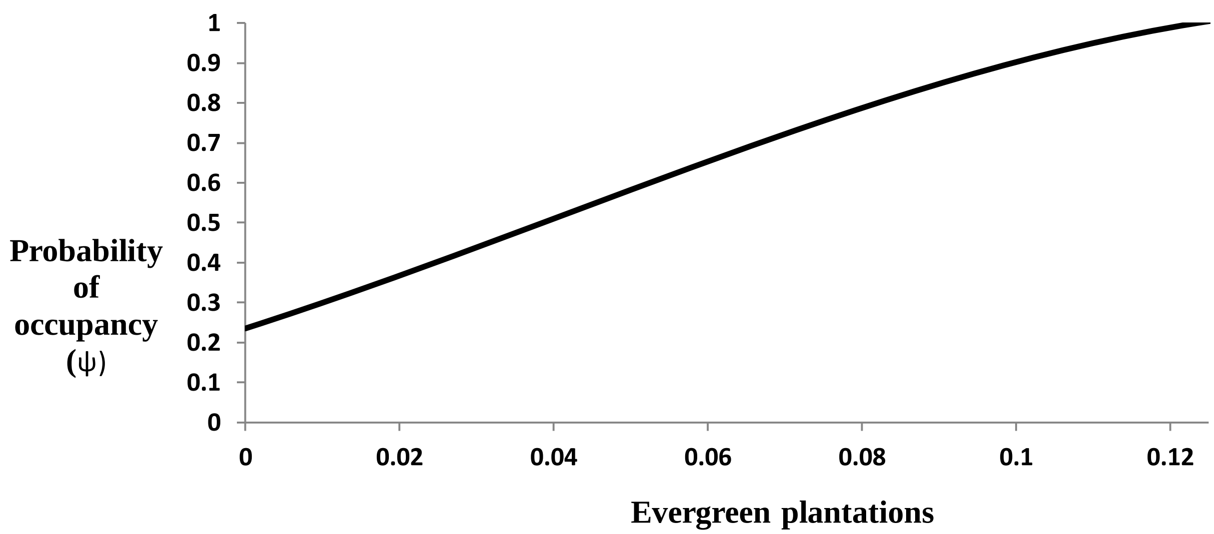

FIG. 2.2. Effect of increasing percentage of evergreen plantations on use and occupancy (ψ) of this habitat by Pine Warblers.

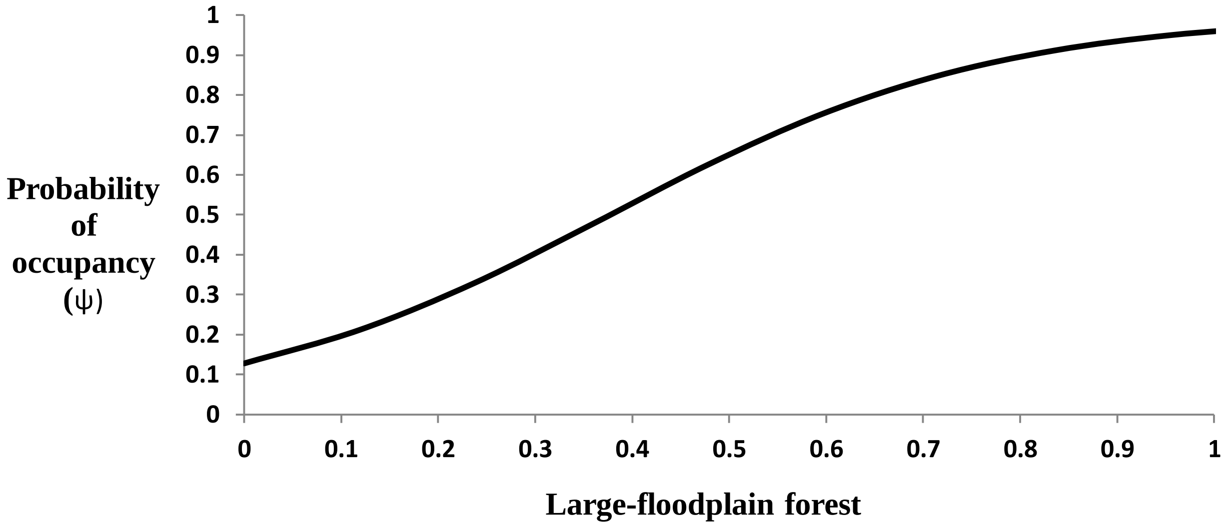

FIG. 2.3. Effect of increasing proportion of large-floodplain forests on use and occupancy (ψ) of this habitat by Prothonotary Warblers.

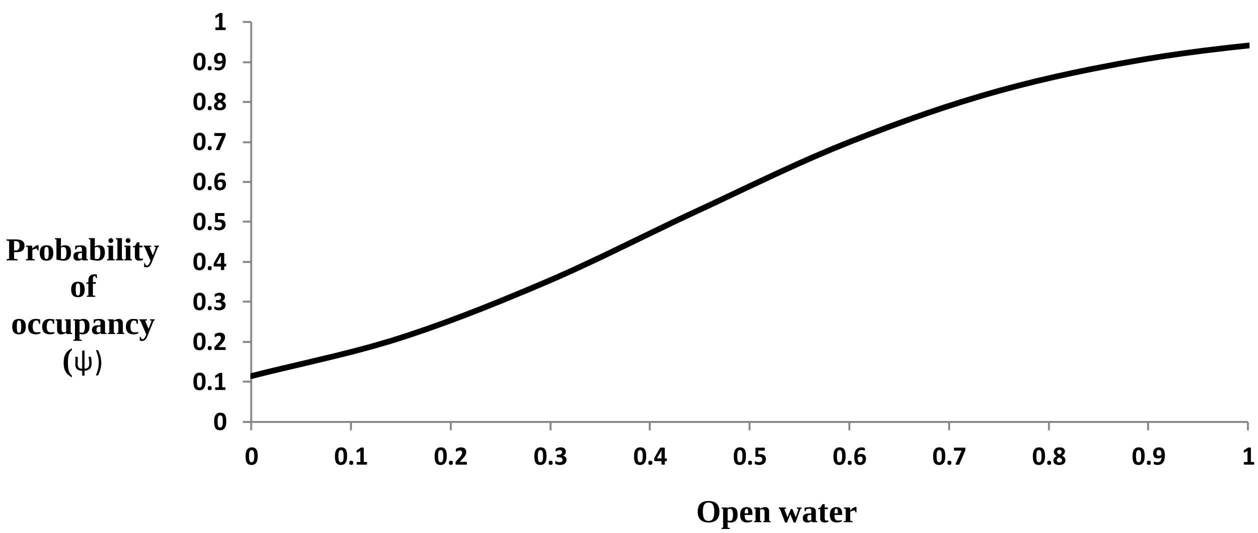

FIG. 2.4. Effect of increasing proportion of open-water habitats on use and occupancy (ψ) of this habitat by Prothonotary Warblers.

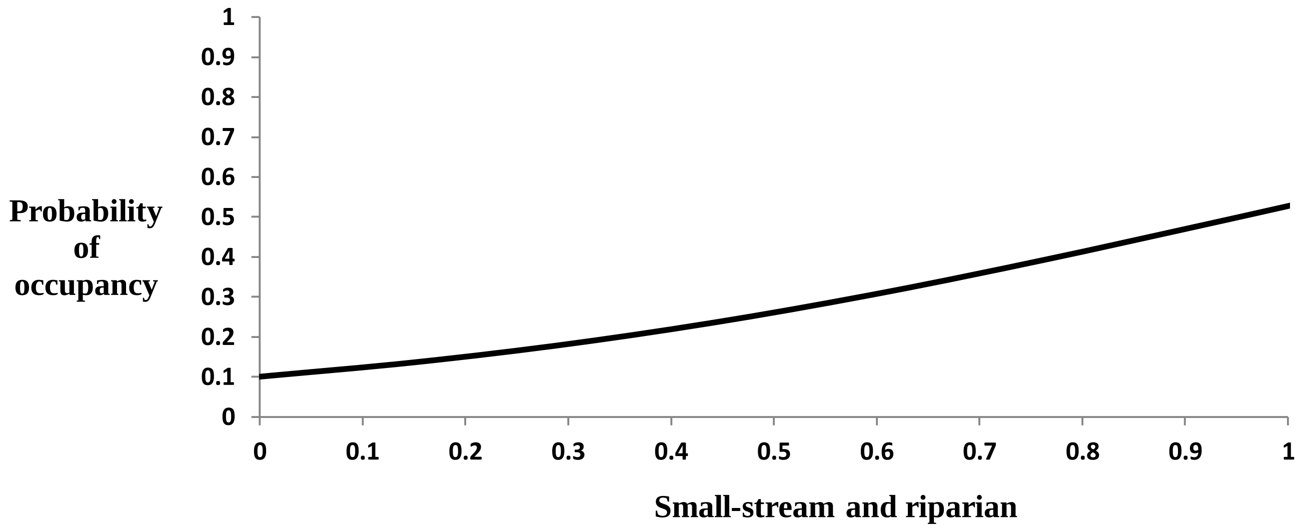

FIG. 2.5. Effect of increasing proportion of small-stream and riparian habitat on use and occupancy (ψ) of this habitat by Prothonotary Warblers.

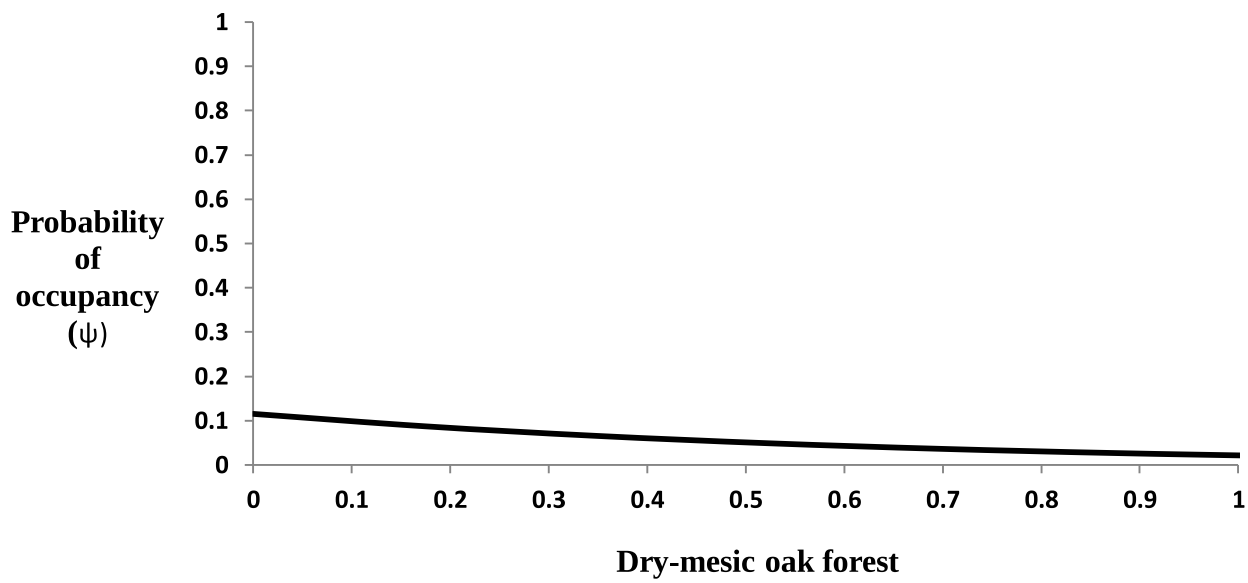

FIG. 2.6. Effect of increasing proportion of dry-mesic oak forest on use and occupancy (ψ) of this habitat by Common Yellowthroats.

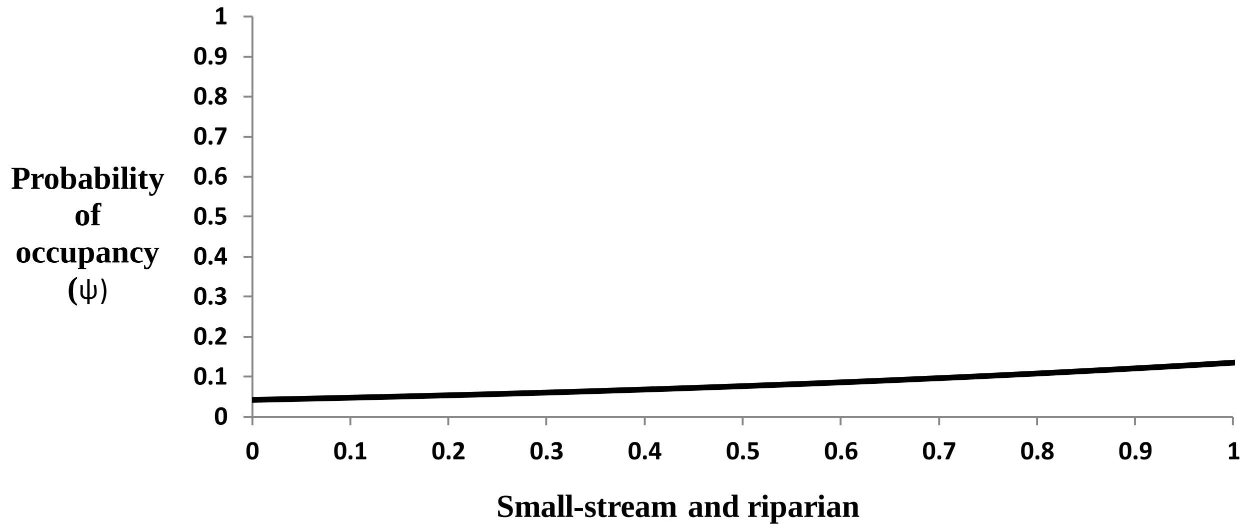

FIG. 2.7. Effect of increasing proportion of small-stream and riparian habitats on use and occupancy (ψ) of this habitat by Common Yellowthroats.

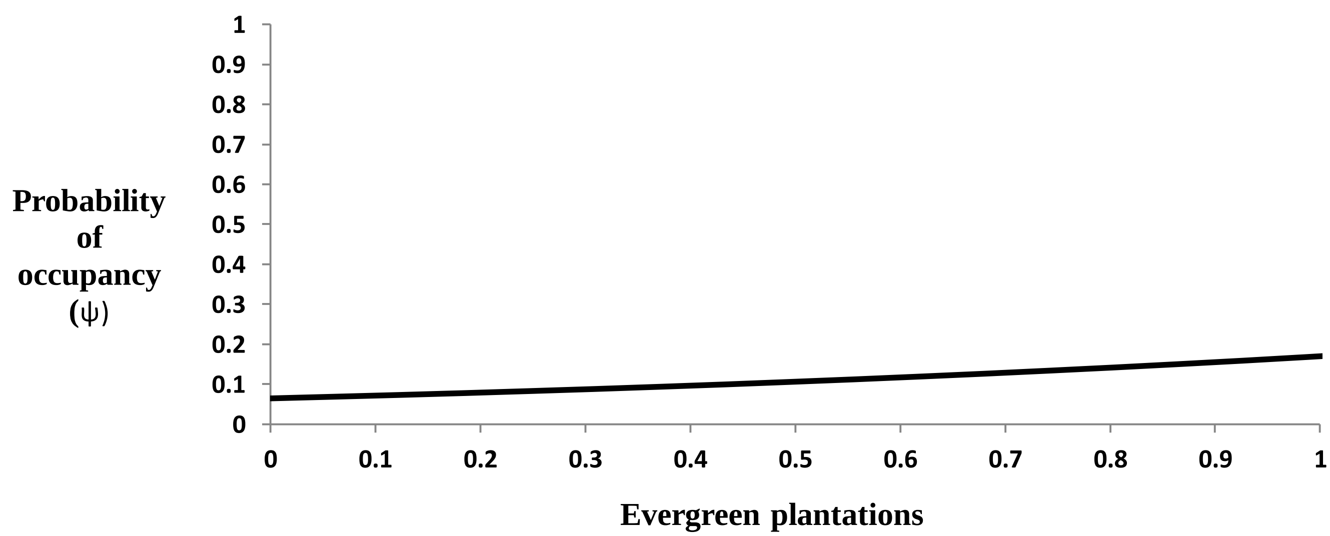

FIG. 2.8. Effect of increasing proportion of evergreen plantations on use and occupancy (ψ) of this habitat by Yellow-breasted Chats.

Chapter 3

HABITAT ASSOCIATIONS OF BIRDS IN NORTHERN ALABAMA

ABSTRACT

I examined habitat associations of 128 species of birds, including 18 species of conservation concern in Alabama, on Redstone Arsenal, Madison County. I used maps of habitats derived from satellite imagery to determine biodiversity within habitats. Discriminant-function analysis revealed that dry-mesic oak forests were occupied by 16% of avian species; the habitat used by the greatest number of species of birds within Redstone Arsenal. Pasturelands were used by 15% of species and were the second highest ranking in avian biodiversity. Small-stream and riparian habitats were selected by 13% of species. Developed open-space and open-water habitats were each used by 8% of species. Evergreen plantations, row crops, and clearcut successional scrub-shrub were each used by 5% of species. Southern-Appalachian pine forests and successional grassland-herbaceous habitats were each used by 4% of species. Each of the remaining habitats was used by 2% of species; medium-intensity developments, large-floodplain forests, and mesophytic forests. Bare soils, high-intensity developments, successional grassland-herbaceous habitats, and anthropogenic successional scrub-shrub habitats were each used by about 1% of species.

INTRODUCTION

Many populations of Neotropical songbirds have declined since the 1970s, primarily due to loss and fragmentation of habitats because of urbanization and production of agricultural crops (Donovan and Flather 2002). Considering this decline in populations, knowledge about habitats occupied by a species is essential for successful management programs (Carter et al. 2006). Modeling of habitat associations can be a valuable tool for prioritizing conservation of biodiversity and in planning use of land (De Wan et al. 2009). In a study of birds in South Carolina, models at the scale of landscape had the highest fit-to-field and were as predictive as models of microhabitats. Birds choose habitats based on type of habitat; however, predictive models of distribution of birds based on variables derived from maps tend to have limited resolution. Maps with thematic (ground-truth data) and satellite imagery produced the best models to predict distributions of birds (Seoane et al. 2004) and both can be integrated using Geographic Information Systems (GIS).

Satellite imagery and GIS have the potential to elucidate distributions of species and habitats at large spatial scales (Osborne et al. 2001). Application of remote-sensing data and GIS provides powerful tools when used to investigate species and their habitats with an analytical or modeling approach (Gottschalk et al. 2005). Evaluation of digitally based information and ecological models might overcome many problems associated with assessing habitats occupied by wildlife. Maps of vegetation are available for most areas and GIS-based analyses using satellite images of habitats and data on distribution of birds provide an efficient means of assessing relationships between ecosystems and species (Gottschalk et al. 2005). This digital assessment may reduce costs and increase accuracy of modeling; thus, providing managers with more information that is useful in making decisions (Newton-Cross et al. 2007).

Scale or size of research site is important to consider when investigating effects of environment on a species. Many species are affected adversely by activities of humans at large spatial scales and conservation of those species requires information at the same large scales (Winkler and Christie 2002). Examining habitat associations of birds at these scales can be difficult as habitat variables may be difficult to collect. Tools that allow managers to evaluate habitats on a larger scale are valuable. Intensive assessments of ground cover may not keep pace with rate of change in use of land over large areas; new methods are needed to evaluate habitats at a regional scale.

Associations of birds and landscapes may change with small-scale changes in habitats (Brennan and Schnell 2005). Many birds select habitats based on characteristics of microhabitats; however, many select habitats on a coarser scale (MacFaden and Capen 2002). Lichstein et al. (2002) reported that abundance of songbirds in large managed forests was moderately to weakly linked to effects of landscapes. They suggested that abundance of birds in forested landscapes primarily reflects the quantity of different habitats in the landscape, rather than spatial arrangement of habitats. Mitchell et al. (2006) evaluated models of landscapes generated for eight of nine guilds and detected a relationship between number of species present and availability and configuration of features in the landscape. Fit of their model was strong for Neotropical songbirds compared to their model for short-distance migrators.

Alabama is characterized by some of the highest avian diversities within the United States, which includes 420 species of birds (Haggerty et al. 2004) that represent nearly one-half of all species in the country. Of these, 178 species breed in Alabama, 174 overwinter in Alabama, and 80 migrate through the state, 18 of which are of conservation concern (Haggerty et al. 2004). Since many species of birds northern Alabama are of moderate or high conservation concern, this region is of special interest for conservation and management. Identifying which species of birds are present and which habitats they occupy are critical to making management decisions. Goals of my study were 1) to determine which species of birds were present, 2) to determine habitat associations at the landscape spatial scale, 3) to determine if presence of species can be predicted by type of habitat, and 4) to make management recommendations that would maintain or enhance habitats occupied by birds, particularly those species of conservation concern.

MATERIALS AND METHODS

My study area was Redstone Arsenal, a 15,305-ha military installation in southwestern Madison County, Alabama. Redstone Arsenal is in the Tennessee Valley physiographic region and the Tennessee River borders the installation on the south. Redstone Arsenal contains a variety of habitats, including croplands, pasturelands, upland forests, wet mesic forests in the floodplain, and forested palustrine wetlands.

During 2008-2010, presence of birds was assessed using 884 point-count transects following Hamel et al. (1996). Sites that were surveyed were selected using information on habitats provided by personnel of the Cultural and Natural Resources Environmental Management Division of Redstone Arsenal. Each surveying site was ≥250 m from all other sites. Information on habitats was provided as GIS maps. Each site was assigned a unique identification number, and GPS (Global Positioning System) coordinates, temperature, wind speed, weather conditions, date, time, and observer were recorded.

Upon arrival at each site, the observer waited 5 minutes to begin the survey to allow the area to recover from intrusion. Activity (calls, songs, visual sightings) were recorded using a bulls-eye datasheet over three time intervals (0-3, 3-6, and 6-10 minutes) as described by Hamel et al. (1996). Surveys were not conducted on days with inclement weather, such as rain or winds >25 km/hour. GIS was used to determine habitats within a circle that had a radius of 125 m and an area of 4.91 ha.

I listed common names of the 128 species of birds in alphabetical order and divided them into seven groups, which were analyzed separately using discriminant-function analysis (Appendix 3-9). Species were divided into seven groups because discriminant-function analysis requires that the number of factors examined is similar to the number of classes to be reclassified (Ramsey and Shafer 2002). I report results of the seven discriminant-function analysis combined based on habitats contributing the most to reclassification of each species.

RESULTS

During January 2008-July 2010, 884 sites were surveyed that encompassed a total area of 4,337 ha; 13,707 birds representing 128 species were identified. All 17 types of habitats on Redstone Arsenal were included in surveys (Appendix 1). The three habitats contributing most to reclassification of each species in discriminant-function analyses are listed in Appendices 3-9.

Dry-mesic oak forests accounted for 30% of habitats in my study area and were characterized by upland hardwoods comprised of *Quercus* and *Carya*. Dry-mesic oak forests were occupied most often by Barn Swallows (*Hirundo rustica*), Black-and-white Warblers (*Mniotilta varia*), Black-billed Cuckoos (*Coccyzus erythropthalmus*), Brown-headed Nuthatches (*Molothrus ater*), Carolina Chickadees (*Poecile carolinensis*), Carolina Wrens (*Thryothorus ludovicianus*), Cerulean Warblers (*Dendroica cerulea*), Chipping Sparrows (*Spizella passerina*), Common Grackles (*Quiscalus quiscula*), Eastern Wood-Peewees (*Contopus virens*), Great-crested Flycatchers (*Myiarchus crinitus*), Gray Catbirds (*Dumetella carolinensis*), Golden-winged Warblers (*Vermivora chrysoptera*), House Wrens (*Troglodytes aedon*), Painted Buntings

(*Passerina ciris*), Rose-breasted Grosbeaks (*Pheucticus ludovicianus*), Red-bellied Woodpeckers (*Melanerpes carolinus*), Red-eyed Vireos (*Vireo olivaceus*), Swamp Sparrows (*Melospiza geogiana*), and Worm-eating Warblers (*Helmitheros vermivorum*).

Pasturelands represented 19% of habitats surveyed and was characterized by grasses and legumes planted for livestock grazing. This habitat was used most often by American Crows (*Corvus brachyrhynchos*), American Kestrels (*Falco sparverius*), Bobolinks (*Dolichonyx oryzivorus*), Dickcissels (*Spiza americana*), Eastern Kingbirds (*Tyrannus tyrannus*), Eastern Meadowlarks (*Sturnella magna*), Eastern Towhees (*Pipilo erythrophthalmus*), Field Sparrows (*Spizella pusilla*), Fox Sparrows (*Passerella iliaca*), Grasshopper Sparrows (*Ammodramus savannarum*), Least Flycatchers (*Empidonax minimus*), Loggerhead Shrikes (*Lanius ludovicianus*), Prairie Warblers (*Dendroica discolor*), Red-tailed Hawks (*Buteo jamaicensis*), Savannah Sparrows (*Passerculus sandwichensis*), Song Sparrows (*Melospiza melodia*), White-breasted Nuthatches (*Sitta carolinensis*), White-throated Sparrows (*Zonotrichia albicollis*), and Yellow-breasted Chats (*Icteria virens*).

Small-stream and riparian areas were at 8% of sites. These areas were characterized by the hardwoods *Quercus*, *Acer, Platanus*, and *Liquidambar* with understory. Closure of canopy varied and these habitats lacked soils that were developed by floodplains. Small-stream and riparian habitats had highest loadings for Barred Owls (*Strix varia*), Black-crowned Night Herons (*Nycticorax nycticorax*), Blue-gray Gnatcatchers (*Polioptila caerulea*), Downy Woodpeckers (*Picoides pubescens*), Great Blue Herons (*Ardea herodias*), Hairy Woodpeckers (*Picoides villosus*), Hermit Thrushes (*Catharus guttatus*), Indigo Buntings (*Passerina cyanea*), Little Blue Herons (*Egretta caerulea*), Louisiana Waterthrushes (*Seiurus motacilla*), Mallards (*Anas platyrhynchos*), Northern Flickers (*Colaptes auratus*), Northern Mockingbirds (*Mimus *polyglottos*), Ruby-throated Hummingbirds (*Archilochus colubris*), Scarlett Tanagers (*Piranga olivacea*), Wood Ducks (*Aix sponsa*), and Yellow-throated Warblers (*Dendroica dominica*).

Developed areas represented 16% of habitats and were areas with herbaceous cover such as parks or golf courses. Developed open spaces were occupied most often by American Goldfinches (*Spinus tristis*), American Tree Sparrows (*Spizella arborea*), Cattle Egrets (*Bubulcus ibis*), Cedar Waxwings (*Bombycilla cedrorum*), Dark-eyed Juncos (*Junco hyemalis*), Eastern Bluebirds (*Sialia sialia*), Mourning Doves (*Zenaida macroura*), Yellow-bellied Sapsuckers (*Sphyrapicus varius*), Yellow-rumped Warblers(*Dendroica coronata*), and Yellow-throated Vireos (*Vireo flavifrons*).

Low-intensity developments represented 7.1% of study areas and were areas with human-made structures. Impervious surface was 20-49% of the total area. Areas with low-intensity developments were important to American Robins (*Turdus migratorius*), Broad-winged Hawks (*Buteo platypterus*), Chimney Swifts (*Chaetura pelagica*), Eastern Phoebes (*Sayornis phoeba*), European Starlings (*Sturnus vulgaris*), House Finches (*Carpodacus mexicanus*), Killdeer (*Charadrius vociferus*), Northern Rough-winged Swallows (*Stelgidopteryx serripennis*), Sharp-shinned Hawks (*Accipiter striatus*), and Wood Thrushes (*Hylocichla mustelina*).

Open-water habitats accounted for 2% of the area surveyed. These areas generally were open and contained >25% vegetative cover and soil. This habitat was occupied most often by Belted Kingfishers (*Megaceryle alcyon*), Blue Jays (*Cyanocitta cristata*), Blue-winged Warblers (*Vermivora pinus*), Canada Geese (*Branta canadensis*), Common Yellowthroats (*Geothlypis trichas*), Hooded Mergansers (*Lophodytes cucullatus*), Least Bitterns (*Ixobrychus exillis*), Prothonotary Warblers (*Protonotaria citrea*), Red-winged Blackbirds (*Agelaius phoeniceus*), and Yellow-crowned Night Herons (*Nyctanassa violacea*).

Evergreen plantations accounted for 3.5% of the area and were even-aged pine trees planted with even spacing. Evergreen plantations were used most often by Acadian Flycatchers (*Empidomax virescens*), Brown Creepers (*Certhia americana*), Ovenbirds (*Seiurus aurocapilla*), Pine Warblers (*Dendroica pinus*), Red-headed Woodpeckers (*Melanerpes erythrocephalus*), and Whip-poor-wills (*Caprimulgus vociferus*).

Successional scrub-shrub habitats represented 5% of the area and was characterized by shrubs <5 m in height and making up 20% of the canopy. These areas were a result of natural regeneration or planting of trees following harvesting of timber. This habitat was important for American Bitterns (*Botaurus lentiginosus*), Bachman's Sparrows (*Aimophila aestivalis*), Chuck-will's-widows (*Caprimulgus carolinensis*), Northern Parulas (*Parula americana*), Purple Martins (*Progne subis*), Yellow-billed Cuckoos (*Coccyzus americanus*), and White-eyed Vireos (*Vireo griseus*). Southern-Appalachian pine forests were important to Hooded Warblers (*Wilsonia citrina*), Northern Cardinals (*Cardinalis cardinalis*), Pine Siskins (*Spinus pinus*), Veerys (*Catharus fuscescens*), and Wild Turkeys (*Meleagris gallopavo*).

Successional grassland-herbaceous habitats were surveyed at 0.5% of sites and were characterized by herbaceous ground cover following a disturbance such as clearcutting. This habitat was occupied most often by American Redstarts (*Setophaga ruticilla*), Common Nighthawks (*Chordeiles minor*), Kentucky Warblers (*Oporornis formosus*), Pileated Woodpeckers (*Dryocopus pileatus*), and Ruby-crowned Kinglets (*Regulus calendula*).

Row crops were 2.6% of the area and were used for producing crops such as cotton, corn, and soybeans. These habitats were occupied most often by Blue Grosbeaks (*Passerina caerulea*), Northern Bobwhites (*Colinus virginianus*), Orchard Orioles (*Icterus spurius*), Tree

Swallows (*Tachycineta bicolor*), Yellow Warblers (*Dendroica petechia*), Warbling Vireos (*Vireo gilvus*), and Turkey Vultures (*Cathartes aura*).

Medium-intensity developments were 1.8% of the area surveyed and was characterized by human-made construction and impervious surface was 50-80% of the cover. Medium-intensity development was selected by Fish Crows (*Corvus ossifragus*), House Sparrows (*Passer domesticus*), and Rock Doves (*Columba livia*).

Large-floodplain forests represented 0.5% of area surveyed and was characterized by hardwoods such as *Quercus, Acer, Platanus*, and *Liquidambar* intermixed with shrubs. These areas typically experienced flooding at least once per year. Large-floodplain forests were most important to Green Herons (*Butorides virescens*) and Red-shouldered Hawks (*Buteo lineatus*).

Mesophytic forests were 2% of the area surveyed and are highly diverse predominantly deciduous forests on highly enriched soils. Mesophytic forests were occupied by Great-horned Owls (*Bubo virginianus*) and Summer Tanagers (*Piranga rubra*).

Bare soils were at <0.1% of sites. These sites were unvegetated and were next to developed areas that had organic soils. Bare soils were associated most closely with Brown Thrashers (*Toxostoma rufum*).

High-intensity developments were <0.5% of the area surveyed and was characterized by high densities of people and impervious surfaces covering 80-100% of the area. This habitat was most important to Tufted Titmice (*Baeolophus bicolor*).

Successional grassland-herbaceous habitats occurred in 0.4% of the area surveyed and were areas dominated by herbaceous cover following a disturbance such as fire. Successional grassland-herbaceous habitats were occupied by American Woodcocks (*Scolopax minor*).

Anthropogenic successional scrub-shrub habitats were 4.8% of the area surveyed and was characterized by dominant shrubs 5 m in height with shrub canopy >20%. These areas typically were anthropocentrically altered. Anthropogenic successional scrub-shrub habitats commonly were occupied by Brown-headed Cowbirds (*Molothrus ater*).

Discussion

I used discriminant-function analysis to determine which habitats were selected most often by 128 species of birds on Redstone Arsenal in northern Alabama. While the variables I examined did not include characteristics of microhabitats, models based on large-scale variables of landscapes are useful when prioritizing conservation of biodiversity and in planning (De Wan et al. 2009). Maps of habitats are available and could prove useful when making management decisions in areas as dynamic as military installations.

Dry-mesic oak forests were selected by 16% of species and represented 30% of the total area I surveyed. Brown-headed Nuthatches selected this habitat and is a species of conservation concern within Alabama. Brown-headed Nuthatches occur in habitats that predominantly are associated with pine trees (Jackson 1988). In the Southeast, these habitats contain loblolly-shortleaf pines (*P. taeda-P. echinata*) in upper coastal plains and longleaf-slash pines (*P. palustris-P. elliottii*) in lower coastal plains (Jackson 1988). These two habitats account for the largest populations of this species in the Southeast (Hamel 1992). This habitat is not threatened; however, regeneration of dry-mesic oak forests is costly in time and money and should be protected.

Pasturelands represented 19% of the area surveyed and was used by 15% of the avian fauna. Loggerhead Shrikes a species of conservation concern used this habitat and pasturelands supported a large amount of avian biodiversity. These habitats occur throughout the southeastern

United States and are not threatened. However, many pasturelands have been converted to pine plantations in Alabama and could become an issue if those trends continue. Prices of cattle have risen recently and are predicted to stay high, which is expected to slow conversion of pasturelands to production of pines.

On Redstone Arsenal, 13% of avian species selected small-stream and riparian habitats. These habitats were 8% of the total area I surveyed and was selected by several species of conservation concern. Black-crowned Night Herons, and Downy and Hairy woodpeckers, occupied this habitat at a higher rate than other habitats. Of the birds of conservation concern within Redstone Arsenal, 22% selected small-stream and riparian habitats. Black-crowned Night-herons select habitats near foraging areas (Kushlan 1978), which include swamps, rivers, streams, ponds, lakes, lagoons, marshes, human-made ditches and canals, and moist-wet agriculture areas (Hancock and Kushlan 1984). The Hairy Woodpecker occurs in small populations throughout North America and it inhabits a variety of forested and woodland habitats; in the southeastern United States, it primarily occupies pine forests. Care should be taken to protect and improve small-stream and riparian habitats by maintaining buffer zones around these areas during logging and construction (Castelle et al. 1994).

I grouped habitats containing developments together. These areas were selected by about 20% of species and consisted of open developed spaces, bare soil, and low-intensity, medium-intensity, and high-intensity developed areas. They represented 26% of the total area I surveyed. Many of these habitats were manicured lawns and were characterized by park-like conditions (Appendix 1), which could explain the high usage by birds. The Wood Thrush, a species of conservation concern in Alabama selected these habitats. Vega Rivera et al. (1998) suggested that Wood Thrushes selected early successional areas such as fallow fields and that they also were associated with edges along fallow fields. The association of Wood Thrushes with developed habitats may be due to the large amount of forested edges that exist there. Fallow fields with plenty of edges should be maintained to aid this species, as well as providing food in the form of fruits and other soft-mass-producing trees and shrubs (Vega Rivera et al. 1998).

Open-water habitats were selected by 8% of species, they comprised 2% of the area, and they often were used by Belted Kingfishers, Prothonotary Warblers, and Yellow-crowned Night Herons, all of which are species of conservation concern representing 17% of species of conservation concern on my study area.

Evergreen plantations were used by 5% of the species of birds. These habitats accounted for 4% of the area and were selected by two species of conservation concern; Red-headed Woodpecker and Whip-poor-will.

Agricultural areas consisting of row crops were used by 5% of species and was 3% of the area surveyed. While this habitat was not selected by any species of conservation concern, it was often used by the Northern Bobwhite, a species that has experienced huge declines within its range during the past 30 years (Sauer et al. 2011).

Clearcut successional scrub-shrub habitats were selected by 5% of species and was <1% of the total area. However, four species of conservation concern were observed in this habitat: American Bittern, Bachman's Sparrow, Chuck-will's-widow, and Northern Parula. These represented 22% of species of conservation concern on Redstone Arsenal. Southern-Appalachian pine forests were selected by 4% of species and represented <1% of the total area. No bird of conservation concern selected southern-Appalachian pine forests. Successional grassland-herbaceous habitats were selected by 5% of species; it was <1% of the total area and it was occupied for by two species of conservation concern: Kentucky Warbler and American Woodcock.

Large-floodplain forests represented <1% of the total area of Redstone Arsenal and was selected by 2% of species including the Green Heron, a species of conservation concern. Mesophytic forests were selected by 2% of species and represented 2% of the study area. This habitat was not selected by any species of conservation concern. Anthropogenic successional scrub-shrub habitats were 5% of the total area and were used by <1% of species.

Osborne et al. (2001) demonstrated the usefulness of satellite imagery and GIS to elucidate distributions of species. Investigations of wildlife continues to be expensive and difficult, and tools such as remote sensing and GIS may prove to be useful in analyzing species and their habitats in a much more cost effective (Osborne et al. 2001) and efficient way than in the past. Models derived from layers of vegetation from remote sensing may not adequately explain the ecological importance of microhabitats selected by birds, but they may be useful in rapid assessment of available habitats and in addressing conservation concerns on a large scale.

Many populations of songbirds have been declining since the 1970s (Donavan and Flather 2002). Decline of birds has been linked to many causes but loss and fragmentation of habitats are major concerns (Donovan and Flathers 2002). The ability to recognize and distinguish habitats most important to birds or groups of birds are critical in managing declining populations (Carter et al. 2006). I used discriminant-function analysis and maps derived from satellite images to examine habitat associations of birds. This method has been used to rapidly distinguish and prioritize conservation and protection of habitats important to birds (De Wan et al. 2009). This has allowed us to examine habitats and their importance to birds in less time than methods that require associations to be modeled one or a few species at a time.

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Chapter 4

HABITAT ASSOCIATIONS OF BIRDS OF CONSERVATION CONCERN IN NORTHERN ALABAMA

ABSTRACT

I examined habitat associations of 18 species of birds of conservation concern on Redstone Arsenal, Madison County, Alabama. I used maps derived from satellite imagery to determine habitats occupied by each species. Discriminant-function analysis indicated that pine plantations were occupied most often by Downy, Hairy, and Red-headed woodpeckers, and Whip-poor-wills. Successional grassland-herbaceous habitats were selected by American Woodcocks, Brown-headed Nuthatches, and Wood Thrushes. Successional scrub-shrub habitats were used by American Bitterns and Bachman's Sparrows, large-floodplain forests by Black-crowned Night Herons and Belted Kingfishers, and small-stream and riparian habitats by Green Herons and Yellow-crowned Night Herons. Clearcut scrub-shrub habitats were occupied most often by Chuck-will's-widows, Northern Parulas, and Kentucky Warblers, pasturelands by Loggerhead Shrikes, and open-water habitats by Prothonotary Warblers.

INTRODUCTION

Loss and fragmentation of habitats primarily due to urbanization and production agriculture have caused declines in many populations of Neotropical songbirds (Donovan and Flather 2002). Managers are in need of methods and data that will aid in making decisions that will maintain or enhance habitats for birds. Knowledge of habitats occupied by a species is essential for successful management (Carter et al. 2006). Prioritizing conservation of biodiversity and planning use of land can be a valuable tool accomplished by modeling habitat associations (De Wan et al. 2009).

Birds may change their associations with landscapes in response to small-scale changes in their habitats (Brennan and Schnell 2005). Birds may select habitats based on characteristics of microhabitats; however, MacFaden and Capen (2002) reported that birds may also select habitats on coarser scales. Abundance of songbirds in large managed forests has been linked to effects of landscape (Lichstein et al. 2002). Lichstein et al. (2002) indicated that abundance in forested habitats primarily reflects the quantity of habitats, rather than spatial arrangement of habitats. Models derived from landscape characteristics of habitats generated for eight of nine guilds of birds detected a relationship between number of species present and availability and configuration of features in the landscape (Mitchell et al. 2006). This model was stronger for Neotropical songbirds than the model for short-distance migrators and these models may be adequate for use in management of birds at an increased spatial scale.

Alabama has one of the richest avian biodiversities in the United States, which includes 420 species of birds (Haggerty et al. 2004) that represent nearly one-half of all species in the country. Of these, 178 breed in Alabama, 174 overwinter there, and 80 species migrate through the state (Haggerty et al. 2004). Haggerty et al. (2004) listed 18 of these as species of conservation concern. Because many species in northern Alabama are of moderate or high conservation concern, this region is of special interest for conservation and management of birds. Knowing which species are present and which habitats they occupy are critical to making management decisions. Goals of my study were to determine which species of birds were present, to determine habitat associations at the landscape spatial scale, to determine if presence of species can be predicted by habitat, and to make management recommendations that would maintain or enhance habitats occupied by birds of conservation concern.

MATERIALS AND METHODS

My study area was Redstone Arsenal, a 15,305-ha military installation in southwestern Madison County, Alabama. Redstone Arsenal is in the Tennessee Valley physiographic region and the Tennessee River borders the installation on the south. Redstone Arsenal contains a variety of habitats, including croplands, pasturelands, upland forests, wet mesic forests in the large-floodplain, and forested palustrine wetlands.

During 2008-2010, presence of birds was assessed using 884 point-count transects following Hamel et al. (1996). Surveying sites were selected using information on 17 habitats provided by personnel of the Cultural and Natural Resources Environmental Management Division of Redstone Arsenal. Each surveying site was ≥250 m from all other sites. Information on habitats was provided as GIS maps and data. Each site was assigned a unique identification number, and GPS (Global Positioning System) coordinates, temperature, wind speed, weather conditions, date, time, and observer were recorded.

Upon arrival at each site, the observer waited 5 minutes to begin the survey to allow the area to recover from intrusion. Activity (calls, songs, visual sightings) was recorded using a bulls-eye datasheet over three time intervals (0-3, 3-6, and 6-10 minutes) as described by Hamel et al. (1996). Surveys were not conducted on days with inclement weather, such as rain or winds >25 km/hour. GIS was used to determine habitats within a circle that had a radius of 125 m and an area of 4.91 ha. Discriminant-function analysis was used to statistically determine which of the 17 habitats were associated with each species following Nie (1975).

RESULTS

During May 2008-July 2010, 884 sites were surveyed that encompassed a total area of 4,337 ha; 717 birds representing 18 species of high or moderate conservation concern were identified. All 17 habitats on Redstone Arsenal were included in surveys (Appendix 1).

Discriminant-function analysis revealed that pine plantations were selected most often by Downy (*Picoides pubescens*), Hairy (*Picoides vollosus*), and Red-headed woodpeckers (*Melanerpes erythrocephalus*), and Whip-poor-wills (*Caprimulgus vociferus*). Successional grassland-herbaceous habitats were selected by American Woodcocks (*Scolopax minor*), Brown-headed Nuthatches (*Sitta pusilla*), and Wood Thrushes (*Hylocichla mustelina*). Clearcut successional scrub-shrub habitats were used by American Bitterns (*Botaurus lentiginosus*) and Bachman's Sparrows (*Aimophila aestivalis*), large-floodplain forests by Black-crowned Night Herons (*Nycticorax nycticorax*) and Belted Kingfishers (*Megaceryle alcyon*), and small-stream and riparian habitats by Green Herons (*Butorides virescens*) and Yellow-crowned Night Herons (*Nyctanassa violacea*). Anthropogenic successional scrub-shrub habitats were selected by Chuck-will's-widows (*Caprimulgus carolinensis*), Northern Parulas (*Parula americana*), and clearcut successional scrub-shrub habitats by Kentucky Warblers (*Oporornis formosus*), pasturelands by Loggerhead Shrikes (*Lanius ludovicianus*), and open-water habitats by Prothonotary Warblers (*Protonotaria citrea*).

DISCUSSION

Bachman's Sparrow typically is associated with open pine woodlands or open habitats characterized by a dense layer of grasses and forbs in the understory (Hardin et al. 1982, Dunning and Watts 1990). In the southern United States, habitats preferred by Bachman's Sparrows traditionally have been characterized by mature stands of pines where wiregrass (*Aristida*) or broomsedge (*Anthropogon*) are dominant plants in the understory. Large populations also have been reported in areas managed for Red-cockaded Woodpeckers (*Picoides borealis*) (Engstrom et al. 1984, Gobris 1992). Engstrom et al. (1984) and Gobris (1992) also reported that populations of Bachman's Sparrows tended to decline in habitats where fire had been suppressed. In areas where stands of mature pines with suitable understory were lacking, areas of regeneration or new plantings can provide suitable habitat for 1-6 years until growth of trees shades the understory (Dunning and Watts 1990). In my study, clearcut successional scrub-shrub habitats, characterized by areas dominated by shrubs <5 m tall with canopy of shrubs typically $>20\%$ of total vegetation, were selected by Bachman's Sparrows. Management efforts should focus on preserving and enhancing pine plantations by thinning trees and maintaining understory with frequent prescribed fire.

Dunford and Owen (1973) described habitats of the American Woodcock as young forests and abandoned farmlands with openings in the forests adjacent to fallow farmlands that contained grasses, herbaceous cover, and low shrubs. My study indicated that successional grassland-herbaceous habitats were selected most often by this species and it may be similar to plants in fallow fields as described by Dunford and Owen (1973). Early successional habitats should be maintained by incorporating disturbances such as disking, prescribed fire, or other management actions that reset habitats to early successional stages.

Ideal habitats for the Kentucky Warbler are bottomland hardwoods and streams with dense understories (Robbins et al. 1992). Robbins et al. (1992) noted that Kentucky Warblers rarely were in agricultural areas or small fragments of wooded habitats and suggested that >500 ha are needed for this species to breed successfully. In my study, Kentucky Warblers selected clearcut successional scrub-shrub habitats, which provide dense vegetation similar to forested edges of streams and bottomland hardwoods (Robbins et al. 1992). Selection of these bottomland habitats may be based on characteristics of understories as opposed to the canopy provided by mature hardwoods, and clearcut successional scrub-shrub habitats may provide adequate resources. However, my sample was small with only 10 detections (Appendix 2) and increased observations of Kentucky Warblers probably are needed to adequately assess habitats selected by this species on Redstone Arsenal.

The Wood Thrush inhabits interiors and edges of deciduous and mixed forests and has been in steady decline over much of its range since the 1970s (Evans et al. 2011). This species occurs in forests that are well developed, mesic, and with characteristics of uplands (Evans et al. 2011). In my study, the Wood Thrush selected successional grasslands-herbaceous habitats. Low-intensity developments also were selected by Wood Thrushes (Chapter 3). Conservation efforts should include further research to obtain a better understanding of habitats occupied by this species; especially, to determine how habitats vary between breeding season and wintering grounds. Mesic forests should be maintained and protected because mature mesic forests are costly to establish and may be important to this species.

Black-crowned Night-herons select habitats near foraging areas (Kushlan 1978), which include swamps, rivers, streams, ponds, lakes, lagoons, marshes, human-made ditches and canals, and moist-wet agriculture areas (Hancock and Kushlan 1984). My study indicated that this species selected large-floodplain forests and my previous analysis indicated that small-stream and riparian habitats were selected (Chapter 3). Large-floodplain forests, small-streams, and riparian areas typically were near the Tennessee River. Large-floodplain forests should be protected and clearing for use as agricultural cropland should be discouraged. Small-stream and riparian habitats should be protected by implementing buffer zones free from intrusions and manipulations, especially during harvesting of timber.

Belted Kingfishers select habitats characterized by water that contains aquatic animals on which to feed and where there is access to steep earthen banks where they can build nesting cavities (Davis 1982). In my study, this species selected large-floodplain forests. Small-stream and riparian habitats may also be important (Chapter 3). In my study area, large-floodplain forests typically were in the floodplain of the Tennessee River. Small-stream and riparian habitats were in upper parts of the watershed in areas north of the Tennessee River and were characterized by areas that lacked development of soils and closure of canopies present in large-floodplain forests. However, nesting habitats and nesting sites may have been available along the Tennessee River and were critical to Belted Kingfishers. Conservation efforts should focus on protecting watersheds and surrounding habitats comprised of earthen banks and large trees.

Brown-headed Nuthatches occur in habitats that predominantly are associated with pine trees (Jackson 1988). In the Southeast, these habitats contain loblolly-shortleaf pines (*P. taeda*-*P. echinata*) in upper coastal plains and longleaf-slash pines (*P. palustris*-*P. elliottii*) in lower coastal plains (Jackson 1988). These two habitats account for the largest populations of this species in the Southeast (Hamel 1992). My study indicated that successional grassland-herbaceous habitats were selected by Brown-headed Nuthatches. This is contrary to Jackson (1988). However, Hamel (1992) reported that this species may occur in areas of mixed-hardwood-pine forests, as well as residential areas and parks. Large amounts of habitats within my study area were park-like. A previous analysis to detect habitats selected by Brown-headed Nuthatches indicated that they selected dry-mesic oak forests (Chapter 3) and were similar to the report of Hamel (1992). Differences between my two assessments may have been caused by differences in grouping species for analyses. However, dry-mesic oak forests were the third most-important habitat in correctly reclassifying this species (Table 4.1). Conservation efforts for Brown-headed Nuthatches should focus on protecting mature forests of different types, especially deciduous-hardwoods because generation of mature forests takes many years.

Green Herons select swampy thickets (Meyerriecks 1962), such as riparian zones along creeks and streams, marshes, human-made irrigation ditches, canals, ponds, edges of lakes, and open floodplains (Brown et al. 1982, Clarke et al. 1984, Kaiser and Fritzell 1984). In my study, Green Herons selected small-stream and riparian habitats. Analysis in an earlier study indicated Green Herons selected large-floodplain forests (Chapter 3) and agree with current analysis, which indicates that large-floodplain forests were important in reclassifying this species correctly (Table 4.1). My results are similar to those of Meyerriecks (1962), Brown et al. (1982), Clarke et al. (1984), and Kaiser and Fritzell (1984) and suggest that Green Herons select habitats with water. Protection of habitats near sources of water should help to protect Green Herons. This protection can be accomplished by designating and maintaining buffer zones around riparian areas, swamps and marshes, and rivers and streams that limit intrusion into these habitats.

American Bitterns selected clearcut successional scrub-shrub habitats. There is a paucity of information on habitats occupied by American Bitterns in the Southeast. However, Gibbs et al. (1991) reported that American Bitterns selected habitats with water and tall emergent vegetation in the northeastern United States. Gibbs et al. (1991) reported that American Bitterns were frequently in scrub-shrub and aquatic-bed wetlands (moist grassy areas). Many of the successional scrub-shrub habitats in my study area were near water and included marshy areas. Conservation efforts should protect and enhance brushy swamps and marshes.

Anthropogenic successional scrub-shrub habitats were selected by Northern Parulas. This result differed from a previous study in northern Alabama that reported this species selected floodplain forests (Chapter 1). The Northern Parula selects habitats within riparian areas with epiphytic growth (James 1971). In the southern part of the range, habitats typically are canopies and subcanopies of bottomland forests near rivers, swamps, and lakes; especially, where Spanish moss (*Tillandsia usneoides*) is present (James 1971). Results reported by James (1971) do not coincide with my analyses of habitats occupied by the Northern Parula. In my study area, anthropogenic successional scrub-shrub habitats did not contain mature trees with epiphytic growth as suggested by (James 1971). This could be due partially to the lack of fine-scale characteristics of habitats, such as epiphytic growth not being depicted on satellite-based maps or that these maps were not updated often enough to account for changes in habitats.

Anthropogenic successional scrub-shrub habitats were selected by Chuck-will's-widow. This species occupies habitats consisting of deciduous, pine (*Pinus.)*, oak-hickory (*Quercus-Carya*), and mixed forests (Burleigh 1958, Mengel 1965, Oberholser 1974, Robbins 1996). However, Brewer et al. (1991) reported that in areas where the Chuck-will's-widow is sympatric with Whip-poor-wills, Chuck-wills-widows occupy more open areas with a mixture of open agricultural habitats and mixed forests, instead of forested habitats where Whip-poor-wills are present. My results may be indicative of Chuck-will's-widows being excluded from forested habitats by Whip-poor-wills (Brewer et al. 1991) or simply that they choose anthropogenic successional scrub-shrub habitats because competition for resources was less than in forested habitats. Pine plantations were an important habitat for this species (Table 4.1) and may contain understory's with characteristics similar to early successional habitats especially if these plantations have recently been thinned. Additional research may be needed to accurately assess habitats most important to Chuck-will's-widow. However, increasing or improving habitats for Whip-poor-wills by protecting and enhancing mature forests also should benefit Chuck-will's-widows.

Loggerhead Shrikes typically are associated with open country with short vegetation, such as pastures with fencerows, fallow orchards, mowed roadsides, golf courses, agricultural fields, riparian areas, and open woodlands (Yosef 1994). Gawlik and Bildstein (1993) reported that Loggerhead Shrikes were in open pasturelands and that these were common habitats for this species in Missouri (Kridelbaugh 1982), Illinois (Smith and Kruse 1992), and New York (Novak 1989). I also detected that pasturelands were important habitats for Loggerhead Shrikes in northern Alabama. These habitats did not seem to be threatened on Redstone Arsenal, but many pastures have been converted to pine plantations within Alabama. Because prices for cattle have increased significantly, this may slow conversion of pasturelands to production of pine trees. Pasturelands should continue to be maintained to ensure adequate habitat for Loggerhead Shrikes.

Whip-poor-wills are associated with dry deciduous forests with little or no underbrush (Wilson 1985). In Kentucky, this species was in a variety of semi-open habitats including farmlands, powerline and utility right-of-ways, fallow fields, reclaimed surface mines, clearcuts, and selectively harvested timberlands (Palmer-Ball 1996). My study demonstrated that evergreen plantations were used most by this species. Pines have been reported to be of minor importance (Hall 1983 , Sibley 1988), but shade near open areas with sparse ground cover is important habitat for this species (Eastman 1991). Pine plantations are plentiful in Alabama and may adequately provide resources required by this species in the absence of dry deciduous forests.

In the southern part of its range, Yellow-crowned Night Herons inhabit swamps, forested wetlands, and forested uplands near lakes, rivers, and streams (Watts 1989, Bentley 1994). These habitats should be near water containing high densities of crustaceans (Mumford and Keller 1984). My study indicated that small-stream and riparian habitats were selected and that this species may also select open-water habitats (Chapter 3). My results were similar to habitats that were associated with water as reported by Watts (1989) and Bentley (1994). Conservation efforts should focus on protecting and implementing buffer zones around riparian areas and open-water habitats.

The Hairy Woodpecker occurs in small populations throughout North America and it inhabits a variety of forested and woodland habitats. In the southeastern United States, it primarily occupies pine forests. Although this is among the most ecologically variable species in North America, it has been the focus of few studies (Jackson et al. 2002). The species is neither threatened nor endangered but is of concern because of declining populations, and it probably suffers from fragmentation of forested habitats, loss of old-growth forests, and competition with European Starlings (*Sturnus vulgaris*; Tate 1986). Evergreen plantations were the habitats selected most often and support the study by Jackson et al. (2002). My previous discriminant-function analysis also indicated that small-stream and riparian habitats were selected by Hairy Woodpeckers (Chapter 3). Jackson et al. (2002) indicated that Hairy Woodpeckers may use several types of forested habitats and may simply be an indication of their use of various habitats. Previously, I reported that Hairy Woodpeckers selected habitats of dry-mesic oak forest, small-stream and riparian areas, and evergreen plantations (Chapter 1). Fragmentation of habitats should be reduced and mature forests should be maintained to protect this species.

The Downy Woodpecker inhabits most of North America (Jackson and Ouellet 2002). These woodpeckers live in urban woodlots and wilderness forests and primarily are insectivorous (Jackson and Ouellet 2002). Clearcutting has helped this species because it does well in early successional and edge habitats. Thinning forests can be an improvement of habitats because Downy Woodpeckers occupy open woodlands (Conner et al. 1975, Raphael et al. 1988). My results indicated that evergreen plantations were selected by this species and a previous analysis (Chapter 3) suggested that small-stream and riparian habitats were used most by Downy Woodpeckers. Forested habitats from virgin bottomlands to sparse forests along tops of ridges are suitable (Schroeder 1983). A study examining habitat associations of this species in northern Alabama reported that this species was associated with dry-mesic oak and mesophytic forests (Chapter 1). Based on data from Christmas Bird Counts and Breeding Bird Surveys, this is the most abundant woodpecker in eastern North America (Plaza 1975, 1978, Hess 2000). However, clearing lands for agricultural practices probably has had a negative impact because many roosting sites in the 1900s were wooden fence posts (Sherman 1996). Downy Woodpeckers are not threatened or endangered, but concerns exist regarding degradation of habitats and conflicts with humans, such as damage inflicted on wooden sidings of homes and other buildings (Jackson and Ouellet 2002). During harvesting of timber, possible nesting sites in hollow trees should not be disturbed. Wooden fence posts should remain intact whenever possible to provide additional nesting sites.

The Red-headed Woodpecker is a sexually monomorphic species occurring in the eastern United States (Smith et al. 2000). These woodpeckers are omnivorous, they are excellent flycatchers, they often occur in deciduous woodlands of oak (*Quercus*) and beech (*Fagus*) trees (Reller 1972), and they may be present in lowlands, uplands, river bottoms, and open habitats (DeGraaf et al. 1980, Kahl et al. 1985, Hamel 1992). My analysis indicated that evergreen plantations were important to this species. A previous study of habitat associations of this species in northern Alabama indicated that it selected habitats of dry-mesic oak forests and southern-Appalachian pine forests (Chapter 1). Use of pesticides and chemicals is an important conservation issue because Red-headed Woodpeckers use nesting cavities in utility poles that have been treated with the wood preservative and insect-repellant creosote. Loss of suitable habitat and nesting cavities are concerns. However, reforestation in many areas has improved some habitats. Conservation efforts should work to minimize use of pesticides and to maintain integrity of mature forests.

Petit in (1999) reported that the Prothonotary Warbler occurs primarily in swampy habitats. My research indicates that open water is an important characteristic of habitats selected by this species. This is similar to my previous assessment, where this species was strongly associated with open water and habitats comprised of small-stream and riparian areas in northern Alabama (Chapter 1). Key habitats are near water and contain adequate cavities for nesting sites (Petit 1999). These habitats include seasonally flooded bottomland-hardwood and bald cypress (*Taxodium distichum*) forests (Walkinshaw 1953, Blem and Blem 1991). Kleen (1973) suggested that nests usually are over water but also may be placed over areas that are flooded temporarily. My results indicated that open-water habitats were an important component of habitats used by Prothonotary Warblers. Other important components consist of low-elevations, flat terrains, and shady overstories (Kahl et al. 1985, Robbins et al. 1989). Petite (1999) also reported that Prothonotary Warblers are tolerant of disturbances caused by humans. The most important conservation concern for this species is loss of bottomland habitats from logging and conversions to pastures and croplands (Dickson et al. 1995). Several studies indicate that removal of dead and decaying trees also is detrimental to this species (Pashley and Barrow 1993, Dickson et al. 1995). However, degradation of habitats dominated by mangroves (*Rhizophora mangles*), which are used by Prothonotary Warblers in wintering areas, may be the greatest threat to this species (Terborgh 1989). Forested river bottoms should be protected from logging or clearcutting to protect habitat of Prothonotary Warblers.

Identifying habitats occupied by a species is a basic element for successful management (Carter et al. 2006). Modeling habitat associations can be a valuable tool for planning use of lands and for prioritizing conservation of biodiversity (De Wan et al. 2009). Studies of birds in forests of South Carolina, using models derived from characteristics of landscapes and microhabitats, similarly were predictive in determining use of habitats. Variables derived from land-use and land-cover maps tend to have limited resolution when used in predictive models. Best models to predict distributions of birds are produced by mixed maps with ground-truth data and information from satellites (Seoane et al. 2004) and both can be integrated into models using a Geographic Information System. Data on habitats that are generated by imagery obtained by satellites may be adequate for more generalist species, bit it may not be adequate to model characteristics of microhabitats that some species use to select habitats.

Further monitoring and surveying of habitats used by species of conservation concern in Alabama is recommended. Failing to monitor critical habitats may result in loss of habitats crucial to maintaining population of birds of conservation concern or to preventing declines in these populations.

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Table 4.1. Results of discriminant-function analysis of species of conservation concern with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Total Percentage Contribution to Reclassification
American Bittern	Anthropogenic successional scrub-shrub	Bare soil	Successional grassland-herbaceous	51
American Woodcock	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Bare soil	51
Bachman's Sparrow	Clearcut successional scrub-shrub	Bare soil	Dry-mesic oak forest	34
Belted Kingfisher	Bare soil	Large-floodplain forest	Clearcut successional scrub-shrub	51
Black-crowned Night Heron	Large-floodplain forest	Successional grassland-herbaceous	Clearcut successional scrub-shrub	52
Brown-headed Nuthatch	Bare soil	Successional grassland-herbaceous	Dry-mesic oak forest	60
Chuck-will's Widow	Anthropogenic successional scrub-shrub	Developed open space	Evergreen plantations	50
Downy Woodpecker	Bare soil	Evergreen plantations	Successional grassland-herbaceous	40
Green Heron	Small-stream and riparian	Developed open space	Large-floodplain forest	38
Hairy Woodpecker	Bare soil	Evergreen plantations	Clearcut successional scrub-shrub	36
Kentucky Warbler	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	37
Loggerhead Shrike	Pasture	Dry-mesic oak forest	Anthropogenic successional scrub-shrub	53
Northern Parula	Bare soil	Anthropogenic successional scrub-shrub	Row crop	37
Prothonotary Warbler	Open water	Small-stream and riparian	Bare soil	41
Red-headed Woodpecker	Bare soil	Evergreen plantations	Dry-mesic oak forest	35
Yellow-crowned Night Heron	Open water	Developed open space	Small-stream and riparian	52
Whip-poor-will	Evergreen plantations	Dry-mesic oak forest	Developed open space	35
Wood Thrush	Bare soil	Successional grassland-herbaceous	Dry-mesic oak forest	38

Table 4.2. Summary of observations of species of birds of conservation concern in habitats at Redstone Arsenal, Madison County, Alabama.

Species	Large-floodplain forest	Successional grassland-herbaceous	Dry-mesic oak forest	Mesophytic forest	Open water	Evergreen plantations	Small-stream and riparian forest	Clearcut shrub-scrub	Southern-Appalachian pine forest	Developed open space	Number observed
American Bittern	0	0	0	0	2	0	1	0	0	0	3
American Woodcock	0	1	0	0	0	0	2	0	0	0	3
Bachman's Sparrow	0	0	2	0	2	0	0	0	0	0	4
Black-crowned Night-heron	0	0	0	0	2	0	1	1	0	0	4
Belted Kingfisher	1	0	0	0	1	0	0	0	0	1	3
Brown-headed Nuthatch	3	2	14	3	1	15	1	3	1	0	43
Chuck-will's-widow	0	0	1	0	0	0	0	0	0	0	1
Downy Woodpecker	15	22	16	9	11	16	20	7	0	13	129
Green Heron	1	1	0	1	3	0	2	0	0	0	8
Hairy Woodpecker	10	7	13	5	29	12	10	6	0	1	73
Kentucky Warbler	0	0	1	2	0	5	0	1	0	1	10
Loggerhead Shrike	2	0	0	3	1	1	0	0	0	0	7
Northern Parula	1	5	2	1	0	4	1	11	0	1	26
Prothonotary Warbler	21	3	5	7	10	11	13	2	1	0	73
Red-headed Woodpecker	28	15	28	2	1	101	4	21	4	13	217
Wood Thrush	14	7	38	37	6	23	22	11	0	14	174
Whip-poor-will	0	2	2	0	0	2	0	0	0	0	6
Yellow-crowned Night-heron	0	0	0	0	4	0	0	0	0	0	4

Appendix 1. Habitats at Redstone Arsenal, Madison County, Alabama.

Names of Habitats Used Herein	Names of Habitats from Alabama-GAP Program	Descriptions of Habitats
Bare soil	Bare Soil	Unvegetated areas of organic soils usually adjacent to development.
Developed open space	Developed Open Space	Developed open areas that are primarily herbaceous (golf courses, road sides, parks, air fields).
Evergreen plantations	Evergreen Plantations	Planted pines, even-aged and spaced, in the process of afforestation and reforestation.
High-intensity development	High Intensity Developed	Highly developed areas where numerous people reside or work. Impervious surface accounts for 80-100% of total cover.
Low-intensity development	Low Intensity Developed	Includes areas of constructed materials and vegetation. Impervious surfaces account for 20-49% of total cover.
Medium-intensity development	Medium Intensity Developed	Includes areas of constructed materials and vegetation. Impervious surfaces account for 50-80% of total cover.
Open water	Open Water (Fresh)	All areas are open, generally <25% cover of vegetation or soil.
Pasture	Pasture-Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or production of hay crops.
Row crop	Row Crop	Areas used for production of annual crops such as corn, soybeans, vegetables, tobacco, and cotton.
Large-floodplain forest	South-Central Interior Large Floodplain - Forest Modifier	Consists of hardwoods such as *Quercus*, *Acer*, *Platanus*, and *Liquidambar* intermixed with shrubs. Typically experiences flooding at least once a year, usually in spring.
Mesophytic forest	South-Central Interior Mesophytic Forest	High diversity, predominantly deciduous forests occurring on deep or enriched soils.
Small-stream and riparian	South-Central Interior Small Stream and Riparian	Similar to large-floodplain forests, but lacks development of floodplain and closure of canopy varies.
Dry-mesic oak forest	South Central Low Plateau Dry-Mesic Oak Forest	Upland-hardwood forest dominated by *Quercus* and *Carya* along gentle-to-sleep slopes of various aspects.
Southern-Appalachian pine forest	Southern Appalachian Low Mountain Pine Forest	Forests dominated by short-leaf and Virginia pines in lower elevations of the southern Appalachian Mountains.
Clearcut successional scrub-shrub	Successional scrub-shrub (clearcut)	Areas dominated by shrubs <5 m tall with shrub canopy typically >20% of total vegetation. This habitat includes true shrubs and young trees in early successional stages. Specifically, this is recently harvested standing tress in the process of naturally regenerating either before planting for creation or development of timber.
Successional grassland-herbaceous	Successional Grassland-Herbaceous	Areas dominated by herbaceous ground cover following a disturbance, such as clearcutting or catastrophic fire.
Anthropogenic successional scrub-shrub	Successional Scrub-Shrub (Other)	Areas dominated by shrubs <5 m tall with canopy if shrubs typically >20% of total vegetation. Anthropogenically altered areas.

Appendix 2. Summary of observations of species of birds by habitat at Redstone Arsenal, Madison County, Alabama.

Species	Open water	Developed open space	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Acadian Flycatcher	0	3	0	0	0	0	8	0	0
American Bittern	0	1	0	0	0	0	1	0	0
American Crow	14	119	50	3	0	0	223	4	9
American Goldfinch	2	20	49	0	0	0	13	0	0
American Kestrel	0	1	0	0	0	0	0	0	0
American Redstart	0	0	0	0	0	0	3	0	0
American Robin	2	44	59	4	0	0	46	1	0
American Tree Sparrow	0	18	0	0	0	0	5	0	0
American Woodcock	0	0	0	0	0	0	0	0	0
Bachman's Sparrow	0	0	0	0	0	0	1	0	0
Barn Swallow	8	10	32	0	0	0	8	0	0
Barred Owl	0	1	1	0	0	0	6	0	0
Belted Kingfisher	1	1	0	0	0	0	1	0	0
Black and White Warbler	0	0	0	0	0	0	6	0	0
Black-billed Cuckoo	0	2	0	0	0	0	14	0	0
Black-crowned Night Heron	0	0	0	0	0	0	0	0	0
Blue Grosbeak	0	4	1	0	0	0	9	0	0
Blue Jay	13	182	88	13	0	0	321	14	13
Blue-gray Gnatcatcher	0	4	2	0	0	0	38	4	0
Blue-winged Warbler	0	0	0	0	0	0	0	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Acadian Flycatcher	0	0	1	0	3	1	0	0
American Bittern	0	0	1	0	0	0	0	0
American Crow	1	10	15	2	140	12	2	29
American Goldfinch	0	2	0	0	4	0	0	0
American Kestrel	0	0	0	0	6	0	0	0
American Redstart	0	0	1	0	0	0	0	0
American Robin	0	0	6	0	86	4	0	9
American Tree Sparrow	0	0	0	0	12	0	0	0
American Woodcock	0	0	0	0	0	0	0	0
Bachman's Sparrow	0	0	2	0	0	0	0	0
Barn Swallow	1	0	1	0	120	2	0	3
Barred Owl	0	0	0	0	0	0	0	4
Belted Kingfisher	0	0	0	0	0	0	0	0
Black and White Warbler	0	0	0	0	1	1	0	1
Black-billed Cuckoo	0	0	0	0	2	0	0	6
Black-crowned Night Heron	0	0	1	0	1	0	0	2
Blue Grosbeak	0	0	2	0	5	1	0	0
Blue Jay	1	4	22	0	182	9	1	55
Blue-gray Gnatcatcher	0	0	3	0	10	8	1	18
Blue-winged Warbler	0	0	0	0	0	0	0	1

Appendix 2. Continued.

Species	Open water	Developed open space	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Bobolink	0	0	0	0	0	0	0	0	0
Broad-winged Hawk	1	0	3	0	0	0	0	0	0
Brown Creeper	0	0	0	0	0	0	1	0	0
Brown Thrasher	1	8	13	4	0	0	26	1	0
Brown-headed Cowbird	0	10	7	0	0	0	23	0	1
Brown-headed Nuthatch	0	7	0	0	0	0	24	0	0
Canada Goose	6	0	0	0	0	0	8	0	0
Carolina Chickadee	18	52	19	1	0	0	213	8	9
Carolina Wren	1	49	17	2	0	0	137	1	5
Cattle Egret	0	1	0	0	0	0	0	0	0
Cedar Waxwing	0	0	2	0	0	0	0	5	0
Cerulean Warbler	0	3	0	0	0	0	14	0	0
Chimney Swift	1	30	24	2	1	0	10	1	0
Chipping Sparrow	0	42	25	2	1	0	23	1	0
Chuck-will's-widow	0	0	0	0	0	0	0	0	0
Common Grackle	0	9	11	7	0	0	0	7	0
Common Nighthawk	0	0	1	3	0	0	0	8	0
Common Yellow-throat	8	2	0	0	0	0	2	0	0
Dark-eyed Junco	0	7	1	0	0	0	4	0	1
Dickcissel	0	0	0	0	0	0	0	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Bobolink	0	0	0	0	1	0	0	0
Broad-winged Hawk	0	0	0	0	0	0	0	1
Brown Creeper	0	0	0	0	0	0	0	0
Brown Thrasher	0	0	3	0	11	1	0	1
Brown-headed Cowbird	0	1	1	0	20	0	0	1
Brown-headed Nuthatch	0	0	0	0	7	2	0	3
Canada Goose	0	0	3	0	46	1	0	2
Carolina Chickadee	1	6	3	0	48	8	1	46
Carolina Wren	0	2	5	0	34	0	2	36
Cattle Egret	0	0	0	0	0	0	0	0
Cedar Waxwing	0	0	0	0	0	1	0	0
Cerulean Warbler	0	0	3	0	1	1	0	2
Chimney Swift	0	0	1	0	16	1	1	12
Chipping Sparrow	0	0	0	0	41	4	0	5
Chuck-will's-widow	0	0	1	0	0	0	0	0
Common Grackle	0	0	2	21	0	177	1	0
Common Nighthawk	0	0	0	1	0	1	0	0
Common Yellow-throat	0	0	0	0	4	1	0	12
Dark-eyed Junco	0	0	1	0	14	2	0	0
Dickcissel	0	0	0	0	1	0	0	0

Appendix 2. Continued.

Species	Open water	Developed open space	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Downy Woodpecker	5	15	3	2	0	0	51	1	2
Eastern Bluebird	1	38	26	2	0	0	13	0	1
Eastern Kingbird	0	8	0	0	0	0	1	0	0
Eastern Meadowlark	0	17	4	0	0	0	4	1	0
Eastern Phoebe	0	5	4	0	0	0	5	0	0
Eastern Towhee	2	64	20	6	0	0	103	6	7
Eastern Tufted Titmouse	14	55	20	1	0	0	298	10	11
Eastern Wood Peewee	4	23	9	0	0	0	99	1	7
European Starling	0	86	141	21	8	0	62	0	0
Field Sparrow	0	55	29	2	1	0	63	0	1
Fish Crow	0	0	6	3	0	0	0	0	0
Fox Sparrow	0	0	0	0	0	0	0	0	0
Golden-winged Warbler	0	0	0	0	0	0	1	0	0
Grasshopper Sparrow	0	1	2	1	0	0	8	0	0
Gray Catbird	0	3	2	0	0	0	11	0	0
Great Blue Heron	4	5	7	0	1	0	18	0	0
Great Crested Flycatcher	1	4	0	0	0	0	7	0	1
Great-horned Owl	0	1	0	0	0	0	1	0	0
Green Heron	1	0	0	0	0	0	2	0	0
Hairy Woodpecker	0	4	0	0	0	0	32	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Downy Woodpecker	1	1	2	0	19	0	1	26
Eastern Bluebird	0	0	1	0	74	2	0	1
Eastern Kingbird	0	0	0	0	18	0	0	2
Eastern Meadowlark	0	0	0	0	112	3	0	1
Eastern Phoebe	0	0	2	0	5	0	0	1
Eastern Towhee	2	1	13	0	68	15	0	9
Eastern Tufted Titmouse	1	1	15	3	51	10	3	72
Eastern Wood Peewee	0	1	2	0	26	0	0	34
European Starling	4	0	6	0	830	28	0	2
Field Sparrow	0	1	19	0	268	12	0	2
Fish Crow	0	0	0	0	0	0	0	0
Fox Sparrow	0	0	0	0	10	0	0	0
Golden-winged Warbler	0	0	0	0	0	0	0	0
Grasshopper Sparrow	0	0	1	0	24	6	0	0
Gray Catbird	0	0	0	0	4	1	0	3
Great Blue Heron	0	0	3	0	16	1	2	18
Great Crested Flycatcher	0	0	0	0	9	0	0	0
Great-horned Owl	0	0	0	0	0	0	0	0
Green Heron	0	0	0	0	1	0	0	4
Hairy Woodpecker	0	0	4	0	12	1	2	18

Appendix 2. Continued.

Species	Open water	Developed open space	Low intensity-development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Hermit Thrush	0	0	0	0	0	0	1	1	0
Hooded Merganser	0	0	0	0	0	0	0	0	0
Hooded Warbler	0	0	0	0	0	0	11	0	0
House Finch	0	5	3	0	0	0	0	0	0
House Sparrow	0	0	18	5	0	0	0	0	0
House Wren	0	0	1	0	0	0	13	0	0
Indigo Bunting	19	99	30	3	0	0	236	12	21
Kentucky Warbler	0	1	0	0	0	0	7	0	0
Killdeer	1	8	23	1	0	0	8	0	0
Least Bittern	3	0	0	0	0	0	1	0	0
Least Flycatcher	0	0	0	0	0	0	0	0	0
Little Blue Heron	0	0	0	0	0	0	0	0	0
Loggerhead Shrike	0	0	0	0	0	0	0	0	0
Louisiana Water Thrush	0	0	0	0	0	0	5	0	0
Mallard Duck	0	4	0	0	0	0	3	0	0
Mourning Dove	7	62	41	10	0	0	87	0	1
Northern Bobwhite	2	38	21	0	0	0	64	0	7
Northern Cardinal	31	209	92	15	0	0	628	23	27
Northern Flicker	6	11	12	1	0	0	40	2	1
Northern Harrier	0	1	2	0	0	0	0	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Hermit Thrush	0	0	0	0	0	0	0	4
Hooded Merganser	0	0	0	0	0	0	0	3
Hooded Warbler	0	0	1	0	0	0	0	0
House Finch	0	0	0	0	3	0	0	0
House Sparrow	0	0	0	0	7	0	0	1
House Wren	0	0	1	0	4	0	0	3
Indigo Bunting	0	5	18	1	141	10	0	30
Kentucky Warbler	0	1	0	0	0	0	0	1
Killdeer	1	0	0	0	21	3	0	0
Least Bittern	0	0	0	0	0	0	0	2
Least Flycatcher	0	0	0	0	1	0	0	0
Little Blue Heron	0	0	0	0	0	0	0	3
Loggerhead Shrike	0	0	0	0	1	0	0	0
Louisiana Water Thrush	0	0	1	0	0	0	0	1
Mallard Duck	0	0	0	0	0	0	0	4
Mourning Dove	0	5	4	3	138	8	0	18
Northern Bobwhite	0	1	6	0	58	16	0	2
Northern Cardinal	5	12	54	3	320	23	11	171
Northern Flicker	0	1	4	0	21	6	0	25
Northern Harrier	0	0	0	0	0	0	0	0

Appendix 2. Continued.

Species	Open water	Developed open space	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Northern Mocking Bird	1	124	113	10	6	0	178	6	18
Northern Parula	1	5	1	0	0	0	6	0	0
Northern Roughed-winged Swallow	0	17	25	4	0	0	1	0	0
Orchard Oriole	0	0	0	0	0	0	0	0	0
Ovenbird	0	0	0	0	0	0	1	0	0
Painted Bunting	0	0	0	0	0	0	1	0	0
Pileated Woodpecker	2	12	1	0	0	0	40	0	2
Pine Siskin	0	2	0	0	0	0	1	0	0
Pine Warbler	0	7	5	0	0	0	29	0	5
Prairie Warbler	0	0	0	0	0	0	1	0	0
Prothonatary Warbler	5	3	4	0	0	0	25	1	1
Purple Martin	3	12	0	0	0	0	1	0	0
Red-bellied Woodpecker	6	40	12	2	0	0	241	14	13
Red-eyed Vireo	5	10	1	0	0	0	97	3	0
Red-headed Woodpecker	0	24	13	1	0	0	126	0	9
Red-shouldered Hawk	0	2	1	0	0	0	10	0	0
Red-tailed Hawk	1	10	5	0	0	0	12	0	1
Red-winged Blackbird	23	21	1	1	0	0	32	0	0
Rock Dove	0	0	5	0	0	0	0	0	2
Rose-breasted Grosbeak	0	0	0	0	0	0	1	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian Forest
Northern Mocking Bird	2	4	4	0	212	19	0	12
Northern Parula	0	0	7	0	2	2	0	2
Northern Roughed-winged Swallow	0	0	0	0	24	0	0	0
Orchard Oriole	0	0	0	0	0	2	0	0
Ovenbird	0	0	0	0	0	0	0	0
Painted Bunting	0	0	0	0	0	0	0	0
Pileated Woodpecker	0	2	0	0	8	2	1	11
Pine Siskin	0	0	0	0	0	0	0	0
Pine Warbler	0	0	1	1	5	0	0	1
Prairie Warbler	0	0	0	2	6	0	0	1
Prothonatary Warbler	0	0	2	0	5	1	1	25
Purple Martin	0	0	3	0	1	0	0	0
Red-bellied Woodpecker	1	1	11	0	59	2	4	71
Red-eyed Vireo	0	0	3	0	11	2	4	9
Red-headed Woodpecker	0	0	6	2	18	1	0	16
Red-shouldered Hawk	0	0	0	0	2	1	2	4
Red-tailed Hawk	0	0	1	0	32	2	0	3
Red-winged Blackbird	0	8	5	0	41	6	0	22
Rock Dove	0	0	0	0	3	0	0	0
Rose-breasted Grosbeak	0	0	0	0	0	0	0	0

Appendix 2. Continued.

Species	Open water	Developed open apace	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Ruby-crowned Kinglet	0	0	0	0	0	0	3	0	0
Ruby-throated Hummingbird	0	0	2	0	0	0	5	0	0
Savannah Sparrow	0	4	0	0	0	0	2	0	0
Scarlet Tanager	0	1	2	0	0	0	10	0	0
Sharp-shinned Hawk	0	0	0	0	0	0	1	0	0
Song Sparrow	0	0	1	3	0	0	0	6	0
Summer Tanager	0	14	6	1	0	0	89	6	5
Swamp Sparrow	0	0	0	0	0	0	0	0	0
Tree Swallow	0	7	0	0	0	0	4	0	0
Tufted Titmouse	9	42	8	1	0	0	184	7	6
Turkey Vulture	0	2	0	0	0	0	0	0	0
Veery	0	0	0	0	0	0	3	0	0
Warbling Vireo	0	0	0	0	0	0	0	0	0
Whip-poor-will	0	0	0	0	0	0	6	0	0
White-breasted Nuthatch	0	4	0	0	0	0	13	0	0
White-eyed Vireo	0	5	2	0	0	0	21	0	0
White-throated Sparrow	0	0	0	0	0	0	4	0	0
Wild Turkey	1	5	0	0	0	0	26	0	0
Wood Duck	10	0	0	0	0	0	9	0	0
Wood Thrush	7	9	8	2	0	0	84	9	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Ruby-crowned Kinglet	0	1	0	0	0	0	0	0
Ruby-throated Hummingbird	0	0	2	1	4	1	0	5
Savannah Sparrow	0	0	0	0	2	0	0	0
Scarlet Tanager	0	0	1	0	1	1	0	3
Sharp-shinned Hawk	0	0	0	0	0	0	0	0
Song Sparrow	0	0	0	0	0	4	0	0
Summer Tanager	0	1	1	0	9	0	1	26
Swamp Sparrow	0	0	0	0	0	1	0	0
Tree Swallow	0	0	1	0	8	1	0	0
Tufted Titmouse	0	0	7	0	31	5	0	25
Turkey Vulture	0	0	0	0	2	5	0	0
Veery	0	0	0	0	0	0	0	0
Warbling Vireo	0	0	0	0	1	1	0	0
Whip-poor-will	0	0	0	0	0	0	0	0
White-breasted Nuthatch	0	0	0	0	2	0	0	12
White-eyed Vireo	0	0	0	0	4	2	2	11
White-throated Sparrow	0	0	0	0	6	0	1	0
Wild Turkey	0	0	3	0	3	1	0	4
Wood Duck	0	0	5	0	2	0	0	17
Wood Thrush	1	3	5	0	7	0	1	38

Appendix 2. Continued.

Species	Open water	Developed open space	Low-intensity development	Medium-intensity development	High-intensity development	Bare soil	Dry-mesic oak forest	Mesophytic forest	Evergreen plantations
Worm Eating Warbler	0	1	0	0	0	0	13	0	0
Yellow Warbler	0	0	0	0	0	0	5	0	0
Yellow-bellied Sapsucker	0	1	0	0	0	0	3	0	0
Yellow-billed Cuckoo	11	20	4	0	0	0	86	2	3
Yellow-breasted Chat	4	13	2	0	0	0	29	0	0
Yellow-crowned Night Heron	4	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	0	1	0	0	0	0	0	0	0
Yellow-throated Vireo	1	0	0	0	0	0	7	0	0
Yellow-throated Warbler	0	0	0	0	0	0	2	0	0

Appendix 2. Continued.

Species	Southern-Appalachian pine forest	Clearcut successional scrub-shrub	Anthropogenic successional scrub-shrub	Successional grassland-herbaceous	Pasture	Row crop	Large-floodplain forest	Small - stream and riparian forest
Worm Eating Warbler	0	0	1	0	0	1	0	3
Yellow Warbler	0	0	0	0	0	2	0	1
Yellow-bellied Sapsucker	0	0	0	0	2	0	0	0
Yellow-billed Cuckoo	0	4	4	2	20	4	5	35
Yellow-breasted Chat	0	0	1	0	11	5	0	2
Yellow-crowned Night Heron	0	0	0	0	0	0	0	0
Yellow-rumped Warbler	0	0	0	0	0	0	0	0
Yellow-throated Vireo	0	0	0	0	0	0	0	4
Yellow-throated Warbler	0	0	0	0	1	0	0	0

Appendix 3. Results of discriminant-function analysis of species in Group 1 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Total Percentage Contribution to Reclassification
Acadian Flycatcher	Evergreen plantations	Row crop	Dry-mesic oak forest	46
American Bittern	Anthropogenic successional scrub-shrub	Open water	Clearcut successional scrub-shrub	44
American Crow	Pasture	Evergreen plantations	Dry-mesic oak forest	37
American Goldfinch	Developed open space	Clearcut successional scrub-shrub	Small-stream and riparian	39
American Kestrel	Pasture	Dry-mesic oak forest	Low-intensity development	53
American Redstart	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Dry-mesic oak forest	45
American Robin	Low-intensity development	Medium-intensity development	Dry-mesic oak forest	45
American Tree Sparrow	Developed open space	Southern-Appalachian pine forest	Open water	51
American Woodcock	Developed open space	Pasture	Dry-mesic oak forest	36
Bachman's Sparrow	Anthropogenic successional scrub-shrub	Open water	Developed open space	52
Barn Swallow	Dry-mesic oak forest	Pasture	Low-intensity development	43
Barred Owl	Small-stream and riparian	Dry-mesic oak forest	Pasture	37
Belted Kingfisher	Open water	Small-stream and riparian	Large-floodplain forest	50
Black and White Warbler	Dry-mesic oak forest	Developed open space	Pasture	41
Black-billed Cuckoo	Dry-mesic oak forest	Small-stream and riparian	Low-intensity development	43
Black-crowned Night Heron	Small-stream and riparian	Open water	Developed open space	48
Blue-gray Gnatcatcher	Small-stream and riparian	Pasture	Large-floodplain forest	41
Brown-headed Cowbird	Clearcut successional scrub-shrub	Pasture	Southern-Appalachian pine forest	31
Brown-headed Nuthatch	Dry-mesic oak forest	Low-intensity development	Pasture	43

Appendix 4. Discriminant-function analysis of Group 2 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Blue Grosbeak	Row crop	Small-stream and riparian	Open water	43
Blue Jay	Open water	Small-stream and riparian	Pasture	47
Blue-winged Warbler	Small-stream and riparian	Dry-mesic oak forest	Developed open space	58
Bobolink	Pasture	Dry-mesic oak forest	Anthropogenic successional scrub-shrub	54
Broad-winged Hawk	Low-intensity development	Row crop	Open water	43
Brown Creeper	Evergreen plantations	Anthropogenic successional scrub-shrub	Dry-mesic oak forest	55
Brown Thrasher	Bare soil	Medium-intensity development	Small-stream and riparian	37
Canada Goose	Open water	Small-stream and riparian	Southern-Appalachian pine forest	40
Carolina Chickadee	Dry-mesic oak forest	Pasture	Mesophytic forest	35
Carolina Wren	Dry-mesic oak forest	Low-intensity development	Small-stream and riparian	40
Cattle Egret	Developed open space	Dry-mesic oak forest	Anthropogenic successional scrub-shrub	55
Cedar Waxwing	Developed open space	Dry-mesic oak forest	Southern-Appalachian pine forest	36
Cerulean Warbler	Dry-mesic oak forest	Pasture	Low-intensity development	39
Chimney Swift	Low-intensity development	High-intensity development	Dry-mesic oak forest	50
Chipping Sparrow	Dry-mesic oak forest	Developed open space	Medium-intensity development	32
Common Grackle	Dry-mesic oak forest	Open water	Small-stream and riparian	37
Common Nighthawk	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Small-stream and riparian	44
Common Yellow-throat	Open water	Dry-mesic oak forest	Small-stream and riparian	44

Appendix 5. Discriminant-function analysis of Group 3 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Chuck-will's-widow	Anthropogenic successional scrub-shrub	Small-stream and riparian	Pasture	51
Dark-eyed Junco	Developed open space	Row crop	Low-intensity development	42
Dickcissel	Pasture	Dry-mesic oak forest	Low-intensity development	48
Downy Woodpecker	Small-stream and riparian	Pasture	Open water	40
Eastern Bluebird	Developed open space	Dry-mesic oak forest	Small-stream and riparian	38
Eastern Kingbird	Pasture	Dry-mesic oak forest	Low-intensity development	49
Eastern Meadowlark	Pasture	Dry-mesic oak forest	Small-stream and riparian	48
Eastern Phoebe	Low-intensity development	Anthropogenic successional scrub-shrub	Dry-mesic oak forest	35
Eastern Towhee	Pasture	Evergreen plantations	Dry-mesic oak forest	42
Eastern Wood Peewee	Dry-mesic oak forest	Pasture	Evergreen plantations	47
European Starling	Low-intensity development	Medium-intensity development	Dry-mesic oak forest	48
Field Sparrow	Pasture	Small-stream and riparian	Row crop	47
Fish Crow	Medium-intensity development	Low-intensity development	High-intensity development	57
Fox Sparrow	Pasture	Dry-mesic oak forest	Low-intensity development	49
Grasshopper Sparrow	Pasture	Row crop	Small-stream and riparian	31
Gray Catbird	Dry-mesic oak forest	Southern-Appalachian pine forest	Small-stream and riparian	44
Great Blue Heron	Small-stream and riparian	Open water	Developed open space	52
Great Crested Flycatcher	Dry-mesic oak forest	Low-intensity development	Anthropogenic successional scrub-shrub	34
Great-horned Owl	Mesophytic forest	Pasture	Dry-mesic oak forest	56
Green Heron	Large-floodplain forest	Small-stream and riparian	Open water	48

Appendix 6. Discriminant-function analysis of Group 4 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Golden-winged Warbler	Dry-mesic oak forest	Developed open space	Pasture	51
Hairy Woodpecker	Small-stream and riparian	Low-intensity development	Dry-mesic oak forest	37
Hermit Thrush	Small-stream and riparian	Developed open space	Low-intensity development	50
Hooded Merganser	Open water	Small-stream and riparian	Developed open space	62
Hooded Warbler	Southern-Appalachian pine forest	Dry-mesic oak forest	Evergreen plantations	46
House Finch	Low-intensity development	High-intensity development	Dry-mesic oak forest	37
House Sparrow	Medium-intensity development	Low-intensity development	Dry-mesic oak forest	62
House Wren	Dry-mesic oak forest	Developed open space	Small-stream and riparian	42
Indigo Bunting	Small-stream and riparian	Medium-intensity development	Low-intensity development	35
Kentucky Warbler	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Evergreen plantations	40
Killdeer	Low-intensity development	Dry-mesic oak forest	Medium-intensity development	47
Least Bittern	Open water	Small-stream and riparian	Low-intensity development	47
Least Flycatcher	Pasture	Anthropogenic successional scrub-shrub	Low-intensity development	40
Little Blue Heron	Small-stream and riparian	Open water	Developed open space	56
Loggerhead Shrike	Pasture	Dry-mesic oak forest	Anthropogenic successional scrub-shrub	51
Louisiana Water Thrush	Small-stream and riparian	Developed open space	Dry-mesic oak forest	34
Mallard Duck	Small-stream and riparian	Southern-Appalachian pine forest	Open water	59
Mourning Dove	Developed open space	Small-stream and riparian	Mesophytic forest	40

Appendix 7. Discriminant-function analysis of Group 5 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Northern Bobwhite	Row crop	Small-stream and riparian	Developed open space	34
Northern Cardinal	Southern-Appalachian pine forest	Evergreen plantations	Bare soil	42
Northern Flicker	Small-stream and riparian	Developed open space	Open water	48
Northern Harrier	Medium-intensity development	Low-intensity development	Dry-mesic oak forest	35
Northern Mocking Bird	Small-stream and riparian	Low-intensity development	Dry-mesic oak forest	37
Northern Parula	Anthropogenic successional scrub-shrub	Large-floodplain forest	Southern-Appalachian pine forest	36
Northern Roughed-winged Swallow	Low-intensity development	Dry-mesic oak forest	High-intensity development	42
Orchard Oriole	Row crop	Successional grassland-herbaceous	Small-stream and riparian	59
Ovenbird	Evergreen plantations	Developed open space	Dry-mesic oak forest	51
Painted Bunting	Dry-mesic oak forest	Southern-Appalachian pine forest	Pasture	51
Pileated Woodpecker	Successional grassland-herbaceous	Low-intensity development	Clearcut successional scrub-shrub	27
Pine Siskin	Southern-Appalachian pine forest	Developed open space	Successional grassland-herbaceous	42
Pine Warbler	Evergreen plantations	Pasture	Successional grassland-herbaceous	26
Prairie Warbler	Pasture	Successional grassland-herbaceous	Dry-mesic oak forest	45
Prothonatary Warbler	Open water	Small-stream and riparian	Developed open space	48
Purple Martin	Anthropogenic successional scrub-shrub	Open water	Evergreen plantations	42
Red-bellied Woodpecker	Dry-mesic oak forest	Low-intensity development	Small-stream and riparian	42
Rose-breasted Grosbeak	Dry-mesic oak forest	Pasture	Developed open space	39

Appendix 8. Discriminant-function analysis of Group 6 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Eastern Tufted Titmouse	High-intensity development	Row crop	Mesophytic forest	41
Red-eyed Vireo	Dry-mesic oak forest	Mesophytic forest	Low-intensity development	41
Red-headed Woodpecker	Evergreen plantations	Mesophytic forest	Southern-Appalachian pine forest	37
Red-shouldered Hawk	Large-floodplain forest	Mesophytic forest	Small-stream and riparian	38
Red-tailed Hawk	Pasture	Dry-mesic oak forest	Row crop	46
Red-winged Blackbird	Open water	Dry-mesic oak forest	Pasture	45
Rock Dove	Medium-intensity development	Low-intensity development	Dry-mesic oak forest	50
Ruby-crowned Kinglet	Successional grassland-herbaceous	Clearcut successional scrub-shrub	Evergreen plantations	58
Ruby-throated Hummingbird	Small-stream and riparian	Open water	Successional grassland-herbaceous	38
Savannah Sparrow	Pasture	Successional grassland-herbaceous	Southern-Appalachian pine forest	37
Scarlet Tanager	Small-stream and riparian	Pasture	Open water	38
Sharp-shinned Hawk	Low-intensity development	Dry-mesic oak forest	Developed open space	47
Song Sparrow	Pasture	High-intensity development	Dry-mesic oak forest	47
Summer Tanager	Mesophytic forest	Pasture	Dry-mesic oak forest	38
Swamp Sparrow	Dry-mesic oak forest	Pasture	Small-stream and riparian	45
Tree Swallow	Dry-mesic oak forest	Row crop	Developed open space	45
Turkey Vulture	Row crop	Pasture	Dry-mesic oak forest	53
Veery	Southern-Appalachian pine forest	Dry-mesic oak forest	Successional grassland-herbaceous	53
Warbling Vireo	Row crop	Small-stream and riparian	Pasture	54

Appendix 9. Discriminant-function analysis of Group 7 with the three habitats that were most important in reclassifying species and the total percentage of their contribution.

Species	Habitat 1	Habitat 2	Habitat 3	Percent Used for Reclassification
Whip-poor-will	Evergreen plantations	Developed open space	Anthropogenic successional scrub-shrub	39
White-breasted Nuthatch	Pasture	Mesophytic forest	Anthropogenic successional scrub-shrub	37
White-eyed Vireo	Anthropogenic successional scrub-shrub	Dry-mesic oak forest	Low-intensity development	30
White-throated Sparrow	Pasture	Small-stream and riparian	Large-floodplain forest	45
Wild Turkey	Southern-Appalachian pine forest	Dry-mesic oak forest	Low-intensity development	31
Wood Duck	Small-stream and riparian	Open water	Dry-mesic oak forest	51
Wood Thrush	Low-intensity development	High-intensity development	Evergreen plantations	37
Worm Eating Warbler	Dry-mesic oak forest	Mesophytic forest	Developed open space	37
Yellow Warbler	Row crop	Large-floodplain forest	Pasture	50
Yellow-bellied Sapsucker	Developed open space	Small-stream and riparian	Southern-Appalachian pine forest	38
Yellow-billed Cuckoo	Anthropogenic successional scrub-shrub	Evergreen plantations	Successional grassland-herbaceous	34
Yellow-breasted Chat	Pasture	Small-stream and riparian	Medium-intensity development	38
Yellow-crowned Night Heron	Open water	Developed open space	Dry-mesic oak forest	57
Yellow-rumped Warbler	Developed open space	Pasture	Small-stream and riparian	50
Yellow-throated Vireo	Developed open space	Small-stream and riparian	Pasture	41
Yellow-throated Warbler	Small-stream and riparian	Evergreen plantations	Pasture	35

Appendix 10. Discriminant-function reclassification of birds based on habitats occupied at Redstone Arsenal, Madison County, Alabama: number of birds classified (%).

Species	American Bittern	American Woodcock	Bachman's Sparrow	Black-crowned Night-heron	Belted Kingfisher	Brown-headed Nuthatch	Chuck-will's Widow	Downy Woodpecker	Green Heron
American Bittern[1]	1 (33.33%)	0	1 (33.33%)	0	0	1 (33.33%)	0	0	0
American Woodcock[2]	1 (33.33%)	2 (66.67%)	0	0	0	0	0	0	0
Bachman's Sparrow[3]	0	0	3 (100%)	0	0	0	0	0	0
Black-crowned Night-heron[4]	0	0	1 (25.00%)	3 (75.00%)	0	0	0	0	0
Belted Kingfisher[5]	1 (33.33%)	0	0	0	1 (33.33%)	1 (33.33%)	0	0	0
Brown-headed Nuthatch[6]	3 (7.14%)	6 (14.29%)	5 (11.90%)	2 (4.76%)	1 (2.38%)	22 (52.38%)	0	2 (4.76%)	0
Chuck-will's Widow[7]	0	0	0	0	0	0	1 (100.00%)	0	0
Downy Woodpecker[8]	0	0	0	0	0	0	6 (5.88%)	7 (6.86%)	13 (12.75%)
Green Heron[9]	0	0	0	0	0	0	0	0	4 (66.67%)
Hairy Woodpecker[10]	0	0	0	0	0	0	5 (8.20%)	3 (4.92%)	9 (14.75%)
Kentucky Warbler[11]	0	0	0	0	0	0	0	0	0
Loggerhead Shrike[12]	0	0	0	0	0	0	0	0	0
Northern Parula[13]	0	0	0	0	0	0	2 (10.53%)	1 (5.26%)	4 (21.05%)
Prothonotary Warbler[14]	0	0	0	0	0	0	2 (3.85%)	0	11 (21.15%)
Red-headed Woodpecker[15]	0	0	0	0	0	0	10 (6.33%)	5 (3.16%)	8 (5.06%)
Wood Thrush[16]	0	0	0	1 (1.00%)	0	0	9 (9.00%)	6 (6.00%)	14 (14.00%)
Whip-poor-will[17]	0	0	0	0	0	0	0	0	0
Yellow-crowned Night-heron[18]	0	0	0	0	0	0	0	0	0
Total	6 (1.06%)	8 (1.40%)	10 (1.75%)	6 (1.05%)	2 (0.35%)	24 (2.41%)	35 (6.14%)	24 (2.41%)	63 (11.05%)

Appendix 10. Continued.

Species	Hairy Woodpecker	Kentucky Warbler	Louisiana Waterthrush	Northern Parula	Prothonotary Warbler	Red-headed Woodpecker	Wood Thrush	Whip-poor-will	Yellow-crowned Night-heron	Total
American Bittern	0	0	0	0	0	0	0	0	0	3 (100.00%)
American Woodcock	0	0	0	0	0	0	0	0	0	3 (100.00%)
Bachman's Sparrow	0	0	0	0	0	0	0	0	0	3 (100.00%)
Black-crowned Night-heron	0	0	0	0	0	0	0	0	0	4 (100.00%)
Belted Kingfisher	0	0	0	0	0	0	0	0	0	3 (100.00%)
Brown-headed Nuthatch	0	0	0	0	0	0	0	0	0	42 (100.00%)
Chuck-will's Widow	0	0	0	0	0	0	0	0	0	1 (100.00%)
Downy Woodpecker	16 (15.69%)	2 (1.96%)	6 (5.88%)	6 (5.88%)	11 (10.78%)	12 (11.76%)	6 (5.88%)	12 (11.76%)	5 (4.90%)	102 (100.00%)
Green Heron	1 (16.67%)	0	0	0	0	1 (16.67%)	0	0	0	6 (100.00%)
Hairy Woodpecker	19 (31.15%)	0 (0.00%)	4 (6.56%)	2 (3.28%)	4 (6.56%)	6 (9.84%)	2 (3.28%)	5 (8.20%)	2 (3.28%)	61 (100.00%)
Kentucky Warbler	3 (42.86)	1 (14.29%)	0	0	0	0	0	3 (42.86%)	0	7 (100.00%)
Loggerhead Shrike	0	0	0	0	0	0	0	0	0	1 (100.00%)
Northern Parula	4 (21.05%)	0	0	6 (31.58%)	0	1 (5.26%)	0	0	1 (5.26%)	19 (100.00%)
Prothonotary Warbler	8 (15.38%)	0	0	6 (11.54%)	11 (21.15%)	2 (3.85%)	2 (3.85%)	4 (7.69%)	6 (11.54%)	52 (100.00%)
Red-headed Woodpecker	24 (15.19%)	1 (0.63%)	5 (3.16%)	19 (12.03%)	6 (3.80%)	41 (25.95%)	5 (3.16%)	33 (20.89%)	1 (0.63%)	158 (100.00%)
Wood Thrush	16 (16.00%)	4 (4.00%)	2 (2.00%)	4 (4.00%)	2 (2.00%)	16 (16.00%)	9 (9.00%)	11 (11.00%)	6 (6.00%)	100 (100.00%)
Whip-poor-will	0	0	0	0	0	0	0	3 (100.00%)	0	3 (100.00%)
Yellow-crowned Night-heron	0	0	0	0	0	0	0	0	2 (100.00%)	2 (100.00%)
Total	91 (15.96%)	8 (1.40%)	18 (3.16%)	43 (7.54%)	34 (5.96%)	79 (13.86%)	24 (4.21%)	72 (12.63%)	23 (4.04%)	570 (100.00%

Appendix 11. Pooled within-class standardized means for the 18 species of birds of conservation concern on Redstone Arsenal, Madison County, Alabama.

Variable	American Bittern	American Woodcock	Bachman's Sparrow	Black-crowned Night-heron	Belted Kingfisher	Brown-headed Nuthatch	Chuck-will's Widow	Downy Woodpecker	Green Heron
Open water	0.682	0.396	0.682	0.716	1.432	-0.268	-0.384	0.085	0.413
Developed open space	0.381	-0.142	-0.430	-0.590	-0.229	0.271	0.561	-0.033	-0.814
Low-intensity development	-0.419	0.325	-0.419	-0.419	-0.101	0.010	-0.419	0.037	-0.419
Medium-intensity development	-0.222	-0.222	-0.222	-0.222	-0.222	0.082	-0.222	0.156	-0.222
High-intensity development	-0.120	-0.120	-0.120	-0.120	-0.120	0.027	-0.120	0.085	-0.120
Bare soil	3.094	2.344	3.965	1.221	4.067	5.115	-0.508	-0.508	-0.508
Dry-mesic oak forest	-1.543	-1.543	-1.543	-1.543	-1.543	-1.435	0.114	-0.039	0.005
Mesophytic forest	-0.275	0.240	-0.275	-0.275	0.088	0.381	-0.275	0.119	-0.275
Evergreen plantation	-0.517	-0.074	-0.517	-0.517	-0.517	-0.499	-0.517	-0.212	-0.146
Southern-Appalachian pine forest	0.661	-0.362	-0.362	-0.362	-0.362	-0.362	-0.362	-0.118	-0.069
Clearcut successional scrub-shrub	4.012	1.246	7.008	1.879	2.223	1.319	-0.282	-0.184	-0.282
Anthropogenic successional scrub-shrub	-0.682	-0.682	-0.682	-0.682	-0.682	-0.666	2.790	0.017	0.332
Successional grassland-herbaceous	-0.118	3.014	-0.118	-0.118	-0.118	0.102	-0.118	-0.021	-0.118
Pasture	-0.713	-0.061	-0.713	-0.713	-0.713	-0.374	-0.017	0.127	0.163
Row crop	0.226	-0.297	-0.297	-0.297	0.346	-0.100	-0.297	0.037	-0.297
Large-floodplain forest	1.979	1.615	1.318	4.830	2.963	0.591	-0.286	-0.140	0.640
Small-stream and riparian	-0.630	-0.630	-0.630	-0.630	-0.630	-0.630	0.163	0.167	0.839

Appendix 11. Continued.

Variable	Hairy Woodpecker	Kentucky Warbler	Loggerhead Shrike	Northern Parula	Prothonotary Warbler	Red-headed Woodpecker	Wood Thrush	Whip-poor-will	Yellow-crowned Night-heron
Open water	-0.049	-0.384	-0.384	-0.028	0.682	-0.248	-0.080	-0.384	3.772
Developed open space	-0.041	0.080	0.350	0.073	-0.457	0.197	-0.076	0.738	-0.925
Low-intensity development	-0.173	-0.225	-0.419	-0.182	-0.264	0.123	0.146	-0.419	-0.419
Medium-intensity development	-0.073	0.080	-0.222	0.066	-0.164	-0.040	0.046	-0.222	-0.222
High-intensity development	-0.019	-0.120	-0.120	-0.120	-0.001	-0.120	0.169	-0.120	-0.120
Bare soil	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508
Dry-mesic oak forest	0.220	0.492	-1.543	0.006	0.009	0.310	0.221	0.958	-0.528
Mesophytic forest	0.122	-0.275	-0.275	-0.116	-0.131	-0.217	0.149	-0.275	-0.275
Evergreen plantation	-0.299	0.776	-0.517	-0.368	-0.180	0.407	0.140	1.087	-0.517
Southern-Appalachian pine forest	-0.241	-0.362	-0.362	0.293	0.189	0.143	0.105	0.225	-0.362
Clearcut successional scrub-shrub	-0.282	0.939	-0.282	-0.282	-0.282	-0.282	-0.087	-0.282	-0.282
Anthropogenic successional scrub-shrub	0.131	-0.544	-0.682	0.450	0.016	0.146	-0.014	-0.682	-0.082
Successional grassland-herbaceous	-0.118	1.004	-0.118	-0.118	-0.118	-0.100	0.162	-0.118	-0.118
Pasture	0.193	-0.477	3.524	0.236	-0.149	0.075	-0.081	-0.713	0.447
Row crop	0.032	-0.297	-0.297	0.440	0.124	0.003	-0.096	-0.297	-0.297
Large-floodplain forest	-0.113	-0.286	-0.286	0.149	0.089	-0.230	-0.176	-0.286	-0.286
Small-stream and riparian	0.198	0.165	-0.630	0.015	0.524	-0.229	0.101	-0.310	0.573