Research Article

Abundance of Diurnal Raptors in Relation to Prairie Dog Colonies: Implications for Bird–Aircraft Strike Hazard

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ABSTRACT Some diurnal raptors are frequently observed at prairie dog (*Cynomys* sp.) colonies. As a result, some military installations have conducted prairie dog control activities to reduce the bird–aircraft strike hazard (BASH) potential of low-flying aircraft. To evaluate the validity of this management strategy, we assessed raptor associations with prairie dog colonies at 2 short-grass prairie study areas: southern Lubbock County, Texas, USA, and Melrose Bombing and Gunnery Range in east-central New Mexico, USA. We quantified diurnal raptors (i.e., Falconiformes) at plots occupied (colony plots) and unoccupied (noncolony plots) by black-tailed prairie dogs (*Cynomys ludovicianus*) at both sites throughout 2002. We compared the number of individual birds of a given species at colony and noncolony plots within each study area by season. Ferruginous hawks (*Buteo regalis*) and northern harriers (*Circus cyaneus*) were more abundant at colony plots, whereas Swainson's hawks (*B. swainsoni*) and American kestrels (*Falco sparverius*) were more abundant at noncolony plots. Red-tailed hawk (*B. jamaicensis*) abundance did not differ between the 2 plot types. Our results suggest prairie dog control as a method of reducing BASH potential may be effective at some sites but may be ineffective or even increase the BASH potential at others. Thus, bird-avoidance models assessing the BASH potential should be conducted on a site-specific basis using information on relative and seasonal abundances of individual raptor species and the relative strike risks they pose to aircraft. (JOURNAL OF WILDLIFE MANAGEMENT 71(3):811–815; 2007)

DOI: 10.2193/2006-373

KEY WORDS bird–aircraft strike hazard, black-tailed prairie dog, *Cynomys ludovicianus*, Falconiformes, hawk, raptor.

Aircraft collisions with birds are a serious economic and human safety issue. This has become increasingly problematic due to increases in air traffic and populations of some species of birds that pose a high bird–aircraft strike hazard (BASH; Dolbeer et al. 2000, Sodhi 2002, Cleary et al. 2004). Cleary et al. (2004) estimated that from 1990 to 2003, wildlife strikes cost the United States civil aviation industry $502.9 million per year, with the majority of this cost resulting from collisions with birds. Furthermore, bird strikes resulted in 124 human injuries and 8 fatalities over the same time period (Cleary et al. 2004). Similarly, the United States Air Force (USAF) experienced an average of $35 million per year in bird-strike damage from 1985 to 1998 (Zakrajsek and Bissonette 2005). For both human safety issues and economic concerns, it is important to develop and implement sound wildlife management techniques to reduce BASH potential (Sodhi 2002, Zakrajsek and Bissonette 2005).

Raptors pose a BASH risk because of their comparatively large body sizes and the habit of many species of soaring over large, open grasslands such as airfields. From 1990 to 2003, diurnal raptors (including Cathartidae and Falconiformes) were the third most common bird group struck by United States civil aircraft (exceeded by gulls [Laridae] and doves [Columbidae]) and the third most common group involved in strikes resulting in aircraft damage (exceeded by waterfowl [Anatidae] and gulls; Cleary et al. 2004). Red-tailed hawks (*Buteo jamaicensis*) were involved in 445 strikes with USAF aircraft from 1985 to January 2005, making them the ninth most commonly struck species and ninth most costly (>$13 million) species in terms of damage caused (Air Force Safety Center 2005). Of 21 wildlife species or species groups ranked by relative hazard to civilian aircraft in the United States, Dolbeer et al. (2000) concluded that *Buteo* hawks are the eighth most hazardous species or group, eagles ninth, and American kestrels (*Falco sparverius*) sixteenth. Similarly, a hazard index developed by Zakrajsek and Bissonette (2005) ranked vultures (Cathartidae) as the highest risk species and *Buteo* hawks as fifth; other raptor species and groups were ranked from seventeenth to twenty-second. However, 46 species or species groups were allotted into the 22 ranks, indicating multiple ties for rankings (Zakrajsek and Bissonette 2005).

Regardless of ranking scheme or types of aircraft, birds of prey appear to pose a substantive BASH risk (Dolbeer et al. 2000, Cleary et al. 2004, Air Force Safety Center 2005, Zakrajsek and Bissonette 2005). This has led to control of black-tailed prairie dogs (*Cynomys ludovicianus*) in some localities as a method to decrease potential BASH risk associated with raptors (Robinette 1992; D. Davis, Melrose Bombing and Gunnery Range [MBGR], personal communication). This management strategy is based on the premise that prairie dog colonies attract raptors, thereby increasing BASH risk. Indeed, some diurnal raptors appear to be

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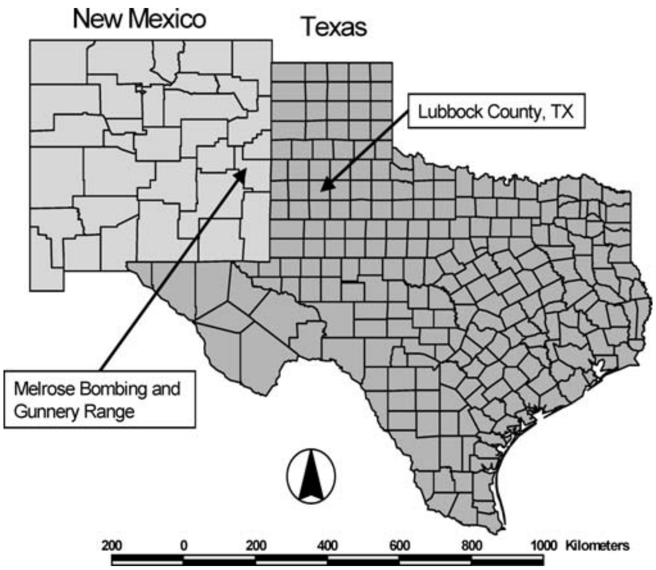

Figure 1. Study sites for assessing associations of raptors with black-tailed prairie dog colonies at Melrose Bombing and Gunnery Range in Roosevelt County, New Mexico, USA, and southern Lubbock County, Texas, USA, 2002.

associated with prairie dog colonies. Previous studies addressing raptor–prairie dog relationships have focused on ferruginous hawks (*B. regalis*; Schmutz and Fyfe 1987, Plumpton and Andersen 1997, Bak et al. 2001, Giovanni 2005), the abundance of raptors during plague-induced prairie dog declines (Cully 1991, Seery and Matiatos 2000), or the relative abundance of raptors at survey plots in relation to plot distances from prairie dog colonies (Berry et al. 1998). There is little information concerning associations or dissociations between Falconiformes and prairie dog colonies or associated seasonal influences. Perhaps more importantly, previous studies were, by design, only capable of identifying positive relationships between raptors and prairie dogs. No studies have assessed the possibility that some raptor species may be equally distributed across grasslands or more abundant in grassland areas without prairie dog colonies.

We conducted this study to quantify the relative abundance of raptors whose distributions may differ in grasslands occupied and unoccupied by prairie dogs. We describe species-specific patterns of relative abundance of raptors at areas occupied and unoccupied by prairie dogs and use the information to assess the efficacy of prairie dog control as a management strategy to reduce BASH risk.

STUDY AREA

We conducted this study at 2 short-grass prairie sites located approximately 190 km apart within the Southern High Plains (Fig. 1). The first study area was at approximately 1,002 m elevation in southern Lubbock County, Texas, USA (LCTX). The second study area was on, and in the vicinity of, the USAF's MBGR, a low-level bombing and strafing training site situated at an elevation of 1,326 m in east-central New Mexico, USA. Both areas were generally level with few topographic features. Average daily temperatures in the region were approximately 24.5° C in summer and 4.8° C in winter (Thompson 2003). Historically, these areas were short- and mixed-grass prairies dominated by buffalograss (*Buchloë dactyloides*) and blue grama (*Bouteloua gracilis*), with some low shrubs, especially mesquite (*Prosopis gladulosa*), and cholla and prickly pear cactus (*Opuntia* spp.; e.g., Savage 2004). During our study the MBGR was predominantly open rangeland used for cattle production, whereas agriculture, especially cotton (*Gossypium hirsutum*) production, was the dominate land use in the LCTX area.

METHODS

We measured the relative abundance of raptors using 300-m fixed-radius point counts (Berry et al. 1998, Bak et al. 2001). At each study area we established survey plots occupied by active prairie dog colonies (colony plots) and plots unoccupied by prairie dogs (noncolony plots). We separated plots by at least 1 km and we located noncolony plots $\geq$1 km from the nearest prairie dog colony. Each plot consisted of $\geq$50% grassland, and all were traversed by power lines and associated support structures to assure that perch-site availability was similar for all plots. Seven colony plots and 4 noncolony plots were located in LCTX, and 4 colony and 4 noncolony plots were located at MBGR.

At each site we established a fixed route encompassing all plots. We conducted counts within each plot along the survey routes in the morning and evening, beginning 30 minutes after sunrise and ending 30 minutes before sunset, respectively. Each count lasted approximately 3–3.5 hours. We did not conduct counts during rain or periods of wind-blown dust that affected visibility. We conducted equal numbers of morning and evening surveys within each season, and we randomly assigned the direction the route was traversed for each pair of morning and evening surveys. Data collection commenced immediately upon arrival at a plot (Ralph et al. 1995), at which time we recorded all raptors detected within 10 minutes. We used an optical range finder to assure that birds located were within the 300-m radius.

Since raptor presence in a given area may vary spatially and temporally due to species' patterns of seasonal distribution and behavior, our data collection spanned a full year. We conducted all counts in 2002: 14 counts at each plot in winter, 18 counts in spring, 24 counts in summer, and 18 counts in autumn. We based delineation of seasons on dates used by HawkWatch International (http://www.hawkwatch.org) to define migratory periods at hawk watch sites in central New Mexico (winter = 6 Nov–23 Feb; spring = 24 Feb–5 May; summer = 6 May–14 Aug; and autumn = 15 Aug–5 Nov).

We compared the seasonal and annual mean abundances of birds detected at colony and noncolony plots at each study site with a one-way analysis of variance. We conducted the comparison on a species-specific basis only for those species detected $\geq$10 times within the applicable time periods (all other data are available in Merriman 2003). We tested assumptions of normality and homoscedasticity with

Table 1. Mean detections of diurnal raptors per survey on a seasonal and annual (yr) basis at colony and noncolony plots in Lubbock County, Texas, USA, 2002.

Species	Season	Colony		Noncolony		P
		$\bar{x}$	SE	$\bar{x}$	SE	
Northern harrier	Yr	0.125	0.032	0.088	0.032	0.462[a]
	Winter	0.184	0.058	0.161	0.034	0.787[a]
	Spring	0.246	0.064	0.125	0.062	0.246[a]
	Autumn	0.127	0.040	0.111	0.075	0.840[a]
Swainson's hawk	Yr	0.014	0.007	0.047	0.020	0.078[b]
	Summer	0.018	0.012	0.094	0.055	0.120[b]
Red-tailed hawk	Yr	0.141	0.034	0.142	0.068	0.989[a]
	Winter	0.265	0.081	0.232	0.054	0.781[a]
	Spring	0.183	0.063	0.153	0.076	0.619[b]
	Autumn	0.183	0.072	0.236	0.182	0.847[b]
Ferruginous hawk	Yr	0.280	0.104	0.064	0.032	0.088[b]
	Winter	0.776	0.285	0.107	0.046	0.010[b]
	Spring	0.357	0.161	0.139	0.092	0.253[b]
	Autumn	0.190	0.081	0.042	0.014	0.136[b]
American kestrel	Yr	0.068	0.021	0.152	0.020	0.028[a]
	Winter	0.163	0.046	0.143	0.101	0.837[a]
	Spring	0.056	0.021	0.222	0.075	0.014[b]
	Summer	0.036	0.017	0.063	0.021	0.326[b]
	Autumn	0.048	0.031	0.208	0.035	0.019[b]

[a] Analysis of variance test.
[b] Kruskal–Wallis test.

Shapiro–Wilk's and Levene's tests, respectively (Levene 1960, Shapiro and Wilk 1965). If variances were heterogeneous, we used Welch's test (denoted as W) instead of the standard F-test. If data were nonnormal, we compared distribution functions with a Kruskal–Wallis test (denoted as H) of ranks, though we interpreted the results as a comparison of means (Conover 1999). All tests used an alpha level of 0.05 and we performed them using SAS software, version 8.2 (SAS Institute, Inc., Cary, NC). We did not attempt to compare raptor numbers between the 2 sites due to differences in geographical range of the raptor species involved and anthropogenic influences on the landscape. We conducted this study under approval of the Texas Tech University Animal Care and Use Committee Number 01294X.

RESULTS

During the course of the study, we detected 12 species of diurnal raptors at the study sites. We detected northern harrier (*Circus cyaneus*), Swainson's hawk (*B. swainsoni*), red-tailed hawk, ferruginous hawk, and American kestrel in sufficient numbers to allow analysis of individual patterns of abundance in relation to prairie dog colonies. We did not detect the remaining species, Mississippi kite (*Ictinia mississippiensis*), Cooper's hawk (*Accipiter cooperii*), rough-legged hawk (*B. lagopus*), golden eagle (*Aquila chrysaetos*), merlin (*F. columbarius*), peregrine falcon (*F. peregrinus*), and prairie falcon (*F. mexicanus*), frequently enough to allow individual analyses of patterns of abundance.

Lubbock County, Texas

Northern harriers were numerically more abundant and Swainson's hawks were less abundant at colony plots, though differences were not significant (Table 1). Red-tailed hawks were equal in relative abundance at both plot types. Ferruginous hawks were numerically more abundant at colony plots than noncolony plots among seasons, significantly so in winter ($H_1 = 6.57$, $P = 0.010$). American kestrels were significantly more abundant at noncolony plots than at colony plots during spring ($H_1 = 5.99$, $P = 0.014$), autumn ($H_1 = 5.52$, $P = 0.019$), and for the year in total ($F_{1,9} = 6.84$, $P = 0.028$; Table 1). Overall, they were numerically more abundant at noncolony plots in all seasons with the exception of winter.

Melrose Bombing and Gunnery Range

Northern harriers were numerically, but not statistically, more abundant at colony plots than noncolony plots among all seasons, especially in autumn (Table 2). Swainson's hawks were significantly less abundant at colony plots than noncolony plots in spring ($F_{1,6} = 10.00$, $P = 0.020$), summer ($F_{1,6} = 14.55$, $P = 0.009$), autumn ($H_1 = 4.98$, $P = 0.026$), and for the year ($F_{1,6} = 23.70$, $P = 0.003$; Table 2). Though red-tailed hawks were not present in sufficient numbers to allow seasonal analysis, we observed no difference for this species when examined over the entire study period (Table 2). We did not find any statistically significant differences for ferruginous hawks, but they were numerically more abundant at colony plots across the year. American kestrels were significantly more abundant at noncolony plots than colony plots during spring ($H_1 = 4.05$, $P = 0.044$) and autumn ($F_{1,6} = 6.38$, $P = 0.045$), as well as over the entire year ($W_{1,5.04} = 25.92$, $P = 0.006$; Table 2).

DISCUSSION

We detected 5 raptor species frequently enough to analyze patterns of abundance between areas occupied and unoccupied by prairie dogs in our study areas. We found that

Table 2. Mean detections of diurnal raptors per survey on a seasonal and annual (yr) basis at colony and noncolony plots at Melrose Bombing and Gunnery Range, New Mexico, USA, 2002.

		Colony		Noncolony		
Species	**Season**	$\bar{x}$	**SE**	$\bar{x}$	**SE**	***P***
Northern harrier	Yr	0.101	0.034	0.024	0.016	0.085[a]
	Spring	0.125	0.014	0.056	0.039	0.178[b]
	Autumn	0.250	0.151	0.028	0.016	0.225[b]
Swainson's hawk	Yr	0.074	0.034	0.389	0.055	0.003[a]
	Spring	0.083	0.048	0.361	0.073	0.020[a]
	Summer	0.146	0.063	0.781	0.154	0.009[a]
	Autumn	0.028	0.028	0.194	0.036	0.026[b]
Red-tailed hawk	Yr	0.027	0.015	0.014	0.010	0.468[a]
Ferruginous hawk	Yr	0.135	0.047	0.068	0.021	0.240[a]
	Winter	0.143	0.051	0.107	0.046	0.620[a]
	Autumn	0.403	0.148	0.153	0.035	0.151[a]
American kestrel	Yr	0.051	0.022	0.172	0.010	0.006[c]
	Spring	0.042	0.014	0.111	0.023	0.044[b]
	Summer	0.063	0.050	0.083	0.083	0.741[b]
	Autumn	0.069	0.035	0.431	0.139	0.045[a]

[a] Analysis of variance test.
[b] Kruskal–Wallis test.
[c] Welch's test.

ferruginous hawks were strongly associated with prairie dog colonies. Thus, this species may pose an increased strike risk when prairie dogs are present. Similarly, northern harriers seemed to be weakly associated with colonies, so they may pose an increased but less notable risk at colonies. Conversely, Swainson's hawks and American kestrels were strongly dissociated with colonies and, therefore, pose less strike risk at prairie dog colonies. Red-tailed hawks occurred equally among colony and noncolony plots, so strike risk for this species would presumably be independent of presence or absence of prairie dogs.

To more fully evaluate the BASH potential of these species in relation to prairie dog colonies, managers should also consider the difference in risk posed by each species (Burger 1985, Dolbeer et al. 2000, Sodhi 2002). Dolbeer et al. (2000) ranked wildlife species and species groups by their relative hazard to aircraft. On a scale of 1–100 (1 being lowest risk, 100 being highest), they assigned *Buteo* hawks a hazard ranking of 25, owls 16, and American kestrel 14. However, a more useful metric may be the total cost of damage accrued in strikes with a species per total number of individuals of that species or species group struck (cost/count), as is compiled by the USAF (Air Force Safety Center 2005). For example, aircraft striking red-tailed hawks incur an average of $29,522 of damage, those striking Swainson's hawks incur an average of $42,507 of damage, and those striking the diminutive kestrel incur, on average, only $1,198 of damage. On an individual basis, it is clear that *Buteo* hawks present a higher strike risk than American kestrels. A hazard index that accounted for damage caused and number of incidents also indicated that *Buteo* hawks represent a high hazard risk (Zakrajsek and Bissonette 2005), whereas the kestrel represents comparatively little risk.

One shortcoming of previously reported data was the lumping of species into groups. Both Dolbeer et al. (2000) and Zakrajsek and Bissonette (2005) pooled all *Buteo* hawks into a single group. This approach is understandable because it is how the data are collected and reported (Air Force Safety Center 2005). However, the genus *Buteo* consists of a diverse suite of species that occupy different habitats and employ different flying and hunting methods (e.g., Johnsgard 1990). Pooling all *Buteo* hawks suggests equal BASH risk when some species may pose little or no risk. This could lead to inefficient management planning.

The strong association of ferruginous hawks, and the possible association of northern harriers, with prairie dog colonies suggest prairie dog control may be effective in reducing the abundance of these 2 raptor species in strike risk areas. However, by their lack of inclusion in data provided by the USAF BASH team (Air Force Safety Center 2005), these 2 species do not appear to be involved in bird–aircraft strikes with any frequency, despite their preference for open areas, their large body sizes, and their tendencies to hunt on the wing (Johnsgard 1990). Red-tailed hawks, however, are known to pose a high BASH risk (Dolbeer et al. 2000, Zakrajsek and Bissonette 2005) but, in our study, occurred with equal frequency over both prairie dog colonies and noncolonies. Thus, prairie dog control would likely have no discernible effect in reducing presence of red-tailed hawks. In contrast, Swainson's hawks pose a high strike risk (Dolbeer et al. 2000, Air Force Safety Center 2005) and were strongly dissociated with prairie dog colonies. Similarly, although not a highly ranked strike risk (Zakrajsek and Bissonette 2005), kestrels also were dissociated with prairie dog colonies. Therefore, controlling prairie dogs and allowing colony areas to revert to grassland could conceivably increase the presence of Swainson's hawks and kestrels and correspondingly increase the strike risk in a given area. Thus, it is difficult to legitimize prairie dog control as a management technique to reduce BASH risk at a broad scale.

When the strike risk posed by an individual raptor species, the relationship of that species with prairie dog colonies, and the seasonal and geographic distribution of the raptor species are considered, it becomes evident that site-specific evaluation is necessary to assess the need and potential effectiveness of prairie dog control to reduce raptor–aircraft strike risk. For example, if ferruginous hawks were the strike-risk of concern at a given site, prairie dog control may have value in reducing such risk. However, as discussed above, prairie dog control may make an area attractive to another species that may pose an even greater strike risk, such as the Swainson's hawk. Therefore, multiple management techniques may need to be employed that include not only prairie dog control but also manipulation of the area of concern (e.g., cutting regimes and grass heights, standing water, etc.) to reduce the attractiveness of the area to strike-risk species.

MANAGEMENT IMPLICATIONS

Our data suggest prairie dog control is not a tool to be applied in all situations to reduce raptor–aircraft strikes and that it likely would be inefficient as the only management technique. We suggest that in locations where prairie dogs are present and raptor–aircraft strike risk is a concern, managers should determine the relative and seasonal abundance of high-risk raptor species before taking management action. Only by incorporating the relative strike risk posed by each species and the abundance and relationships of the species present with prairie dogs can the likely effect of prairie dog control on aircraft strike risk be determined.

ACKNOWLEDGMENTS

The United States Air Force, Texas Tech University, and the United States Geological Survey-Texas Cooperative Fish and Wildlife Research Unit provided funding and support for this project. We thank M. Wallace and W. Ballard for assistance and support, as well as J. Boatright and S. Swearingen for field assistance. B. Bivings, R. Spaulding, K. Le Vering, and an anonymous referee provided thoughtful reviews of earlier versions of the manuscript. We thank the Wildlife Society Bulletin staff for seeing this manuscript through the review process before transferal to the Journal of Wildlife Management. The opinions and conclusions in this paper are those of the authors and do not necessarily reflect those of the United States Air Force or the federal government.

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Associate Editor: Euler.