Using Prescribed Fire and Biosolids Applications as Grassland Management Tools: Do Wildlife Respond?

Brian E. Washburn
brian.e.washburn@usda.gov
United States Department of Agriculture, National Wildlife Research Center
Michael J. Begier
USDA Wildlife Services

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Abstract

Prescribed burning is a management tool commonly used in forested ecosystems in the southeastern United States, but the influence of this method on grassland vegetation and wildlife in this geographic region are unknown. During 2009–2015, we conducted a study to determine if the application of prescribed burning and/or long-term biosolids applications have altered plant communities and/or wildlife use of grassland areas at Marine Corps Air Station Cherry Point, Havelock, NC. We monitored vegetation growth, measured plant community composition, and documented wildlife activity in four study plots for 3 year after the implementation of annual winter prescribed burns. Prescribed burning reduced the amount of litter, increased bare ground during spring and altered the plant community composition relative to areas that were not burned. We observed similar (*P* = 0.55) total birds per 3-min survey using prescribed burn treatment plots (5.6 ± 0.6 birds; $\bar{x}$ ± SE) and unburned (5.0 ± 0.5 birds) plots. Few species-specific differences in avian use of prescribed burned and unburned grasslands were found. In contrast, white-tailed deer (*Odocoileus virginianus*) use of areas that were burned in winter, as well as the adjacent unburned areas, was drastically reduced. Winter prescribed burning appeared to remove forage plants at the time of year deer would use them the most. Our findings suggest that prescribed burning, with and without biosolids, might be a viable grassland management tool to alter wildlife use of grassland areas, specifically white-tailed deer; however, similar research at additional locations should be conducted.

Introduction

Fire was historically a major influence shaping grassland and forested ecosystems in the eastern United States (Waldrop et al. 1992; Elliott et al. 1999; Johnson and Hale 2000; van Lear and Harlow 2000). Prescribed fire is a tool that is widely used by resource management agencies, private landowners, and other entities to mimic previously occurring natural processes (e.g., lightning-caused wildfires; Wood 1998). Burning alters the structure, composition, and patterns of vegetation within wildlife habitats. Consequently, the vegetation communities present within these areas provides habitat for wildlife and directly influences the composition of those wildlife communities.

Prescribed burning has been recognized as an important management tool in the maintenance and manipulation of forested ecosystems in the southeastern United States (Waldrop et al. 1992; Elliott et al. 1999; Main and Richardson 2002). Land managers use prescribed fire in this way because there are several ecological and socio-economic benefits, including reducing the probability of catastrophic wildfires, improving habitat quality for wildlife and livestock, and altering plant communities to favor the growth of tree species valuable for timber and other forest products (van Lear and Harlow 2000; Main and Richardson 2002; Funlendorf et al. 2006). Much of the research regarding applications of prescribed fire to grassland ecosystems has occurred on Midwestern rangelands, most notably native prairie communities (Washburn et al. 2000; Funlendorf et al. 2006; Coppedge et al. 2008), whereas the effects of prescribed burning on vegetation within existing cool-season and native grasslands in the eastern United States is relatively unknown.

Wildlife responses to prescribed burning in eastern grasslands have not been well studied and empirical data regarding these responses are lacking. Prescribed burning of these grasslands and rangelands might alter the attractiveness of these habitats to wildlife by inducing changes in the characteristics of the plant communities contained therein. Such information is essential for land use planners and wildlife managers attempting to assess the environmental impacts of prescribed burning of grassland ecosystems and habitats. This information might be particularly useful for resource managers who are tasked with managing wildlife habitats that are heavily influenced by anthropogenic activities (e.g., parks, nature preserves, airfields, etc…).

The objectives of this study were to compare: (1) plant communities, (2) bird use, and (3) white-tailed deer use of grassland habitats with and without the application of prescribed burning and long-term applications of biosolids. The National Wildlife Research Center Institutional Animal Care and Use Committee approved procedures involving birds and white-tailed deer (QA-1932).

Methods

Study Site

We conducted this study from January 2009 through January 2015 at Marine Corps Air Station (MCAS) Cherry Point, Craven County, North Carolina (lat 34°54'N, long 76°52'W). MCAS Cherry Point is a U.S. Department of Defense aviation facility located on the south side of the Neuse River basin adjacent to Havelock, NC approximately 80 km inland from the Atlantic Ocean. Mean annual precipitation at the study area is 1,300 mm yr^{-1} with 60% typically falling as rain during April – September (Goodwin 1989). The average daily temperature during summer is 26.1 ºC and 8.3 ºC during winter. Soils on the study area consisted of Norfolk loamy fine sands (very strongly acidic, well-drained, moderate permeability), Bragg soils altered by construction methods (extremely acidic, well-drained, moderate permeability), and Rains fine sandy loams (extremely acidic, poorly drained, moderate permeability) (Goodwin 1989).

Grassland habitats on the MCAS Cherry Point airfield are managed in accordance with air safety regulations and mowed during the growing season. These grassland areas consist of a variety of plants, whose origins are likely from post-airfield construction seeding efforts and from the herbaceous layer of Mesic Pine Flatwoods forest communities (Schafale and Weakley 1990) that surround the airfield grasslands. Dominant plants on the study area included tall fescue (*Lolium arundinaceum* (Schreb.) S.J. Darbyshire), bahiagrass (*Paspalum notatum* Flueggé), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), hairy crabgrass (*Digitaria sanguinalis* (L.) Scop.), trumpet creeper (*Campsis radican* (L.) Seem. ex Bureau), goldenrod (*Solidago* sp. L.), poison ivy (*Toxicodendron radicans* (L.) Kuntze), and Virginia creeper (*Parthenocissus quinquefolia* (L.) Planch.).

An integrated wildlife damage management program is conducted at MCAS Cherry Point to reduce the risk of collisions between wildlife (e.g., birds, deer) and military aircraft. Birds common to suburban and grassland areas in coastal areas of North Carolina (e.g., American robin [*Turdus migratorius*], eastern meadowlark [*Sturnella magna*], European starling [*Sturnus vulgaris*], laughing gull [*Larus atricilla*], red-tailed hawk [*Buteo jamaicensis*]) are commonly observed on the airfield at MCAS Cherry Point. We used USDA ITIS (2015) as the source for plant and animal scientific nomenclature.

Prescribed Burning Applications and Study Plots

In November 2011, we established two sets of paired study plots that each contained a 5.25-ha control (unburned) and a 5.25-ha prescribed burn monitoring plots in the grassland areas of the MCAS Cherry Point airfield (Fig. 1). Two plots were established in a northern area of the airfield grasslands that has never received any biosolids. The other two plots were established in a southern area of the airfield grasslands that has annually received surface-applied lime-stabilized biosolids (e.g., sewage sludge) at a rate of 7.6 Mg ha^{-1} on a dry weight basis (using an average of 194 887 L ha^{-1} of water as a carrier) annually during a 27-yr period (1989–2015). The two sets of paired plots were approximately 2 km apart and were similar in distance to forested areas, runways, and other landscape characteristics. Plant communities in the plots were dominated by herbaceous vegetation, consisting of a variety of grasses, forbs, and woody plants.

Prescribed burning activities were conducted during January of 2012 and February of 2013 and 2014. We conducted winter burning activities in late afternoon and early evening when wind was low (2–16 kph), relative humidity was rising (25–60%), and air temperatures ranged from 10 to 20°C (Packard and Mutel 1997).

Vegetation Measurements

Throughout the growing season (April – October), we measured vegetation height each month during 2012, 2013, and 2014. During each month, 30 sample points were randomly selected in each of the 4 study plots using a random numbers table. At each sample point, we measured the vegetation height by placing a 1-m stick vertically and recording the average height (in cm) of living vegetation surrounding the stick (i.e., within 25 cm of the stick).

Plant communities were further described by randomly establishing and sampling 30 1-m^2 herbaceous sampling plots within each study plot during fall of 2011 (1–3 November; prior to prescribed burning), spring of 2012 (23–24 April), fall of 2012 (22–23 October), spring of 2013 (29–30 April), fall of 2013 (13–15 November), spring of 2014 (6–7 May), and fall 2014 (28–29 October). We visually estimated the total vegetative canopy cover (%), bare ground (%), litter (%), and canopy cover (%) of each individual plant species for each herbaceous sampling plot (Bonham 1989). Plant species richness was determined by identifying and counting the total number of different plant species within each herbaceous sampling plot (Bonham 1989). In addition, we determined the relative percent plant community composition of 4 vegetation classes (i.e., grasses, forbs & legumes, vines, and woody plants) by totaling the percent cover of all plants categorized within the vegetation classes within each individual herbaceous sampling plot (Bonham 1989).

Avian Surveys

Bird surveys (3-min fixed area point-counts; Ralph et al. 1995; Bibby et al. 2000) were conducted each month from January 2013 through January 2015, equally distributed among three different time periods (i.e., morning, mid-day, evening). Bird observations were conducted an average of 5.6 days month^{--1} (range = 2–7) starting at randomly chosen plots and times. We observed each study plot from a fixed point within 30 m of the center of the plot for 3 min once during each bird survey. The number of birds observed on the ground or on a plant within the plot, flying and feeding over the plot, or flying over the plot was recorded by species and activity.

White-tailed Deer Surveys

We estimated white-tailed deer (*Odocoileus virginianus*) use of the unburned and prescribed burn study areas, as well as the entire airfield. During 2009–2014, we conducted a total of 148 white-tailed deer surveys (average of 24.7 surveys yr^{--1}) associated with the four study plots. White-tailed deer surveys began approximately 30 min after sunset. During each survey, we used a pick-up truck to travel to each of the four study plots. Using a 1 000 000 candle power spotlight, two observers examined each study plot for a 5-min period and counted the total number of white-tailed deer observed within each plot.

In addition to the deer surveys conducted in the study plots, we evaluated historical and concurrent MCAS Cherry Point airfield white-tailed deer surveys (n = 148; 2.1 surveys per month) conducted by USDA Wildlife Services during 2009–2014. The entire white-tailed deer spotlight survey route was approximately 26.2 km in length and encompassed all portions of the airfield.

Statistical Analyses

Vegetation data (mean vegetation height and plant community composition) were normally distributed. We used 2-way analysis of variance (ANOVA) (Zar1996) to compare vegetation height between control and prescribed burn plots as well as between biosolids-treated and those without biosolids for 2012, 2013, and 2014 independently.

We used two-way analysis of covariance (ANCOVA) and Fisher's Protected LSD tests to compare the plant community characteristics (i.e., total vegetative canopy cover, bare ground, litter, and plant species richness) among the four treatments and six sampling seasons (i.e., spring and fall each year) (Neter et al. 1990, Zar 1996). We used the appropriate pre-treatment (i.e., fall of 2011) plant community characteristics as a covariate.

Two-way ANCOVA and Fisher's Protected LSD tests were also used to compare the vegetation composition components (i.e., grass, forbs & legumes, vines, and woody plants) among the four treatments and six sampling seasons (i.e., spring and fall each year) (Neter et al. 1990 Zar 1996). We used the appropriate pre-treatment (i.e., fall of 2011) vegetation composition components as a covariate.

We wanted to consider only birds actually associated with (e.g., using) the plots and thus removed birds with the “flying” activity codes from the data prior to analyses. Additionally, we assigned all birds observed using the control or biosolids-treated monitoring plots into foraging guilds using a standard classification (DeGraff et al. 1985). We compared bird use (number of birds per 3-min survey) among the four treatments using repeated measures ANOVA and Fisher’s Protected LSD tests (Neter et al. 1990, Zar 1996). We compared the proportion of birds within foraging guilds using the four treatment plots using *G*-tests for goodness-of-fit tests (Zar 1996).

We compared white-tailed deer use (number of deer observed per plot) among the four treatments and before and after burning implementation using two-way repeated measures ANOVA and Fisher’s Protected LSD tests (Neter et al. 1990, Zar 1996). In addition, we compared white-tailed deer relative abundance (total number of deer observed per airfield survey) on the MCAS Cherry Point airfield during 2009–2011 to the relative abundance of deer on the airfield during 2012–2014 using repeated measures ANOVA and Fisher’s Protected LSD tests (Zar 1996). We considered differences significant at $P \leq 0.05$ and conducted all analyses using SAS statistical software version 9.1 (SAS Institute, Cary, NC). Data are presented as mean ± 1 standard error (SE).

Results

Plant Communities

During the first three growing seasons following the implementation of prescribed burning (2012, 2013, and 2014), there was a significant interaction (all $P < 0.001$) between the “burn” and “biosolids” factors for mean vegetation height. Vegetation in the unburned, non-biosolids treated study plot was shorter (all $P < 0.001$) than in the other three study plots in all three years (Table 1).

We found a significant treatment x sampling season interaction for all four plant community characteristics (total vegetative canopy cover: $F_{15,695} = 5.68$, $P < 0.0001$; bare ground: $F_{15,695} = 14.09$, $P < 0.0001$; litter: $F_{15,695} = 14.66$, $P < 0.0001$; and plant species richness: $F_{15,695} = 4.19$, $P < 0.0001$). During the fall of 2012 and 2013, study plots that received biosolids had less total vegetative canopy cover (all $P \leq 0.001$) and more bare ground (all $P \leq 0.001$) than study plots that did not receive biosolids (Fig. 2). Prescribed burn study plots had more bare ground (all $P \leq 0.001$) and less litter (all $P \leq 0.001$) than unburned study plots during Spring of 2012, 2013, and 2014 (Fig. 2).

We found a significant treatment x sampling season interaction for all four vegetation composition components (grass: $F_{15,695} = 4.46$, $P < 0.0001$; forbs & legumes: $F_{15,695} = 5.24$, $P < 0.0001$; vines: $F_{15,695} = 16.21$, $P < 0.0001$; and woody plants: $F_{15,695} = 4.88$, $P < 0.0001$).

Prescribed burning in the burn only study plot altered the plant community within that area by increasing the amount of vines, woody plants, and forbs and legumes (Fig. 3). Prescribed burning also changed the composition of those plant communities by removing blueberry (*Vaccinium* spp. L.) and increasing the amount of Virginia creeper, blackberry (*Rubus* spp. L.), mouse-ear chickweed (*Cerastium brachypodum* (Engelm. ex A. Gray) B.L. Rob.), and three-seed mercury (*Acalypha rhomboidea* Raf.).

The plant communities in the 2 study plots that received biosolids changed rather drastically during the study (2012–2014). The proportion of grasses (primarily tall fescue) decreased while the amount of forbs and legumes [mostly Carolina crane's-bill (*Geranium carolinianum* L.), tall buttercup (*Ranunculus acris* L.), polygonums (*Polygonum* spp. L.), and wild strawberry (*Fragaria virginiana* Duchesne)] increased considerably (Fig. 3). Although these changes occurred in both the prescribed burned and unburned biosolids-treated plots, the shift in plant community composition was more prominent in the prescribed burn plot (Fig. 3).

Avian Responses

During 202 3-min avian point-count surveys, we observed a total of 4,581 individual birds, representing 46 different species. A total of 340 (7.4 %) of these birds were categorized as “pass flying”, a behavior that did not appear to be associated with a study plot. Consequently, these birds were removed from the dataset prior to further analyses.

Overall, we observed birds 4,241 times that exhibited a behavior associated with the study plots (e.g., on the ground in the plot). Forty-four different bird species were observed, but Eastern meadowlarks (36.2 % of observations), European starlings (17.8 %), song sparrows (*Melospiza melodia*; 16.6 %), and killdeer (*Charadrius vociferus*; 4.9 %) were the species most frequently observed during the study (Table 2).

We observed more ($F_{3,760}$ = 2.24; P < 0.001) birds per 3-min survey using (i.e., on the ground or on plants) the two plots that received biosolids than using the two study plots that did not (Table 3). Also, the number of birds per 3-min survey using the burn only treatment plot was higher than bird use of the untreated (control) study plot (Table 3). The diversity of bird species using the four treatment study plots was similar. We observed a total of 28, 28, 30, and 30 individual bird species using the untreated (control), burn only, biosolids only, and burn and biosolids treatment plots, respectively, over the 25-month period.

Limited species-specific variation occurred in bird use of the prescribed burn and unburned study plots. Although most bird species and guilds did not appear to exhibit a preference among the four treatment study plots, a few interesting patterns were evident (Table 3). Fewer eastern meadowlarks ($F_{3,760}$ = 4.43; P = 0.01) used the biosolids only study plot compared to the other 3 treatment plots, whereas shorebirds [excluding killdeer (*Charadrius vociferus*)] were found almost exclusively in the biosolids only plot. Warblers used the 2 plots that did not receive biosolids more ($F_{3,760}$ = 3.22; P = 0.03) than the 2 treatment plots that had biosolids applied; however, the opposite was true ($F_{3,760}$ = 6.83; P = 0.001) for European starlings (Table 3). Song sparrows (*Melospiza melodia*) used the biosolids only plot the most and the untreated (control) study plot the least ($F_{3,760}$ = 5.80; P = 0.003).

Overall, the composition of avian foraging guilds using the unburned and prescribed burned areas were relatively similar (Fig. 4). The proportions of birds within the carnivore, omnivore: ground forager, insectivorous aerial foraging, insectivorous ground gleaning birds, and “other” avian feeding guilds using the 4 treatment plots were similar (all $P > 0.10$). Interestingly, compared to the other 3 treatment plots, a higher

($G_3 = 10.3$; $P = 0.02$) proportion of granivore: ground gleaner birds used the biosolids only treatment plot during this study (Fig. 4).

White-tailed Deer Responses

We conducted white-tailed deer surveys ($n = 71$) within the study plots prior to implementation of prescribed burning (during 2009–2011) and counted a total of 248 white-tailed deer (67 in unburned control plots and 181 in prescribed burn plots). During the white-tailed deer surveys ($n = 67$) conducted within the four study plots after prescribed burning activities (during 2012–2014), we counted a total of 64 white-tailed deer (20 in unburned control plots and 54 in prescribed burn plots).

The relative abundance of white-tailed deer observed in all 4 study plots decreased after prescribed burning was initiated. We found there was a significant treatment x timing (i.e., pre- vs. post) interaction ($F_{3,456} = 9.70$; $P < 0.0001$). Compared to the 3 years prior to burning activities, white-tailed deer use of the 2 plots that were prescribed burned was lower, whereas deer use of the 2 unburned treatment plots was not different (Fig. 5).

During 2009–2014, the abundance of white-tailed deer observed across the entire MCAS Cherry Point airfield was relatively unchanged. The average number of deer observed on the airfield per survey during the 3 years prior to prescribed burning (10.8 ± 1.0) was similar ($F_{1,137} = 2.24$; $P = 0.16$) to the number of deer observed (on average) during the first 3 years after the initiation of prescribed burning (12.9 ± 1.0).

White-tailed deer use of the study plots varied among the months of the year and was highest during winter months (December through March) and lowest during fall (September and October). Prescribed burning of the study plots drastically reduced the use of the burned plots by deer during late winter as well as during summer.

Discussion

Prescribed burning activities resulted in significant changes to the plant communities within grassland habitats on the MCAS Cherry Point airfield. Prescribed burning in winter reduced the amount of litter and increased bare ground in grassland habitats during spring months. The composition of plant communities in grassland areas that were prescribed burned had increased levels of vines, woody plants, and herbaceous forbs and legumes than unburned areas.

Overall, prescribed burning of the grasslands at MCAS Cherry Point had limited influence on the avian communities that used those grasslands. A few species-specific responses to the prescribed burning of grassland habitats were evident. Warblers and song sparrows (*Melospiza melodia*) used the burn only study plot the most, likely attracted by some aspect of the plant community in that area – possibly taller woody plants or forbs that were useful as perch sites and/or foraging substrates (Burger et al. 1990; Millenbah et al. 1996; Norment et al. 1999).

Land application of biosolids influenced the bird communities present in those areas in this study, a finding consistent with a previous study conducted in the grasslands at MCAS Cherry Point (Washburn and Begier 2011). American robins (omnivore: ground forager), European starlings (omnivore: ground forager), and mourning doves (granivore: ground gleaner) were observed almost exclusively in the 2 plots that received biosolids, potentially because these grasslands provided a specific foraging opportunity for these species, such as plant seeds or insects (Delisle and Savidge 1997; Fisher and Davis 2010).

Eastern meadowlarks were the most abundant bird using grassland habitats on the MCAS Cherry Point airfield in this study, a finding consistent with Washburn and Begier (2011). Meadowlarks (omnivore: ground forager) were commonly observed using all 4 study plots, but they were more abundant in the prescribed burn and bio-solids treated plots. These plots had the tallest vegetation and thus the birds were likely using the vegetation in these plots to meet their life-history requirements, such as nesting, singing perches, or foraging (Bollinger 1995; Lanyon 1995; Warren and Anderson 2005).

Prescribed burning of grasslands at MCAS Cherry Point resulted in drastic reductions in white-tailed deer use in both study plots that received winter prescribed burns, as well as the adjacent unburned study plots. This finding was unexpected, as we predicted burning would result in an initial increase in plant diversity and forages available to deer.

White-tailed deer were observed in the grasslands on the MCAS Cherry Point airfield throughout the year, but used those grassland habitats more during winter and spring months (Washburn and Begier 2011). Broad-leaved herbaceous plants [e.g., clovers (*Trifolium* spp. L.), common dandelion (*Taraxacum officinale* G. H. Weber ex Wiggers)] and woody plants comprise the majority of white-tailed deer diets, with relatively small amounts of grass consumed (Nixon et al. 1970; Korschgen et al. 1980; Rose and Harder 1985). Washburn and Seamans (2007) found that decreasing forbs and legumes (via herbicide applications) reduced white-tailed deer use of cool-season grasslands during summer months. In this study, we suspect that the winter prescribed burning activities removed available forages within the study plots concurrent with the time of year that white-tailed deer use airfield grasslands the most.

Conclusions

Prescribed burning and applications of biosolids activities in eastern grasslands altered plant community characteristics and wildlife use of study plots. Prescribed burning altered grassland habitats the most during the first few months following burning activities. Responses by birds to prescribed burning was species-specific and related to foraging guilds of grassland birds. White-tailed deer exhibited a strong negative response to annual prescribed burning in winter. Additional research is needed to determine if and how plant community and wildlife responses to prescribed burning, alone and in conjunction with biosolids applications, of grassland habitats might vary among exotic and native grassland and rangeland system types, among geographic areas, and among other species of wildlife.

Land managers and planners considering the use of prescribed burning in eastern grasslands should consider wildlife responses (both potentially positive and negative) during decision-making processes and cost-benefit analyses. Depending on the goals and objectives associated with wildlife resources within exotic cool-season and native grasslands areas, prescribed burning might be a useful mechanism for accomplishing species-specific habitat management objectives for wildlife, in particular for decreasing white-tailed deer use.

Declarations

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Compliance with Ethical Standards

Conflict of Interest

The authors declare they have no conflict of interest.

Ethical Approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in this study involving animals were in accordance with the ethical standards of the National Wildlife Research Center of the U.S. Department of Agriculture, Animal Plant Health Inspection Service, Wildlife Services.

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Tables

Table 1 Mean (± SE) vegetation height (cm) in four treatment study plots located in grassland habitats on the Marine Corps Air Station Cherry Point airfield, Havelock, NC, during 2012, 2013, and 2014 (the first 3 growing seasons after prescribed burning treatments were applied)

	Untreated Control	Prescribed Burn-Only	Biosolids Only	Burn and Biosolids-treated
-				
2012	19.3 ± 0.8 a[1]	28.8 ± 1.3 b	27.7 ± 1.3 b	29.5 ± 0.9 b
2013	8.6 ± 5.7 a	14.8 ± 0.8 c	13.4 ± 0.7 c	11.0 ± 0.5 b
2014	17.1 ± 0.7 a	29.4 ± 1.4 c	23.4 ± 0.9 b	26.7 ± 1.2 bc

[1] Means within the same row with the same letter are not significantly different ($P > 0.05$).

Table 2 Mean (± SE) no. of birds observed • 3-min survey^{-1} of selected individual species and guilds of birds associated with or in four treatment study plots study plots at Marine Corps Air Station Cherry Point, Havelock, NC, January 2013 through January 2015

Species or Guild	Untreated Control	Prescribed Burn-Only	Biosolids Only	Burn and Biosolids-treated
-				
Eastern meadowlark (*Sturnella magna*)	1.70 ± 0.24 ab[1]	2.24 ± 0.29 a	1.18 ± 0.19 b	2.50 ± 0.33 a
Song sparrow (*Melospiza melodia*)	0.28 ± 0.09 a	1.01 ± 0.24 bc	1.41 ± 0.27 c	0.78 ± 0.17 ab
European starling (*Sturnus vulgaris*)	0.07 ± 0.06 a	0.10 ± 0.06 a	1.62 ± 0.55 b	1.95 ± 0.82 b
Killdeer (*Charadrius vociferus*)	0.03 ± 0.02 a	0.18 ± 0.06 a	0.20 ± 0.07 a	0.61 ± 0.32 a
Mourning dove (*Zenaida macroura*)	0.02 ± 0.02 a	0.01 ± 0.01 a	0.52 ± 0.34 a	0.14 ± 0.10 a
Horned lark (*Eremophila alpestris*)	0.04 ± 0.04 a	0.21 ± 0.11 a	0.20 ± 0.07 a	0.05 ± 0.03 a
American robin (*Turdus migratorius*)	0 a	0 a	0.21 ± 0.12 a	0.37 ± 0.28 a
Northern bobwhite (*Colinus virginianus*)	0.09 ± 0.04 a	0.15 ± 0.07 a	0.02 ± 0.02 a	0.15 ± 0.01 a
Brown-headed cowbird (*Molothrus ater*)	0.06 ± 0.04 a	0.10 ± 0.07 a	0.18 ± 0.17 a	0.14 ± 0.11 a
Red-winged blackbird (*Agelaius phoeniceus*)	0.03 ± 0.03 a	0.09 ± 0.06 a	0.08 ± 0.03 a	0.23 ± 0.08 a
Swallows[2]	0.12 ± 0.04 a	0.16 ± 0.05 a	0.08 ± 0.04 a	0.17 ± 0.06 a

Crows[3]	0.05 ± 0.04 a	0.03 ± 0.02 a	0.03 ± 0.02 a	0.05 ± 0.03 a
Raptors[4]	0.05 ± 0.03 a	0.08 ± 0.03 a	0.10 ± 0.06 a	0.03 ± 0.01 a
Shorebirds[5]	0.01 ± 0.01 a	0 a	0.14 ± 0.08 b	0 a
Warblers[6]	0.04 ± 0.02 ab	0.11 ± 0.04 a	0.01 ± 0.01 b	0.01 ± 0.01 b
All Species Combined	2.66 ± 0.29 a	4.54 ± 0.47 b	7.36 ± 0.92 c	6.44 ± 1.20 c

[1] Means within the same row with the same letter are not significantly different ($P > 0.05$).

[2] Swallows include barn swallow (*Hirundo rustica*), cliff swallow (*Hirundo pyrrhonota*), Northern rough-winged swallow (*Stelgidopteryz serripennis*), tree swallow (*Tachycineta bicolor*), and purple martin (Progne subis).

[3] Crows include American crow (*Corvus brachyrhynchos*) and fish crow (*Corvus ossifragus*).

[4] Raptors include American kestrel (*Falco sparverius*), bald eagle (*Haliaeetus leucocephalus*), Cooper's hawk (*Accipiter cooperii*), Northern harrier (*Circus cyaneus*), red-tailed hawk, and turkey vulture (*Cathartes aura*).

[5] Shorebirds include least sandpiper (*Calidris minutilla*), upland sandpiper (*Bartramia longicauda*), and Wilson's snipe (*Gallinago delicata*); but not killdeer (listed separately above as a species).

[6] Warblers include common yellowthroat (*Geothlypis trichas*), prairie warbler (*Setophaga discolor*), prothonotary warbler (*Protonotaria citrea*), and yellow-rumped warbler (*Setophaga coronata*).

Figures

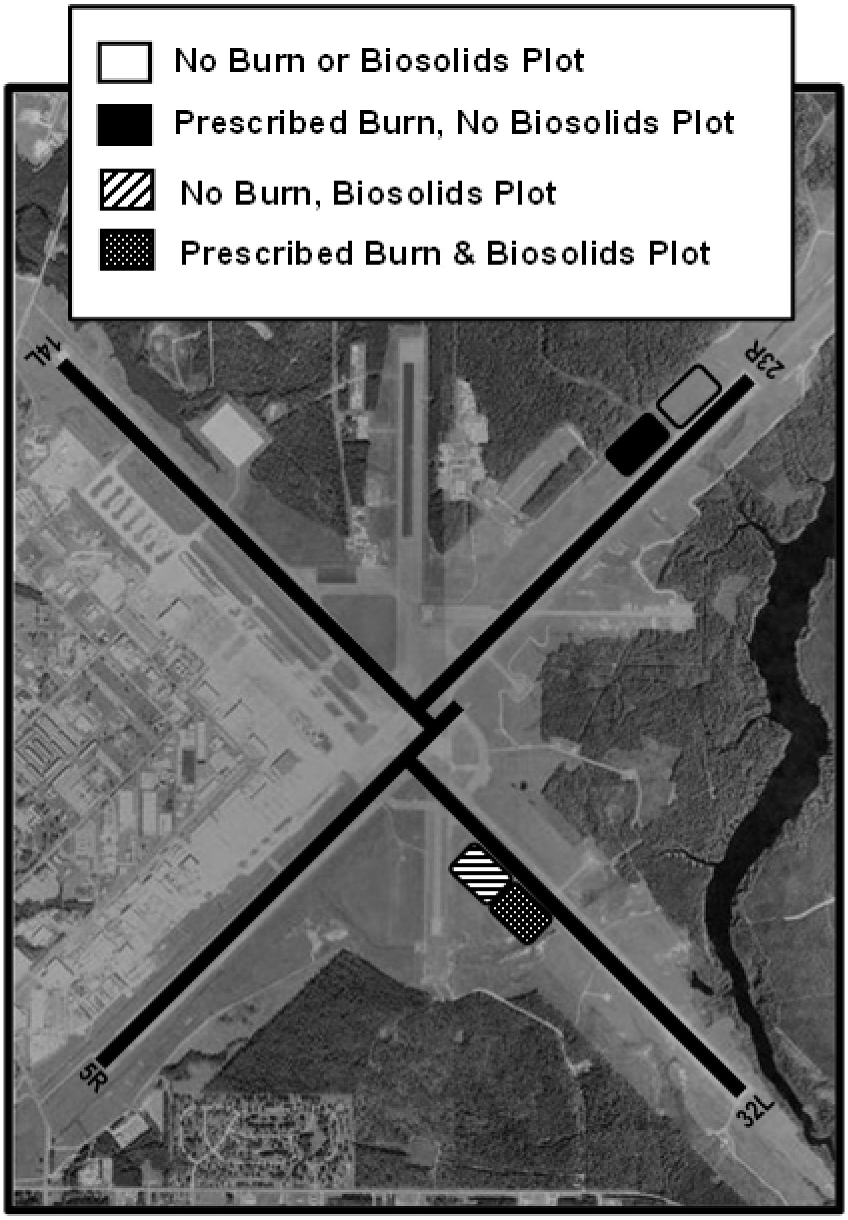

Figure 1

Schematic map of Marine Corps Air Station Cherry Point, Havelock, NC, showing the location of airfield grassland habitats and the location of the 4 treatment study plots

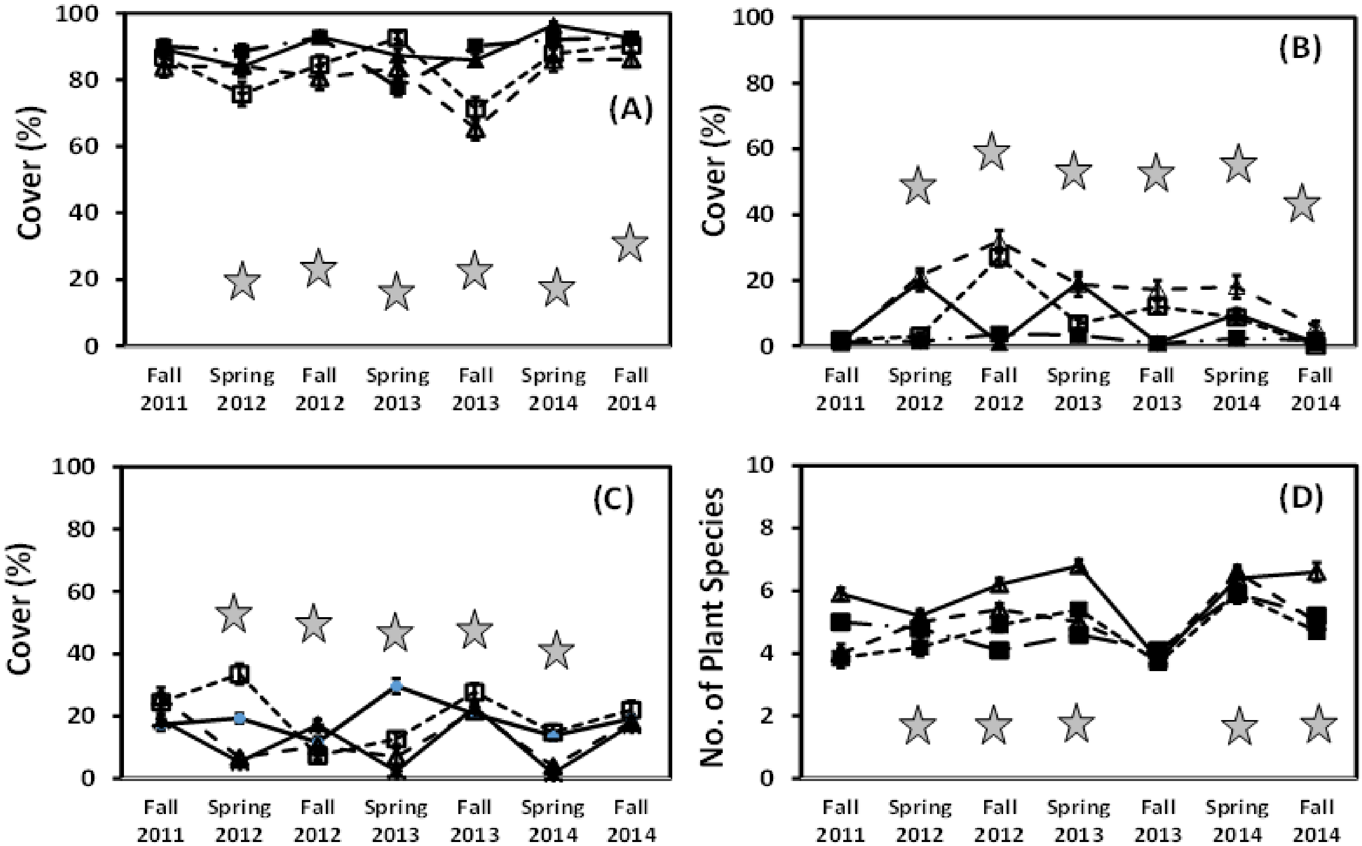

Figure 2

Relative percent cover of plant community characteristics (i.e., (A) total vegetative canopy cover, (B) bare ground, (C) litter, and (D) plant species richness) in four treatment study plots located in grassland habitats on the Marine Corps Air Station Cherry Point airfield, Havelock, NC, during spring and fall of 2012, 2013, and 2014 (after prescribed burning treatments were applied). “Stars” represent sampling periods when 2 or more of the treatment plots were statistically different ($P < 0.05$)

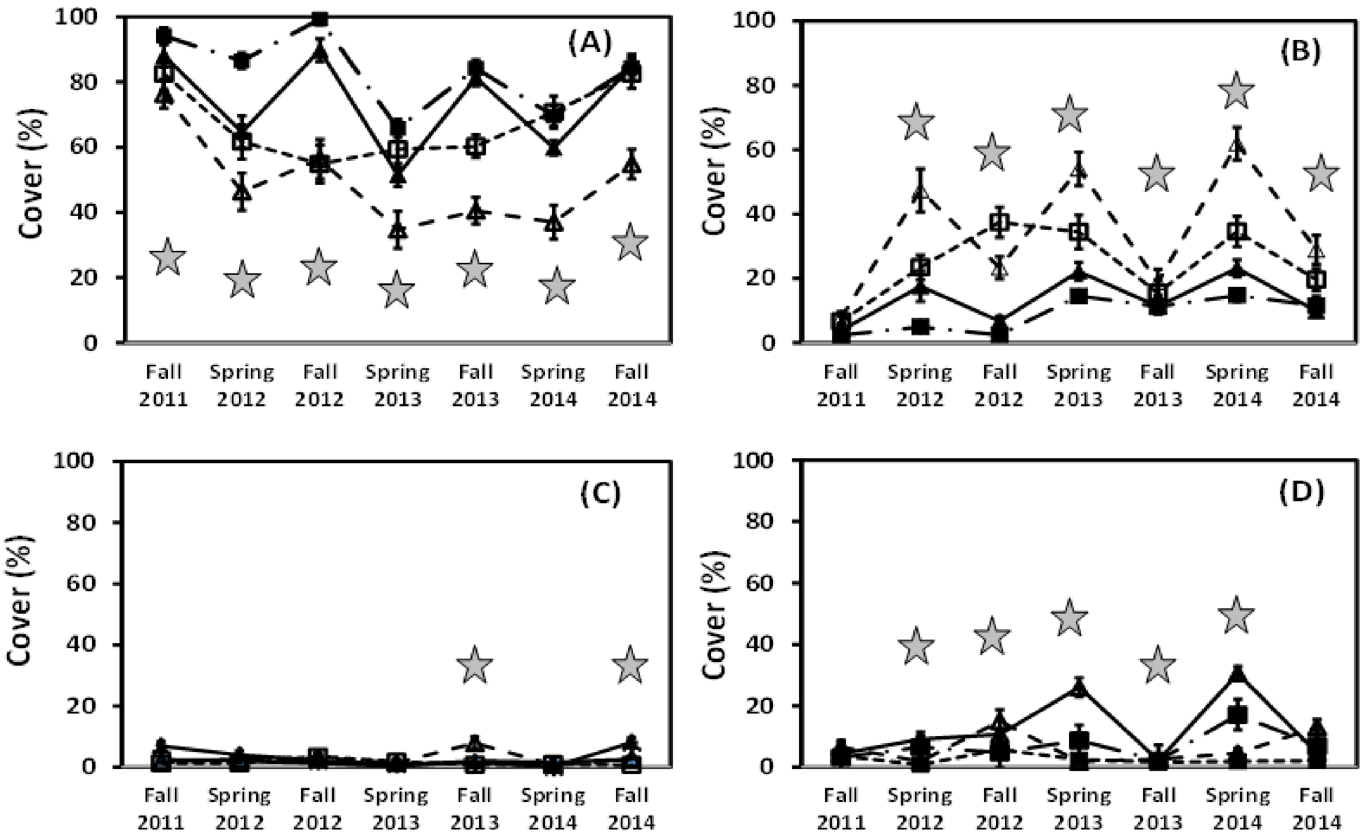

Figure 3

Relative percent cover of vegetation composition components (i.e., (A) grasses, forbs & (B) legumes, (C) vines, and (D) woody plants) in four treatment study plots located in grassland habitats on the Marine Corps Air Station Cherry Point airfield, Havelock, NC, during spring and fall of 2012, 2013, and 2014 (after prescribed burning treatments were applied). “Stars” represent sampling periods when 2 or more of the treatment plots were statistically different

($P < 0.05$)

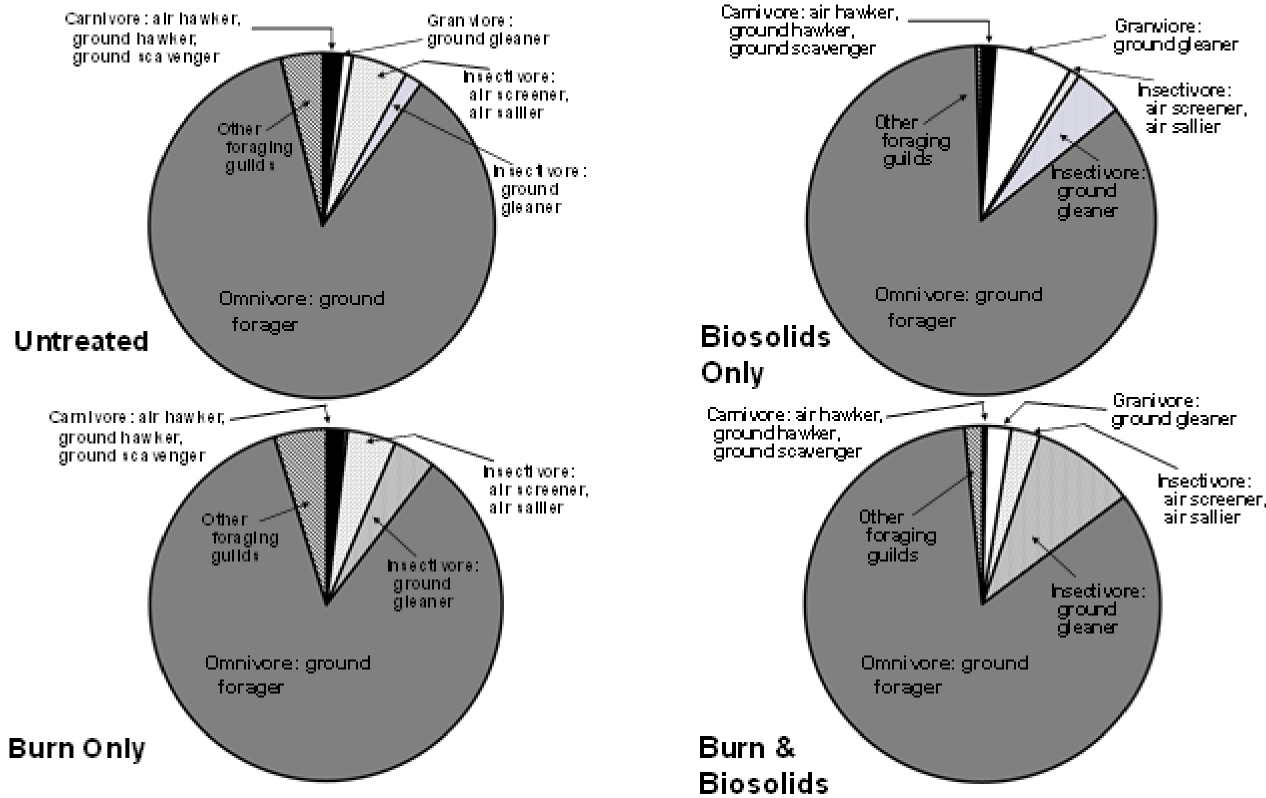

Figure 4

Proportion of birds from various foraging guilds observed using unburned and prescribed burn-treated plots at Marine Corps Air Station Cherry Point, Havelock, NC, January 2012 through January 2015

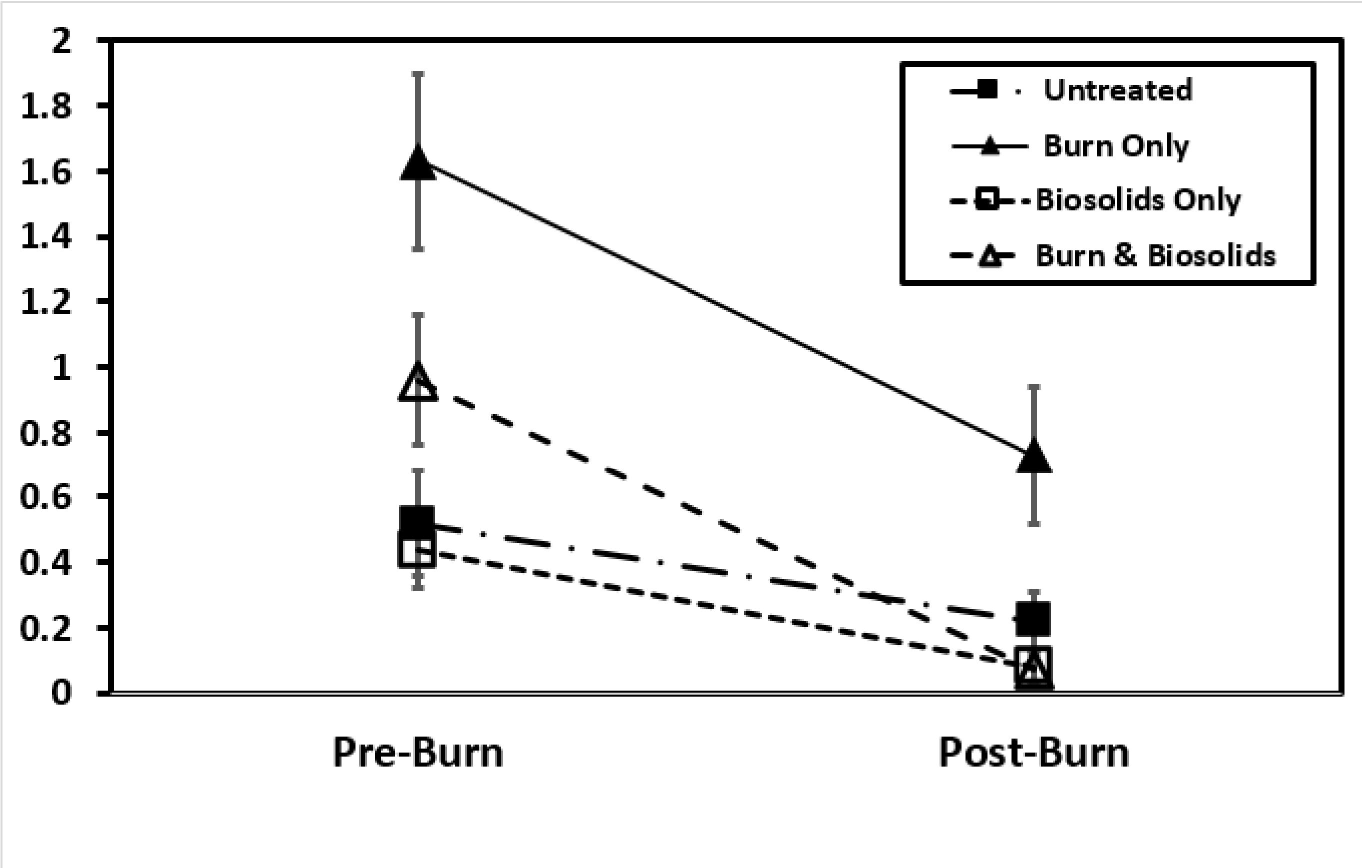

Figure 5

Mean number of white-tailed deer observed per survey in two unburned (one with and one without biosolids) and two prescribed burn (one with and one without biosolids) study plots located on the airfield at Marine Corps Air Station Cherry Point, Havelock, NC during 3-yr prior to (2009––2011) and during the first 3-yr after an annual prescribed burning program was initiated (2012—2014)