BIRD HABITAT USE AND BIRD-AIRCRAFT STRIKES AT BEALE AIR FORCE BASE, CALIFORNIA

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ABSTRACT: Bird-aircraft strikes are a major safety hazard to aircraft. The majority of bird strikes occur near airports, at low altitudes, and during the take-off and landing. Airports near areas that act as attractants for birds may be particularly dangerous. Our goal was to provide information that may be used to minimize the potential for bird-aircraft strikes at Beale Air Force Base (AFB), California. We determined: (1) bird activity, behavior, and use of vegetation, water sources, and manmade structures in the flight line; (2) bird flight direction and altitude in the flight line; and (3) bird use of roosting and feeding locations from November 2000 to February 2001. Nine bird-aircraft strikes were reported at Beale AFB during this study. American widgeon (*Anas americana*) and snow goose (*Chen caerulescens*) were involved in 2 bird-aircraft strikes; the other 7 strikes involved unknown species. The majority of birds we observed were species commonly involved in bird-aircraft strikes. Approximately 69% of the birds observed during the flight line censuses were flying and at altitudes $\leq$100 m. Sixty-three percent of observed birds were flying north, northwest, west, and southwest, which was the direction of rice fields adjacent to Beale AFB. The presence of food, water, and perching sites act as attractants, and may increase the potential for bird-aircraft strikes. Agriculture and other land uses surrounding the base can attract birds and may increase bird activity in and around the flight line. Manipulation of foraging and perch, and modification of land-use practices in areas near the flight line may reduce bird activity. Features that cannot be modified or removed could be avoided by aircraft, particularly during periods of high bird activity.

Key words: bird-aircraft collisions, vegetation use, land use, bird assemblages

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Bird-aircraft strikes represent a major safety hazard to pilots and passengers of both commercial and military aircraft. In the United States, damage to aircraft from bird-aircraft strikes has been estimated at over $400 million (Sodhi 2002). Bird strikes have resulted in over 350 human deaths worldwide (Conover et al. 1995, Sodhi 2002). The majority of bird strikes occur near airports, at low altitudes, and during the take-off and landing phases of flights (Neubauer 1990, Cleary et al. 1999). Military aircraft are more susceptible to bird-aircraft strikes because they often fly at low altitudes (30-300 m) and practice touch-and-go landings (Kuenzi et al. 1991, Ellison et al. 1992, Kuenzi and Morrison 1998, Sodhi 2002). Airports near areas that attract birds, such as grasslands, water sources, waste disposal sites, or agricultural areas may be particularly dangerous because of increased bird activity (Ellison et al. 1992, Dolbeer et al. 1993, Kuenzi and Morrison 1998). Birds that are active within the flight line of airfields represent a potential threat to aircraft; however, due to variation in size and behavior patterns not all bird species pose the same level of risk (Dolbeer et al. 2000). For example, waterfowl, gulls, and raptors are considered more hazardous to aircraft due to their size than are smaller blackbirds, sparrows, or swallows (Dolbeer et al. 2000). However, flocking species, such as starlings (*Sturnus vulgaris*), also cause considerable damage to aircraft (Sodhi 2002).

From 1997 to 2000, there were 56 bird-aircraft strikes at Beale Air Force Base (AFB), California (Beale AFB Wing Safety, unpublished data). Fifty percent of these strikes occurred between the months of November and February and accounted for 76% of repair costs for aircraft damaged by bird-aircraft strikes (Beale AFB Wing Safety, unpublished data). The purpose of our study was to as-

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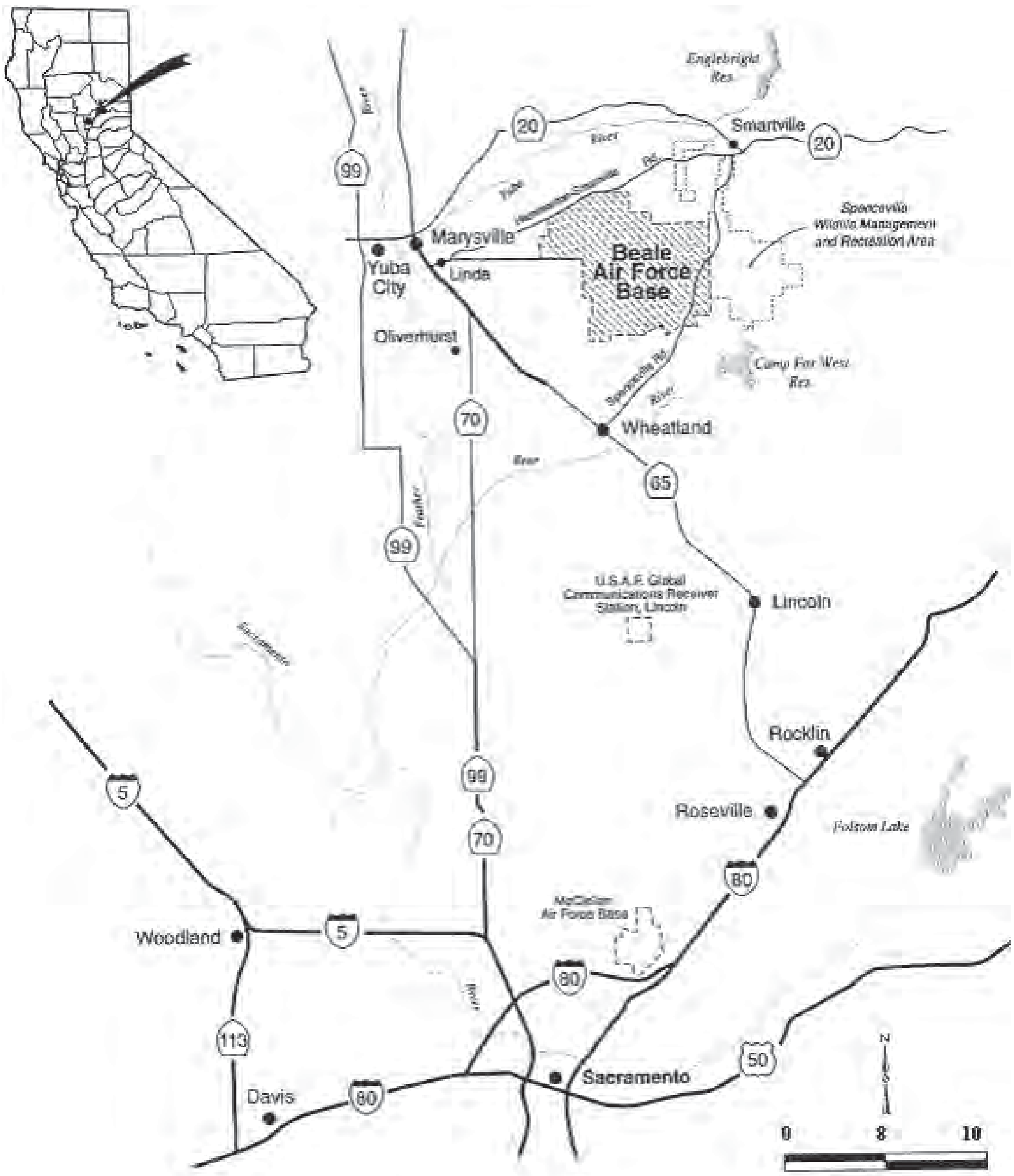
sess avian behavior and habitat use in and around the flight line at Beale AFB. Our goal was to provide information that may be used to minimize the potential for bird-aircraft strikes at Beale AFB. Our specific objectives were to determine: (1) bird activity, behavior, and use of different vegetation types, water sources, and manmade structures near the flight line; (2) bird flight direction and altitude in the flight line; and (3) bird use of roosting and feeding locations, both on Beale AFB and in adjacent agricultural and industrial areas.

STUDY AREA

Beale AFB is located in Yuba County, California on the eastern edge of the Central Valley and in the foothills of the western Sierra Nevada mountain range (Fig. 1). The base is approximately 9,285 ha, of which approximately 80% is undeveloped and 60% currently supports cattle grazing. Elevation varies from 26 to 213 m, with higher elevations on the east side of the base (U. S. Army Corps of Engineers 1999). The climate is Mediterranean, with cool, moist winters and hot, dry summers.



U. S. Army Corps of Engineers 1999

Figure 1. Location of Beale AFB, Marysville, California.

Average annual precipitation is approximately 52 cm, with most rainfall occurring between November and March. The average monthly temperature ranges from 4°C in December and January to 36°C in July (Beale AFB Combat Climatology Center, unpublished data).

The primary vegetation type at Beale AFB is exotic annual grassland, a majority of which supports cattle grazing from November through May. Common non-native grasses found at the base include medusahead (*Taeniatherum caput-medusae*), ripgut brome (*Bromus diandrus*), Italian ryegrass (*Lolium mulitflorum*), soft chess (*Bromus hordeaceus*), and wild oat (*Avena fatua*). Forbs and native perennial grasses also occur on the base. Much of the grassland area is infested with non-native yellow starthistle (*Centaurea solstitialis*). The base also supports small areas of cottonwood-riparian forest, oak (*Quercus* spp.) woodlands and savannahs, and seasonal wetlands and vernal pools.

Agricultural lands, primarily rice fields and livestock pastures, and a wildlife conservation area lie adjacent to the base. Other potential bird attractants near the base include a solid waste landfill approximately 0.4 km south of the base boundary and an aggregate mine approximately 0.8 km north of the base. Potential bird attractants on the base include a riparian woodland conservation area (298 ha), open water (86 ha), and vernal pool management areas (3,727 ha) (U. S. Army Corps of Engineers 1999).

METHODS

Bird-Aircraft Strikes

A base-level Bird-Aircraft Strike Hazard (BASH) Reduction Operating Plan prepared by Beale AFB outlines procedures for documenting bird strikes. For damaging and non-damaging bird strikes, the aircrew involved in the bird strike are required to report incident information

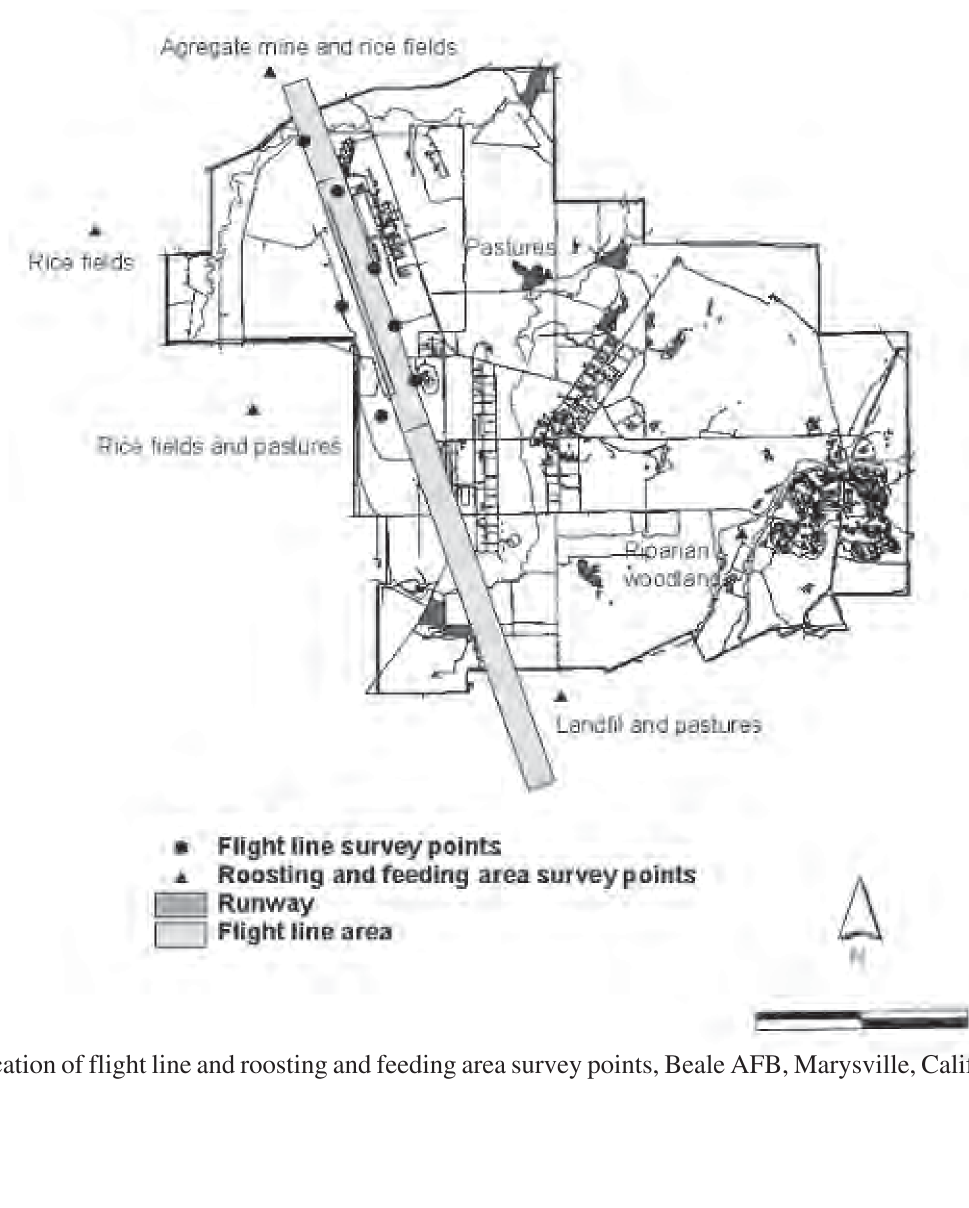


Figure 2. Location of flight line and roosting and feeding area survey points, Beale AFB, Marysville, California.

including date, time, and altitude of the strike. The aircrew's Squadron Flight Safety Officer must report bird strikes to the Wing Safety Office within 48 hr of the incident. Maintenance crews must also report any evidence of bird strikes. Bird strike data are compiled and submitted to the Air Force BASH Team at Kirtland AFB, New Mexico twice per year. When bird remains are found on an aircraft or airfield, non-fleshy parts (e.g., feathers, beaks, feet) must be sent to the Smithsonian National Museum of Natural History in Washington, D.C. for identification. We used bird-aircraft strike data collected by Beale AFB personnel for this study.

Bird Activity and Habitat Use within the Flight Line

We used a modified version of Kuenzi's et al. (1991) study design to assess bird activity and habitat use in and around the flight line at Beale AFB. Because birds on the taxiway and beyond the ends of the runway represent a potential bird-aircraft strike hazard, we included these areas in the flight line surveys. We established 7 survey points around the flight line spaced 1,000-1,500 m apart to reduce the probability of double counting birds (Fig. 2). The number of survey points was selected to insure complete coverage of the airfield and locations were selected based on issues of access and personnel safety. At each survey point we recorded the number and species of all birds observed for 30 min.

To assess daily fluctuations of bird activity near the flight line, we surveyed all points during 3 daily time periods from November 2000 to February 2001: morning surveys from sunrise until about 3.5 hours after sunrise; midday surveys from about 3.5 hours after sunrise until about 6.5 hours after sunrise and afternoon surveys from about 6.5 hours after sunrise until sunset. We surveyed each point 5 times/month during each daily time period for a total of 15 surveys/month. To avoid temporal bias, we randomized the order in which each point was surveyed for each time period.

We recorded the substrates used by birds as bare ground, grassland (e.g., grass, yellow star thistle, or grass/ yellow star thistle mixture), manmade structures (e.g., asphalt, buildings, poles, posts, power lines, or fences), trees and shrubs, and water sources (e.g., wetlands, vernal pools, ponds, or standing water). We categorized and recorded the behaviors displayed by birds at initial time of detection as flying, foraging, or loafing. We estimated flight altitude using a clinometer and recorded altitudes as ≤ 100 m, 101 -200 m, or ≥ 201 m. Flight direction was recorded by cardinal direction.

Bird Roosting and Feeding Locations In and Around Beale AFB

We surveyed areas in and around Beale AFB to determine bird use of roosting and feeding locations. Adjacent areas included agricultural and industrial lands. We established 6 observation points; 3 points located on agricultural areas, 1 point located in the riparian woodland, 1 point located near the aggregate mine, and 1 point located near the landfill (Fig. 2). The number and location of survey points was selected from publicly accessible areas that represented the majority of land-use types near Beale AFB. At each point we recorded the number of individuals, species, behavior at initial detection, and land use type of all birds observed for 30 min. We recorded land-use types as riparian woodland, pasture, rice field, landfill, or aggregate mine. We surveyed each point 2 times/month during each daily time period, for a total of 6 surveys/month.

Statistical Analyses

We classified individual species into 7 assemblages (Table 1) based on known life-history characteristics and affinities for particular vegetation types. Species within assemblages exhibit similar behaviors that may influence the probability of involvement in bird-aircraft strikes.

Prior to statistical analyses, we tested the data for normality and homogeneity of variance. Because our data did not meet these criteria, all data were logarithmically transformed prior to analysis. To examine differences in bird abundances between the daily time periods, assemblages, and substrate use during the flight line surveys, we conducted analysis of covariance using the univariate General Linear Model procedure (GLM) in SPSS (SPSS 9.0 1998). We entered time of day, assemblage, and substrate use as fixed factors. To account for potential differences among survey points, we entered survey point as a covariate. We used Pearson chi-square analysis to determine if there were differences among flight directions.

To examine differences among bird abundances in and around the base between the daily time periods, assemblages, and land use types during the roosting and feeding area surveys, we conducted analysis of covariance using the univariate GLM procedure (SPSS 9.0 1998). We entered time of day, assemblage, and land use type as fixed factors. To account for potential differences among survey points, we entered survey point as a covariate.

RESULTS

Bird-aircraft strikes

From November 2000 to February 2001, there were 9 bird-aircraft strikes at Beale AFB. An American widgeon and snow goose were involved in 2 bird-aircraft strikes, and U.S. Air Force personnel were unable to identify the species involved in the other 7 bird-aircraft strikes due to a lack of remains. One bird-aircraft-strike occurred during an unknown phase of the flight, 5 occurred during the landing phase of the flight, and 3 occurred during touch-and-go maneuvers.

Table 1. Bird species grouped by assemblage for surveys conducted from November 2000 to February 2001 at Beale AFB, Marysville, California.

Assemblage	Species
Wading-birds	Great-blue heron (*Ardea herodias*)
	Great egret (*Casmerodius albus*)
	Snowy egret (*Egretta thula*)
	Black-crowned night heron (*Nycticorax nycticorax*)
Waterfowl	Canada goose (*Branta canadensis*)
	Greater white-fronted goose (*Anser albifrons*)
	Snow goose (*Chen caerulescens*)
	Ross's goose (*Chen rossii*)
	Tundra swan (*Cygnus columbianus*)
	Mallard (*Anas platyrhynchos*)
	Northern shoveler (*Anas clypeata*)
	Northern pintail (*Anas acuta*)
	American wigeon (*Anas americana*)
	American coot (*Fulica americana*)
	Ring-necked duck (*Aythya collaris*)
	Double-crested cormorant (*Phalacrocorax auritus*)
	Pied-billed grebe (*Podilymbus podiceps*)
Gulls	California gull (*Larus californicus*)
	Western gull (*Larus occidentalis*)
Raptors	Red-shouldered hawk (*Buteo lineatus*)
	Rough-legged hawk (*Buteo lagopus*)
	Ferruginous hawk (*Buteo regalis*)
	Northern harrier (*Circus cyaneus*)
	Cooper's hawk (*Accipiter cooperii*)
	American kestrel (*Falco sparverius*)
	Prairie falcon (*Falco mexicanus*)
	White-tailed kite (*Elanus caeruleus*)
	Bald eagle (*Haliaeetus leucocephalus*)
	Golden eagle (*Aquila chrysaetos*)
	Turkey vulture (*Cathartes aura*)
Blackbirds	Brewer's blackbird (*Euphagus cyanocephalus*)
	Red-winged blackbird (*Agelaius phoeniceus*)
	European starling (*Sturnus vulgaris*)
Grassland birds	Savannah sparrow (*Passerculus sandwichensis*)
	Vesper sparrow (*Pooecetes gramineus*)
	Horned lark (*Eremophila alpestris*)
	Killdeer (*Charadrius vociferus*)
	American pipit (*Anthus rubescens*)
	Western meadowlark (*Sturnella neglecta*)
Other birds	Rock dove (*Columba livia*)
	Mourning dove (*Zenaida macroura*)
	Northern flicker (*Colaptes auritus*)
	Nutall's woodpecker (*Picoides nuttallii*)
	Downy woodpecker (*Picoides pubescens*)
	Black phoebe (*Sayornis nigricans*)
	Say's phoebe (*S. saya*)
	Loggerhead shrike (*Lanius ludovicianus*)
	Common raven (*Corvus corax*)
	American crow (*Corvus brachyrhynchos*)
	Western scrub-jay (*Aphelocoma californica*)
	Yellow-billed magpie (*Pica nuttalli*)
	Tree swallow (*Tachycineta bicolor*)
	Violet green swallow (*T. thalassina*)
	Oak titmouse (*Baeolophus inornatus*)
	Bushtit (*Psaltriparus minumus*)
	Bewick's wren (*Thryomanes bewickii*)
	Marsh wren (*Cistothorus palustris*)
	Ruby-crowned kinglet (*Regulus calendula*)
	Mountain bluebird (*Sialia currucoides*)
	American robin (*Turdus migratorius*)
	Yellow-rumped warbler (*Dendroica coronata*)
	Spotted towhee (*Pipilo maculatus*)
	House sparrow (*Passer domesticus*)
	White-crowned sparrow (*Zonotrichia leucophrys*)
	Golden-crowned sparrow (*Z. atricapilla*)
	Dark-eyed junco (*Junco hyemalis*)
	Ring-necked pheasant (*Phasianus colchicus*)
	California quail (*Callipepla californica*)

Bird Activity and Habitat Use within the Flight Line

Bird species from the other category composed a relatively small (<3%) of the total observations during flight line surveys and were excluded from flight line analyses. The majority (69%) of birds observed during flight line censuses were flying. Mean altitude of all birds observed flying was 23.6 m (SD = 36.5 m). The majority (94%) of flying birds were observed at altitudes ≤100 m; 96% were observed at altitudes ≤200 m; and 4% were observed at altitudes >200 m. We observed specific flight directions for flying birds (Fig. 3) (χ^2 = 105.14, df = 7, P<0.001). Approximately 63% were flying towards the north (11%), northwest (20%), west (17%), and southwest (16%), whereas, only 6%, 6%, 14%, and 10% were observed flying towards the northeast, east, southeast, and south, respectively. These flight patterns were similar each of the daily time periods (Pearson χ^2 = 17.68, df = 14, P = 0.22).

Twelve percent of the birds observed in the flight line area were foraging and 19% were loafing. Eighty-seven percent of foraging bird observations were in grassland areas, 11% on manmade structures, 1% on bare ground, and 1% at water sources. Fifty-four percent of loafing bird observations were in grassland areas, 33% on manmade structures, 6% at water sources, 6% in trees and shrubs, and 1% on bare ground.

There was no significant difference in the number of birds observed by count point ($F_{6, 992}$ = 0.38, P = 0.54) or by time period ($F_{2, 992}$ = 0.58, P = 0.56); however, there was a significant time period by assemblage interaction ($F_{7, 992}$ = 1.97, P = 0.05) (Table 2). We observed gulls (*Larus* spp.) and waterfowl 2 to 24 times more frequently than all other assemblages, and blackbirds 2 to 7 times more frequently than grassland birds, raptors, and wading birds. We observed grassland birds approximately 4 to 7 times more often than raptors or wading birds. Grassland birds, waterfowl, and blackbirds were observed more frequently in the morning. The mean number of gull observations was highest during the early evening and raptor and wading bird observations were highest during midday.

There was also a significant interaction between substrate and avian assemblage ($F_{12, 992}$ = 2.14, P = 0.01)

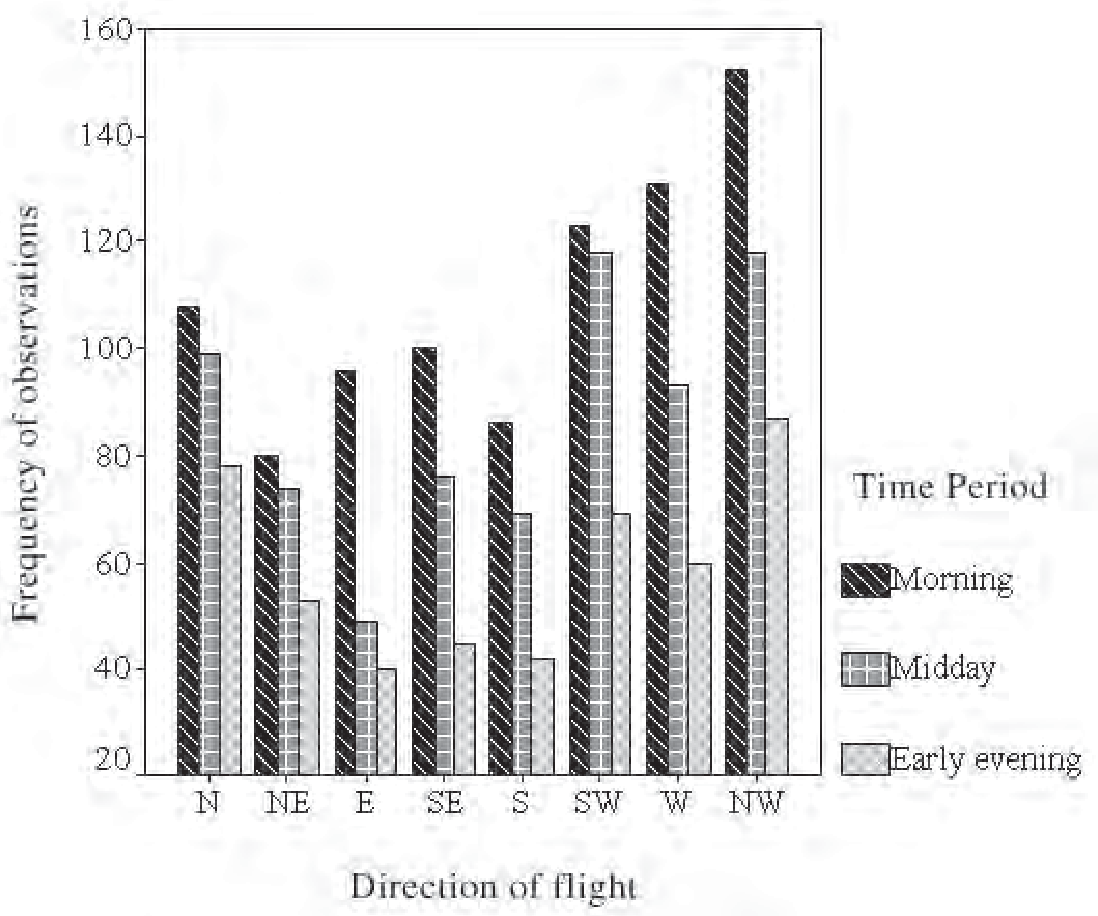


Figure 3. Number of bird observations by direction of flight and daily time period during flight line surveys, November 2000 to February 2001, Beale AFB, Marysville, California.

(Table 3). Mean grassland bird observations was highest on bare ground. Waterfowl were only observed using grassland areas, manmade structures, and water sources. Raptors were most commonly observed using grassland areas and gulls were only observed using grassland areas and manmade structures. The mean number of blackbird observations was highest on grassland areas and wading birds had the highest mean number of observations on manmade structures.

Bird Roosting and Feeding Locations In and Around Beale AFB

Species from the other category composed a relatively small proportion of the birds observed and most were only observed in the riparian area and were therefore excluded from further analyses. The majority (70%) of birds observed during roosting and feeding area censuses were observed in rice fields; 18% in pastures, 9% in the landfill, 2% in the riparian area, and 1% in the aggregate mine. Forty-three percent of birds observed during the roosting and feeding area censuses were flying; 23% were foraging, and 34% were loafing. Of birds observed foraging, 71% were foraging in the rice fields, 16% in the landfill, 10% in pastures, and 3% in the riparian woodland. Of birds observed loafing, 67% were in rice fields, 23% in pastures, 7% in the landfill, 2% in the riparian woodland, and 1% in the aggregate mine.

There was no significant difference in the number of birds observed by census point ($F_{5, 558} = 0.14$, $P = 0.24$) or in the number of birds observed by time period ($F_{2, 558} = 2.54$, $P = 0.08$). There was a significant assemblage by land use type interaction ($F_{20, 558} = 7.44$, $P < 0.01$) (Table 4). Blackbirds were the most frequently observed assemblage in the different land use areas around Beale AFB. Black-

Table 2. Mean activity[a] ($\bar{x}$ = mean number of birds detected per point), 95% confidence interval[a] (95% CI), and number of detections (*n*) by survey period for each assemblage detected during flight line surveys from November 2000 to February 2001, Beale AFB, Marysville, California.

	Time period					
	Morning		Midday		Early Evening	
Assemblage	$\bar{x}$ (n)	95% CI	$\bar{x}$ (n)	95% CI	$\bar{x}$ (n)	95% CI
grassland birds	9.0 (280)	7.8 - 10.3	7.2 (230)	6.1 - 8.4	8.4 (185)	7.1 - 9.9
waterfowl	34.4 (60)	22.8 - 51.8	25.9 (37)	13.7 - 48.2	24.3 (30)	12.2 - 47.5
raptors	1.8 (116)	1.5 - 2.1	2.9 (149)	2.5 - 3.3	2.8 (122)	2.4 - 3.2
gulls	42.5 (5)	9.4 - 180.6	41.8 (7)	27.0 - 64.2	79.8 (2)	36.0 - 176.3
blackbirds	14.3 (138)	11.1 - 18.5	10.4 (90)	7.4 - 14.4	10.9 (70)	7.8 - 15.0
wading birds	2.0 (9)	0.5 - 4.9	5.8 (9)	0.7 - 25.8	5.5 (3)	-1.0 - 1044.2
Total	8.7 (608)	7.7 - 9.8	6.8 (522)	6.0 - 7.7	7.1 (412)	6.2 - 8.1

[a]Means and 95% confidence intervals presented in the table were back-transformed.

Table 3. Mean activity[a] ($\bar{x}$ = mean number of birds detected per point) and 95% confidence interval[a] (CI) by substrate-use for each assemblage detected during flight line surveys from November 2000 to February 2001, Beale AFB, Marysville, California.

	Substrate									
	Grassland		Bare Ground		Manmade Structures		Trees/Shrubs		Water Sources	
Assemblage	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI
grassland birds	11.8 (293)	10.4 – 13.3	13.5 (4)	2.8 – 54.4	4.9 (167)	4.1 – 5.7	2.7 (92)	-1.0 – 10,699	1.0 (1)	[b]
waterfowl	12.1 (15)	4.1 – 32.8	-	-	1.0 (1)	b	-	-	15.0 (16)	8.9 – 24.8
raptors	3.3 (243)	3.0 – 3.7	1.0 (3)	1.0 - 1.0	1.3 (90)	1.1 - 1.4	1.1 (20)	1.0 - 1.3	-	-
gulls	50.0 (1)	b	-	-	21.0 (1)	b	-	-	-	-
blackbirds	22.0 (71)	15.6 – 30.8	3.0 (2)	-1.0 – 26,634	7.3 (80)	5.2 – 10.1	12.8 (18)	6.5 – 24.5	15.1 (5)	6.1 – 35.7
wading birds	12.7 (4)	-0.6 – 475.3	-	-	32.0 (1)	b	2.0 (2)	2.0 – 2.0	1.0 (1)	[b]
Total	8.0 (627)	7.2 – 8.9	4.6 (9)	1.4 – 12.4	4.0 (340)	3.5 – 4.6	3.9 (42)	2.4 – 6.2	12.3 (23)	7.7 – 19.6

[a]Means and 95% confidence intervals presented in the table were back-transformed.

[b]95% Confidence interval could not be calculated.

Table 4. Mean activity[a] ($\bar{x}$ = mean number of birds detected per point) and 95% confidence interval[a] (CI) by land-use type for each assemblage detected during roost surveys from November 2000 to February 2001, Beale AFB, Marysville, California.

	Land use type									
	Rice Field		Pastures		Landfill		Aggregate Mine		Riparian Woodland	
Assemblage	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI	$\bar{x}$ (*n*)	95 % CI
Grassland birds	24.7 (54)	19.5 – 31.1	14.3 (57)	11.0 – 18.6	11.1 (18)	7.1 – 17.1	3.2 (3)	-0.4 – 26.0	6.2 (14)	3.6 – 10.2
Waterfowl	54.1 (24)	23.6 – 123.0	29.2 (19)	12.7 – 65.0	2.7 (6)	1.2 – 5.3	8.9 (2)	-1.0 – $4x10^7$	2.8 (5)	0.9 – 6.8
Raptor	3.0 (49)	2.4 – 3.7	2.2 (56)	1.8 – 2.7	2.0 (9)	1.3 – 2.8	3.0 (14)	2.2 – 4.0	2.8 (14)	1.9 – 4.1
Gull	3.6 (5)	1.3 – 7.8	1.0 (2)	1.0 – 1.0	11.6 (5)	0.4 – 115.7	-	-	-	-
Blackbirds	87.2 (49)	54.9 – 137.9	25.3 (38)	15.4 – 41.1	110.2 (16)	85.5 – 141.6	8.0 (4)	2.6 – 21.5	7.2 (9)	1.8 – 22.9
Wading birds	2.4 (32)	1.8 – 3.1	1.5 (9)	1.1 – 2.0	-	-	-	-	1.6 (8)	1.0 – 2.4
Total	15.0 (263)	12.1 – 18.5	7.5 (216)	6.1 – 9.2	14.9 (72)	10.4 – 21.0	3.9 (29)	2.7 – 5.5	6.3 (68)	4.7 – 8.3

[a]Means and 95% confidence intervals presented in the table were back-transformed.

birds and gulls were most frequently detected at the landfill while grassland birds, raptors, waterfowl, and wading birds were most frequently detected at rice fields.

DISCUSSION

Waterfowl activity near the flight line represents a significant bird-strike hazard at Beale AFB. Waterfowl were 1 of the assemblages exhibiting high activity near the flight line and comprised 2 bird-aircraft strikes. Furthermore, of 67 bird-aircraft strikes involving known species on Beale AFB from 1985 - 1999, 19 (28%) involved waterfowl (Beale AFB Wing Safety, unpublished data). Blackbirds and grassland birds also exhibited high activity, but Beale AFB did not document species from these assemblages as being involved in bird-aircraft strikes during our study. Since, only 22% of species involved in 9 bird-aircraft strikes during this study and only 23% of 287 bird-aircraft strikes occurring from 1985 - 1999 were identified, many species may have been involved in strikes and gone undetected. During 1985 - 1999, 26 of 67 (38%) strikes involving known species involved blackbirds and grassland birds (Beale AFB Wing Safety, unpublished data).

Differences in the daily activity patterns of the bird assemblages likely influenced the potential for bird strikes by these species. The higher abundance and activity of blackbirds and waterfowl in the morning possibly increased the potential for strikes involving these species during this time period. Raptor and wading bird activity tended to increase in the midday and afternoon and a strike involving raptors may be more probable later in the day than in the early morning. Blackbirds, waterfowl, gulls, and grassland birds made up most of the detections of birds during the flight line surveys. Species in these assemblages are commonly involved in bird-aircraft strikes and all represent a significant threat to aircraft (Burger 1985, Kuenzi and Morrison 1998, Dolbeer et. al 2000, Barras and Wright 2002, Sodhi 2002). Raptor abundance was low compared to species in the other assemblages; however, their continuous presence in the flight line and their flight behaviors (i.e., hovering, soaring and circling) increases their potential for involvement in bird-aircraft strikes (Dolbeer et al. 2000, Byron and Downs 2002, Sodhi 2002).

The presence of features including food, water, and perching sites within the flight line act as an attractant, and may increase the potential for bird-aircraft strikes. The majority of birds observed either foraging or loafing within the flight line area were using the grassland areas and manmade structures (i.e., fences, poles, posts) adjacent to the runway. Species, such as horned larks (*Eremophila alpestris*), killdeer (*Charadrius vociferus*), American pipits (*Anthus rubescens*), and blackbirds forage in areas with short grass and these species were frequently observed foraging in grassy areas in the flight line. Many species, including raptors, were observed perching on manmade structures within the flight line.

The extent of agriculture and other land use types surrounding airfields can also influence bird abundance and behavior. They may attract birds and increase bird activity in and around the flight line (Ellison et al. 1992, Kuenzi and Morrison 1998, Burger 2001, Sodhi 2002). For example, rice farmers in the Central Valley of California flood their fields during winter to aid in the decomposition of rice straw. This practice attracts large numbers of waterfowl, many of which over-winter near these fields (Elphick and Oring 1998). We frequently observed both waterfowl and large numbers of blackbirds and starlings foraging and loafing in rice fields near Beale AFB. In addition, the majority of birds observed flying during the flight line surveys were flying in the direction of the rice fields (north, northwest, west, and southwest of the base). These birds also flew at altitudes where bird-aircraft strikes involving Air Force aircraft commonly occur (Neubauer 1990).

The landfill south of Beale AFB also attracted a large number of birds. Gulls and blackbirds were commonly observed foraging in the landfill and turkey vultures (*Cathartes aura*) and gulls were also often observed circling in thermals above the landfill. High bird abundances and the location of the landfill, directly in path of landing aircraft, combine to create a significant bird-aircraft strike threat (Burger 2001, Sodhi 2002).

The predominant form of agriculture on Beale AFB is livestock grazing and substantial numbers of birds were observed on pastures both on base and in the areas around the base. On base grazing occurs within 500 m of the north, south, and west sides of the flight line. By maintaining short vegetation heights, grazing may increase the number and type of birds using pastures near the flight line and thereby increase the potential for bird-aircraft strikes.

MANAGEMENT RECOMMENDATIONS

Given the high bird activity in rice fields and adjacent landfill (particularly of blackbirds, gulls, and waterfowl), flight patterns during takeoff and approach could be adjusted to avoid low approaches over these areas. This may be particularly important during the morning when blackbird and waterfowl activity is greatest near the rice fields and throughout the day near the landfill.

Features in the flight line that attract birds should be removed or minimized. The removal of perch sites near the flight line may reduce the risk of bird-aircraft strikes (Solman 1969). Trees, shrubs and nonessential poles, posts, and fences could be removed. Many bird species forage in areas of short grass. Grass could be allowed to grow to a height 20 cm (Blockpoel 1976, Brough and

Bridgman 1980) either naturally or through stimulation by watering or fertilization. By increasing grass height, airfield managers may discourage species such as horned larks, starlings, killdeer, and American pipits which often form large flocks, from foraging in these areas (Caithness et al. 1967, Blockpoel 1976, Sodhi 2002). However, these effects may be offset by increased raptor foraging activity if the increase in grass biomass results in higher small mammal abundance (Sodhi 2002). Finally, when feasible, alteration of land-use patterns in and around Beale AFB may also reduce the potential for bird-aircraft strikes.

In summary, manipulation of foraging and perch areas near the flight line to make them less attractive to birds may serve to reduce the potential for bird-aircraft strikes at Beale AFB. Features that are more difficult and or costly to modify or remove (i.e., rice fields) could be avoided by pilots at times of high bird activity when the potential for bird aircraft-strikes is likely to be greatest. Finally, pilots should be educated concerning the particular features around the flight line and airfield that influence the abundance of birds at and near Beale AFB.

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