ABSTRACT

Title of dissertation: BIRD COMMUNITY RESPONSE TO CONSERVATION RESERVE PROGRAM HABITAT IN MARYLAND

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The populations of many bird species in the United States that use early-successional habitats have been substantially declining over the last 40 years. The main reason for these declines is habitat loss. Land enrolled in the U.S. Department of Agriculture's Conservation Reserve Program (CRP) often represents the only uncultivated herbaceous areas on farmland in the mid-Atlantic and therefore may be important habitat for early-successional bird species. CRP filter strips are strips of herbaceous vegetation that are planted along agricultural field margins and are usually planted with native warm-season grasses or introduced cool-season grasses. We studied the breeding and wintering bird use of CRP filter strips adjacent to wooded edges in Maryland from 2004–2007. We conducted bird and vegetation surveys in filter strips and measured landscape attributes around CRP plantings. We used 5 bird community metrics (total bird density, species richness, scrub-shrub bird density, grassland bird density, and total avian conservation value), species-specific densities and abundances, nest densities, and nest survival estimates to assess the habitat value of filter strips for birds. Bird community metrics were greater in filter strips than in field margins without filter strips, but did not differ between cool-season and warm-season grass filter strips. Most breeding bird community metrics were negatively related to the percent cover of orchardgrass (*Dactylis glomerata*). Several grassland birds were more common in wide filter strips (>60 m) compared to narrower filter strips (<30 m). The density of early-successional bird species was greater in filter strips with higher plant species richness and shorter and less dense grasses. Wintering bird use was significantly less in filter strips mowed in the fall than in unmowed filter strips. The abundance of northern bobwhite (*Colinus virginianus*), an important game bird and species of conservation concern, was positively associated with the percent cover of CRP land in the surrounding landscape. These results suggest that the CRP has created additional habitat for many early-successional bird species, but changes in the planning and management of CRP plantings may improve their habitat value for breeding and wintering birds.

BIRD COMMUNITY RESPONSE TO
CONSERVATION RESERVE PROGRAM HABITAT IN MARYLAND

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2010

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Dedication

To my father, who always encouraged me to continue my education.

I miss you and wish you were here to see me accomplish this goal.

Acknowledgements

I would like to thank my advisor, Galen Dively, who was always helpful, supportive, and fun to be around. I admire that he can be such a superb scientist while remaining one of the most relaxed people I've ever met. Doug Gill acted as a co-advisor to me and I will always be grateful for his advice and friendship. Thanks to the rest of my committee – Lowell Adams, Pete Marra, and Gwen Brewer – for their advice and for taking the time to serve on my committee.

I am grateful for the love and encouragement of my friends and family. Special thanks to Sarah Rockwell for her support.

I could not have done this work without the help of my field assistants: Maren Gimpel, Jason Guerard, Leanna Kelly, Beth Olsen, Jared Parks, Zach Parks, and Dan Small. I received help with data analysis, study design, or both from Bahram Momen, Mike Runge, John Sauer, Terry Shaffer, Evan Grant, Scott Sillett, Chris Che-castaldo, Larry Douglass, Dilip Venugopal, and Maile Neel.

Thanks to the many farm owners and managers who allowed me and my field crew to work on their properties. This project really would not have been possible without their generosity. Chino Farms provided housing for our field staff and allowed us to work on many of their fields.

Charlie Rewa at the U.S Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) helped secure funding for the project and was a friend and colleague throughout my graduate work. The NRCS and USDA-Farm Service Agency staff in Caroline, Kent, Queen Anne's, and Talbot counties in Maryland and Kent county in Delaware, helped with locating CRP land and provided technical information. Patricia Engler, Anne Lynn, and Steve Strano at NRCS-Maryland, assisted with technical information. Philip Barbour at NRCS reviewed one of my chapters. Ned Gerber and the staff at the Chesapeake Wildlife Heritage provided technical information and advice.

Funding was provided by the NRCS Agricultural Wildlife Conservation Center, the Maryland Department of Natural Resources, and the University of Maryland – Department of Entomology.

Table of Contents

List of Tables

List of Figures

Introduction

The populations of many bird species in eastern North America that use open or early-successional habitats are experiencing substantial population declines (Askins 1993, Hunter et al. 2001). The main reason for these declines is habitat loss, primarily due to large-scale conversion of early-successional habitats to agriculture (Askins 1993, Warner 1994). The intensification of row crop agriculture starting around the 1950's led to the demise of diversified, patchwork farming and the loss of pastures, savannas, and grasslands (Warner 1994). In the mid-Atlantic region, habitats such as grasslands, weedy fields, and hedgerows were converted to intense agricultural production, leaving little habitat for early-successional birds. According to the North American Breeding Bird Survey, 71% of grassland bird species and 47% of scrub-shrub bird species have significant negative population trends in eastern North America over the last 40 years (Sauer et al. 2008).

The Conservation Reserve Program (CRP) could reverse some of these trends by providing habitat for breeding and wintering birds. The CRP is a provision of the Food Security Act of 1985 and implemented by the United States Department of Agriculture (USDA). It offers economic incentives to encourage the conversion of highly erodible and other environmentally sensitive agricultural land to approved, perennial, vegetative cover. The goals of the program are to improve water quality, reduce soil erosion, and establish wildlife habitat. In 1997 Maryland joined with the USDA to establish a Conservation Reserve Enhancement Program (CREP). Maryland's CREP offers further financial incentives to encourage farm owners to enroll land in the CRP in contracts of 10 to 15 years in duration. About 12.5 million ha of land are enrolled in the CRP nationwide, with about 32,000 ha in Maryland (USDA 2010a).

The majority of CRP land in Maryland is planted to herbaceous practices. Herbaceous filter strips [USDA Conservation Practice (CP) 21] are the most common practice (47% of all CRP), while smaller percentages are planted to herbaceous practices such as introduced grasses (CP1; 14%) and native warm-season grasses (CP2; 4%) (USDA 2010a). Filter strips are strips of herbaceous vegetation that are planted along agricultural field margins adjacent to streams or wetlands and are designed to intercept sediment, nutrients, and agrichemicals. Filter strips in Maryland are usually planted either to native warm-season grasses or introduced cool-season grasses, with the addition of native wildflowers or introduced legumes, and range in width from 11–91 m. Filter strips often represent the only uncultivated herbaceous areas on farmland and therefore may be important habitat for early-successional birds.

Efforts to quantify the wildlife response to the CRP have focused on the bird use of herbaceous CRP fields (Haufler 2005). Many of these studies have documented significant benefits of these fields for grassland birds (e.g. Johnson and Schwartz 1993, Best et al. 1997, Delisle and Savidge 1997, McCoy et al. 1999, Gill et al. 2006, Wentworth et al. 2010). Some studies have also investigated the response of birds to herbaceous strip-cover habitats (i.e. narrow or linear habitats) enrolled in the CRP, such as filter strips (e.g. Davros 2005, Henningsen and Best 2005) and field borders (e.g. Smith et al. 2005b, Conover et al. 2007, Conover et al. 2009). Herbaceous strip-cover habitats are often referred to as herbaceous or grass buffers. However, many questions remain about the wildlife response to the characteristics and management of herbaceous strip-cover habitats (Clark and Reeder 2005).

The USDA Natural Resources Conservation Service (NRCS) has requested information on the response of birds to CRP habitat in the mid-Atlantic region (C. A. Rewa, USDA-NRCS, pers. comm.). Although several studies have shown that CRP land can provide valuable habitat for birds, most studies have been conducted on breeding birds in the mid-west and the south, and their scope of inference is limited. Trends in the response of birds in one geographic location often do not apply to other locations (Bakker et al. 2002, Riffell et al. 2008). Because filter strips are the most common CRP buffer practice in Maryland, knowledge about the bird community response to filter strip characteristics and management is necessary to allow for informed conservation decision-making. Additionally, few studies have evaluated the bird response to herbaceous strip-cover habitat >40 m (Clark and Reeder 2005), such as filter strips created through Maryland's CREP. Therefore, there is a need for information on how birds respond to the CRP in the mid-Atlantic region, and specifically in Maryland. This dissertation provides that information.

There are four chapters in this dissertation. Chapter 1 evaluates the breeding and wintering bird community response to filter strip presence, grass type, and width. Chapter 2 looks at the response of early-successional breeding birds to vegetation and landscape attributes of filter strips. Chapter 3 assesses the response of wintering birds to fall mowing of filter strips. And Chapter 4 addresses the response of northern bobwhite to CRP land and landscape attributes. These topics were chosen because we believe they are important to understanding the bird response to the CRP in the mid-Atlantic region.

The results and management recommendations generated from this research will be relevant to a variety of stakeholders including federal, state, and local conservation agencies, farm owners, and natural resources land managers. Additionally, this work will be included in the USDA’s ongoing effort to quantify the environmental benefits of conservation practices used by private landowners participating in USDA conservation programs.

CHAPTER 1: BIRD COMMUNITY RESPONSE TO FILTER STRIP PRESENCE, GRASS TYPE, AND WIDTH

ABSTRACT

Filter strips are strips of herbaceous vegetation that are planted along agricultural field margins adjacent to streams or wetlands and are designed to intercept sediment, nutrients, and agrichemicals. Roughly 16,000 ha of filter strips have been established in Maryland through the U.S. Department of Agriculture's Conservation Reserve Enhancement Program. Filter strips often represent the only uncultivated herbaceous areas on farmland in Maryland and therefore may be important habitat for early-successional bird species. Most filter strips in Maryland are planted to either native warm-season grasses or cool-season grasses and range in width from 10.7 m to 91.4 m. From 2004–2007 we studied the breeding and wintering bird communities in filter strips adjacent to wooded edges and non-buffered field edges and the effect that grass type and width of filter strips had on bird community composition. We used 5 bird community metrics (total bird density, species richness, scrub-shrub bird density, grassland bird density, and total avian conservation value), species-specific densities, nest densities, and nest survival estimates to assess the habitat value of filter strips for birds. Breeding and wintering bird community metrics were greater in filter strips than in non-buffered field edges but did not differ between cool-season and warm-season grass filter strips. Most breeding bird community metrics were negatively related to the percent cover of orchardgrass (*Dactylis glomerata*) in at least 1 year. Breeding bird density was greater in narrow (<30 m) compared to wide (>60 m) filter strips. Our results suggest that narrow filter strips

adjacent to wooded edges can provide habitat for many bird species but that wide filter strips provide better habitat for grassland birds, particularly obligate grassland species. If bird conservation is an objective, avoid planting orchardgrass in filter strips and reduce or eliminate orchardgrass from filter strips through management practices.

INTRODUCTION

The U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) offers economic incentives to encourage the conversion of highly erodible and other environmentally sensitive agricultural land to approved, perennial, vegetative cover. The goals of the CRP are to improve water quality, reduce soil erosion, and establish wildlife habitat. The 1996 Farm Bill (Federal Agricultural Improvement and Reform Act) established the Conservation Reserve Enhancement Program (CREP) provision within the CRP to enable states to enter into partnerships with the USDA to target specific resource concerns by offering enhanced incentives for landowner enrollment. In 1997, the State of Maryland and the USDA established Maryland's CREP initiative to implement conservation practices on private agricultural lands designed to reduce sediment and nutrient inputs to the Chesapeake Bay and improve wildlife habitat.

Filter strips are strips of herbaceous vegetation that are planted along agricultural field margins adjacent to streams or wetlands and are designed to intercept sediment, nutrients, and agrichemicals. Roughly 16,000 ha of filter strips (USDA Practice CP21) are enrolled in Maryland's CREP, which comprises 47% of the total CRP acreage (USDA 2009b) and 1.9% of the total farmland in Maryland (USDA 2009a). Filter strips are usually planted either to native warm-season grasses or cool-season grasses, with the addition of native wildflowers or introduced legumes (usually clovers). Native warm-season grasses begin growth in late spring, set seed near the end of summer, and then go dormant in early fall. Common warm-season grasses in Maryland filter strips include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*). Cool-season grasses begin growth in early spring, set seed in early summer, and then go dormant until they start growing again in the fall. The most common cool-season grass in Maryland filter strips is orchardgrass (*Dactylis glomerata*; S. Strano, Natural Resources Conservation Service [NRCS], Maryland, personal communication), but other cool-season grasses such as red fescue (*Festuca rubra*) and sheep fescue (*Festuca ovina*) are also planted. Orchardgrass and most other cool-season grasses in Maryland filter strips are non-native.

Filter strips often represent the only uncultivated herbaceous areas on farmland in Maryland and therefore may be important habitat for early-successional bird species. Warm-season grasses are known to provide nesting, foraging, and brood-rearing habitat for northern bobwhite (*Colinus virginianus*) and other ground-nesting birds (Whitmore 1981, Burger et al. 1990, Harper et al. 2007). However, there is no consensus in the literature regarding whether cool-season or warm-season grasses are preferable to most early-successional bird species (McCoy et al. 2001). For example, Henningsen and Best (2005) found that breeding bird abundance and relative nest abundance were similar between cool-season and warm-season grass filter strips in Iowa.

Filter strips in Maryland range from 10.7 m to 91.4 m wide. Bird communities are affected by the width of strip-cover habitats (i.e., narrow or linear habitats; Best 2000, Clark and Reeder 2005). Wider strip-cover habitats are often associated with greater bird abundance or species richness (e.g., Stauffer and Best 1980, Davros 2005, Conover et al.

2007, Conover et al. 2009). However, few studies have evaluated the bird response to herbaceous strip-cover habitat >40 m (Clark and Reeder 2005) such as filter strips created through Maryland's CREP.

We conducted this study in response to the needs of land managers and conservation planners seeking to improve the habitat quality of filter strips for birds on agricultural land in the Mid-Atlantic region. Our primary objectives were to determine the composition of the breeding and wintering bird communities in CREP filter strips and non-buffered field edges, and to determine how bird use is affected by filter strip grass type (cool-season vs. warm-season) and width. We chose a community-based approach because although some individual species require specific conservation attention (Hunter et al. 2001, Wiens et al. 2008), effective conservation efforts should be focused on entire communities (Hunter et al. 2001). We focused particular attention on the response of grassland and scrub-shrub species because these guilds are experiencing substantial population declines (Askins 1993, Hunter et al. 2001), and because they include early-successional species that will likely benefit from the installation of filter strips.

STUDY AREA

The Eastern Shore of Maryland (the area of the state east of the Chesapeake Bay) has approximately 46% of land in farms (USDA 2009a) and approximately 77% of the CREP filter strips in the state (USDA 2007). Our goal was to select a representative sample of CREP filter strips on Maryland's Eastern Shore that included cool-season and warm-season grass filter strips across a range of widths. With the assistance of NRCS staff and local contacts, we identified farms with CREP filter strips in 3 counties on Maryland's Eastern Shore (Caroline, Queen Anne's, and Talbot) and selected study sites among farms where we were granted access. We attempted to select roughly equal numbers of cool-season and warm-season grass filter strips but were granted access to more warm-season grass sites (Table 1.1). We also selected a sample of non-buffered field edges (controls) from the same farms as those with filter strips. We classified the grass type of each filter strip as either cool-season or warm-season based on the original conservation plan of operation indicated by local NRCS county office records, and verified the grass type through vegetation surveys or visual inspections.

Study sites were established in CREP filter strips and non-buffered field edges based on the following criteria: (1) study sites were on separate fields, (2) at least 100 m from other study sites, (3) and at least 50 m from the end of the field or from an edge where there was a distinct habitat change (e.g. roads, pastures, houses, etc.). All filter strips were between rowcrop (corn or soybean) fields and a deciduous wooded edge and were originally planted between 1997 and 2004. Non-buffered field edge sites were also adjacent to deciduous wooded edges and planted to either corn or soybean.

We classified filter strips as either narrow (<30 m), medium width (30–60 m), or wide (>60 m). Non-buffered field edge sites were 45 m wide in the breeding season and 40 m wide in winter, to approximate the average width of filter strip sites in each season. Study site widths coincided with the width of each filter strip or non-buffered field edge. In 2004 and 2005, study sites spanned as much of the length of the filter strip or non-buffered field edge as possible (breeding season: $\bar{x}$ = 446 m, SD = 225 m; winter: $\bar{x}$ = 444 m, SD = 182 m). In 2006 and 2007, to increase efficiency and allow for more time to survey other sites, we established shorter study sites (breeding season: $\bar{x}$ = 301 m, SD =

21; winter: $\bar{x}$ = 269 m, SD = 73 m) that were randomly placed along the length of filter strip or non-buffered field edge.

METHODS

Study Site Dimensions

We defined filter strip width as the distance from crop edge to the wooded edge and calculated filter strip width by averaging width measurements taken every 50 m over the length of the filter strip. We measured study site length from aerial photographs in a Geographic Information System and calculated the area of each site by multiplying the site width times the site length.

Bird Surveys

During the breeding seasons of 2004–2006 we surveyed birds in 67 filter strips and 15 non-buffered field edges (Table 1.1). Nineteen of these filter strips were surveyed in 2 years and 2 were surveyed in all 3 years. Breeding bird surveys in non-buffered field edges were conducted only in 2005. During the winters of 2005–2007 we surveyed birds in 40 filter strips and 16 non-buffered field edges. Eleven of these filter strips were surveyed in 2 years and 2 were surveyed in all 3 years. We surveyed wintering birds in non-buffered field edges in 2005 and 2007, and surveyed 4 sites in both years.

We surveyed breeding birds in filter strips twice between 19 May and 22 July (once from mid-May–mid-June and a second time from mid-June–mid-July), and once in non-buffered field edges between 25 May and 30 June in 2005. Surveys in non-buffered field edges were not repeated twice because the corn crops were too tall by July for observers to conduct a second round of surveys. All breeding bird surveys were conducted between sunrise and 3.5 hrs after sunrise. We surveyed wintering birds between 4 January and 10 March, twice in filter strips in 2005 and 2006, three times in filter strips in 2007, and twice in non-buffered field edges in 2005 and 2007. All winter surveys were conducted between one hour after sunrise and one hour before sunset. We did not conduct surveys in rain, fog, falling snow, or wind >16 km/hr.

We conducted bird surveys at each study site by using a strip-transect method with multiple observers. The width of the strip-transect coincided with the width of the filter strip or non-buffered field edge. During breeding bird surveys in filter strips ≤60 m, and wintering bird surveys in filter strips ≤40 m wide, 2 observers spread out evenly along the width of the filter strip and walked parallel to the wooded edge. During breeding bird surveys in filter strips >60 m wide, a third observer was added and we used the same technique. In filter strips >40 m wide in winter, the observers walked ≤20 m apart, turning around at the end of the study site to survey the remainder. Observers counted all birds within the filter strip area and communicated regularly in order to reduce the risk of double-counting. We surveyed birds in non-buffered field edges by using the same techniques as those used in filter strips. Using these methods, the average distance from an observer to all points in the strip-transects was approximately 8 m in both seasons (breeding season: SD = 4.2 m, max = 16.2 m; winter: SD = 2.4 m, max = 10 m), which is sufficient to determine bird densities in fixed areas of herbaceous habitat (Diefenbach et al. 2003, Roberts and Schnell 2006). We identified the species of all birds seen or heard, except in the rare events when birds were not observed clearly enough to identify. We counted birds observed foraging in the air above the study sites and breeding birds observed in branches overhanging the study sites because many birds use the wooded edges as perches.

To estimate detection probability during the primary bird surveys we conducted an additional double-observer (Nichols et al. 2000) strip-transect method in 21 of the filter strips surveyed in winter 2006 and in 8 of the filter strips surveyed in the breeding season of 2006. We established 1 300-m-long strip-transect in each filter strip, with a half-strip width of 10 m in winter and 15 m in the breeding season. One observer walked down the center line of the strip-transect while a second dependent observer walked 5–10 m behind the first observer recording any birds that the first observer missed. Double-observer surveys were conducted on separate days from the primary surveys or several hours after the primary surveys.

Nest Searching and Monitoring

We searched for nests in 31 filter strips in the breeding seasons of 2005 and 2006. We searched 14 cool-season grass filter strips (8 narrow, 2 medium, and 4 wide) and 17 warm-season grass filter strips (7 narrow, 3 medium, and 7 wide). We searched 28 filter strips in only 1 year and 3 in 2 years. In 2005, we randomly chose a 300 m long section of each filter strip to search for nests regardless of its width (Henningsen and Best 2005). In 2006 we searched a 6,000-m^2 section in order to standardize the area searched at each site (due to the wide range of areas among filter strips in the study). We conducted nest searches twice each year, once in late June–early July and again in early July–late July, with 2–8 people spaced approximately 2 m apart. Searchers parted vegetation with poles to scan for nests and flushed birds. We checked active nests every 3-4 days and considered nests successful if at least 1 of the host young fledged (Henningsen and Best 2005). We also measured the distance from each nest to the crop edge and the wooded edge.

Vegetation Surveys

We estimated the percent cover of all cool-season and warm-season grasses in 36 filter strips in 2005 (16 cool-season and 20 warm-season) and in 22 filter strips in 2006 (9 cool-season and 13 warm-season) during the breeding season. We surveyed vegetation once each year within 5 days of the second bird survey at each site. In filter strips <45 m wide we established 1 transect line down the center of the strip. In filter strips >45 m wide we divided the strip into 2 sections and established a transect line down the center of each section. We visually estimated the percent cover (non-overlapping) of all cool-season and warm-season grass species within a 1-m^2 frame located at random distances perpendicular to points spaced 50 m apart along each transect line.

Statistical Analyses

Bird community metrics and species' densities.– We calculated detection probabilities from the double-observer strip-transects in Program DOBSERV (Nichols et al. 2000). The data allowed for detection estimations when observers were the maximum distance apart during the primary strip-transect surveys. Detection probability was ≥ 0.95 during the breeding season and ≥ 0.89 in winter. Given these high rates of detection we made no adjustments for detection to the counts.

We omitted 20 surveys from winter 2005 (29% of the surveys from that year) due to the presence of snow on the ground during those surveys that we felt prohibited foraging by wintering birds and reduced available cover. We omitted 2 observations of large flocks (≥300 individuals) of red-winged blackbirds (*Agelaius phoeniceus*) and common grackles (*Quiscalus quiscula*), respectively, to improve normality. We omitted observations of eastern bluebirds (*Sialia sialis*) because they were most often observed near bluebird houses that were not evenly distributed among study sites.

We categorized early-successional bird species as either grassland or scrub-shrub birds based on the Birds of North America species accounts (Poole 2010), the North American Breeding Bird Survey Results and Analysis (Sauer et al. 2008), literature on grassland birds (McCoy et al. 1999, Vickery et al. 1999, Hunter et al. 2001, Kammin 2003) and scrub-shrub birds (Askins 1993, Schlossberg and King 2008), and personal observations. We combined obligate grassland birds and facultative grassland birds into a general grassland bird category due to the relatively low abundance of obligate grassland birds observed in filter strips. Scrub-shrub communities include species associated with scrub-shrub, early-successional, and forest edge conditions (Hunter et al. 2001). We included common yellowthroat (*Geothlypis trichas*), field sparrow (*Spizella pusilla*), mourning dove (*Zenaida macroura*), and northern bobwhite in both the grassland guild and the scrub-shrub guild because they cannot easily be classified into one or the other.

We used 5 bird community metrics in the analyses: total bird density, species richness, grassland bird density, scrub-shrub bird density, and total avian conservation value (TACV). We calculated density estimates by dividing the number of birds counted by the area of the site. Species richness is a measure of the number of species recorded at each site. TACV is an index that incorporates demographic information about each species that has been used effectively to assess the relative conservation value of different habitat types (Nuttle et al. 2003). We calculated TACV for each site by multiplying each species' density by its Partners in Flight conservation priority rank (Carter et al. 2000, Nuttle et al. 2003) for the Mid-Atlantic Bird Conservation Region (http://www.rmbo.org/pif/scores/scores.html) and then summing the TACV scores of all species within the site (Conover et al. 2007).

We analyzed differences in bird community metrics and species-specific densities among treatments with mixed model analyses of variance (ANOVAs) by using PROC MIXED in SAS (SAS Institute, Cary, NC). For comparisons of filter strips with non-buffered field edges during the breeding season we used a 1-way ANOVA, only included data from the first round of surveys in 2005 (because non-buffered field edges were surveyed only once in 2005), and included wooded edge length as a covariate because it significantly differed among treatments. For all other analyses, we averaged bird community metrics and species' densities from surveys at the same site within a season and used the means for subsequent analyses. We used a 2-way ANOVA to compare filter strip treatments in the breeding season, with grass type (cool-season or warm-season), filter strip width class (narrow, medium, or wide), and their interaction included as fixed effects, and year and site (nested within treatment) as random terms. For analyses of species richness, site area was used as a covariate to account for species-area effects. The interaction between grass type and filter strip width class was not significant for all breeding season models, therefore we evaluated main effects individually. We tested differences between levels of the fixed factors by using pair-wise contrasts. Due to the difficulty of finding replicates of medium width and wide, un-mowed, cool-season grass filter strips in winter, we tested grass type and filter strip width in winter in separate 1-way models. We also analyzed responses for species with average densities >20birds/100ha (Table 1.2), and for grasshopper sparrow (*Ammodramus savannarum*) and savannah sparrow (*Passerculus sandwichensis*) because they are obligate grassland bird species of high conservation concern in Maryland (Maryland DNR 2004). When necessary, we log or square-root transformed response variables to improve normality. When transformations did not improve normality we conducted a 1-way, non-parametric, Kruskal-Wallis test with PROC NPAR1WAY in SAS, using the mean across all years as the response variable. For the non-parametric test of grassland bird density in filter strips compared to non-buffered field edges in winter, we standardized bird density by the length of the wooded edge. We tested the relationships between bird community metrics and the percent cover of four common grass species with simple linear regressions. Statistical significance was set at $P \leq 0.05$.

Nest densities and nest survival.– We tested for differences in nest densities among filter strip types by using the same mixed model method as that used for comparing breeding bird community metrics among filter strips. The interaction between filter strip grass type and filter strip width was significant for grassland bird nest density, therefore we examined the differences among simple effect means. We did not find enough grassland bird nests in medium width filter strips to reliably estimate nest densities in that width class so we only compared differences between narrow and wide filter strips.

We used the logistic-exposure method (Shaffer 2004, Shaffer and Thompson 2007), by using PROC GENMOD in SAS, to estimate daily survival rate of nests in filter strips and to model nest survival as a function of multiple explanatory variables. We analyzed all nests combined due to the relatively low numbers of nests found for each species. We considered all possible candidate models including filter strip grass type, filter strip width, the interaction of filter strip grass type and width, the distance from the nest to the wooded edge, and year. We only included the interaction of grass type and width in models that included both terms in the interaction. We also considered a constant survival model with no parameters other than the intercept. We evaluated models by using Akaike's Information Criterion adjusted for small sample sizes (AICc), ΔAICc values, and Akaike weights (Burnham and Anderson 2002). We estimated model parameter uncertainty by using model averaged parameter estimates, and evaluated the relative importance of predictor variables by summing the Akaike weights across all models in which the variable occurred (Burnham and Anderson 2002). We did not include the nests from 1 warm-season grass filter strip in 2005 (n = 21 nests) in the analysis because a disproportionate number of nests were found in that filter strip and were found to have a high influence on the model selection results. We calculated nest survival over the entire nesting period (laying, incubation, and nestling stages combined), assuming constant daily survival, by raising the daily survival rate to the power of days in the nesting period (Shaffer and Thompson 2007). We assumed a 24-day nesting period based on estimates of the lengths of the nesting periods for the suite of species we found nesting in filter strips (Poole 2010).

RESULTS

Bird Community and Species' Response

We recorded 64 bird species (53 in the breeding season and 23 in winter) in filter strips, including 26 grassland or scrub-shrub species (Table 1.2). Red-winged blackbirds, indigo buntings (*Passerina cyanea*), and common yellowthroats had the highest breeding bird densities in filter strips, and song sparrows (*Melospiza melodia*), white-throated sparrows

(*Zonotrichia albicollis*), and dark-eyed juncos had the highest wintering bird densities in filter strips.

Filter strips vs. non-buffered field edges.– Every breeding and wintering bird community metric was greater in filter strips than in non-buffered field edges (Table 1.3). Scrub-shrub bird density and TACV in the breeding season were 5.6 and 5.4 times greater in filter strips than in non-buffered field edges, respectively.

Warm-season vs. cool-season grasses.– We found no differences among the 5 bird community metrics between cool-season and warm-season grass filter strips in either season. Common yellowthroat density was 2.9 times greater in warm-season grass filter strips ($\bar{x}$ = 0.9 birds/ha, CL = 0.5–1.4 birds/ha) than in cool-season grass filter strips ($\bar{x}$ = 0.3 birds/ha, CL = 0.0–0.8 birds/ha; $F_{1,61}$ = 8.21, P = 0.006) in the breeding season, but we detected no other differences in species' densities between cool-season and warm-season grass filter strips.

We analyzed the relationship between breeding bird community metrics and the percent cover of 4 commonly planted and relatively abundant grass species in 2005 and 2006. These included 2 cool-season grasses (fescue spp. [2005: $\bar{x}$ = 7.4%, SD = 10.6%; 2006: $\bar{x}$ = 6.5%, SD = 10.9%] and orchardgrass [2005: $\bar{x}$ = 13.0%, SD = 21.4%; 2006: $\bar{x}$ = 9.2%, SD = 19.7%]) and 2 warm-season grasses (big bluestem [2005: $\bar{x}$ = 6.9%, SD = 13.1%; 2006: $\bar{x}$ = 13.3%, SD = 22.4%] and switchgrass [2005: $\bar{x}$ = 6.0%, SD = 17.1%; 2006: $\bar{x}$ = 0.5%, SD = 1.7%]). Percent cover of orchardgrass was negatively related to total bird density, species richness, grassland bird density, and TACV in 2005, and was negatively related to grassland bird density in 2006 (Table 1.4).

Filter strip width.– Breeding bird density was greater closer to the wooded edge of filter strips (Fig. 1), resulting in total bird density being greater in narrow filter strips than in wide filter strips (Table 1.5). TACV was 1.8 times greater in narrow filter strips than in wide filter strips. The density of indigo buntings was 6.0 times greater in narrow filter strips ($\bar{x}$ = 4.1 birds/ha, CL = 3.3–4.9 birds/ha) than in wide filter strips ($\bar{x}$ = 0.7 birds/ha, CL = −0.3–1.7 birds/ha; t_{61} = 5.31, $P \leq 0.001$). Grasshopper sparrow and red-winged blackbird densities were greater in wide filter strips than in narrow filter strips (grasshopper sparrow: $\chi^2_1 = 16.6$, $P \leq 0.001$; red-winged blackbird [narrow: $\bar{x}$ = 0.2 birds/ha, CL = 0.0–0.6 birds/ha; wide: $\bar{x}$ = 1.0 birds/ha, CL = 0.5–1.7 birds/ha; t_{61} = 2.64; $P = 0.010$]). Ninety-percent of grasshopper sparrows were observed in wide filter strips and >60 m away from the wooded edge.

In winter, several bird community metrics were greater in wide filter strips compared to narrower filter strips (Table 1.5). Total bird density and species richness were 7.1 and 4.6 times greater in wide filter strips than in medium width filter strips, respectively. The densities of field sparrow, savannah sparrow, and swamp sparrow (*Melospiza georgiana*) were greater in wide filter strips than in narrow filter strips (field sparrow: $\chi^2_1 = 12.23$, $P \leq 0.001$; savannah sparrow: $\chi^2_1 = 15.33$, $P \leq 0.001$; swamp sparrow: $\chi^2_1 = 4.15$, $P = 0.042$) and medium width filter strips (field sparrow: $\chi^2_1 = 7.59$, $P = 0.006$; savannah sparrow: $\chi^2_1 = 7.59$, $P = 0.006$; swamp sparrow: $\chi^2_1 = 3.99$, $P = 0.046$). Song sparrow density was greater in wide compared to medium filter strips (χ^2_1 = 5.95, $P = 0.014$). Seventy-six percent of savannah sparrows were observed in wide filter strips and >60 m away from the wooded edge.

Nest Location, Density, and Survival

We found 95 nests in filter strips in 2005 and 2006 (Table 1.6). The vegetative types in which nests were located were: forbs (59%), grass (13%), shrubs (17%), and young trees (11%). The location of nests among grassland bird nests and scrub-shrub bird nests showed similar trends, with the majority of nests being located in forbs. Nests were found in 27 different plant species (Appendix 1). Most grassland bird nests were in goldenrods and most scrub-shrub bird nests were in blackberry thickets. Other plant species commonly found with nests included curly dock (*Rumex crispus*), Indianhemp (*Apocynum cannabinum*), Eastern groundsel (*Baccharis halimifolia*), big bluestem, sweetgum (*Liquidambar styraciflua*), and black cherry (*Prunus serotina*).

Sixty-seven nests were found within designated nest searching areas and of 9 different species: common yellowthroat (n = 8), field sparrow (n = 8), grasshopper sparrow (n = 1), song sparrow (n = 1), northern cardinal (*Cardinalis cardinalis*; n = 1), blue grosbeak (*Passerina caerulea*; n = 3), indigo bunting (n = 22), red-winged blackbird (n = 21), orchard oriole (*Icterus spurious*; n = 2). We found no differences in total nest density or scrub-shrub nest density between filter strip grass type or filter strip width classes. Grassland bird nest density was higher in wide, warm-season grass filter strips ($\bar{x}$ = 2.7 nests/ha, CL = 1.2–4.8 nests/ha) than in narrow, warm-season grass filter strips ($\bar{x}$ = 0.1 nests/ha, CL = −0.1–0.8 nests/ha, t_{22} = 3.17, P = 0.005), and in narrow ($\bar{x}$ = 0.2 nests/ha, CL = −0.1–0.8 nests/ha; t_{22} = 3.32, P = 0.003) and wide ($\bar{x}$ = 0.2 nests/ha, CL = −0.1–1.1 nests/ha, t_{22} = 3.1, P = 0.005) cool-season grass filter strips.

We evaluated daily nest survival rates in filter strips for 61 total nests. None of the candidate models had high Akaike weights (>0.20). The constant survival model was the top ranked model. Four other models including only filter strip grass type, filter strip width, distance from the nest to the wooded edge, and year, respectively, had ΔAIC_c values <2.0. No predictor variable was consistently included in the top ranked models. All of the variables we considered had low relative importance (range: 0.27–0.40). Given these model selection results, we assumed a constant survival model to estimate daily nest survival rate and nest survival over the entire nesting period, for all nesting species combined. Daily nest survival rate was 0.91 (CL = 0.88–0.93) and nest survival for the entire nesting period was 10.7% (CL = 5.1%–18.8%).

DISCUSSION

In this study, every bird community metric was substantively greater in filter strips than in non-buffered field edges, indicating that the establishment of filter strips has achieved some of the wildlife benefits intended by Maryland's CREP. These results agree with the findings of other studies that have compared bird community metrics in herbaceous strip-cover habitats to non-buffered field edges (e.g., Smith et al. 2005a, Conover et al. 2007, Conover et al. 2009). In Mississippi, species richness was greater in agricultural fields with herbaceous field borders than in those without field borders during the breeding season (Smith et al. 2005a). In the Mississippi Alluvial Valley, total bird abundance, species richness, and TACV were greater in field borders than in non-bordered field margins in winter, particularly in field borders >30 m wide (Conover et al. 2007).

We recorded 53 breeding bird species using filter strips in Maryland, which is more than other studies of breeding bird use in herbaceous strip-cover habitats (Best 2000, Kammin 2003, Davros 2005). We counted birds in overhanging tree branches along the wooded edge because many species use tree branches as perches. In most other studies birds were recorded only if they were seen in the strip. Furthermore, some studies of birds in herbaceous strip-cover habitat were conducted in more open agricultural landscapes containing fewer bird species associated with forested and transitional habitats.

Our finding that most bird community metrics did not differ between cool-season and warm-season grass filter strips is similar to other studies conducted in grassland habitats. In a study of CRP fields in Nebraska, Delisle and Savidge (1997) did not find differences in total bird abundance between cool-season grass fields and warm-season grass fields. Henningsen and Best (2005) found relative bird abundance and relative nest abundance to be similar between cool-season and warm-season grass filter strips in Iowa. Both cool-season and warm-season grasses can provide habitat for breeding and wintering birds, and bird response varies depending on vegetative diversity and habitat structure (McCoy et al. 2001).

We found a negative relationship with most bird community metrics and the percent cover of orchardgrass. Orchardgrass is non-native, is highly competitive and can often dominate other grasses and forbs (Grime 1973), and its wildlife value is considered very low (Harper et al. 2007). Some grassland birds prefer less dense and more diverse grassland plantings over single-species monocultures (e.g. Whitmore 1981, McCoy et al. 2001, Gill et al. 2006). Filter strips dominated by orchardgrass may lack the openness and plant diversity necessary to attract early-successional birds. Light discing could improve habitat for early-successional birds, such as northern bobwhite, by encouraging more bare ground and forbs and decreasing litter and grass cover (Greenfield et al. 2002). However, because a primary purpose of filter strips is to remove non-point source pollutants from agricultural runoff, opening filter strip vegetation to increase bird habitat value must be balanced with the need for maintaining the ability of filter strip vegetation to filter runoff from agricultural fields.

We used bird densities as measures of habitat quality because although abundance will tend to increase as the area of habitat increases (Stauffer and Best 1980, Davros 2005), bird density measures the relative number of birds in areas of different size. We found that total bird density, scrub-shrub bird density, and TACV in the breeding season decreased with increasing filter strip width. This was because most breeding birds were near the wooded edge regardless of the filter strip width. In contrast, several bird community metrics and species-specific densities in winter were greater in wide filter strips compared to narrower filter strips.

Grasshopper sparrows and savannah sparrows were the only obligate grassland bird species observed in filter strips. The densities of grasshopper sparrows in the breeding season and savannah sparrows in winter were greater in wide filter strips, and most individuals were >60 m from the wooded edge. This is not surprising considering that obligate grassland birds exhibit area sensitivity (Ribic et al. 2009) and prefer large areas farther from wooded edges (Helzer and Jelinski 1999). Grassland bird nest density was also greater in wide, warm-season grass filter strips. These results suggest that filter strips that are adjacent to wooded edges and >60 m wide provide better habitat for grassland birds, particularly obligate grassland species, than filter strips <60 m wide. However, wide filter strips adjacent to wooded edges may still be too narrow to provide adequate habitat for a diverse community of grassland birds that require abundant grassland interior areas (Helzer and Jelinski 1999). Although some small grassland patches are important for grassland birds (Ribic et al. 2009), large blocks of early-successional habitat may be necessary to maintain populations of grassland and shrubland birds that are adversely affected by fragmentation (Askins 1993).

High bird density and species richness does not necessarily indicate high quality habitat for birds (Van Horne 1983). Although bird abundance and nest densities in herbaceous strip-cover habitats are generally much greater than those in CRP fields, nest survival is generally lower in strip-cover habitats than in CRP fields with comparable vegetation (Best 2000). We estimate that for the suite of species we found nesting in filter strips, nest survival over the entire nesting period was 10.7%. Other studies have found similarly low nest survival in herbaceous strip-cover habitats (Bryan and Best 1994, Kammin 2003, Knoot 2004, Henningsen and Best 2005) compared to CRP fields (e.g., McCoy et al. 1999, McCoy et al. 2001). For example, Henningsen and Best (2005) reported that nest survival of common yellowthroats and song sparrows in filter strips adjacent to woody vegetation was 5.4% and 7.5%, respectively. Bryan and Best (1994) reported that nest survival of red-winged blackbirds was 8.4% in grassed waterways. Predation is the most significant reason for nest failure in herbaceous strip-cover habitats (Bryan and Best 1994, Kammin 2003, Davros 2005, Henningsen and Best 2005). These results have raised concern that filter strips act as reproductive sinks for birds. We did not attempt to determine if filter strips were sources or sinks but rather sought to understand how nest survival was related to filter strip characteristics. None of the variables we included in our candidate models were strongly related to daily nest survival. This may be due to the relatively low number of nests we found compared to other studies of nest survival in filter strips (Kammin 2003, Davros 2005, Henningsen and Best 2005).

MANAGEMENT IMPLICATIONS

State and federal conservation agencies should continue to encourage land owners to install filter strips to provide better bird habitat than non-buffered field edges in agricultural landscapes. Wide filter strips >60 m along wooded edges will likely be better habitat for grassland birds, particularly obligate grassland species. Increasing filter strip length can provide additional habitat for many bird species and may be more feasible in working agricultural landscapes. We found a negative relationship between the percent cover of orchardgrass and most bird community metrics. Given that orchardgrass is non-native, highly competitive, and considered to be of low value to wildlife, we recommend against planting orchardgrass in filter strips and reducing or eliminating orchardgrass from filter strips through management practices.

Table 1.1. Study site characteristics on the Eastern Shore of Maryland, USA, from 2004–2007.

Season Habitat type Width class	*n*	Length (m) $\bar{x}$[a]	Length (m) SD	Width (m) $\bar{x}$[a]	Width (m) SD
Breeding season[b]					
Non-buffered field edges	15	369.3	206.5	45.0	0.0
Cool-season grass filter strips					
Narrow	12	452.3	243.3	16.7	5.9
Medium	3	576.2	427.7	38.2	8.4
Wide	7	511.6	287.9	82.1	14.2
Warm-season grass filter strips					
Narrow	23	415.8	160.4	18.9	3.6
Medium	11	394.5	126.1	34.2	4.8
Wide	11	317.0	78.3	91.0	5.3
Winter[c]					
Non-buffered field edges	16	313.2	96.8	40.0	0.0
Cool-season grass filter strips					
Narrow	11	230.0	76.0	17.5	5.3
Medium	1	119.0		31.2	
Wide	1	210.0		91.4	
Warm-season grass filter strips					
Narrow	14	370.2	72.0	19.8	2.7
Medium	7	417.0	76.7	35.6	5.3
Wide	6	299.4	72.9	93.1	2.5

[a] Mean across all years.
[b] Number of study sites during the breeding season by year: 2004: $n = 32$; 2005: $n = 51$; 2006: $n = 22$.
[c] Number of study sites during winter by year: 2005: $n = 35$; 2006: $n = 21$; 2007: $n = 20$.

Table 1.2. Grassland and scrub-shrub bird species (mean density/100 ha) in filter strips on the Eastern Shore of Maryland, USA, during the breeding seasons (May–July) of 2004–2006 and the winters (January–March) of 2005–2007.

Common Name	Scientific name	Bird community guild[a]	Season observed in filter strips	Breeding season		Winter	
				$\bar{x}$ [b]	SE	$\bar{x}$ [b]	SE
Northern Bobwhite	*Colinus virginianus*	FG and SS	Year-round	8.7	5.7	21.7	15.6
American Kestrel	*Falco sparverius*	FG	Winter	0.0	0.0	0.2	0.2
Mourning Dove	*Zenaida macroura*	FG and SS	Year-round	5.5	3.0	21.9	18.0
Eastern Bluebird	*Sialia sialis*	FG	Year-round	2.2	1.1	2.7	2.1
Eastern Kingbird	*Tyrannus tyrannus*	FG	Breeding	11.6	4.0	0.0	0.0
White-eyed Vireo	*Vireo griseus*	SS	Breeding	2.2	1.2	0.0	0.0
Warbling Vireo	*Vireo gilvus*	SS	Breeding	2.1	1.8	0.0	0.0
Gray Catbird	*Dumetella carolinensis*	SS	Breeding	12.6	5.4	0.0	0.0
Brown Thrasher	*Toxostoma rufum*	SS	Breeding	3.1	1.5	0.0	0.0
Common Yellowthroat	*Geothlypis trichas*	FG and SS	Breeding	102.4	14.9	0.0	0.0
Yellow-breasted Chat	*Icteria virens*	SS	Breeding	2.7	1.7	0.0	0.0
Eastern Towhee	*Pipilo erythrophthalmus*	SS	Year-round	3.2	1.5	4.4	4.4
Field Sparrow	*Spizella pusilla*	FG and SS	Year-round	81.6	18.8	71.9	42.7
Savannah Sparrow	*Passerculus sandwichensis*	OG	Winter	0.0	0.0	36.6	19.2
Grasshopper Sparrow	*Ammodramus savannarum*	OG	Breeding	3.5	1.2	0.0	0.0
Song Sparrow	*Melospiza melodia*	SS	Year-round	4.2	2.6	455.0	94.5
Swamp Sparrow	*Melospiza georgiana*	SS	Winter	0.0	0.0	35.1	13.0
White-throated Sparrow	*Zonotrichia albicollis*	SS	Winter	0.0	0.0	160.9	87.5
Dark-eyed Junco	*Junco hyemalis*	SS	Winter	0.0	0.0	154.7	137.1
Northern Cardinal	*Cardinalis cardinalis*	SS	Year-round	19.1	5.6	11.9	9.2
Blue Grosbeak	*Passerina caerulea*	SS	Breeding	38.6	8.1	0.0	0.0
Indigo Bunting	*Passerina cyanea*	SS	Breeding	251.6	32.1	0.0	0.0
Red-winged Blackbird	*Agelaius phoeniceus*	FG	Breeding	110.9	24.9	0.0	0.0

Brown-headed Cowbird	*Molothrus ater*	FG	Breeding	9.6	3.0	0.0	0.0
Orchard Oriole	*Icterus spurious*	SS	Breeding	33.9	9.3	0.0	0.0
American Goldfinch	*Spinus tristis*	SS	Year-round	46.8	12.5	2.1	2.1

[a] Abbreviations: FG = facultative grassland; OG = obligate grassland; SS = scrub-shrub.

[b] Mean across all years.

Table 1.3. Least squares means and 95% confidence limits of bird community metrics in filter strips and non-buffered field edges on the Eastern Shore of Maryland, USA, in the breeding season of 2005 and winters of 2005 and 2007.[a]

Season Bird community metric	Filter strips $\bar{x}$	Filter strips CL	Non-buffered field edges $\bar{x}$	Non-buffered field edges CL	F
Breeding season[b]					
Total bird density[c]	6.4	4.8–8.5	1.2	0.5–2.3	27.39***
Species richness[d]	4.6	3.9–5.3	1.9	0.8–3.0	17.89***
Grassland bird density[c]	1.9	1.3–2.7	0.2	−0.2–0.7	17.14***
Scrub-shrub bird density	3.9	2.8–5.3	0.7	0.2–1.5	19.94***
Total avian conservation value[c]	13.5	10.5–17.2	2.5	0.7–5.0	28.25***
Winter[e]					
Total bird density[c]	3.6	1.9–6.3	0.6	−0.1–2.0	8.9**
Species richness[d]	1.6	1.2–2.0	0.2	−0.2–0.7	21.47***
Grassland bird density[f]					
Scrub-shrub bird density[c]	2.9	1.6–4.7	0.2	−0.3–1.1	14.73***
Total avian conservation value[c]	6.0	3.1–10.8	0.8	−0.1–2.8	10.06**

[a] All density metrics are in units of birds/ha. Length of edge was used as a covariate in all analyses because edge length was significantly different between treatments.

[b] Analysis of variance (Df = 1, 48) with treatment type as a fixed effect.

[c] Geometric means and confidence limits are presented after back-transformation.

[d] Site area used as a covariate in the analysis to account for species-area effects.

[e] Mixed-model analysis of variance (Df = 1, 46) with treatment type as a fixed effect and year and site (nested within treatment) as random effects.

[f] Data could not be transformed to meet the analysis of variance assumptions. A Kruskal-

Wallis test indicated that grassland bird density was greater in filter strips compared to non-buffered field edges ($\chi^2_1 = 3.98$, $P = 0.046$).

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 1.4. Test statistics from simple linear regressions of breeding bird community metrics on the percent cover of four commonly planted grass species in filter strips on the Eastern Shore of Maryland, USA, from 2005–2006.[a]

Year	Cool-season grasses				Warm-season grasses			
	Fescue spp.		Orchardgrass		Big bluestem		Switchgrass	
Bird community metric	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*
2005[b]								
Total bird density	−0.02	0.938	−2.61	0.013	−0.15	0.878	0.13	0.896
Species richness[c]	0.20	0.842	−2.3	0.028	0.61	0.543	−0.61	0.544
Grassland bird density	−0.27	0.792	−3.26	0.003	0.35	0.728	0.24	0.812
Scrub-shrub bird density	−0.88	0.386	−1.8	0.081	−0.29	0.776	0.51	0.614
Total avian conservation value	0.01	0.992	−2.87	0.007	−0.16	0.872	0.12	0.908
2006[b]								
Total bird density	0.92	0.370	−1.48	0.154	−0.43	0.674	−0.43	0.674
Species richness[c]	1.62	0.122	−2.08	0.051	−0.65	0.524	0.27	0.789
Grassland bird density	1.36	0.190	−2.22	0.038	−0.48	0.636	0.58	0.571
Scrub-shrub bird density	1.09	0.289	−1.16	0.259	−1.09	0.287	−0.28	0.783
Total avian conservation value	0.99	0.336	−1.93	0.067	−0.44	0.667	−0.21	0.840

[a] Scientific names of grasses: big bluestem = *Andropogon gerardii*; fescue spp. = *Festuca* spp.; orchardgrass = *Dactylis glomerata*; switchgrass = *Panicum virgatum*.

[b] Df = 1, 34 in 2005; Df = 1, 20 in 2006.

[c] Study site area used as a covariate in the regression analysis.

Table 1.5. Least squares means and 95% confidence limits of bird community metrics, by filter strip width class, in filter strips on the Eastern Shore of Maryland, USA, during the breeding seasons of 2004–2006 and the winters of 2005–2007.[a]

Season	Narrow (<30 m)		Medium (30−60 m)		Wide (>60 m)		Narrow vs. Medium	Narrow vs. Wide	Medium vs. Wide
Bird community metric	$\bar{x}$	CL	$\bar{x}$	CL	$\bar{x}$	CL	t	t	t
Breeding season[b]									
Total bird density	11.2	6.5–15.8	7.6	2.0–13.2	5.6	0.5–10.6	1.68	3.24**	0.89
Species richness[c]	4.5	2.4–6.5	4.4	2.1–6.8	3.2	0.9–5.5	0.04	1.22	1.16
Grassland bird density[d]	1.8	0.9–3.1	2.4	1.0–4.8	2.0	0.9–3.6	0.72	0.28	0.46
Scrub-shrub bird density[d]	5.9	3.5–9.7	4.0	1.9–7.7	2.00	0.9–3.8	1.42	4.53***	2.11*
Total avian conservation value	21.8	12.8–30.9	15.6	4.5–26.7	11.6	1.8–21.4	1.41	2.82**	0.82
Winter[e]									
Total bird density[d]	4.9	2.4–9.2	1.3	–0.1–4.5	9.1	3.0–24.5	2.02	1.07	2.46*
Species richness[c]	1.5	1.0–2.0	0.8	0.0–1.6	2.8	1.9–3.7	1.57	2.37*	3.32**
Grassland bird density[f]									
Scrub-shrub bird density[d]	3.4	1.6–6.4	1.1	−0.1–3.9	3.8	1.0–10.3	1.67	0.19	1.46
Total avian conservation value[d]	8.7	3.8–16.9	2.0	0.0–7.5	18.7	5.6–58.1	2.03*	1.28	2.64*

[a] All density metrics are in units of birds/ha.

[b] Mixed-model analysis of variance (Df = 2, 61) with grass type and filter strip width class as fixed factors and year and site (nested within treatment factors) as random effects.

[c] Site area was used as a covariate in the analysis to account for species-area effects.

[d] Geometric means and confidence limits are presented after back-transformation.

[e] Mixed-model analysis of variance (Df = 2, 37) with filter strip width class as a fixed factor and year and site (nested within filter strip width class) as random effects.
[f] Data could not be transformed to meet the analysis of variance assumptions. Kruskal-Wallis tests indicated that grassland bird density in winter was no different between narrow and medium width filter strips ($\chi^2_1 = 0.73$, $P = 0.394$), but was greater in wide compared to narrow ($\chi^2_1 = 10.56$, $P = 0.001$) and medium width ($\chi^2_1 = 8.70$, $P = 0.003$) filter strips.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 1.6. Number of nests, by bird species, filter strip grass type, and filter strip width[a], found in 14 cool-season and 17 warm-season grass filter strips on the Eastern Shore of Maryland, USA from 2005–2006.

	Cool-season grass filter strips			Warm-season grass filter strips			
Species	Narrow (*n* = 8)	Medium (*n* = 2)	Wide (*n* = 4)	Narrow (*n* = 7)	Medium (*n* = 3)	Wide (*n* = 7)	Total
Blue Grosbeak	1	0	0	1	0	2	4
Common Yellowthroat	0	0	1	2	3	5	11
Field Sparrow	1	0	1	1	0	8	11
Grasshopper Sparrow	0	0	0	0	0	2	2
Indigo Bunting	11	1	5	7	2	2	28
Northern Cardinal	0	0	0	1	0	0	1
Orchard Oriole	0	0	0	0	0	2	2
Red-winged blackbird	1	0	4	0	1	29	35
Song Sparrow	0	0	0	1	0	0	1
Total	14	1	11	13	6	50	95

[a] Filter strip widths: narrow = <30 m, medium = 30–60 m, wide = >60 m.

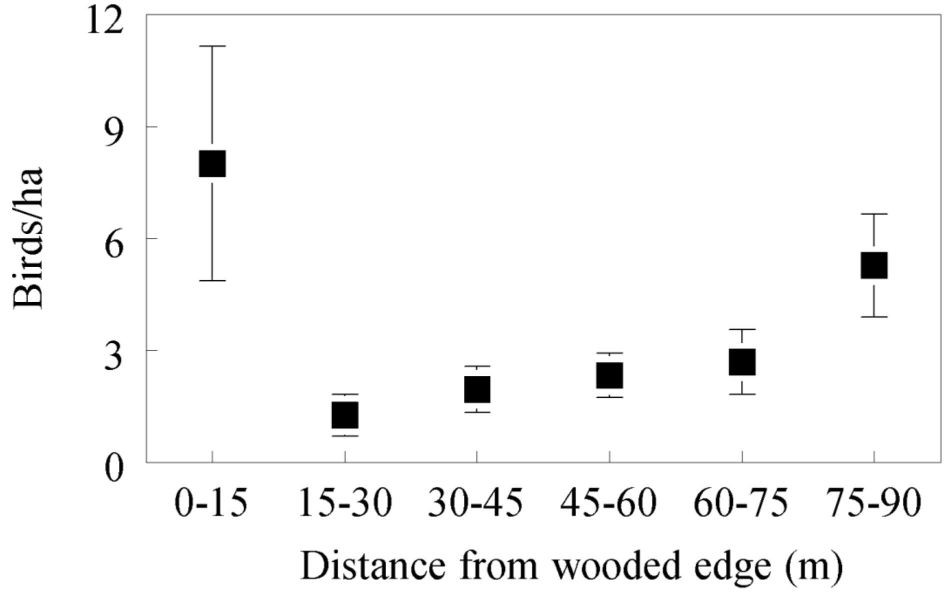

Figure 1.1. Total breeding bird density (mean across years ± SE), by distance from the wooded edge, in filter strips >90 m wide on the Eastern Shore of Maryland, USA, from 2004–2006. The 0–15 m distance category includes birds observed in branches overhanging the filter strips because many birds use the wooded edges as perches.

CHAPTER 2: EARLY-SUCCESSIONAL BIRD COMMUNITY RESPONSE TO VEGETATION AND LANDSCAPE ATTRIBUTES OF FILTER STRIPS IN MARYLAND

ABSTRACT

Filter strips are strips of herbaceous vegetation that are planted along agricultural field margins adjacent to streams or wetlands and are designed to intercept sediment, nutrients, and agrichemicals. Over 15,000 ha of filter strips are enrolled in Maryland through the U.S. Department of Agriculture's Conservation Reserve Program. Most filter strips in Maryland are planted to either native warm-season grasses or exotic cool-season grasses. Filter strips in Maryland often represent the only uncultivated herbaceous areas on farmland and therefore may be important for birds that use early-successional habitats. We conducted bird and vegetation surveys in 38 filter strips from 2005–2006 and measured landscape attributes within 1 km of each filter strip. We used Partial Redundancy Analysis to assess the early-successional bird community response to vegetation and landscape characteristics. The bird communities in cool-season and warm-season grass filter strips were not significantly different. Bird densities were positively associated with plant species richness and negatively associated with litter depth in filter strips. Filter strips with greater plant species richness had higher forb richness and shorter and less dense grasses. Several bird species had higher densities in filter strips in predominantly agricultural landscapes. Our findings suggest that early-succesional bird habitat would be improved if filter strips included shorter and less dense grasses, greater

forb richness and cover, lower litter depth and cover, and if filter strip enrollments were targeted for agricultural landscapes with low landscape cover type diversity.

INTRODUCTION

The populations of many bird species in the eastern North America that use early-successional habitats, such as grassland and scrub-shrub species, are experiencing substantial population declines (Askins 1993, Hunter et al. 2001). The main reason for these declines is habitat loss, primarily due to large-scale conversion of early-successional habitats to agriculture (Askins 1993, Warner 1994). According to the North American Breeding Bird Survey, 71% of grassland bird species and 47% of scrub-shrub bird species have significant negative population trends in eastern North America over the last 40 years (Sauer et al. 2008).

The U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) could reverse some of these trends by providing habitat for birds that use early-successional habitats. The CRP offers economic incentives to encourage farm owners to convert highly erodible and other environmentally sensitive agricultural land to perennial, vegetative cover. The goals of the CRP are to improve water quality, reduce soil erosion, and establish wildlife habitat. The 1996 Farm Bill (Federal Agricultural Improvement and Reform Act) established the Conservation Reserve Enhancement Program (CREP) provision within the CRP to enable states to enter into partnerships with the USDA to target specific resource concerns by offering enhanced incentives for landowner enrollment. In 1997, the State of Maryland and the USDA established Maryland's CREP initiative to implement conservation practices on private agricultural lands designed to reduce sediment and nutrient inputs to the Chesapeake Bay and improve wildlife habitat.

Filter strips are strips of herbaceous vegetation that are planted along agricultural field margins adjacent to streams or wetlands and are designed to intercept sediment, nutrients, and agrichemicals. Over 15,000 ha of filter strips [USDA Conservation Practice (CP) 21] are enrolled in Maryland's CREP, which comprises 47% of the total CRP acreage (USDA 2010a) and 1.9% of the total farmland in Maryland (USDA 2009a). Filter strips are usually planted either to native warm-season grasses or cool-season grasses, with the addition of native wildflowers or introduced legumes (usually clovers). Native warm-season grasses begin growth in late spring, set seed near the end of summer, and then go dormant in early fall. Cool-season grasses begin growth in early spring, set seed in early summer, and then go dormant until they start growing again in the fall.

Filter strips in Maryland often represent the only uncultivated herbaceous areas on farmland in Maryland and therefore may be important for species that use early-successional habitats. Warm-season grasses are known to provide nesting, foraging, and brood-rearing habitat for northern bobwhite (*Colinus virginianus*) and other ground-nesting birds (Whitmore 1981, Burger et al. 1990, Gill et al. 2006, Harper et al. 2007). However, there is no consensus on whether cool-season or warm-season grasses are preferable to most bird species in early-successional habitats (McCoy et al. 2001)

Vegetation structure in herbaceous CRP plantings influences bird communities (King and Savidge 1995, Patterson and Best 1996, Best 2000, McCoy et al. 2001). For example, in a study of CRP fields in Missouri, McCoy et al. (2001) found that shorter, more diverse, cool-season grass fields were equal or better habitat for grassland birds than taller, more vertically dense, switchgrass (*Panicum virgatum*) dominated fields. Some grassland birds tend to prefer less dense stands of grass in CRP fields (Gill et al.

2006, Wentworth et al. 2010). Davros (2005) reported that bird abundance and species richness were positively associated with thick, vertically heterogeneous vegetation in CRP filter strips in Minnesota. However, there is no one planting type that suits all bird species that use herbaceous CRP plantings (Best 2000).

The landscape around herbaceous plantings influences bird community composition (Pearson 1993, Ribic and Sample 2001, Fletcher and Koford 2002, Davros 2005, Ribic et al. 2009, Wentworth et al. 2010). For example, early-successional bird density is greater in some agriculture-dominated landscapes than in forest-dominated landscapes (Riddle 2007). Obligate grassland birds prefer large areas farther from wooded edges (Helzer and Jelinski 1999) and may be less abundant in landscapes with high edge density (Fletcher and Koford 2002). And grassland bird density may be negatively related to landscape cover type diversity (Ribic and Sample 2001). However, we are just beginning to understand the influence of landscape factors on grassland bird communities (Ribic et al. 2009).

The bird community response to vegetation and landscape characteristics of filter strips in the mid-Atlantic region has never been studied. The influence of vegetation structure and landscape composition on bird communities varies across regions and results from one region should not be extrapolated to others (Bakker et al. 2002, Riffell et al. 2008). Conservation decisions affecting the CRP should be made based on region-specific information when possible (Riffell et al. 2008). Therefore, we conducted a study in response to the needs of land managers and conservation planners seeking to improve the habitat quality of filter strips for birds in the Mid-Atlantic region. From 2005–2006 we assessed the response of breeding early-successional bird species to grass type (cool-season and warm-season), vegetation composition and structure, and landscape attributes of filter strips in Maryland.

Early-successional habitats include a wide variety of natural open habitats, including grasslands, shrublands, open woodlands, savannas, and tree-fall gaps (Hunter et al. 2001). In this paper, we use the phrase “early-successional birds” to describe obligate grassland, facultative grassland, and scrub-shrub bird species. We focused on the response of grassland and scrub-shrub birds because they are guilds experiencing population declines and are of high conservation concern (Askins 1993, Hunter et al. 2001), and because they are likely to be affected by the characteristics of filter strips in Maryland. We chose a community-based approach because although some individual species require specific conservation attention (Hunter et al. 2001, Wiens et al. 2008), effective conservation efforts should be focused on entire communities (Hunter et al. 2001).

STUDY AREA

The Eastern Shore of Maryland (the area of the state east of the Chesapeake Bay) has approximately 46% of land in farms (USDA 2009a) and approximately 77% of the CREP filter strips in the state (USDA 2007). The region is dominated by rowcrop agriculture interspersed by upland forest blocks and forested wetlands. Our goal was to find a representative sample of CREP filter strips on Maryland’s Eastern Shore that included both cool-season and warm-season grass filter strips. With the assistance of NRCS staff and local contacts, we identified farms with CREP filter strips in 3 counties on Maryland’s Eastern Shore (Caroline, Queen Anne’s, and Talbot) and selected study sites among farms where we were granted access. We conducted bird and vegetation surveys in 38 filter strips from 2005–2006. Twenty-seven filter strips were surveyed in only 1 year and 11 were surveyed in both years (n = 27 in 2005; n = 22 in 2006). All filter strips were between rowcrops (corn or soybean) and a deciduous wooded edge and were originally installed between 1997 and 2004.

We established study sites in 16 cool-season and 22 warm-season grass filter strips. We classified each filter strip as either cool-season or warm-season based on the original planting plan indicated by local NRCS county office records, and verified the grass type through vegetation surveys or visual inspections. Common warm-season grasses in filter strips were big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and broomsedge (*Andropogon virginicus*). The most common cool-season grass in filter strips was orchardgrass (*Dactylis glomerata*), but other cool-season grasses such as red fescue (*Festuca rubra*) and sheep fescue (*Festuca ovina*) were also planted in some filter strips. Orchardgrass and most other cool-season grasses in Maryland filter strips are non-native (S. Strano, Natural Resources Conservation Service [NRCS], Maryland, pers. comm.).

We established 1 study site in each filter strip, based on the following criteria: (1) study sites were on separate fields, (2) at least 100 m from other study sites, (3) and at least 50 m from the end of the field or from an edge where there was a distinct habitat change (e.g. roads, pastures, houses, etc.). In 2005, study sites spanned as much of the length of the filter strip as possible. In 2006, to increase efficiency and allow for more time to survey other sites, we established shorter study sites that were randomly placed along the length of filter strip. We defined the width of each study site as the distance from crop edge to the wooded edge of each filter strip, and calculated the width by averaging measurements taken every 50 m over the length of the study site. We measured the length of each study site in ArcMap (ESRI, Redlands, CA) and calculated the area of each site by multiplying the site width by the site length. Mean study site length and width were 404.7 m (SD = 149.6 m) and 45.3 m (SD = 32.3 m), respectively.

METHODS

Vegetation Surveys

Vegetation surveys were within five days of each bird survey. In filter strips <45 m wide we established 1 transect line down the center of the strip. In filter strips >45 m wide we divided the strip into 2 sections and established a transect line down the center of each section. We established 1-m^2 survey plots at random distances perpendicular to points spaced 50 m apart along each transect line.

In each survey plot the percent cover of grass, forbs, bare ground, leaf litter, and young trees was visually estimated. Cover estimates were non-overlapping and summed to 100%. Vegetation density was measured by taking readings with a Robel pole (Robel et al. 1970) in the four cardinal directions. The maximum height of live vegetation and litter depth were also measured. On the second round of vegetation surveys the forb richness (i.e., the number of forb species) and plant species richness in each plot was recorded. Plant species observed incidentally in filter strips but not during vegetation surveys were also recorded.

Spatial Analysis

We used a National Landcover Data Set (NLCD) raster image from 2001 (Homer et al. 2004) to classify the land cover types around each site in each year. The raster image was converted to a polygon shapefile and merged with a shapefile containing the spatial extent and geographic location of CRP land in Maryland obtained from the USDA. We measured landscape attributes within 1 km of each filter strip. We chose this scale because it encompassed an area that included several farm fields around each filter strip, and because it is a spatial scale that has been found to be related to grassland bird abundance (Fletcher and Koford 2002, Davros 2005). We chose not to investigate patterns at other spatial scales due to the strong correlations of land cover types at different spatial scales (Fletcher and Koford 2002). Within each landscape we calculated the percent cover of open water and emergent wetlands, developed and barren land, forest, agricultural land (including cropland and pastureland), and CRP land, and the Shannon's Diversity Index (SHDI; an index of the diversity of landscape cover types).

Bird Surveys

Breeding bird surveys were conducted between 19 May and 20 July in 2005–2006. At each filter strip, one round of surveys was conducted from May–June, and a second round from June–July. All surveys were from sunrise to 3.5 hrs after sunrise. Surveys were not conducted in rain, fog, or wind >16 km/hr.

We conducted bird surveys at each study site by using a strip-transect method with multiple observers. In filter strips ≤60 m, 2 observers spread out evenly along the width of the filter strip and walked parallel to its edge. In filter strips >60 m wide, a third observer was added and we used the same technique. Observers counted all birds within the filter strip area and communicated regularly in order to reduce the risk of double-counting. Using these methods, the average distance from an observer to all points in the strip-transects was 9.0 m (SD = 4.2 m, max = 16.2 m). We counted all birds seen or heard, including birds observed foraging in the air above the study sites and in branches overhanging the study sites because many birds use the wooded edges as perches.

To estimate detection probability during the primary bird surveys we conducted an additional double-observer (Nichols et al. 2000) strip-transect method in 8 of the filter strips surveyed in the breeding season of 2006. We established 1 300-m-long strip-transect in each filter strip with a half-strip width of 15 m. One observer walked down the center line of the strip-transect while a second dependent observer walked 5–10 m behind the first observer recording any birds that the first observer missed. Double-observer surveys were conducted on separate days from the primary surveys or several hours after the primary surveys.

Statistical Analyses

We classified each species detected in filter strips as either grassland or scrub-shrub species based on the Birds of North America species accounts (Poole 2010), the North American Breeding Bird Survey Results and Analysis (Sauer et al. 2008), literature on grassland birds (McCoy et al. 1999, Vickery et al. 1999, Hunter et al. 2001, Kammin 2003) and scrub-shrub birds (Askins 1993, Schlossberg and King 2008). We omitted observations of eastern bluebirds (*Sialis sialis*) because they were most often observed near bluebird houses that were not evenly distributed among study sites.

We calculated detection probabilities from the double-observer strip-transects in Program DOBSERV (Nichols et al. 2000). The data allowed for detection estimations when observers were the maximum distance apart during the primary strip-transect surveys. Detection probability was ≥ 0.95 for all observers. Given these high rates of detection, and because Diefenbach et al. (2003) found that detection probability of grassland birds was close to 100% at distances <25 m, we made no adjustments for detection to the counts.

We averaged the bird community and vegetation metrics from the two surveys at the same site in the same year and used the means for subsequent analyses. For the 11 sites that were surveyed in more than one year we randomly selected 1 year of data for inclusion in the analyses. Differences in vegetation variables between cool-season and warm-season grass filter strips were tested using Proc Mixed in SAS (SAS Institute, Cary, NC), with year as a random effect. For the tests of the percent cover of bare ground and young trees, we used Proc GLIMMIX in SAS, and specified a Poisson distribution, because those variables were not normally distributed and could not be transformed to meet the assumptions of the analysis of variance.

To assess the effects of environmental variables on the early-successional bird community we used partial redundancy analysis (pRDA), a constrained form of principal component analysis (Legendre and Legendre 1998), in CANOCO 4.54 (Biometris, Plant Research International, Wageningen, The Netherlands). We ran one pRDA to test for differences in the bird community between filter strip grass types (cool-season vs. warm-season) and a second pRDA to test for relationships between bird densities and quantitative environmental variables. We did not include percent cover of grass, forb richness, maximum height of live vegetation, percent of open water and emergent wetlands in the landscape, and SHDI in the analysis because they were highly correlated with other environmental variables (r >0.70, P <0.001), percent cover of bare ground because it was not normally distributed, and percent cover of young trees and developed land in the landscape to reduce the number of variables in the model. Because we were also interested in the effect of explanatory variables not included in the pRDA, we examined a correlation matrix of all continuous explanatory variables. In both pRDAs we used year, filter strip width, and the length of the wooded edge at each site as covariables. We log transformed the species' densities and centered the species data prior to analysis. pRDA uses a linear method of direct ordination to detect compositional differences in species assemblages that are linear combinations of the environmental variables (Lepš and Šmilauer 2003). The pRDA removed the variation explained by the covariables before determining the variation in the species matrix explained by the environmental variables. The forward selection option was used to rank the environmental variables in importance to the bird community. The null hypothesis that differences in bird community composition were not related to the environmental variables was tested using Monte Carlo permutations. The permutation procedure generated 499 new sets of data that were equally likely under the null hypothesis, while keeping the environmental and covariate structure of the data fixed. The significance level was calculated by the proportion of F values greater than or equal to the F value based on the original data set.

We used stepwise multiple regressions in Proc REG in SAS to assess individual species' responses to vegetation and landscape attributes of filter strips. We only fit models for the 5 species with the highest average densities (>20birds/100ha): common yellowthroat (*Geothlypis trichas*), field sparrow (*Spizella pusilla*), indigo bunting (*Passerina cyanea*), red-winged blackbird (*Agelaius phoeniceus*), and American goldfinch (*Carduelis tristis*). We included year, filter strip width, and the length of the wooded edge as covariables in all regression models. We log transformed the density of American goldfinch to meet the regression assumptions. Spatial autocorrelation is common in ecological datasets collected across geographic space (Legendre 1993) and is problematic in statistical modeling because it violates the assumption of independently and identically distributed errors (Dormann et al. 2007). We tested for spatial autocorrelation among the residuals from the full model for each species by using Moran's I tests (Dormann et al. 2007). No models had significant spatial autocorrelation.

RESULTS

Vegetation and Landscape Assessment

We observed 148 plant species in filter strips either during vegetation surveys or incidentally (Appendix 2). Both cool-season and warm-season grass filter strips were dominated by grass and forbs and had relatively little bare ground (Table 2.1). Average plant species richness in vegetation plots was 6.3 species/m^2 (SE = 0.2 species/m^2) and most species in filter strips were forbs (mean = 4.0 species/m^2, SE = 0.2 species/m^2). Cool-season grass filter strips had greater forb cover and lower vertical vegetation density than in warm-season grass filter strips. The landscapes around filter strips were dominated by agriculture, contained moderate amounts of forest cover, had relatively little developed and barren land, and had approximately 8% of land enrolled in the CRP (Table 2.2). Eighty-one percent of the CRP land was herbaceous filter strips, whereas smaller percentages of CRP land included riparian forest buffers (CP22), new grass plantings (CP1 and CP2), and wetland restoration (CP23).

Bird Community Response to Environmental Factors

We recorded 16 early-successional bird species in filter strips from 2005–2006 (Table 2.3). Indigo bunting had the greatest bird densities, followed by common yellowthroat, red-winged blackbird, and American goldfinch. Common yellowthroat and brown-headed cowbird (*Molothrus ater*) densities were greater in warm-season grass filter strips (Fig. 2.1). However there was not a significant difference in the overall bird communities of cool-season and warm-season grass filter strips ($F = 0.92$, $P = 0.47$).

A pRDA indicated that early-successional birds in filter strips were significantly related to quantitative vegetation and landscape characteristics of filter strips ($F = 1.51$, $P = 0.016$; Fig. 2.2). The first 2 canonical axes explained 22.8% of the variation in the species data and 71.9% of the species-environment relationship, after removing the variation due to the covariables. We interpreted axis 1 to represent mostly landscape attributes and axis 2 to represent mostly vegetation characteristics. Most bird species had higher densities at sites with greater plant species richness and forb cover and lower densities at sites with less litter depth and cover. Indigo bunting, common yellowthroat, and field sparrow had higher densities in landscapes with more agriculture. The percent of CRP in the landscape had little effect on the bird community, as exhibited by the relatively short vector for %CRP.

Forward selection indicated that the bird community was significantly related to plant species richness ($F = 2.52$, $P = 0.020$), percent cover of agriculture ($F = 3.32$, $P = 0.004$), and litter depth (at the $P < 0.10$ level; $F = 1.88$, $P = 0.062$). Several explanatory variables not included in the pRDA were correlated with the 3 variables that most influenced the bird community. Plant species richness was negatively correlated with maximum height of live vegetation ($r = -0.41$, $P = 0.011$) and percent cover of grass ($r = -0.60$, $P < 0.001$), and positively correlated with forb richness ($r = 0.79$, $P < 0.001$). Litter depth was negatively correlated with forb richness ($r = -0.54$, $P < 0.001$).

Many of the same trends in the bird community analyses were evident in the multiple regressions of individual species densities (Table 2.4). Common yellowthroat and indigo bunting were positively associated with more agricultural landscapes. American goldfinch was positively associated with plant species richness. Field sparrow and indigo bunting were positively associated with forb cover. Field sparrow was also positively associated with the percent of CRP land in the landscape.

DISCUSSION

The early-successional bird community was positively associated with plant species richness and negatively associated with litter depth in filter strips in Maryland. Several individual bird species were positively associated with filter strips that had greater forb cover and with filter strips in more agricultural landscapes. Filter strips with greater plant species richness had shorter and less dense grasses and higher forb richness. Landscapes with more agriculture had lower landscape cover type diversity. These results suggest that early-successional bird habitat may be improved if filter strips are managed to have shorter and less dense grasses, less litter, greater forb species richness and cover, and if filter strips are targeted for agricultural landscapes with low landscape cover type diversity.

Our results are consistent with other studies that have evaluated habitat associations of early-successional birds. For example, grassland birds such as dickcissel (*Spiza americana*) have been positively associated with forb cover (Fletcher and Koford 2002), and ground-nesting birds such as grasshopper sparrow (*Ammodramus savannarum*) have been negatively associated with vegetation density (Whitmore 1981, Fletcher and Koford 2002, Gill et al. 2006, Wentworth et al. 2010). Early-successional bird abundance has also been positively associated with agriculture-dominated landscapes compared to forest-dominated landscapes (Riddle 2007, Riddle et al. 2008, Riffell et al. 2008). Ribic and Sample (2001) also found that grassland bird density was lower in landscapes with high landscape cover type diversity.

The reasons for such associations between bird densities and environmental characteristics of filter strips may be related to the nesting, foraging, food, and cover requirements of early-successional birds, which ultimately affect fitness (Whitmore 1979). For example, grasshopper sparrows often use open areas between grass clumps as movement corridors and dense sod-forming grasses preclude effective foraging (Whitmore 1981). Abundant forb cover provides the necessary nesting substrate for some grassland birds (Patterson and Best 1996). CRP fields that have fewer weeds, less bare ground, and high vegetation density may not be optimal for northern bobwhite brood-rearing, roosting, and foraging (Burger et al. 1990). CRP plantings with higher plant diversity may also have higher invertebrate densities (Burger et al. 1990) and therefore may provide additional food resources for grassland birds (McIntyre and Thompson 2003, Davros 2005).

Our finding that the early-successional bird community did not differ between cool-season and warm-season grass filter strips is similar to other studies conducted in grassland habitats. In a study of CRP fields in Nebraska, Delisle and Savidge (1997) did not find differences in total bird abundance between cool-season grass fields and warm-season grass fields. Henningsen and Best (2005) found relative bird abundance and relative nest abundance to be similar between cool-season and warm-season grass filter strips in Iowa. This suggests that both cool-season and warm-season grasses can provide habitat for breeding and wintering birds, and that bird response varies depending on vegetative diversity and habitat structure (McCoy et al. 2001).

We analyzed the response of grassland and scrub-shrub species because they are guilds experiencing substantial population declines (Askins 1993, Hunter et al. 2001), and because we believed that these guilds would be the most likely to be affected by filter strips in Maryland. Guild based approaches may not be appropriate for some management situations, for instance when the response of groups of species may not be indicative of the response of individual species (Lindenmayer et al. 2002, Wiens et al. 2008). However, guild-based approaches often allow for more workable management plans than managing for large numbers of individual species (Wiens et al. 2008).

We used bird density as a measure of habitat quality because although abundance will tend to increase as the area of habitat increases (Stauffer and Best 1980, Davros 2005), bird density measures the relative number of birds in areas of different size. Greater bird density and species richness does not necessarily indicate high quality habitat for birds (Van Horne 1983). Although bird abundance and nest densities in filter strips are generally much greater than those in CRP fields, nest success is generally lower in filter strips than in CRP fields (Best 2000). Predation is the most significant reason for nest failure in filter strips (Kammin 2003, Davros 2005, Henningsen and Best 2005). These results have raised concern that filter strips act as reproductive sinks for birds. We did not attempt to determine if filter strips were sources or sinks but rather sought to understand how the early-successional bird community was related to filter strip characteristics.

Managing filter strips to improve bird habitat may not be consistent with the goals of improving water quality in runoff from adjacent crop fields. Filter strips can act as vegetative barriers to temporarily pond water runoff, which allows sediment to settle and the water to gradually move downslope (Dosskey 2001, UMRSHNC 2008). Planting shorter and less dense grasses may improve habitat for early-successional birds (McCoy et al. 2001, Gill et al. 2006), but dense, stiff, and taller grasses function better to reduce sediment loads in high runoff conditions (Dosskey 2001, UMRSHNC 2008). Cool-season grasses usually become established quicker than warm-season grasses and therefore may provide erosion control and sediment trapping benefits quicker than warm-season grasses (USDA 2004). However, once established, warm-season grasses have more above and below-ground biomass than cool-season grasses and therefore can immobilize more soil nutrients (USDA 2004).

MANAGEMENT IMPLICATIONS

Both vegetation and landscape characteristics influence the early-successsional bird community in filter strips in Maryland. Whether filter strips are planted to cool-season or warm-season grasses is not as important as the vegetative diversity and habitat structure of filter strips. Early-successional bird habitat may be improved if filter strips included shorter and less dense grasses, higher numbers of forbs, higher forb cover, and lower litter depth, and if filter strip enrollments were targeted for agricultural landscapes with low landscape cover type diversity. However, managing filter strips to improve bird habitat may not be consistent with water quality goals. Conservation planners and land managers will need to be innovative to design and manage filter strips to improve bird habitat while meeting water quality standards.

Table 2.1. Vegetation characteristics in filter strips on Maryland's Eastern Shore, USA, during the breeding seasons of 2005 and 2006.

		CSG[a]		WSG[a]			
Variable	Abbreviation	Mean	SE	Mean	SE	*F*	*P*
Vertical vegetation density, cm	Veg_Density	44.4	7.3	60.9	6.9	7.2	0.011
Maximum height of live vegetation, cm	Max_Live	112.3	9.9	114.1	9.3	0.1	0.822
Litter depth, cm	Litter_Depth	2.4	0.5	3.6	0.4	4.0	0.055
Percent cover							
Bare ground	%Bare	0.8	0.6	2.6	0.9	2.1	0.158
Grass	%Grass	38.7	6.4	43.3	5.9	0.6	0.443
Forbs	%Forbs	35.4	4.4	23.0	3.8	4.6	0.039
Litter	%Litter	22.5	5.2	27.7	5.0	2.8	0.105
Young trees	%Trees	2.5	1.3	2.4	1.1	0.01	0.921
Forb richness[b]	nForb	4.3	0.3	3.8	0.3	1.2	0.283
Plant species richness	Plant_SR	6.2	0.4	6.4	0.3	0.3	0.620

[a] CSG = cool-season grass filter strips; WSG = warm-season grass filter strips.

[b] number of forb species.

Table 2.2. Landscape attributes calculated from 1-km radius landscapes around filter strips on Maryland's Eastern Shore, USA.

Variable	Abbreviation	Mean	SE
Percent of landscape			
Developed	%Developed	1.3	0.2
Forest	%Forest	22.2	1.5
Agriculture	%Ag	57.8	2.2
Water	%Water	11.2	2.9
CRP land	%CRP	7.7	0.8
Shannon's diversity index	SHDI	0.97	0.03

Table 2.3. Densities (mean density/100 ha) of grassland and scrub-shrub bird species in filter strips on the Eastern Shore of Maryland, USA, during the breeding seasons of 2005–2006.

Common Name	Scientific name	$\bar{x}$	SE
Northern Bobwhite	*Colinus virginianus*	0.5	0.5
Eastern Kingbird	*Tyrannus tyrannus*	14.3	6.9
White-eyed Vireo	*Vireo griseus*	0.3	0.3
Gray Catbird	*Dumetella carolinensis*	13.5	8.2
Common Yellowthroat	*Geothlypis trichas*	61.6	15.0
Eastern Towhee	*Pipilo erythrophthalmus*	4.5	3.4
Field Sparrow	*Spizella pusilla*	39.9	10.7
Grasshopper Sparrow	*Ammodramus savannarum*	4.0	1.7
Song Sparrow	*Melospiza melodia*	2.6	1.9
Northern Cardinal	*Cardinalis cardinalis*	7.1	4.4
Blue Grosbeak	*Passerina caerulea*	19.9	6.7
Indigo Bunting	*Passerina cyanea*	216.6	38.4
Red-winged Blackbird	*Agelaius phoeniceus*	59.4	18.4
Brown-headed Cowbird	*Molothrus ater*	14.3	6.6
Orchard Oriole	*Icterus spurious*	11.8	5.6
American Goldfinch	*Carduelis tristis*	53.3	21.7

Table 2.4. Results of stepwise multiple regressions of species' densities on vegetation and landscape attributes of filter strips in Maryland, USA, in the breeding seasons of 2005 and 2006.

Species	Final model[a]
Common Yellowthroat	+ 2.86 %Ag
Field Sparrow	+ 0.02 %Forbs + 3.76 %CRP
Indigo Bunting	+ 10.79 %Ag + 0.04 %Forbs - 0.02 Width[b]
Red-winged Blackbird	(none)
American Goldfinch ($\log_{10}$ + 0.1)	+ 0.12 Plant_SR + 0.00 Length[c]

[a] See Tables 2.1 and 2.2 for definitions of variables. All variables included in the final models are significant at the $P < 0.05$ level. “None” indicates that no variables remained in the final model.

[b] Width = filter strip width.

[c] Length = filter strip length.

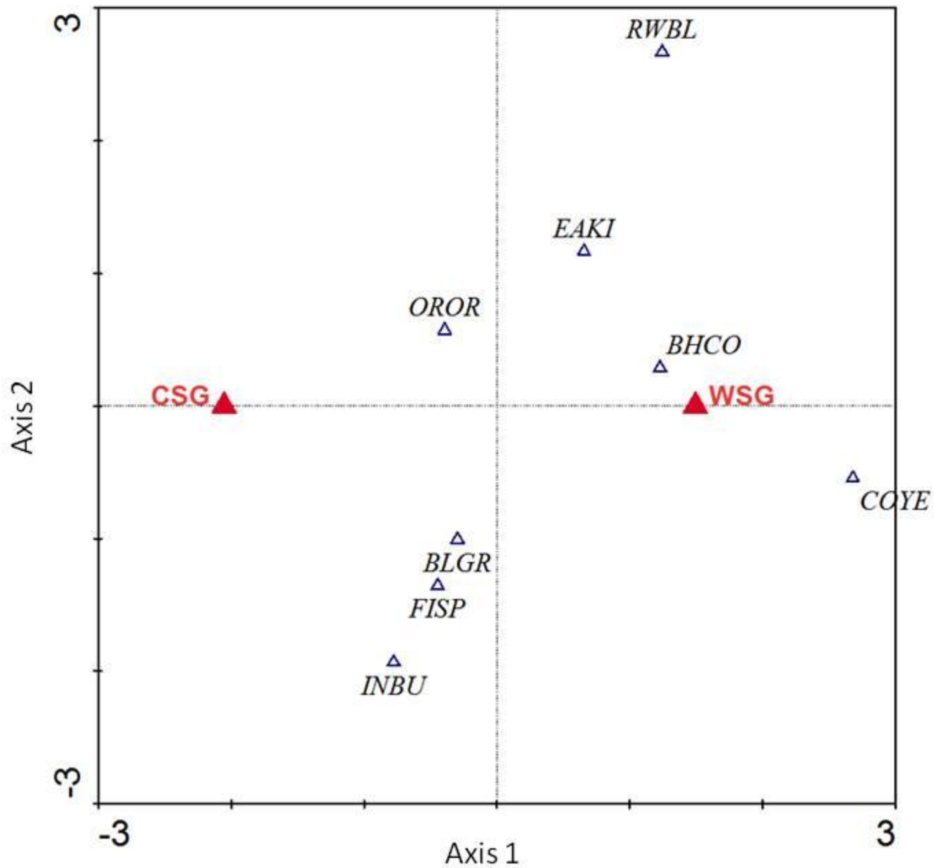

Figure 2.1. Partial Redundancy Analysis biplot of species' densities and grass type in filter strips on the Eastern Shore of Maryland, USA, from 2005–2006. Monte Carlo Permutation Tests indicated that the bird community did not differ between cool-season and warm-season grass filter strips. Species points (hollow triangles) that are closer to the centroid for an environmental class (solid triangles) indicate that the density of that species is predicted to be higher in that class. Only species with a fit of ≥5 % are included. Species abbreviations: BHCO = Brown-headed Cowbird; BLGR = Blue Grosbeak; COYE = Common Yellowthroat; EAKI = Eastern Kingbird; FISP = Field Sparrow; INBU = Indigo Bunting; OROR = Orchard Oriole; RWBL = Red-winged Blackbird. Environmental variable abbreviations: CSG = cool-season grass filter strips; WSG = warm-season grass filter strips.

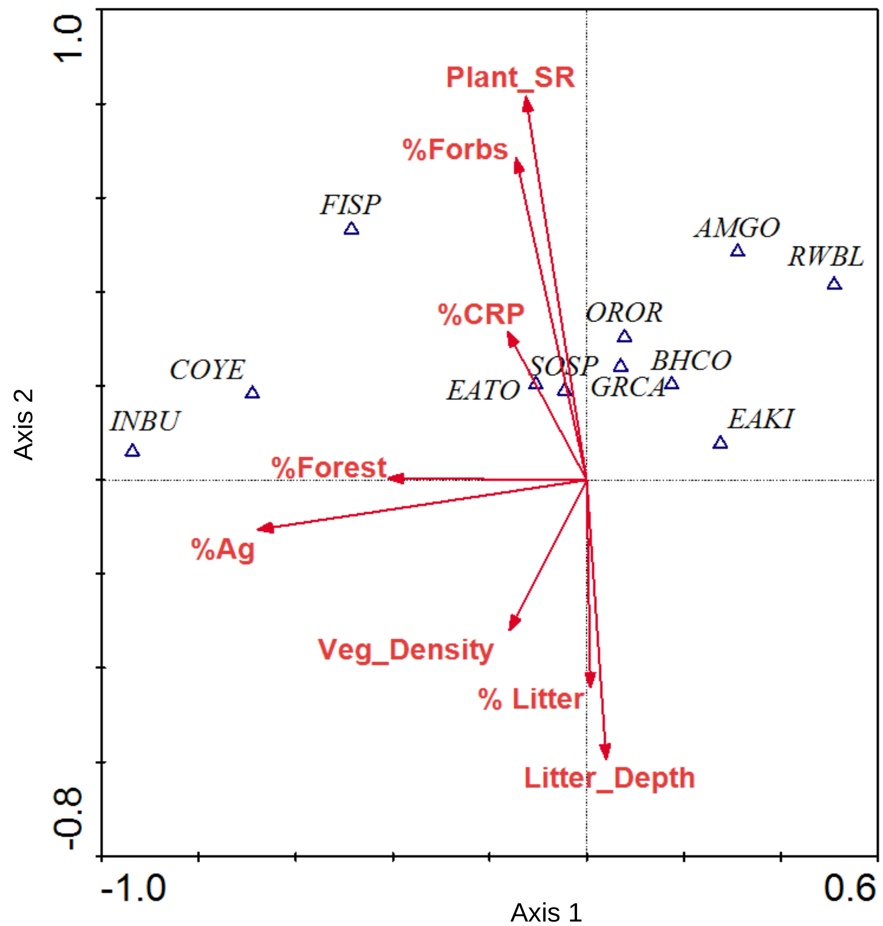

Figure 2.2. Partial Redundancy Analysis biplot of species' densities and quantitative environmental variables in filter strips on the Eastern Shore of Maryland, USA, from 2005–2006. Axes represent the first 2 canonical axes. Monte Carlo Permutation Tests indicated that the bird community was significantly related to the environmental variables. If a species' density (hollow triangle) is in a similar direction to the arrow for an environmental variable, then the species is predicted to be positively correlated with that variable. Longer arrows indicate environmental variables that have more influence on the bird community. The angles between the arrows indicate correlations between variables, with smaller angles indicating more positive. Only species with a fit of ≥5 % are included. Species abbreviations: AMGO = American Goldfinch; BHCO = Brown-headed Cowbird; COYE = Common Yellowthroat; EAKI = Eastern Kingbird; EATO = Eastern Towhee; FISP = Field Sparrow; GRCA = Gray Catbird; INBU = Indigo Bunting; OROR = Orchard Oriole; RWBL = Red-winged Blackbird; SOSP = Song Sparrow. See Tables 2.1 and 2.2 for environmental variable abbreviations.

CHAPTER 3: WINTERING BIRD RESPONSE TO FALL MOWING OF HERBACEOUS BUFFERS

ABSTRACT

Herbaceous buffers are strips of herbaceous vegetation planted between working agricultural land and streams or wetlands. Mowing is a common maintenance practice to control woody plants and noxious weeds in herbaceous buffers. Buffers enrolled in Maryland's Conservation Reserve Program (CRP) cannot be mowed during the primary bird nesting season between 15 April and 15 August. Most mowing of buffers in Maryland occurs in late summer or fall, leaving the vegetation short until the following spring. We studied the response of wintering birds to fall mowing of buffers. In 13 buffers, we mowed one section to 10–15 cm and kept another section unmowed. Most species observed in buffers were grassland or scrub-shrub birds. Ninety-eight percent of all birds detected were in unmowed buffers. Total bird abundance, species richness, and total avian conservation value were significantly greater in unmowed buffers, and Savannah Sparrows, Song Sparrows, and White-throated Sparrows were significantly more abundant in unmowed buffers. Wintering bird use of mowed buffers is less than in unmowed buffers. Leaving herbaceous buffers unmowed through winter will likely provide better habitat for wintering birds.

INTRODUCTION

Herbaceous buffers are strips of herbaceous vegetation planted between working agricultural land and streams or wetlands. They are designed to manage environmental concerns including water quality and can provide habitat for a variety of wildlife species

(Clark and Reeder 2005). The U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) offers several types of herbaceous buffer practices to agricultural producers. Over 15,000 ha of herbaceous buffers have been established in Maryland through the CRP (USDA 2010a). Herbaceous buffers in Maryland are usually planted either to native warm-season grasses or cool-season grasses, with the addition of native wildflowers or introduced legumes (USDA 2009c).

Maintenance is required to keep CRP plantings in Maryland in good condition and functioning properly (USDA 2009c). Mowing is a common maintenance practice to control woody plants and noxious weeds in herbaceous plantings. Mowing is generally not allowed on CRP land during the primary nesting and brood rearing seasons for wildlife (dates vary from state to state), but is allowed during the rest of the year. Maryland's CRP land may not be mowed between 15 April and 15 August (USDA 2009c). Most mowing of buffers in Maryland occurs in late summer or fall (hereafter, fall mowing) and often within a few days of 15 August (P. V. Barry, pers. comm.; J. E. Gerber, pers. comm.). Fall mowing is also a common practice in herbaceous CRP plantings in other states, including Virginia (G. I. Hall, pers. comm.), Ohio (M. D. DeBrock, pers. comm.), and Tennessee (M. E. Zeman, pers. comm.). Fall mowing leaves the vegetation short until growth begins the following spring. Farm managers often choose to mow in fall instead of late winter or spring because they believe shorter grass looks better, the ground may be too wet in spring for mowing, or fall is when they have the most time available (S. V. Strano pers. comm.).

It is recommended that buffers be mowed no more than once every 2 to 3 years, with no more than half of the area mowed in any 1 year (USDA 2009c). A common recommendation is to mow a third of each buffer every year on a 3-year rotation (USDA 2009c). However, some farm managers mow entire buffers each year (PJB, pers. obs.).

Buffers often represent the only uncultivated herbaceous areas on farmland in Maryland and may be important habitat for early-successional birds. Many early-successional bird species, including grassland and scrub-shrub birds, are experiencing substantial population declines and are of high conservation concern (Askins 1993, Hunter et al. 2001). Many studies have evaluated the response of breeding birds to mowing of early-successional habitats (e.g., Swanson et al. 1999, Warren and Anderson 2005, Zuckerberg and Vickery 2006), but few studies have evaluated the effects of mowing on wintering bird communities. We studied the response of wintering birds to fall mowing of herbaceous buffers. We hypothesized that wintering bird abundances, species richness, and total avian conservation value would be less in mowed than in unmowed buffers.

STUDY AREA

The Eastern Shore of Maryland (east of Chesapeake Bay) has ~ 46% of land-cover in farms (USDA 2009a) and 77% of the CRP buffers in the state (USDA 2007). Filter strips (USDA Practice CP21) are the most common type of herbaceous buffers in Maryland (USDA 2010a). We conducted an experiment in 13 filter strips (hereafter, buffers) among two counties (Queen Anne's and Talbot) on Maryland's Eastern Shore.

All buffers selected were installed between 1997 and 2004 and were ≥ 3 years of age at the time of the study. Each buffer was between a rowcrop field and a forested wetland, which is a common location of buffers in Maryland. The adjacent rowcrops had been planted to either corn or soybeans in the previous growing season, and most were planted to winter wheat after fall harvest.

Nine buffers were planted with cool-season grasses and four were planted with warm-season grasses. Common warm-season grasses were big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), and broomsedge bluestem *(A. virginicus).* The most common cool-season grass in buffers was orchardgrass (*Dactylis glomerata*), but other cool-season grasses including red (*Festuca rubra*) and sheep (*F. ovina*) fescue were also planted.

We established two treatments in each buffer: (1) a section (experimental treatment) mowed in fall to 10–15 cm high, and (2) an unmowed section. Mowed and unmowed treatments were randomly located along the length of the buffer and spanned the entire width of the buffer. We established one study site in each treatment. Each study site also spanned the width of the buffer, was ≥50 m from the ends of the buffer and from the interface with the other treatment, and ≥100 m from the other study site in the same buffer. Mowed and unmowed study sites among all buffers were similar ($\bar{x}$ ± SD) in length (mowed: 176.0 ± 50.0 m; unmowed: 176.6 ± 50.3 m).

We defined the width of each buffer as the distance from crop edge to the wooded edge and calculated width by averaging measurements taken every 50 m over the length of the buffer. Buffers ranged in width from 11 to 91 m, and average buffer width was 40.9 m (± 35.7 m). We measured the length of each study site in a Geographic Information System (GIS) and calculated the area of each site by multiplying site width by site length.

METHODS

Vegetation Surveys

We conducted vegetation surveys once at each study site in winter 2007. We established one transect line down the center of the site in buffers <45 m wide, and two transect lines, spaced evenly across the width of the site, in buffers >45 m wide. We measured vegetation structure characteristics within 1-m^2 sampling plots at random distances perpendicular to five points spaced evenly apart along each transect line. Thus, we surveyed vegetation at 5 plots in buffers <45 m wide and 10 plots in buffers >45 m wide. We visually estimated the percent cover (non-overlapping) of grasses, forbs, trees, bare ground, and litter in each plot. We also measured vertical vegetation density (Robel et al. 1970), litter depth, and maximum vegetation height.

Bird Surveys

We conducted three bird surveys at each study site between 19 January and 10 March 2007. All surveys were between 1 hr after sunrise and 1 hr before sunset. We did not conduct surveys in precipitation, fog, or wind >16 km/hr. Bird surveys in the two treatments in the same buffer were subsequent to one another and in random order. Individual birds observed in one study site were not observed to move to any other study sites, and thus study sites were considered independent.

We surveyed birds across the entire width of each buffer by using a strip-transect method with two observers. All surveys were conducted simultaneously by P. J. Blank and J. R. Parks. Our survey method called for each observer to pass within 10 m of each point in the study sites, which is sufficient to determine bird densities in fixed areas of herbaceous habitat (Diefenbach et al. 2003, Roberts and Schnell 2006). We walked parallel to the wooded edge of the buffer ≤20 m apart. The distance between us varied depending on the width of the buffer. We communicated regularly so that individual birds were not counted twice. Nine buffers were ≤40 m wide and required only one pass. Four buffers were >80 m wide and required three passes to survey the entire site. Detection probability of wintering birds in a related study in the same buffers (Blank et al. In Press) was ≥0.89. Given these high rates of detection we made no adjustments for detection to the counts. One observation of an American Kestrel (*Falco sparverius*) observed foraging above a study site during a survey was included in the counts.

Statistical Analyses

We used three bird community metrics to compare the bird use of mowed and unmowed buffers: total abundance, species richness, and total avian conservation value (TACV). The latter is an index used to assess the relative conservation value of different sites that incorporates the biological vulnerability and the regional importance of each species (Nuttle et al. 2003). We calculated TACV by multiplying each species' abundance by its Partners in Flight conservation priority rank (Carter et al. 2000, Nuttle et al. 2003) for the Mid-Atlantic Bird Conservation Region (http://www.rmbo.org/pif/scores/scores.html) and then summing the species-specific TACV scores within a site (Conover et al. 2007, Conover et al. 2009). We categorized each bird species as either a grassland or scrub-shrub species based on literature of species assemblages (Askins 1993, Vickery et al. 1999, Hunter et al. 2001, Sauer et al. 2008, Schlossberg and King 2008, Poole 2010).

We calculated the mean of each bird community metric and species' abundance across the three rounds of bird surveys, and used the means as response variables in statistical analyses. Bird and vegetation metrics were not normally distributed within treatments so we used generalized linear mixed models (GLMM) in Proc GLIMMIX (SAS Institute, Cary, NC) to compare responses in mowed and unmowed treatments. We specified a Poisson distribution for models of bird metrics and either a log-normal or a Poisson distribution for models of vegetation metrics. We treated management type (mowed or unmowed) as a fixed factor, buffer as a random block (to account for the paired study sites), and grass type (cool- or warm-season) as a random factor. We included study site area as an offset in all bird models because study sites differed in area, and included width as a covariate because buffer width influences bird communities (Best 2000, Clark and Reeder 2005). We only analyzed the species-specific responses of Savannah Sparrow (*Passerculus sandwichensis*), Song Sparrow (*Melospiza melodia*), and White-throated Sparrow (*Zonotrichia albicollis*) because we could not fit appropriate models to the distribution of other species due to a lack of detections in most study sites. We considered a test result statistically significant at $P \leq 0.05$.

RESULTS

Vertical vegetation density, maximum height, percent cover of grass, and the percent cover of forbs were significantly greater in unmowed than in mowed buffers (Table 3.1). We detected 412 birds in buffers, of which 98% were in unmowed buffers. We observed 15 species using buffers in winter; five species in mowed and 14 species in unmowed buffers. Eight species were grassland or scrub-shrub birds (Table 3.2) and constituted 91% of all detections. Song Sparrow was the most abundant species (45% of detections), followed by Field Sparrow (*Spizella pusilla*; 19%), and Savannah Sparrow (10%). Savannah Sparrow ($F_{1,12} = 6.36$, $P = 0.027$), Song Sparrow ($F_{1,12} = 16.54$, $P = 0.001$), and White-throated Sparrow ($F_{1,12} = 5.68$, $P = 0.035$) were all more abundant in unmowed than in mowed buffers. Total abundance, species richness, and TACV were all greater in unmowed than in mowed buffers (Table 3.3).

DISCUSSION

The common practice of fall mowing of CRP buffers reduces the use of buffers by wintering birds. All bird community metrics and species' abundances that we tested were significantly greater in unmowed than in mowed buffers, and 98% of all bird detections were in unmowed buffers. Wintering birds use herbaceous habitats for foraging, roosting, and escape cover (Watts 1990, Marcus et al. 2000, Smith et al. 2005b, Conover et al. 2007) and fall mowing removes valuable habitat that wintering birds could otherwise exploit.

These results are especially important because most species detected in unmowed buffers were grassland or scrub-shrub species, two guilds experiencing population declines (Askins 1993, Hunter et al. 2001). Three species detected in buffers (Field Sparrow, Savannah Sparrow, and Dark-eyed Junco [*Junco hyemalis*]) are listed as species of greatest conservation need in Maryland (Maryland DNR 2004). Thus, reducing the practice of fall mowing could provide additional habitat for several birds of conservation concern.

Our findings agree with other studies of wintering bird use in mowed and unmowed herbaceous habitats. Saab and Petit (Saab and Petit 1992) reported relative bird abundance and species richness was lower on grazed pastures maintained by mowing compared to abandoned pastures in Belize. Marcus (2000) found greater sparrow abundance in herbaceous field borders than in mowed field edges in North Carolina.

However, compared to studies of breeding birds, there have been few studies on the response of wintering birds to mowing of herbaceous habitats.

This study focused on the response of wintering birds to fall mowing but did not examine the bird response to mowing at other times of year. Late winter or early spring mowing instead of fall mowing could provide additional habitat for wintering birds. For example, mowing a buffer on 15 March instead of 15 August could provide 7 months of additional unmowed habitat. There are practical reasons why fall mowing may be preferred, including wet weather or lack of time to mow in late winter or early spring, that should be considered prior to altering mowing schedules. Late winter or early spring mowing may also remove critical habitat for wintering birds that may have become dependent on unmowed buffers for food or cover. When mowing is necessary, leaving nearby herbaceous areas unmowed will provide habitat that may be a refuge for some bird species. Following the recommended guideline of mowing 1/3 the area per year will provide more habitat for wintering birds than completely mowing buffers. More research is needed to determine the optimal time of year for mowing that would provide the best habitat for wintering and breeding birds.

MANAGEMENT IMPLICATIONS

Our results clearly indicate the negative impacts of fall mowing of herbaceous buffers on wintering bird communities in Maryland. This study has implications for the mowing schedules of many types of herbaceous habitats, including lawns, meadows, grasslands, and powerline rights-of-ways, and has particular relevance to management of herbaceous CRP plantings. When possible, leaving these herbaceous areas unmowed through winter will likely provide better habitat for wintering birds.

Table 3.1. Vegetation characteristics (mean ± SE) in mowed and unmowed buffers on the Eastern Shore of Maryland, USA, in winter 2007.

	Management type			
Vegetation characteristic	Mowed	Unmowed	*F*	*P*
Vertical density	5.5 ± 0.9	21.9 ± 2.7	115.4	<0.001
Maximum height, cm	3.2 ± 0.1	4.6 ± 0.1	158.3	<0.001
Litter depth, cm	4.7 ± 0.7	4.4 ± 0.7	0.1	0.721
Percent cover				
Grass	3.2 ± 0.2	3.6 ± 0.2	5.1	0.045
Forbs	4.1 ± 2.1	5.7 ± 3.0	8.2	0.016
Trees	0.1 ± 0.1	0.6 ± 0.3	4.0	0.070
Litter	3.9 ± 0.4	3.5 ± 0.4	3.7	0.078
Bare ground	5.1 ± 1.4	2.9 ± 2.6	3.5	0.086

Table 3.2. Mean density (birds/10 ha ± SD) of grassland and scrub-shrub bird species detected in mowed and unmowed buffers on the Eastern Shore of Maryland, USA, in winter 2007.

		Management type	
Common name	Scientific name	Mowed	Unmowed
American Kestrel	*Falco sparverius*	0.0 ± 0.0	0.1 ± 0.5
Eastern Bluebird	*Sialia sialis*	0.0 ± 0.0	0.1 ± 0.4
Field Sparrow	*Spizella pusilla*	0.0 ± 0.0	11.3 ± 34.7
Savannah Sparrow	*Passerculus sandwichensis*	0.6 ± 2.1	7.2 ± 16.2
Song Sparrow	*Melospiza melodia*	2.1 ± 5.3	70.1 ± 60.1
Swamp Sparrow	*Melospiza georgiana*	0.0 ± 0.0	5.5 ± 13.3
White-throated Sparrow	*Zonotrichia albicollis*	1.6 ± 5.7	15.9 ± 51.0
Dark-eyed Junco	*Junco hyemalis*	0.7 ± 2.4	3.4 ± 12.2

Table 3.3. Bird community metrics (mean ± SE) in mowed and unmowed filter strips on the Eastern Shore of Maryland, USA, in winter 2007.

	Management type			
Bird community metric	Mowed	Unmowed	*F*	*P*
Total abundance	0.3 ± 0.2	11.0 ± 3.1	48.77	<0.001
Species richness	0.5 ± 0.3	3.3 ± 0.8	11.03	0.006
Total avian conservation value	0.4 ± 0.2	19.9 ± 5.8	94.43	<0.001

CHAPTER 4: NORTHERN BOBWHITE RESPONSE TO CONSERVATION RESERVE PROGRAM HABITAT AND LANDSCAPE ATTRIBUTES IN MARYLAND AND DELAWARE

ABSTRACT

The Northern bobwhite (*Colinus virginianus*; hereafter bobwhite) has experienced severe population declines in recent decades in the United States. The U.S. Department of Agriculture's Conservation Reserve Program (CRP) could provide additional habitat for bobwhite, leading to an increase in bobwhite abundance. We investigated if bobwhite abundance was related to the percent cover and distribution of CRP land and landscape attributes we hypothesized to be important to bobwhite. We conducted point transect surveys for bobwhite in 139 500-m radius landscapes on Maryland's Eastern Shore and Delaware during the breeding seasons of 2005–2007. The majority of CRP land across our study landscapes was planted to herbaceous filter strips. Bobwhite abundance was positively associated with the percent cover of CRP land and agriculture, but was not related to the spatial distribution of CRP land within the study landscapes. These results suggest that the CRP has created additional habitat for bobwhite in Maryland and Delaware and that landscapes with greater proportions of herbaceous CRP practices support more bobwhite.

INTRODUCTION

The northern bobwhite (*Colinus virginianus*; hereafter bobwhite) has experienced substantial population declines over the last several decades in the United States (Brennan 1991, Burger 2001, Peterson et al. 2002, Sauer et al. 2008). In Maryland and

Delaware the decline in bobwhite populations has been especially steep, with over a 90% decline in the last 40 years (Sauer et al. 2008). Bobwhite declines are linked to factors including weather, harvest, disease, and land cover changes (Guthery 2000, Burger 2001, White et al. 2005). However, the primary cause of bobwhite population declines is the loss or deterioration of bobwhite habitat (Brennan 1991, Guthery 2000, Burger 2001).

Bobwhites prefer relatively open, patchy habitat that includes a mix of shrubs, grasses, forbs, and bare ground (Wilkens and Swank 1992). They utilize a variety of areas for nesting, including grasslands, fallow fields, roadsides, fencerows, pastures, and hayfields (Rosene 1969, Roseberry and Klimstra 1984, Burger 2001, Smith 2004). They often prefer heterogeneous landscapes that contain more cropland, pastureland, and early successional fields, and less forestland (Roseberry and Klimstra 1984, Brennan 1991, Veech 2006b). Leopold (1933) recognized that bobwhite prefer landscapes with high interspersion of cover types and greater amounts of edge habitat. Veech (2006b) suggested that cropland, pastureland, and rangeland together should compose more than half of a landscape in order to sustain populations of bobwhites. Clean-farming practices have reduced the number of weedy fencerows and small fields that once provided nesting and brood-rearing habitat for bobwhite across its geographic range (Brennan 1991). Urban development and an increase in forested land due to plant succession on abandoned farms have also led to a loss of bobwhite habitat (Brennan 1991, Veech 2006b).

The U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) could provide nesting, brood-rearing, and roosting habitat for bobwhite (Burger et al. 1990, Puckett et al. 2000), leading to an increase in bobwhite abundance (Burger et al.

1990, Veech 2006b, Riffell et al. 2008). The CRP offers economic incentives that encourage farm owners to convert highly erodible and other environmentally sensitive agricultural land to perennial, vegetative cover. The goals of the CRP are to improve water quality, reduce soil erosion, and establish wildlife habitat. Of the roughly 34,000 ha of land enrolled in the CRP in Maryland and Delaware, a large percentage is planted to herbaceous filter strips [USDA Conservation Practice (CP) 21; 44.5%], while smaller percentages are planted to herbaceous practices such as introduced grasses (CP1; 12.6%) and native warm-season grasses (CP2; 3.6%) (USDA 2010a). Herbaceous CRP plantings often represent the only uncultivated herbaceous areas on farmland in Maryland and Delaware and therefore may provide important habitat for bobwhite.

Despite being a heavily studied species due to its declining population and its status as an important game bird (Rosene 1969, Burger et al. 1999), few studies have found bobwhite population-level responses to the CRP (Roseberry and David 1994, Best et al. 1998, but see Riffell et al. 2008). For the CRP to be effective at providing bobwhite habitat, evaluating the response of bobwhite to CRP land is needed. Because landscape attributes influence bobwhite abundance (Roseberry and Klimstra 1984, Brennan 1991, White et al. 2005, Veech 2006b), it is also important to assess how landscape features affect bobwhite populations. The objectives of this study were: (1) to determine if bobwhite abundance is related to the percent cover and distribution of CRP land in the landscape, and (2) to assess which landscape attributes influence bobwhite abundance. We conducted this study in response to the needs of land managers and conservation planners seeking to create habitat for bobwhite on agricultural land in the Mid-Atlantic region.

STUDY AREA

Our goal was to select a representative sample of fields with and without CRP plantings in Maryland and Delaware. We selected fields in 4 counties on Maryland's Eastern Shore (Caroline, Dorchester, Queen Anne's, and Talbot) and 1 county in Delaware (Kent). At the time of the study, these 5 counties were composed of approximately 35% farmland (USDA 2009a) and contained about 40% of the CRP across the 2 states (USDA unpubl. data). At least 82% of the CRP land in these counties was planted to herbaceous conservation practices (USDA unpubl. data). Most herbaceous CRP land was planted with native warm-season grasses or introduced cool-season grasses, with the addition of native wildflowers or introduced legumes (USDA 2009c). Common warm-season grasses included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*). The most common cool-season grass in herbaceous CRP in Maryland was orchardgrass (*Dactylis glomerata*; S. Strano, Natural Resources Conservation Service [NRCS], Maryland, pers. comm.), but other cool-season grasses such as red fescue (*Festuca rubra*) and sheep fescue (*F. ovina*) were also planted.

METHODS

Point Transects

Our bobwhite survey protocol followed a modified version of the bobwhite monitoring protocol on upland habitat buffers designed by the Southeast Quail Study Group (Burger et al. 2004). Fields with and without CRP habitat were identified and point transect (Buckland et al. 2001) locations were established on one corner of each field. To improve efficiency and allow for more time to survey other sites, the point was set on the corner of the field that was most accessible by secondary roads or farm lanes. If a road or lane bordered the entire field, the point was randomly chosen from the two corners of the field closest to the road. All point locations were ≥1 km apart.

In the breeding seasons (May–July) of 2005–2007, we surveyed bobwhite at 139 locations. Forty-nine sites were surveyed in 2005, 46 in 2006, and 79 in 2007. One hundred and one sites were surveyed in only one year and 38 sites were surveyed in two different years. Surveys were repeated at each point twice during the breeding season: once in late-May–June and a second time in late-June–mid-July. Surveys were conducted between sunrise and two hours after sunrise. Surveys were not done in >75% cloud cover, >16 km/hr wind, rain, fog, or a dramatic drop in barometric pressure (>0.05 in/Hg). One observer conducted the survey at each point, rotating to face all cardinal directions during the survey.

All distinct calling bobwhite were tallied during 5-minute, unlimited-radius point transects, and the total count represented bobwhite abundance. Therefore, our measure of abundance is an index of abundance based on the number of calling bobwhite and not a measure of actual abundance. The number of calling bobwhite was recorded into 4 distance intervals from the observer (0–50 m, 50–100 m, 100–250 m, and 250–500 m).

Spatial Analysis and Selection of Landscape Metrics

The 139 point transect locations were projected onto a 2001 national land cover dataset (Homer et al. 2004) raster image using ArcMap 9.3 (ESRI, Redlands, CA). The raster image was converted to a polygon shapefile and the land cover classes were reclassified into: open water and emergent wetlands; developed and barren land; forest; or agricultural land (including cropland and pastureland). We merged the reclassified land cover shapefile with a shapefile containing the spatial extent and geographic location of CRP land in Maryland and Delaware obtained from the USDA-NRCS.

We calculated 6 landscape metrics in FRAGSTATS 3.3 (http://www.umass.edu/landeco/research/fragstats/fragstats.html) within 500-m radius (78.5 ha) landscapes centered on each point transect location. This radius was chosen because it approximates the audible range at which an observer is likely to detect a calling bobwhite (Burger et al. 2004). The landscape metrics were: the percent cover of CRP land (%CRP), forest (%Forest), and agriculture (%Ag), the length of total edge (TE), patch density (PD), and the clumpiness index of CRP land (CRP_Clump). We selected these metrics because we hypothesized that they would be important predictors of bobwhite abundance. We predicted that landscapes with greater proportions of CRP land would have more bobwhite. We chose %Forest and %Ag because they were the most common land cover types in our study landscapes and because they have been found to influence bobwhite abundance (Veech 2006b, Riddle et al. 2008, Riffell et al. 2008). TE and PD were chosen because bobwhite may select habitats with greater amounts of edge (Leopold 1933) and because bobwhite nesting locations have been positively associated with landscapes that contain many cover patches (White et al. 2005). CRP_Clump was measured to test if bobwhite abundance was related to the distribution of CRP land, because bobwhite may prefer landscapes where cover is in a block or set of small blocks that are well interconnected (Guthery 2000). The clumpiness index of a land cover class can potentially range from -1 (maximally disaggregated) to 1 (maximally aggregated). CRP_Clump was measured in only 111 landscapes because some landscapes had no CRP land or too little CRP land for CRP_Clump to be estimated.

Statistical Analyses

Probability of detection during surveys of animal populations can vary due to environmental and ecological factors, resulting in biased estimates of abundance (Williams et al. 2002). We used conventional distance sampling in Program DISTANCE 5.0 (Thomas et al. 2006) to estimate the detection probability, density (birds/ha), and abundance of calling bobwhite across our study sites. We right truncated the observations at 500 m so that birds observed outside of the 500-m radius landscapes would not be included in the analysis. We set the distance intervals used during the bobwhite surveys as cutpoints for the detection function, and entered each distance observation as the mid-point of the interval in which it was binned (e.g., observations in the 50-100 m interval were entered as 75 m) (Thomas et al. 2006).

We hypothesized that %Forest could influence the detection probability at a given point count location. To test this hypothesis, we classified each landscape as either low forest cover (%Forest < 12%), medium forest cover (12% < %Forest < 25%), or high forest cover (%Forest > 25%), based on the distribution of %Forest across our study landscapes, and calculated the detection probability within each forest class. We compared models with half-normal and hazard rate key functions and cosine, simple polynomial, and hermite polynomial series expansions (Buckland et al. 2001), and used the model with the lowest Akaike's Information Criterion value adjusted for small sample sizes (AIC_c) (i.e., the most parsimonious model) to estimate the detection probability for each forest class and for all sites combined. The three forest classes had similar detection probabilities (low = 0.32, SE = 0.06; medium = 0.39, SE = 0.07; high = 0.36, SE = 0.09), and detection probability across all sites was 0.36 (SE = 0.04). Given the similarity in detection probabilities across forest classes, we assumed a constant detection probability across all study sites (Williams et al. 2002) and made no adjustments to the original bobwhite counts.

We averaged the 2 bobwhite counts within the same year and used the means for subsequent analyses. We modeled bobwhite abundance as a function of multiple covariates in PROC MIXED in SAS (SAS Institute, Cary, NC), with year as a repeated measure, and used an information-theoretic model selection approach (Burnham and Anderson 2002) to compare competing models. Bobwhite abundance was square root transformed to improve the normality of the residuals. All predictor variables were centered and standardized to improve the interpretability of the regression coefficients (Schielzeth 2010).

We conducted 2 model selection analyses to evaluate the relationships between bobwhite abundance and landscape covariates. The first analysis included data from all 139 landscapes and did not include CRP_Clump because it could not be measured in 28 landscapes (see section on Spatial Analysis and Selection of Landscape Metrics). In this analysis we considered 15 candidate models including combinations of %CRP, %Forest, %Ag, and PD, and a null model. The second analysis was designed to evaluate the relationship between bobwhite abundance and CRP_Clump and was conducted on a subset of 111 landscapes for which we had CRP_Clump values. In this analysis we considered 22 candidate models including the 15 models in the first analysis plus 7 candidate models that included CRP_Clump. We did not include TE in either analysis because it was highly correlated with PD.

We evaluated the candidate models by comparing AIC_c, ΔAIC_c values, and Akaike weights. Models with ΔAIC_c values <2.0 were considered to have more support (Burnham and Anderson 2002). We estimated model parameter uncertainty by using model averaged parameter estimates and estimated the relative importance of predictor variables by summing the Akaike weights across all models in which the variable occurred (Burnham and Anderson 2002). Relative importance values can range from 0 to 1. Spatial autocorrelation is common in ecological datasets collected across geographic space (Legendre 1993) and is problematic in statistical modeling because it violates the assumption of independently and identically distributed errors (Dormann et al. 2007). We tested for spatial autocorrelation among the residuals from the global model in each analysis by using a Moran's I test (Dormann et al. 2007).

RESULTS

The 139 500-m radius landscapes averaged 62% agriculture, 22% forest, and 11% CRP (Table 4.1). One-hundred fifteen landscapes had CRP land. Mean CRP_Clump was 0.66 (SD = 0.21), indicating that most of the CRP land in our study landscapes was aggregated as opposed to randomly distributed or disaggregated. The majority of CRP habitat in the landscapes was herbaceous filter strips (56.7%), wetland restoration (CP23; 7.9%), native warm-season grass plantings (CP2; 7.5%), and existing grass (CP10; 4.4%). At least 77.8% of all CRP land in the study landscapes was planted to herbaceous practices.

The most parsimonious model of bobwhite detection probability was the half-normal key function model without adjustment terms, which adequately fit the data (χ^2_1 = 0.40, P = 0.82). Density of calling bobwhites across all sites was 0.02 bobwhite/ha (CL =

0.01–0.03 bobwhite/ha), and estimated abundance of calling bobwhite across all landscapes was 214 (CL = 149–305 bobwhite).

Three candidate models of bobwhite abundance across all 139 landscapes were well supported ($\Delta AIC_c < 2$; Table 4.2), and each of the four predictor variables we considered were included in the top models. There was strong support that %CRP was positively related to bobwhite abundance. %CRP was included in all models with ΔAIC_c values ≤ 4.2, the 95% confidence interval for %CRP was far from zero ($\beta = 0.37$, CL = 0.25–0.49), and the relative importance of %CRP was 1.0 (Table 4.3). There was also some support for %Ag being positively related to bobwhite abundance. %Ag was included in 2 of the 3 best supported models (Table 4.2), had a positive model averaged parameter estimate ($\beta = 0.12$, CL = −0.01−0.25), and a relative importance value of 0.64 (Table 4.3). There was moderate support for %Forest being negatively associated and PD being positively associated with bobwhite abundance, respectively. Each variable was included in 1 of the 3 best supported models (Table 4.2), however the relative importance values of %Forest and PD were low compared to %CRP and %Ag. There was no significant spatial autocorrelation among the residuals from the global model ($Z = 0.87$, $P = 0.39$).

We found little evidence for a relationship between bobwhite abundance and CRP_Clump in the subset of 111 landscapes for which CRP_Clump could be measured. CRP_Clump was not included in any model with a $\Delta AIC_c < 2.0$, had a relatively small model averaged parameter estimate ($\beta = -0.03$, CL = −0.22−0.17), and a low relative importance value of 0.24. Otherwise, we found the same trends for %CRP, %Ag, %Forest, and PD as in the analysis including all 139 landscapes. To avoid redundancy we do not present tables of the model selection results from this analysis. There was no significant spatial autocorrelation among the residuals from the global model for the subset of 111 landscapes ($Z = 1.35$, $P = 0.18$).

DISCUSSION

We found a strong positive association between %CRP and bobwhite abundance, suggesting a significant population-level response of bobwhite to the CRP in Maryland and Delaware. Because most of the CRP in our study landscapes was planted to herbaceous vegetation, we infer that herbaceous CRP has provided additional habitat for bobwhite leading to an increase in bobwhite abundance. Our results corroborate the findings of Riffell et al. (2008) who reported that bobwhite abundance across their breeding range was positively related to grass-based CRP practices. Herbaceous CRP plantings can provide roosting, brood-rearing, and nesting habitat for bobwhite (Burger et al. 1990, Puckett et al. 2000), and can provide habitat for many grassland bird species (e.g., Johnson and Igl 1995, Best et al. 1997, Veech 2006a, Riffell et al. 2008). Higher bobwhite abundance in CRP habitats could be due to relatively high food availability (e.g., higher invertebrate densities) and therefore higher quality brood cover (Burger et al. 1990).

We are aware of no other study that has evaluated the response of bobwhite to the spatial arrangement of CRP land. We found no evidence that bobwhite abundance is related to the clumpiness (i.e., aggregation) of CRP land in 500-m radius (1-km diameter) landscapes. Therefore, increasing the amount of CRP land within approximately 1 km, regardless of its distribution, may provide additional bobwhite habitat and may increase bobwhite abundance in Maryland and Delaware. However, because most of the CRP land in our landscapes was aggregated, it is possible that there was not enough range in CRP_Clump values to detect an influence on bobwhite abundance.

The vegetation planted and maintained in CRP plantings will affect their usefulness for bobwhite. Warm-season grasses are known to provide nesting, foraging, and brood-rearing habitat for bobwhite (Burger et al. 1990, Guthery 2000) and other ground-nesting birds (e.g., Whitmore 1981, Harper et al. 2007), whereas cool-season grass plantings may not provide the proper vegetation structure and composition necessary for bobwhite (Guthery 2000). For example, tall fescue (*Festuca arundinacea*) is a common cool-season grass planted in CRP fields but provides inferior cover for bobwhites because it grows too dense and lacks sufficient food quality (Barnes et al. 1995). Including perennial forbs in planting mixtures will also provide seeds for bobwhite and may increase the abundance of insects available for bobwhite chicks (Guthery 2000).

Occasional disturbance of CRP habitat is required to reduce litter and vegetation density and to maintain areas of annual weeds and bare ground that are essential for bobwhite (Burger et al. 1990, Brennan 1991, Greenfield et al. 2003). Controlled burning maintains more open habitat and often stimulates the growth of important bobwhite food plants (Brennan 1991). Light discing can improve habitat for bobwhite by encouraging more bare ground and forbs and decreasing litter and grass cover (Greenfield et al. 2002). However, opening vegetation on CRP land must be balanced with the CRP goals of improving water quality and reducing soil erosion.

Our model selection results indicated a positive relationship between bobwhite abundance and %Ag. Landscapes with more agriculture and less forest cover are often associated with higher bobwhite densities during the breeding season (Burger 2001, Veech 2006b, Riddle et al. 2008). Riddle et al. (2008) documented that among farms with experimental field borders established, bobwhite abundance increased more on farms in agriculture-dominated landscapes than on farms in forest-dominated landscapes. Riffell et al. (2008) found that bobwhite were negatively related to forest cover across their range. These results suggest that targeting CRP enrollments for agriculture-dominated landscapes will provide better habitat for bobwhite.

Our results may have been different if severe weather events had occurred during the period of our study. Severe weather, particularly in winter, often leads to sharp bobwhite population declines (Roseberry and Klimstra 1984). For example, heavy snowfall can level weedy vegetation that bobwhite use for cover, and prolonged deep snow coverage can bury food supplies, leading to high winter losses (Roseberry and Klimstra 1984). Availability of woody, brushy, or shrubby cover, that can be used for escape cover and protection from severe winter weather, will be necessary to offset losses during severe weather events (Roseberry 1964, Roseberry and Klimstra 1984).

MANAGEMENT IMPLICATIONS

Our results indicate that the CRP has created additional habitat for bobwhite in Maryland and Delaware and that landscapes with greater proportions of herbaceous CRP practices support more bobwhite. If bobwhite conservation is a priority, conservation agencies should continue to encourage land owners to enroll in the CRP, particularly in herbaceous practices. CRP plantings in agriculture-dominated landscapes as opposed to forest-dominated landscapes will likely provide better bobwhite habitat.

Table 4.1. Landscape attributes calculated from 139 500-m radius landscapes on Maryland's Eastern Shore and Delaware, USA.

Metric	Metric abbreviation	Mean	SD
Percent of landscape			
CRP	%CRP	10.9	12.1
Forest	%Forest	22.1	15.6
Agriculture	%Ag	61.8	18.4
Total Edge (km)	TE	6.5	2.7
Patch density (per 100 ha)	PD	21.7	10.8
Clumpiness index of CRP	CRP_Clump[a]	0.66	0.21

[a] CRP_Clump could only be estimated in 111 landscapes. The clumpiness index of a land cover class can potentially range from -1 (maximally disaggregated) to 1 (maximally aggregated).

Table 4.2. Models of bobwhite abundance on Maryland's Eastern Shore and Delaware, USA, from 2005–2007. Fourteen candidate models were considered. Variables included in the candidate models were percent cover of CRP land (%CRP), Forest (%Forest), and Agriculture (%Ag), and Patch Density (PD). A null model with no fixed parameters was also considered. Models were evaluated by using Akaike's Information Criterion adjusted for small sample sizes (AIC_c). Models with lower ΔAIC_c values and higher Akaike weights (w_i) have more support. Only models with ΔAIC_c <10 (i.e., the models with more support) are shown.

Variables in Model	K[a]	Log Likelihood	AIC_c	ΔAIC_c	w_i
%CRP, %Ag	5	254.30	264.75	0.00	0.26
%CRP, %Ag, PD	6	252.40	265.04	0.29	0.22
%CRP, %Forest	5	255.10	265.55	0.80	0.17
%CRP, %Forest, %Ag	6	254.20	266.84	2.09	0.09
%CRP, %Forest, PD	6	254.40	267.04	2.29	0.08
%CRP, %Forest, %Ag, PD	7	252.40	267.25	2.50	0.07
%CRP	4	259.00	267.30	2.55	0.07
%CRP, PD	5	258.50	268.95	4.20	0.03

[a] K is the number of estimated parameters in the model and includes parameters for the predictor variables, the intercept, error, and the covariance structure.

Table 4.3. Model averaged-parameter estimates, unconditional standard errors, 95% confidence limits, and relative importance values of predictor variables included in candidate models of bobwhite abundance.

Parameter[a]	Estimate	SE	Lower CL	Upper CL	Importance
%CRP	0.37	0.06	0.25	0.49	1.0
%Ag	0.12	0.07	-0.01	0.25	0.64
%Forest	-0.05	0.07	-0.18	0.08	0.42
PD	0.06	0.05	-0.04	0.09	0.41

[a] see Table 4.1 for definitions of abbreviations.

Appendices

Appendix 1. Plant species with nests in filter strips on the Eastern Shore of Maryland, USA. The data are sorted in descending order of the total number of nests found.

				Guild	
Plant species with nest	Common name	Vegetation type	Total nests (n=95)	Grassland bird nests (n=59)	Scrub-shrub bird nests (n=58)
Solidago sp.	Goldenrod	Forb	31	26	8
Rubus sp.	Blackberry and raspberry	Shrub	8	1	8
Rumex crispus	Curly Dock	Forb	7	2	5
Apocynum cannabinum	Indianhemp	Forb	5	1	4
Baccharis halimifolia	Eastern Groundsel	Shrub	5	5	0
Andropogon gerardii	Big Bluestem	Grass	4	4	4
Liquidambar styraciflua	Sweetgum	Tree	4	2	4
Prunus serotina	Black Cherry	Tree	4	0	4
Rosa multiflora	Multiflora Rose	Shrub	3	1	2
Rudbeckia sp.	Coneflower	Forb	3	3	2
Schizachyrium scoparium	Little Bluestem	Grass	3	3	2
Unknown Grass	Grass	Grass	2	2	1
Unknown sp.	Unknown	Forb	2	2	2
Vicia sp.	Vetch	Forb	2	1	2
Asclepias syriaca	Common Milkweed	Forb	1	0	1
Campsis radicans	Trumpet-creeper	Forb	1	1	0
Cirsium arvense	Canada Thistle	Forb	1	0	1
Conyza canadensis	Canadian Horseweed	Forb	1	1	1
Diospyros virginiana	Common Persimmon	Tree	1	0	1
Elymus virginicus	Virginia Wild Rye	Grass	1	1	1

Erigeron sp.	Fleabane	Forb	1	1	0
Juncus sp.	Rush	Grass	1	1	1
Liriodendron tulipifera	Tuliptree	Tree	1	0	1
Onoclea sensibilis	Sensitive Fern	Forb	1	0	1
Panicum virgatum	Switchgrass	Grass	1	1	1
Phytolacca americana	Pokeweed	Forb	1	0	1

[a] *R. allegheniensis* and *R. phoenicolasius*

Appendix 2. Plant species in filter strips on the Eastern Shore of Maryland, USA, observed during vegetation surveys or incidentally.[a]

Scientific Name	Common Name	Symbol
Acer rubrum	Red Maple	ACRU
Achillea millefolium	Common Yarrow	ACMI
Ailanthus altissima	Tree-of-heaven	AIAL
Allium vineale	Wild Garlic	ALVI
Ambrosia artemsiifolia	Common Ragweed	AMAR
Anagallis arvensis	Scarlet Pimpernel	ANAR
Andropogon gerardii	Big Bluestem	ANGE
Andropogon virginicus	Broomsedge	ANVI
Antennaria neglecta	Field Pussytoes	ANNE
Apocynum cannabinum	Indianhemp	APCA
Arctium minus	Common Burdock	ARMI
Asclepias syriaca	Common Milkweed	ASSY
Asparagus officinalis	Garden Asparagus	ASOF
Baccharis halimifolia	Eastern Groundsel	BAHA
Boehmeria cylindrica	Smallspike False Nettle	BOCY
Bouteloua curtipendula	Sideoats Grama	BOCU
Bouteloua gracilis	Blue Grama	BOGR
Bromus inermus	Smooth Brome	BRIN
Bromus tectorum	Cheatgrass	BRTE
Campsis radicans	Trumpet-creeper	CARA
Carex lurida	Shallow Sedge	CALU
Carex vulpinoidea	Fox Sedge	CAVU
Carya tomentosa	Mockernut Hickory	CATO
Cassia fasciculata	Large-flowered Partridge Pea	CAFA
Chenopodium alba	Lamb's Quarters	CHAL
Chondrilla juncea	Rush Skeletonweed	CHJU
Chrysanthemum leucanthemum	Ox-Eye Daisy	CHLE
Chrysanthemum spp.	Daisy	CHRYS
Cichorium intybus	Chicory	CIIN
Cirsium arvense	Canada Thistle	CIAR
Cirsium vulgare	Bull Thistle	CIVU
Commelina communis	Asiatic Dayflower	COCO
Convolvulus arvensis	Field Bindweed	COAR
Conyza canadensis	Canadian Horseweed	COCA
Coreopsis lanceolata	Lance-leaved Tickseed	COLA
Coreopsis tinctoria	Golden Coreopsis	COTI

Croton glandulosus	Tooth-leaved Croton	CRGL
Cyperus esculentus	Yellow Nutsedge	CYRE
Dactylis glomerata	Orchardgrass	DAGL
Datura stramonium	Jimsonweed	DAST
Daucus carota	Queen Anne's Lace	DACA
Desmodium spp.	Ticktrefoil	DESMO
Dianthus armeria	Deptford Pink	DIAR
Digitaria sanguinalis	Crab Grass	DISA
Diospyros virginiana	Common Persimmon	DIVI
Duchesnea indica	Indian Strawberry	DUIC
Echinacea purpurea	Purple Coneflower	ECPU
Eleocharis acicularis	Needle Spikerush	ELAC
Elymus virginicus	Virginia Wildrye	ELVI
Erigeron philadelphicus	Common Fleabane	ERPH
Erigeron strigosus	Daisy Fleabane	ERST
Festuca arundinacea	Tall Fescue	FEAR
Festuca elatior	Meadow Fescue	FEEL
Festuca rubra	Red Fescue	FERU
Gaillardia pulchella	Firewheel	GAPU
Geranium carolinianum	Carolina Cranesbill	GECA
Heterotheca subaxillaris	Camphorweed	HESU
Hypericum perforatum	Common St. Johnswort	HYPE
Impatiens capensis	Jewelweed	IMCA
Ipomoea hederacea	Ivy-leaved Morning Glory	IPHE
Juncus effusus	Soft Rush	JUEF
Juncus tenuis	Path Rush	JUTE
Juniperus virginiana	Eastern Red Cedar	JUVI
Justicia americana	American water-willow	JUAM
Lactuca canadensis	Wild Lettuce	LACA
Lactuca scariola	Prickly Lettuce	LASC
Lepidium virginicum	Wild Peppergrass	LEVI
Lespedeza bicolor	Shrub Lespedeza	LEBI
Lespedeza cuneata	Sericea Lespedeza	LECU
Liquidamber styraciflua	Sweetgum	LIST
Liriodendron tulipifera	Tuliptree	LITU
Lobelia inflata	Indian-tobacco	LOIN
Lobelia siphilitica	Great Blue Lobelia	LOSI
Lolium multiflora	Italian Ryegrass	LOMU
Lonicera japonica	Japanese Honeysuckle	LOJA

Ludwigia spp.	Primrose-willow	LUDWI
Lupinus polyphyllus	Bigleaf Lupine	LUPO
Lychnis alba	White Campion	LYAL
Medicago sativa	Alfalfa	MESA
Microstegium vimineum	Nepalese Browntop	MIVI
Monarda fistulosa	Wild Bergamot	MOFI
Morus alba	White Mulberry	MOAL
Oenothera biennis	Common Evening Primrose	OEBI
Oenothera laciniata	Cut-leaved Evening Primrose	OELA
Onoclea sensibilis	Sensitive Fern	ONSE
Oxalis stricta	Common Yellow Oxalis	OXST
Panicum virgatum	Switchgrass	PAVI
Parthenocissus quinquefolia	Virginia Creeper	PAQU
Phleum pratense	Timothy	PHPR
Physalis pruinosa	Hairy Ground Cherry	PHPR
Physalis subglabrata	Smooth Ground Cherry	PHSU
Phytolacca americana	Pokeweed	PHAM
Pinus taeda	Loblolly Pine	PITA
Plantago lanceolata	English Plantain	PLLA
Plantago major	Common Plantain	PLMA
Platanus occidentalis	Sycamore	PLOC
Polygonum pennsylvanicum	Pennsylvania Smartweed	POPE
Polygonum sagittatum	Arrowleaf Tearthumb	POSA
Potentilla norvegica	Rough Cinquefoil	PONO
Potentilla recta	Rough-fruited Cinquefoil	PORE
Prunus serotina	Black Cherry	PRSE
Quercus rubra	Nortern Red Oak	QURU
Ranunculus spp.	Buttercup spp.	RANUN
Ratibida columnifera	Mexican Hat	RACO
Ratibida pinnata	Prarie Coneflower	RAPI
Robinia pseudoacacia	Black Locust	ROPS
Rosa multiflora	Multiflora-Rose	ROMU
Rubus allegheniensis	Allegheny Blackberry	RUAL
Rubus flagellaris	Common Dewberry	RUFL
Rubus occidentalis	Black Raspberry	RUOC
Rubus phoenicolasius	Wine Raspberry	RUPH
Rudbeckia hirta	Black-eyed Susan	RUSE
Rumex acetosella	Common Sheep Sorrel	RUAC
Rumex crispus	Curly Dock	RUCR

Salix nigra	Black Willow	SANI
Sassafras albidum	Sassafras	SAAL
Schizachyrium scoparium	Little Bluestem	SCSC
Setaria faberii	Chinese Foxtail	SEFA
Smilax rotundifolia	Roundleaf Greenbrier	SMRO
Solanum carolinense	Carolina Horsenettle	SOCA
Solidago spp.	Goldenrod spp.	SOLID
Sonchus asper	Spiny Sowthistle	SOAS
Sonchus uliginosus	Sowthistle	SOUL
Sorghastrum nutans	Indiangrass	SONU
Sorghum halepense	Johnson Grass	SOHA
Specularia perfoliata	Venus' Looking Glass	SPPE
Stellaria media	Common Chickweed	STME
Taraxacum officinale	Common Dandelion	TAOF
Toxicodendron radicans	Poison Ivy	TORA
Tragopogon major	Goat's Beard	TRMA
Tragopogon pratensis	Yellow Goatsbeard	TRPR
Trifolium agrarium	Yellow Hop Clover	TRAG
Trifolium hybridum	Alsike Clover	TRHY
Trifolium arvense	Rabbit's Foot Clover	TRAR
Trifolium pratense	Red Clover	TRPR
Trifolium repens	White Clover	TRRE
Tripsacum dactyloides	Eastern Gamagrass	TRDA
Ulmus rubra	Slippery Elm	ULRU
Verbascum blattaria	Moth Mullein	VEBL
Verbascum thapsus	Common Mullein	VETH
Verbena hastata	Swamp Verbena	VEHA
Verbesina spp.	Crownbeard	VERBE
Vernonia noveboracensis	New York Ironweed	VENO
Veronica spp.	Speedwell	VERON
Vicia cracca	Tufted Vetch	VICR
Viola kitibeliana	Field Pansy	VIKI
Vitis labrusca	Fox Grape	VILA
Xanthium stramarium	Rough Cocklebur	XAST

[a] Plant species names and symbols were checked in the PLANTS Database (USDA 2010b).

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