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Effects of grassland alteration from mowing and fire on bird activity at a Colorado airfield

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Abstract: Grass management has been used for many years at airports in an attempt to reduce numbers of birds and other wildlife and the collisions with aircraft associated with them. We evaluated the impacts of grassland alteration by mowing and fire on the abundance, diversity, and frequency of birds using 1 control and 2 experimental grass plots from 2009 to 2010 on a U.S. Army airfield in Colorado located in short-grass prairie. Density of breeding birds was highest in the mowed plot. Numbers of birds observed in 34 surveys conducted during the non-breeding season in the burned ($\bar{x}$ = 41) and mowed ($\bar{x}$ = 24) plots were greater than in an unmanaged control ($\bar{x}$ = 7) plot. Bird species diversity in the nonbreeding season was greatest in the control plot. Horned larks (*Eremophila alpestris*) was the most frequently observed bird species and occurred in high numbers on the burned and mowed plots, possibly because of its preference for short vegetation and bare ground. This species is recognized as hazardous to aircraft in part because of its habit of forming large flocks in the nonbreeding season. All 3 study plots were dominated by grasses and forbs, with minimal shrub and cactus cover. Litter cover was greatest on the control plot, while the burned plot had the greatest coverage of bare ground. Results from this study are limited because the small size of the airfield precluded placement of multiple treatment plots. Additional study in larger airfields with multiple treatment plots would be required before management recommendations regarding the use of fire and mowing can be made for airfields in areas with short-grass prairie.

Key words: bird–aircraft collisions, bird strikes, controlled burn, fire management, grass management, habitat alteration, horned lark, human–wildlife conflicts, long grass, short-grass prairie, wildlife hazards

Collisions between birds and aircraft (i.e., bird strikes) have occurred since the beginning of aviation and have resulted in human injury and death, physical damage to aircraft, and airline delays (Blokpoel 1976, Cleary and Dolbeer 2005, Dolbeer et al. 2009). According to the U.S. Federal Aviation Administration (FAA), the average annual cost of bird and other wildlife strikes in the United States to the civil aviation industry is estimated at $123 million. Birds were involved in >95% of these reported strikes with civilian aircraft (Dolbeer et al. 2009). The U.S. Department of Defense Partners in Flight program reported that the average cost of bird and other wildlife strikes to U.S. Navy and U.S. Air Force aircraft exceeded $33 million per year (Eberly 2009). However, because it is estimated that only 20% of actual wildlife strikes are reported (Dolbeer et al. 2009, Eberly 2009), damage calculations may be underestimated. Public awareness concerning the potential hazards of birds to aircraft was markedly raised in January 2009 after a commercial jetliner safely crash-landed in the Hudson River after a collision with Canada geese (*Branta canadensis*; Caudell 2009, Dolbeer 2009).

Many efforts by airfield managers to reduce bird strikes focus on the airfield environment, because most strikes occur at or near airfields, primarily during takeoff and landing (Cleary and Dolbeer 2005, Dolbeer et al. 2009). Several studies in Europe (e.g., Mead and Carter 1973, Brough and Bridgman 1980, Morgenroth 2004) found that tall vegetation reduced the number of birds at airfields. It is believed that tall vegetation reduces numbers of birds by making it difficult for them to forage for invertebrates in the soil, inhibiting their ability to detect predators, and hindering their ability to obtain the wing beats necessary for lift off (Brough and Bridgman 1980, MacKinnon et al. 2001). Airfields used in tall-grass studies conducted in the United Kingdom received applications of fertilizers and were subject to grass cutting and thatch removal (Brough and Bridgman 1980, Civil Aviation Authority 2008). Results of studies examining relations between grass height and bird occurrence and abundance at airfields conducted in the United States have not been conclusive or consistent (Buckley and McCarthy 1994, Barras et al. 2000, Barras and Seamans 2002, Seamans et al. 2007). Airfields used in these studies were not managed beyond grass height and contained many bird species not found in Europe. The European and North American studies have taken place in areas with normally abundant precipitation, such as the United Kingdom and the eastern and central United States. Research is lacking in arid and semi-arid areas of western North America where grasses are shorter and precipitation is typically sparse for much of the year.

Historically, fire was an important component of grassland ecosystems in the United States. Fire restructures the vegetation community by stimulating growth of grasses, preventing grass monocultures, reducing the invasion of woody plants, and reducing ground litter (Mutel and Emerick 1992, Knopf and Samson 1997). Controlled burning has been used by humans as a management tool for reducing fuel loads, improving habitat and forage for wildlife and livestock, increasing biodiversity, reducing invasive plant species, and reestablishing normal cycles of disturbance (Duncan 2003, DiTomaso et al. 2006). Most research on the effects of fire on bird abundance in grassland environments has been conducted in mixed-grass (Johnson 1997, Hands 2007, Grant et al. 2010) and tall-grass prairie habitats (Heckert 1994, Robel et al. 1998, Walk and Warner 2000, Swengel and Swengel 2001). The role of fire in short-grass prairie is poorly understood (Knopf and Samson 1997), and little is known about the overall effects of fire on bird abundances in this habitat.

In this study, we evaluate the impacts of grassland alteration from mowing and fire on birds at a U.S. Army airfield in Colorado. The objectives of the study are to: (1) compare abundance, diversity, and frequency of detection of birds in 1 control and 2 experimental grass plots; and (2) identify bird species observed on the plots that may be hazardous to aircraft. Findings from the study can be used in the Wildlife Hazard Management Plan for the U.S. Army airfield and may be useful to researchers and airfield managers working in similar habitats.

Methods

The study was conducted at the 260-ha Butts Army Airfield (BAAF) on the Fort Carson Military Reservation (FCMR), southwest of Colorado Springs in El Paso County, Colorado (latitude 38° 40′ 44″ N, longitude 104° 45′ 43″ W, elevation 1,779 m). The climate is semi-arid, with precipitation occurring primarily in spring and summer (Mutel and Emerick 1992). The airfield received 38 cm of precipitation in 2009 and 33 cm in 2010 (B. Batty, Detachment 1/3rd Weather Squadron, FCMR, personal communication). The airfield is a fenced perimeter of maintained grasslands and improved areas of pavement, runways, taxiways, aircraft parking pads, hangars, and other buildings. BAAF grasslands are routinely mowed during the growing season to maintain heights of 15 to 30 cm in accordance with Army regulations. The airfield was mowed 3 times in 2009 at irregular intervals dictated by vegetation growth (S. LaCoursiere, BAAF, FCMR, personal communication) and approximately once a month in 2010, starting in May, with a final mowing date of October 1 (M. Hurst, Department of Public Works, FCMR, personal communication). Some of the grassy areas on the north and east sections of the airfield are inhabited by black-tailed prairie dogs (*Cynomys ludovicianus*), which are controlled periodically to mitigate possible collisions with moving runway aircraft and to decrease strike-hazard risks attributable to predators, such as coyotes and raptors.

Three study plots were established in spring 2009. One experimental plot (mowed plot) was established in the northwest portion of the airfield and was maintained by mowing. A second experimental plot (burned plot) was established in the southeast portion of the airfield, which had been burned in a wildfire that occurred on March 3, 2009. This study plot was also mowed as scheduled by BAAF managers. A third unmowed study plot that was not recently burned was established as a control. This plot was located 2 km east of BAAF in an area near the FCMR border where training does not occur. The study plot had minimal disturbance and represented a more natural grassland area similar to what likely existed on BAAF before airfield development. The dominant vegetation on the mowed plot was western wheatgrass (*Pascopyrum smithii*) and blue grama (*Bouteloua gracilis*). The dominant vegetation on the burned and control plots was soapweed yucca (*Yucca glauca*) and blue grama (C. Polzin, Directorate of Environmental Compliance and Management, Fort Carson, Colo., unpublished report). Soils underlying all 3 study plots are loams. Each study plot was 8 ha (200 m × 400 m) and was delineated using plastic marking flags placed at 50-m intervals along 9 transect lines running parallel to the shorter side of the study plot (5 flags per transect line). Study plots were located a minimum of 15 m from any airfield fence boundary and 100 m from any runway. A series of electrical towers with high-tension wires ran diagonally east of the control plot boundary. The closest tower was 25 m from the nearest marking flag.

Table 1. Number of pairs of breeding birds per study plot determined from spot-mapping surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period April 6 to June 27, 2010.

Species	Burned	Mowed	Control
Horned lark (*Eremophila alpestris*)	3.5	6–8	0
Lark sparrow (*Chondestes grammacus*)	0	0	0-1
Vesper sparrow (*Pooecetes gramineus*)	0	1	2–2.5
Western meadowlark (*Sturnella neglecta*)	1.5	1.5	2
Total	5	8.5–10.5	4.5–6

Bird surveys

Spot-mapping (territory mapping) surveys (Robbins 1970, Bibby et al. 2000) were conducted to estimate breeding bird density by counting the number of breeding pairs per study plot. During the breeding season, many birds delineate or define their territories with conspicuous activity, such as singing, defending territories from rivals, and performing courtship displays. Breeding activities were recorded for each species and mapped to show distinct breeding territories per pair in each study plot. Each spot-mapping survey was conducted by 1 observer and began no later than 30 minutes after sunrise. The observer started at one of the 4 study plot corners, which was alternated each time a study plot was surveyed, and walked slowly between transect lines to traverse the entire study plot and cause minimal disturbance to breeding birds. Nine spot-mapping surveys were conducted in each plot from April 6 to June 27, 2010.

Modified area-search surveys were conducted weekly from September 4, 2009, to April 25, 2010, for a total of 34 surveys. Birds are not as vocal during the nonbreeding season, and their behavior patterns may make them inconspicuous. Modified area-search surveys consist of a combination of line transects and flush counts to record all birds present on each study plot (Ralph et al. 1993, Perkins et al. 2000, Roberts and Schnell 2005). Survey times were varied throughout the survey period, but all 3 study plots were surveyed in the same time category each week (e.g., early morning and late afternoon). One observer conducted each survey, walking in a zigzag pattern along and between transect lines, making 17 passes (spaced ~25 m apart) per study plot. The observer stopped at least twice during each pass to listen and visually search for birds or bird activity (e.g., a sparrow foraging in grass). This method was employed to survey the study plot thoroughly and to flush any birds that may have been hidden in vegetation. Each bird detected on a study plot or using the air space above was recorded. Birds used the study plots for foraging, concealment, perching, or resting. Raptors soaring over or hovering above a study plot were recorded. Raptors and other birds flying over a study plot in a point-to-point manner were not recorded. Care was taken to not double count birds. If a single bird or a flock was flushed, the observer noted where it landed so it would not be counted again. We did not survey for the presence of

Table 2. Mean number of birds observed per study plot by season determined from modified area-search surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period September 4, 2009, to April 25, 2010.

	Fall		Winter		Spring	
Plot	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Burned	43.9	8.5	51.5	19.8	19.9	7.6
Mowed	34.9	5.0	9.3	3.9	27.5	8.8
Control	13.2	3.5	3.6	1.0	2.8	0.9

nocturnal owl species for this study because of limited resources and the difficulty in making night observations and identifications.

Vegetation surveys

Vegetation surveys were conducted July 24 to August 16, 2009. Data on aerial cover, canopy cover, plant species, and height were collected (Daubenmire 1959, Wiens and Rotenberry 1981, Martin et al. 1997, Coulloudon et al. 1999). A 20-cm by 50-cm Daubenmire frame was placed on the ground at 5-m intervals along each transect line. Ten samples were taken between flags and combined or averaged to produce a single value for each variable associated with each 50-m section of transect line for a total of 36 survey points per study plot. Cover data were collected using modified Breeding Biology Research and Monitoring Database program protocol methods (Martin et al. 1997) for ground cover classes, while a modified Daubenmire method was used for individual plant species (Daubenmire 1959). Estimates of aerial vegetation cover were made by standing above the Daubenmire frame and examining the vegetation within the frame. Estimated percentages of green vegetation, litter, bare ground, and rock were recorded. Separate estimates of percentage of cover for grasses, forbs, shrubs, and cacti were made and recorded as canopy cover. Each plant species that was detected at a sample point was recorded using the scientific name listed in the U.S. Department of Agriculture, Natural Resource Conservation Service's on-line PLANTS database (U.S. Department of Agriculture 2011). A modified Wiens pole (90-cm wooden ruler) was placed in the Daubenmire frame to determine vegetation height (Wiens and Rotenberry 1981). The height of the tallest item of live or dead vegetation was recorded. Stems were counted and classified into 4 height classes. The numbers of stems in each class were summed and divided by the total number of stems in the Daubenmire frame to yield a percentage estimate for each stem height class.

Analysis

The small size of BAAF and the burn area precluded the establishment of multiple experimental plots. Because of insufficient plot replication, statistical analyses were not performed on the bird count and vegetation data. We provide summary statistics and graphs to show data distributions for bird-count data from modified area-search surveys and samples of vegetation data acquired throughout each plot. Summary statistics were calculated using IBM SPSS statistics software (Release 19.0.0.1, 2010). We used the effective number of species as a diversity measure. The effective number of species is a true diversity measure that can be calculated from other diversity indices (e.g., Gini-Simpson index, Shannon-Wiener index) and provides more intuitive values for interpretation than these indices (Jost 2006). For birds and plants, we calculated the effective number of species from Shannon-Wiener index values (Shannon and Wiener 1963) as exp ($-\sum p_i \ln p_i$), where ln is the natural logarithm, and p_i is the proportion of the *i*th species.

Results

Birds

The highest breeding bird density was observed on the mowed plot (Table 1). Species richness was higher on the control plot (4 species) than the mowed plot (3) and the burned plot (2). The data shown represent pairs of breeding birds.

The mean number of birds observed during modified area-search surveys was calculated by season for each of the study plots (Table 2). The highest mean number of birds in fall and winter was found in the burned plot. The mowed plot had the highest mean number of birds in the spring. The lowest mean number of birds was found in the control plot for all seasons. The

Table 3. Number of birds observed per study plot from modified area-search surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period September 4, 2009, to April 25, 2010.

Common name	Scientific name	Burned plot	Mowed plot	Control
Cassin's sparrow	*Peucaea cassinii*	0	0	0.5
Scaled quail	*Callipepla squamata*	0	0	22
Northern harrier	*Circus cyaneus*	3	4	2
Red-tailed hawk	*Buteo jamaicensis*	1	2	4
Ferruginous hawk	*Buteo regalis*	1	0	0
American kestrel	*Falco sparverius*	11	2	1
Merlin	*Falco columbarius*	0	2	0
Prairie falcon	*Falco mexicanus*	1	0	0
Wilson’s snipe	*Gallinago delicata*	0	1	0
Mourning dove	*Zenaida macroura*	28	4	0
Burrowing owl	*Athene cunicularia*	0	1	0
Say’s phoebe	*Sayornis saya*	0	0	3
Western kingbird	*Tyrannis verticalis*	0	0	2
American crow	*Corvus brachyrhynchos*	1	0	0
Common raven	*Corvus corax*	8	6	0
Horned lark	*Eremophila alpestris*	1,044	681	0
Cliff swallow	*Petrochelidon pyrrhonata*	1	0	0
Barn swallow	*Hirundo rustica*	8	8	0
Mountain bluebird	*Sialia currucoides*	133	27	42
American robin	*Turdus migratorius*	0	0	1
European starling	*Sturnus vulgaris*	10	0	0
American pipit	*Anthus rubescens*	69	29	0
Yellow-rumped warbler	*Setophaga coronata*	0	0	1
Lapland longspur	*Calcarius lapponicus*	4	0	0
Chestnut-collared longspur	*Calcarius ornatus*	7	6	1
American tree sparrow	*Spizella arborea*	0	0	64
Chipping sparrow	*Spizella passerina*	0	0	12
Clay-colored sparrow	*Spizella pallida*	0	0	2
Brewer’s sparrow	*Spizella breweri*	0	0	6
Undifferentiated sparrows	*Spizella* spp.	2	7	13
Vesper sparrow	*Pooecetes gramineus*	28	13	16
Lark sparrow	*Chondestes grammacus*	1	0	0
Lark bunting	*Calamospiza melanocorys*	4	0	0
Savannah sparrow	*Passerculus sandwichensis*	0	0	4
Song sparrow	*Melospiza melodia*	0	0	4
White-crowned sparrow	*Zonotrichia leocophrys*	0	0	1
Undifferentiated sparrow		1	7	10
Western meadowlark	*Sturnella neglecta*	13	18	27
House finch	*Carpodacus mexicanus*	0	0	2
American goldfinch	*Spinis tristis*	18	0	0
Undifferentiated small bird		2	3	0
Total		1,399	821	240

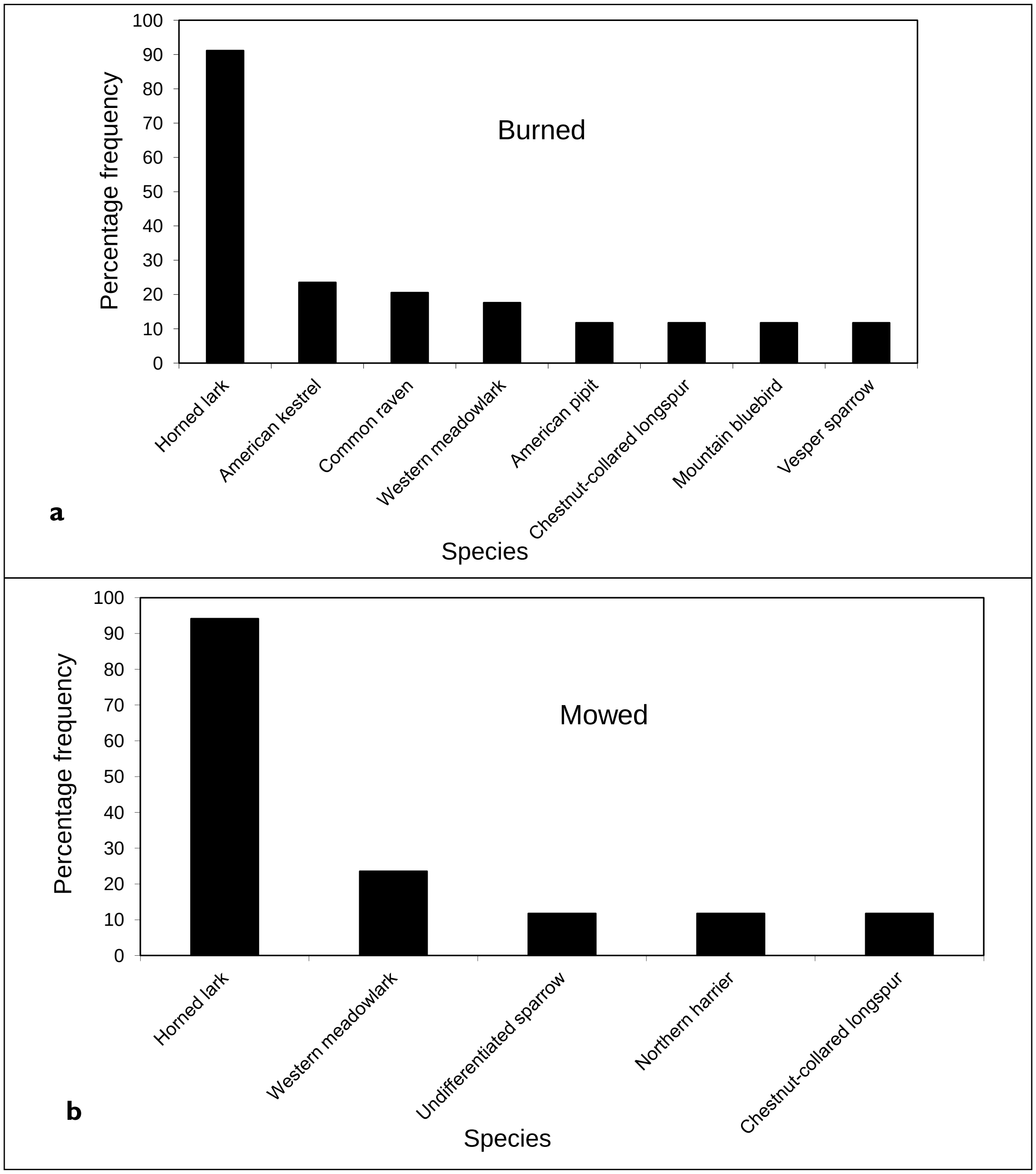

Figure 1. Frequency of detection of bird species observed by study plot (a = burned, b = mowed, c = control) from modified area search surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period September 4, 2009, to April 25, 2010. Species shown were observed on >10% of surveys. (*Figure 1 continued on next page.*)

horned lark (*Eremophila alpestris*) was observed on 91% of surveys on the burned plot and 94% of those on the mowed plot (Figure 1) and was observed in the greatest numbers among all species (Table 3). Among raptors, the American kestrel (*Falco sparverius*) was observed with the highest frequency (24% of surveys on the burned plot), followed by the northern harrier (*Circus cyaneus*; 12% of surveys on the mowed plot) and the red-tailed hawk (*Buteo jamaicensis*; 12% of surveys on the control plot). We observed 24 species in the burned plot, 18 species in the mowed plot, and 22 species in the control plot. The effective number of species calculated was 3.03 for the burned plot, 2.39 for the mowed plot, and 10.7 for the control plot. Overall, the number of bird species observed on the burned and mowed plots was more similar with 15

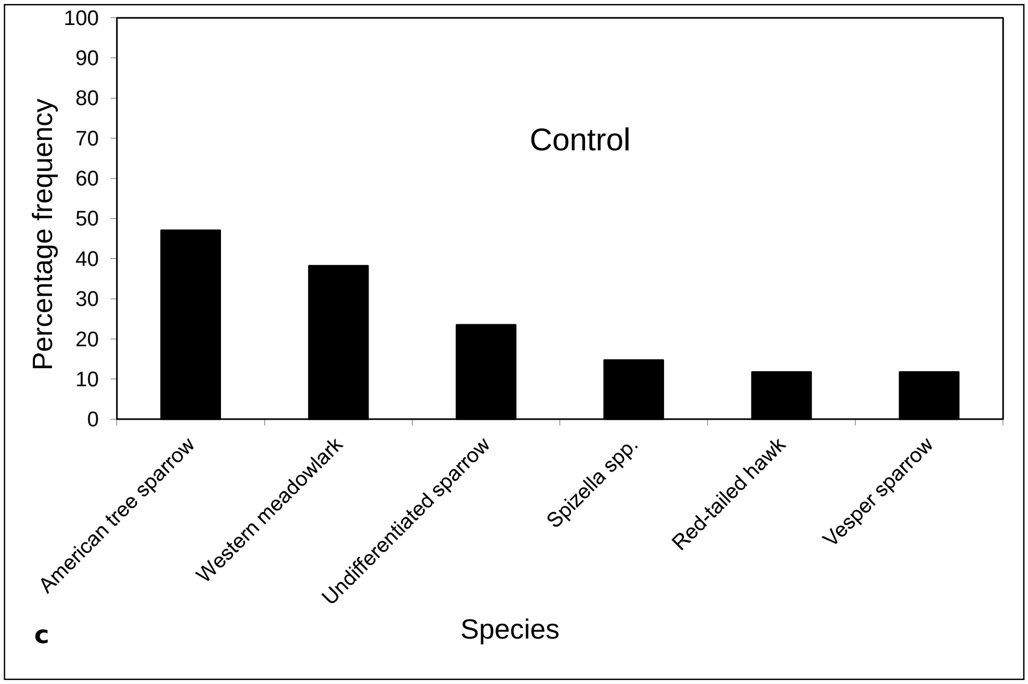

Figure 1 (*Continued from previous page.*)

shared species of the 42 species observed (36% similarity), while the control plot shared fewer bird species with the experimental plots. Control and burned plots shared 9 of 46 bird species (20% similarity), and control and mowed plots shared 9 of 40 bird species (23% similarity).

Zakrajsek and Bissonette (2005) developed a hazard ranking system for individual species or species groups (22 total) that were reported to have caused damage to U.S. Air Force aircraft in the United States. We classified birds observed during modified area-search surveys into these groups (Table 4). The horned lark species group had the greatest number of bird observations in both the burned and mowed plots. On the burned plot, 1,124 individuals in the horned lark group were observed, consisting of horned larks and smaller numbers of American pipits (*Anthus rubescens*), chestnut-collared longspurs (*Calcarius ornatus*), and Lapland longspurs (*C. lapponicus*), which we classified with horned larks. On the mowed plot, 716 individuals in the horned lark group were observed with a similar distribution among constituent species. Other birds observed were distributed in smaller numbers across the blackbird-starling, *Buteo*, and swallow species groups. The fewest hazardous birds were detected on the control plot with

Table 4. Number of hazardous birds observed per study plot from modified area-search surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period September 4, 2009, to April 25, 2010.

Species group[a]	Hazard index[a]	Rank[a, b]	Burned	Mowed	Control
Blackbird-starling[c]	46	4	10	0	0
Buteo (hawk)[d]	30	5	5	6	6
Horned lark[e]	25	6	1,124	716	1
Swallow[f]	23	7	9	8	0
Total			1,148	730	7

[a]Species group, hazard index, and rank developed from military aircraft strike records by Zakrajsek and Bissonette (2005).
[b]Only birds occurring in one of the top ten hazardous groups are shown. Hazard indices for species groups ranking greater than 10 were <2.
[c]Comprised of European starling.
[d]Comprised of northern harrier, red-tailed hawk, and ferruginous hawk.
[e]Comprised of horned lark, American pipit, Lapland longspur, and chestnut-collared longspur.

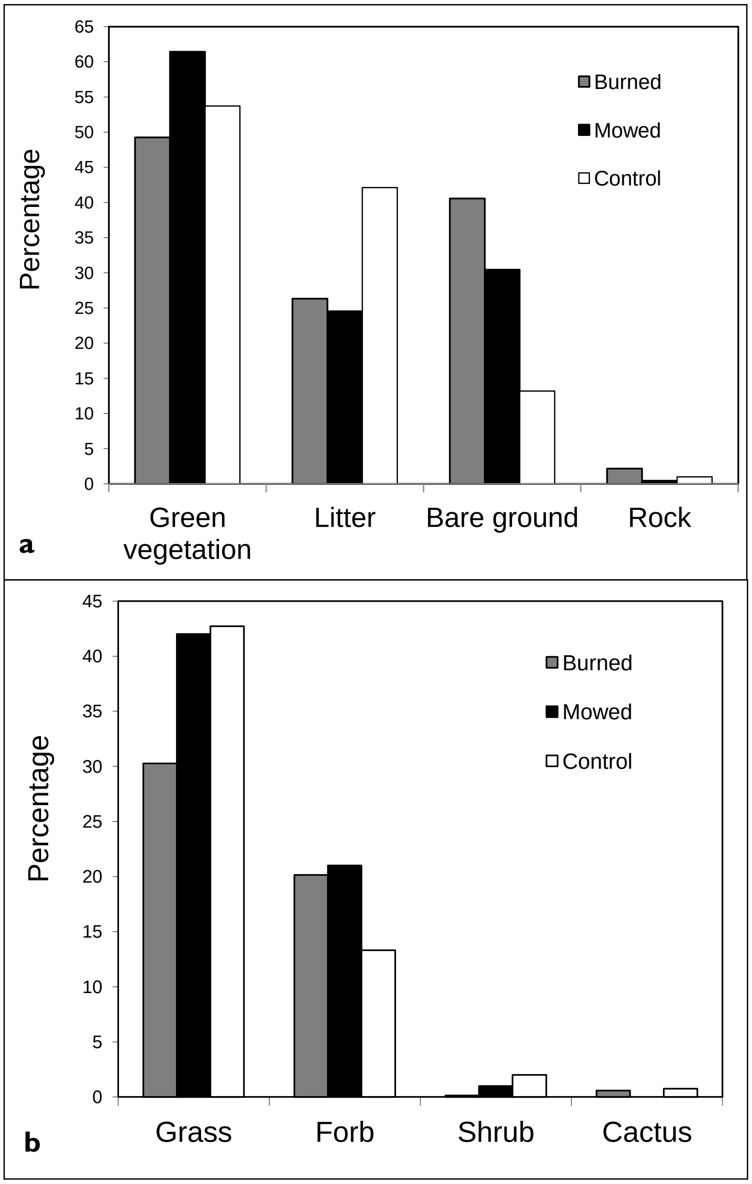

Figure 2. Mean percentages for (**a**) aerial cover types, (**b**) canopy cover types, and (**c**) vegetation height per study plot from vegetation surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period July 24 to August 16, 2009. (*Figure 2 continued on next page.*)

6 individuals from the *Buteo* species group and 1 individual (chestnut-collared longspur) from the horned lark species group.

Birds were also classified into hazard categories developed from bird-strike records for civilian aircraft (Dolbeer and Wright 2009). The number of hazardous species and individual birds showed similar trends in all 3 study plots, with few in the high hazard category and the most in the low and very low hazard categories (Table 5). Birds in the moderate hazard category were mainly mountain bluebirds (*Sialia currucoides*), with a smaller number of mourning doves (*Zenaida macroura*) also contributing to the total observed on the burned plot. Horned larks accounted for the spike in bird numbers in the low hazard category in the burned and mowed plots. During spring and fall migration, mixed sparrow flocks frequented the control plot to forage on grass and forb seeds, which resulted in an increase in the number of birds in the very low category on that plot.

Vegetation

All 3 study plots were dominated by grasses and forbs, with minimal shrub and cactus cover (Figure 2). Over 85% of vegetation in all plots was <20 cm in height. The number of plant species (55) was highest in the burned plot, with 38 species identified on the mowed plot and 46 species identified on the control plot. The effective number of species calculated was 13.6 for the burned plot, 18.4 for the mowed plot, and 13.1 for the control plot.

Discussion

The majority of bird species and individual birds detected on all 3 study plots was ranked low to moderate, using hazard categories previously developed from bird-strike records for civilian aircraft. The number of hazardous individuals observed was lowest in the control plot, with most species on the plot classified as a very low hazard to aircraft. Species observed on the study plots ranked higher within hazardous bird groups developed from military bird-strike records, with the horned lark and associated species dominating numbers of hazardous birds observed on the burned and mowed plots. The horned lark was the most abundant bird species observed at BAAF. More horned larks bred on the burned and mowed plots than any other species, and the horned lark was the most frequently detected species on these plots in the nonbreeding season. The species did not breed on the control plot, and only 15 individuals were observed flying over this plot in the nonbreeding season.

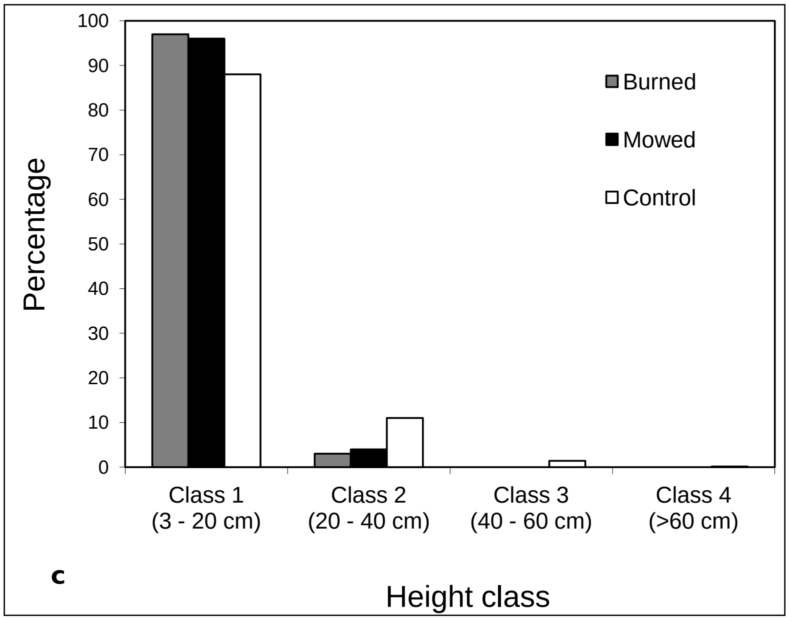

Figure 2 (*Continued from previous page*).

Because of its relatively small size, the discrepancy in hazard rankings for horned lark between military and civilian airfields may be the result of differences in airport operations and underreporting of collisions between aircraft and this species at civilian airfields (Zakrajsek and Bissonette 2005). The horned lark was the most frequently struck of species assessed by the U.S. Air Force (<www.afsc.af.mil>, March 25, 2011, unpublished data), and is the most abundant bird species in Colorado (Ryder 1998). BAAF had no documented bird strike or other wildlife strikes, but strike records from 3 Colorado airports <80 km from BAAF (i.e, Colorado Springs Municipal Airport, Pueblo Memorial Airport, and the U.S. Air Force Academy) showed that the horned lark was the most frequently struck species at each facility (Darrow 2009; Federal Aviation Administration 2010; D. Bell, U.S. Air Force Academy, personal communication). Damage costs from strikes with horned larks at these airports were minimal or not reported.

During the nonbreeding season, horned larks form large, nomadic flocks that move in search of food, primarily forb and grass seeds. Horned larks and associated species often foraged in prairie dog colonies on and adjacent to the airfield where grass was shorter and more bare ground was present than in the surrounding grasslands. Barren areas are particularly important for foraging when snow cover is present. Flock size of horned larks and associated species can reach several hundred birds in snow-free areas (Beason 1995); large

Table 5. Number of hazardous birds observed per study plot from modified area-search surveys conducted at Butts Army Airfield, Fort Carson, Colorado, during the period September 4, 2009, to April 25, 2010.

Hazard category[a]	Burned	Mowed	Control
High[b]	10	8	4
Moderate[c]	173	31	43
Low[d]	1,144	740	30
Very low[e]	54	42	138
Total	1,381	821	215

[a]Hazard categories developed from civilian aircraft strike records by Dolbeer and Wright (2009).
[b]Comprised of red-tailed hawk, American crow, common raven.
[c]Comprised of ferruginous hawk, prairie falcon, mourning dove, mountain bluebird, American robin, European starling.
[d]Comprised of northern harrier, Wilson's snipe, burrowing owl, horned lark, American pipit, Lapland longspur, chestnut-collared longspur, lark bunting, western meadowlark.
[e]Comprised of American kestrel, merlin, Say's phoebe, western kingbird, swallows, sparrows, undifferentiated small birds.

flocks of horned larks (≤150 birds) were observed foraging on bare ground patches in the burned plot when snow cover was present, as well as on and at the edges of runways. Horned larks and associated species were also observed foraging singly or in small flocks (≤15 birds) on runways and other paved areas at BAAF in search of insects that were attracted to paved areas during warm days.

In addition to flocking, horned larks may pose other potential threats to aircraft. Horned larks attract raptors that prey on small birds. During a modified area-search survey, an airborne merlin (*Falco columbarius*) dove toward the ground and pursued a horned lark around the mowed plot. Male horned larks are known to perform elaborate aerial flight songs, singing while ascending in a circular pattern as high as 250 m above ground level (AGL), then diving rapidly back to the ground. These flight songs can last as little as 28 seconds or as long as 8 minutes (Beason and Franks 1974). During spot-mapping surveys, male horned larks were observed performing aerial flight songs greater than 100 m AGL.

Greater areas of bare ground in the burned and mowed plots may have deterred breeding by some grassland bird species that prefer vegetation cover for nest concealment and protection but attracted large flocks of horned larks, especially during snowy conditions. Taller vegetation may deter the presence of horned larks and associated species in areas where they occur. The ability to attain higher target vegetation heights may vary from year to year, however, because of natural variation in precipitation. Vegetation may be shorter than a targeted range if precipitation is low. Maintaining stands of tall grass is difficult, and the cost may be high for many airports in semi-arid and arid regions because of varying soil conditions and the requirements for application of irrigation and fertilizers (MacKinnon et al. 2001, Cleary and Dolbeer 2005). Additionally, vegetation height is a single factor that may not adequately explain the presence or absence of birds using grassland habitats (Seamans et al. 2007). Vegetation density and other factors may influence bird usage in short-grass prairie and other grassland habitats. Mowing forbs and grasses before seeds form may deter flocking birds and reduce potential strike hazards. The mower height should be optimized to cut seed heads but not significantly reduce vegetation height if one is managing for taller grass. This objective may be difficult to achieve, because timing of seed production and height of seed heads varies by plant species and perhaps in response to precipitation. Alternatively, herbicides could be applied to reduce or eliminate undesirable species in favor of those producing minimal seeds.

Results from this limited study showed that single plots managed by mowing and a combination of burning and mowing contained greater numbers of birds (particularly horned larks) than an unmanaged plot. Further study in a larger airfield with multiple treatments and control plots would be necessary to determine if burning or mowing cause increases (or perhaps decreases) in hazardous bird numbers in areas with native short-grass prairie. Monitoring programs should be established to detect changes in numbers and species of birds and other wildlife over time whenever an airfield vegetation management strategy is altered (Deacon and Rochard 2000, MacKinnon et al. 2001, Barras and Seamans 2002, Cleary and Dolbeer 2005). It is crucial to know which species pose the greatest bird-strike risk so that changes in habitat management do not inadvertently create a more attractive environment for high-risk species that were previously absent or present at low abundance.

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