AVIAN HABITAT USE AND FLIGHT BEHAVIOR IN RELATION TO BIRD-AIRCRAFT STRIKES IN WESTERN U.S. AGRICULTURAL LANDS

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ABSTRACT: We studied flight altitude and habitat use by birds in agricultural lands on 11 Naval bases in Arizona, California, and Nevada from 1989-91 to collect data necessary to develop management plans for reduction of bird-aircraft collisions. The mean altitude of flight at all bases was under 370 m. Blackbirds were the most numerous bird observed; these and other small-sized birds accounted for about 66% of all bird-aircraft strikes. Medium-sized (primarily gulls) and large-sized birds accounted for about 34% of all bird-aircraft strikes. Most strikes occurred during take-offs and landings, and while approaching a landing field. Bird abundance was correlated primarily with buildings, weeds, alfalfa fields, fallow fields, and drainage ditches. Reduction of bird resting and nesting areas, removal of weeds and windbreaks, and modification of buildings could lower bird-aircraft strikes.

Key words: Bird-aircraft collisions, bird strike statistics, blackbirds, habitat use.

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Bird-aircraft collisions are of major concern to the entire aviation community. Annual losses in the United States due to bird strikes have been estimated at $200 million in damages to civilian aircraft and $45 million to military aircraft (Conover et al. 1995). In response to this costly problem, the U.S. Department of the Navy (USN) began a mandatory bird aircraft strike hazard (BASH) program in 1981 to document collisions when they occur and to develop management plans for avoiding bird-aircraft interactions.

The majority of bird-aircraft collisions occur directly at or very near airports, often during take-offs and landings (Blokpoel 1976, Neubauer 1990). Management programs to reduce bird-aircraft strikes have often focused on controlling bird numbers around runways. A variety of pest control methods have been used including sonic devices (Brough 1968), selective bird removal (Blokpoel 1976), and killing (Dolbeer et al. 1993). Unfortunately these methods often only work for short periods of time (Caithness et al. 1967). A more permanent management solution involves habitat alteration. If the features of an airfield that are attractive to birds can be identified it may be possible to eliminate or change these features to make them less attractive to problem species.

Our study was initiated to gather information on bird flight behavior and habitat use at 11 western United States Naval bases. The Navy was specifically interested in bird use of the agricultural lands on and surrounding these bases. The USN currently participates in an agricultural program where their land is leased to local farmers. Certain crops are more attractive to birds than others because they provide better cover or preferred food (Blockpoel 1976), so an understanding of crop type and phenology and how this relates to bird abundance is important for an effective BASH management plan.

Our specific objectives were (1) to determine the species composition and abundance of birds on a seasonal basis, and relate these data to crop types and crop phenology; (2) to determine the altitudes of flight by common bird species; (3) to summarize data collected from the BASH reporting system.

STUDY AREA

Our study sites were located in Arizona, California, and Nevada. The Arizona study area was the Marine Corps Air Station, Yuma, Yuma County in southwestern Arizona. The 9 California study areas were the Naval Auxiliary Landing Field, Crow's Landing (Stanislaus County), and the Naval Air Station (NAS) at Lemoore (Fresno and King Counties), both located in the San Joaquin Valley; NAS Point Mugu (Ventura County) on the southern coast of California; the Marine Corps Air Stations El Toro and Tustin, located in Santa Ana (Orange County) south of Los Angeles; the Outlying Landing Field at Imperial Beach (San Diego County) on the southwestern coast of California near the Mexican border; NAS, Miramar (San Diego County); Moffett Field NAS (Santa Clara County) south of the San Francisco Bay; and the Naval Air Field at El Centro (San Diego County) in the Imperial Valley south of the Salton Sea. The Nevada study area was NAS, Fallon (Churchill County) located east of Reno. The study sites include the installations themselves and the immediate surrounding area. Study sites were located across a broad geographic area to maximize evaluation of natural resources on a wide spread of Naval bases.

METHODS

We collected data from September 1989 through July 1991. We divided the year into 3 sampling seasons: late summer-fall, August through November; late fall-winter, December through March; spring-summer, April through July. These seasons were chosen to correspond with fall migration, over-wintering, and breeding. We collected data at each base for 3 days per season per year.

Bird Flight Behavior

Points were established for determining the flight atltitude of birds at each base. Between 3 and 6 points from 1000 to 1500 m apart were established around the airfield, the specific number depending upon the size of the base. These distances between points reduced the probability of double-counting birds. Data were collected for 30 min at each point in the morning for 2-3 h after sunrise and in the afternoon for 2-3 h before sunset. Morning and afternoon points were done in the same order, then reversed the following day. We estimated distance to the bird in meters, and used a clinometer (in conjunction with the distance estimate) to estimate the bird's altitude of flight .

The mean altitude of flight for all birds combined was calculated for each sampling period at a base, as well as the percentage of birds flying in height categories of $\leq$10 m, >10-25 m, >25-100 m, and >100 m. Means between periods at each base were compared using a one-way analysis of variance and Tukey's multiple comparisons procedure (Sokal and Rohlf 1969). The numbers of birds in each of the 4 height categories were compared between sampling seasons using a chi-square test (Zar 1984). Mean altitudes of flight were also calculated for the most common groups of birds (e.g., gulls, shorebirds).

Habitat Use

Transect lines were established to observe habitat use by birds in and around the agricultural areas. We used the point-count method to collect data at points along a transect (Verner 1985). The distance between transect points was 400 to 600 m to minimize double counting of birds between points. The transects were walked in the morning beginning 15 min after sunrise and ending with the completion of the transect (1.5-3 hours after sunrise). This process was repeated in the afternoon with the last point concluding approximately 15 minutes before sunset. Morning and afternoon transects were run in the same direction, then reversed the following day.

Birds were observed for 7 min at each point. This time was adequate to count most if not all birds within our radius distance, and was also short enough to reduce the probability of double counting birds (Reynolds et al. 1980). All birds seen or heard within a 200-m-radius were recorded. Distance (m) to the bird, the bird's behavior (e.g., foraging, resting, preening), and the habitat (see below) the bird was detected in were also recorded. We assumed equal detectability of all birds within the 200-m radius and across study sites. This assumption is not completely valid. However, given the similar vegetation structure among points, generally uniform, low growing monocultures, the error introduced by this assumption is probably a small part of the overall variation.

A visual estimate of the habitats within a 200-m-radius was made for each point (Kuenzi et al. 1991). The percent of birds recorded by habitat was calculated for each base using the combined years of transect data. Indices of abundance (the number of birds counted per number of points) were determined for both morning and afternoon time periods for each base on a seasonal basis.

Stepwise multiple linear regression was used to examine the relationship between bird abundance for individual bird species and habitat variables (Morrison et al. 1987, Morrison et al. 1992). Separate regression models were developed for each base. The standardized regression coefficients that comprised the final regression models indicated the relative importance of each variable to the model. Habitat variables (percentages) were transformed (arcsin-square root) prior to analysis to correct for 0-values (Sokal and Rohlf 1969). Species abundance variables were also transformed (log + 1) prior to analysis due to the prevalence of 0-values (Sokal and Rohlf 1969). Regressions were done using SPSS (SPSS 1988).

Bird-aircraft Strike Reports

Bird-aircraft strike reports were obtained form the Navy for all bases in the study from 1981 to 1991. Bird strike data are usually reported in the form of strike-rates, which are the number of strikes per 10,000 aircraft movements (Burger 1983). However, the Navy would not release the number of flights at each base for security reasons. Thus, since the numbers could not be standardized, no meaningful interbase comparisons could be made. Hence, we summarized the BASH report data by number of strikes by season, by solitary birds, flocks of birds, phase of flight, and by type of bird.

RESULTS

Bird Flight Behavior

The mean altitudes of flight varied by bases, but all means were under 370 m (Appendix 1). Mean altitudes of flight differed significantly between seasons for all bases (all $P < 0.0001$, ANOVA), with the exception of Fallon ($P = 0.056$) and Miramar ($P = 0.714$). The majority (67%) of bases with seasonal differences had significantly higher altitudes of flight during the late fall-winter compared to the other seasons. Imperial Beach, El Toro, and Point Mugu were the exceptions. Flight altitudes at these bases were highest during the late summer-fall. The numbers of birds flying in each height category differed by season at each of the bases (all $P < 0.0001$), with the exception of Miramar ($P = 0.532$; Appendix 1).

Small-sized birds accounted for about 56% of all observations, with two species of blackbirds, Brewers (*Euphagus cyanocephalus*) and red-winged (*Agelaius phoeniceus*) accounting for about 82% of all small birds (Table 1). Gulls (*Larus* spp.), considered medium-sized accounted for about 25% of all observations. Larger birds totaled only about 4% of the observations.

Habitat Use

Crops present at a base differed between seasons, hence percent habitat use also differed between seasons (Table 2). Crow's Landing, for example, had high percentages of birds detected in fallow fields during the late summer-fall and during the late fall-winter (33% and 24%, respectively). During the spring-summer, when tomatoes largely replaced fallow fields, the percent of birds detected in fallow fields decreased to 12% and birds detected in the tomato fields increased.

Some of the changes in percentages were not due to changes in habitats present. The percent of habitat offered by the aqueduct, where water levels remained constant, at Crow's Landing was consistent during the entire study. However, few birds were detected using this habitat during late summer-fall and late fall-winter 1 and 2 (5% and 3%, respectively). During spring-summer, swallows were observed foraging over the aqueduct in large numbers, increasing the percentage of birds detected there to 19%. The percent of cotton at Lemoore was consistent throughout the year, however, use changed seasonally with changes in phenology. In the late summer-fall cotton plants were high, with dense foliage and the percentage of birds detected here was 12.7%. During the late fall-winter, the fields contained very small immature plants and the percentage of birds detected dropped to 1.5%. In the spring-summer, plants were starting to mature, with 9.5% of birds detected here.

Certain habitats consistently had high percentages of birds detected in them. Lemon groves at Yuma, strawberry fields at El Toro, and stables at Imperial Beach all contained high percentages of birds during each of the 3 seasons. High percentages of birds were also detected during each season around buildings. The percentage of birds detected in weeds and weedy drainage ditches was consistent between seasons. Percentages of birds in these habitats were high despite the small percentage of total habitat they made up.

Most (61%) regression models included ≤2 variables. The majority of R-values (87 of 213) were between 0.30 and 0.50, 25 were less than 0.30, 80 were between 0.50 and 0.70, and 21 were >0.70. R-values where high for small sparrow-sized birds and swallows. The lowest R's were obtained for larger birds and blackbirds. The number of models developed (213) were too numerous to present here. In summary (Table 3), for all bases com-

Table 1. Flight altitudes (m) of birds observed at 11 western United States Naval Bases, 1989-1991.

Bird Group	$\bar{x}$	SD	n	Percent[1]
Small Birds				
Blackbirds	187	219.5	16,309	46.4
Larks[2]	47	70.9	833	2.4
Shorebirds	173	176.4	796	2.3
Pigeons/Doves	56	105.0	1,914	5.4
Medium Birds				
Gulls	256	218.8	8728	24.8
Large Birds				
Raptors	168	220.5	176	0.5
Herons/egrets	244	257.3	775	2.2
Waterfowl	239	242.5	462	1.3
All Birds[3]	194	227.8	35,161	

[1]Percent = n/35,161.

[2]Larks include horned larks (*Eremophila alpestris*) and western meadowlarks (*Sturnella neglecta*); combined for ecological, not taxonomic affinity.

[3]All birds are all birds observed, including those not represented in groups in this table.

bined, 21% of the regression models contained buildings, 14% drainage ditches, 14% fallow fields, 15% alfalfa, and 15% weeds.

Bird-aircraft Strike Reports

Eight hundred bird-aircraft collisions were reported for all bases combined from 1981 through June 1991. The majority of these strikes (55%) occurred during landing or awhile approaching an airstrip to land (Table 4). A high percentage (21%) of strikes also occurred while planes were taking off. Only 12% of all strikes occurred during actual flights (cruising and traffic patterns)

About 44% of bird strikes were not identified to species, specific-group, or size (Table 5). Of the remaining strikes, birds categorized as being small accounted for about 66%, medium sized birds 22%, and large birds 12%. Most medium sized birds involved in collisions were identified as gulls; gulls accounted for about one-quarter of all strikes.

DISCUSSION

The majority of birds we observed were blackbirds flying at low altitudes. Not surprisingly, the majority of strikes at our study sites occurred at low altitudes (take off and landing) and involved single birds of blackbird size. Similar findings have been reported by others. Langley (1970) reported that small-sized birds such as starlings and blackbirds were a major concern at many

Table 2. The range of percentage of birds recorded in various habitats at 9 United States Naval bases[1] during 1989 through 1991.

Habitat[2]	Late summer-fall	Late fall-winter	Spring-summer
Alfalfa	3 - 27	11 - 64	3 - 15
Aquaduct	0 - 5	0 - 3	1 - 19
Beans	9	1 - 4	11 - 18
Bermuda grass	5	0	2
Brocolli	0	1	4
Buildings	0 - 34	1 - 15	0 - 11
Cabbage	4	11 - 16	1 - 7
Cauliflower	9	0 - 13	0
Celery	2	2	4
Chives	1	2	0
Corn			16
Cotton	13	2	10
Desert Shrub	7 - 12	5 - 6	5 - 6
Drainage Ditch	1 - 12	0 - 17	0 - 25
Fallow Field	0 - 33	0 - 27	1 - 12
Hay/straw	0	1 - 4	1 - 3
Lemons	31	19 - 22	23 - 56
Lettuce	10	10 - 20	14
Nursery		15	5
Onions	0	0 - 1	2 - 9
Oranges	3	6	2
Orchard	16	10	9
Pasture	64	2 - 60	29
Sod		32	23
Stables	27	2 - 33	3 - 22
Strawberries	25	25	19
Sugar Beets	6	1	19
Tomatoes	1		2 - 24
Weeds	0 - 20	0 - 13	3 - 44
Windbreaks	1 - 21	0 - 4	1 - 11

[1]Data on habitat use were not collected at NAS Miramar and NAS Moffett Field due to the lack of agricultural fields.
[2]Blanks indicate that habitat was not present during the season.

Table 3. Percentage of regression models containing each habitat variable, at 9 United States Naval bases, 1989-91.

Variable	Occurrence in models (%)[1]
Buildings	21
Weeds	15
Alfalfa	15
Drainage ditch	14
Fallow fields	14
Windbreaks	13
Short grass or Sod	7
Medium to tall grass	7
Pasture	7
Hay, straw, bermuda grass	6
Landfill, or junkyard	6
Aquaduct, small pond	6
Immature lettuce	5
Immature tomatoes	5
Mature sugar beets	5
Plowed under crops	5
Mature tomatoes	4
Beans	4
Deciduous orchard	4
Stables	3
Immature sugar beets	3
Onions	3
Citrus grove	3
Mature lettuce	3
Mature celery	2
Immature cotton	2
Mature cotton	2
Strawberries	1

[1]All bases combined.

airports because they frequently use airport grounds for both roosting and foraging. Linnell et al. (1996) found that 91% of strikes at an airport in Hawaii involved single individuals of commonly occurring species. Although he did not report the species involved Neubauer (1990) determined that 56% of Air Force bird strikes occurred at altitudes below 305 m. Because airfields provide bird habitat, and because aircraft must use this zone of concentrated bird activity to take-off and land, it is apparent that some type of habitat modification should be conducted to reduce bird abundance.

Bird abundance is influenced by topography, structure and composition of vegetation (Brown 1984, Noon et al. 1985), and various human factors (e.g., dumps, agriculture), all of which vary with location. The structure and composition of vegetation change seasonally in a controlled environment such as agriculture. Seasonal changes in bird use reflected responses to seasonal crop phenology. An increase in vegetative cover in fields resulted in birds moving into the fields for the cover and or food they provided (Besser 1985, Cummings et al. 1989).

Bird abundance may vary with season and location, but our regression models indicated that buildings, weeds, alfalfa fields, fallow fields, drainage ditches, and windbreaks were important predictors of bird abundance at many of our study sites. Birds were detected in these habitats consistently in all 3 seasons. Weeds and drainage ditches at all bases were generally found along edges of roads and fields. Edges have long been known to effect wildlife populations and windbreaks are considered to be valuable avian habitats in areas of intense agriculture (Yahner 1982, 1983). Alfalfa has been shown to support greater numbers of breeding species per unit area than corn and small grain fields (Dambach and Good 1940).

Table 4. Number and percent of bird-strikes during different phases of flight at 11 western United States Naval bases from 1981 through June 1991.

Phase of Flight	Number of strikes[1]	%
Climbing	30	3.8
Cruise, in flight	12	1.5
Descent	8	1.0
Final Approach	106	13.3
Landing	169	21.1
Low Level Flight	33	4.1
Touch and Go	167	20.9
Range	8	1.0
Take-off	162	20.3
Traffic Pattern	87	10.9
Unknown	18	2.3

[1]All bases combined.

Although many have recommended that agricultural land on airfields be eliminated (Solman 1973, Blokpoel 1976, Hild 1985) our regression models suggest that conditions related to agriculture (e.g. weeds, drainage ditches, windbreaks) may be more attractive to bird species than the actual crops themselves. Keeping weeds to a minimum in drainage ditches, and at the edges of fields close to runways may aid in reducing bird abundance at an airfield. Being aware of seasonal changes in crop availability and potential bird responses to these changes could be used as an aid in scheduling aircraft activity or in increasing pilots awareness of were birds are that may pose a threat.

In addition to vegetation, birds at many of our bases were attracted to features of the military operation itself (e.g., hangars, buildings). Many methods for preventing birds from resting and/or nesting in and around buildings have been suggested (see Blokpoel 1976). Some of these include keeping hangars closed, blocking small openings that may provide access, and adding sharp projections to ledges to make them unattractive as resting sites.

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Table 5. Number and percent of bird-strikes by type of bird at 11 western United States Naval bases from 1981 through June 1991.

Phase of Flight	Number of strikes[1]	% of all identified
SmallBirds		
Blackbird	20	4.4
Larks[2]	4	0.9
Shorebirds	6	1.3
Pigeon/doves	25	5.5
Unknown	243	53.8
Medium Birds		
Gulls	88	19.5
Unknown	11	2.4
Large Birds		
Raptors	20	4.4
Herons/egrets	5	1.1
Waterfowl	13	2.4
Unknown	17	3.8
Unknown Size	348	

[1]All bases combined.

[2]Includes horned larks and western meadowlarks (See Table 1).

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Appendix 1. Mean flight altitude of birds and percentages of birds flying by height classification at 11 western United States Naval bases during 1989-91.

		Altitude			Percent birds flying (m)			
Base	Season[1]	$\bar{X}$	SD	N	≤10	>10 to 25	>25 to 100	>100
Crow's	1	86	152	1353	17	32	30	21
Landing	2	367	351	1617	7	9	22	62
	3	28	21	107	31	27	42	0
El Centro	1	105	179	556	4	18	69	0
	2	259	235	10939	3	5	33	59
	3	88	144	803	21	16	45	18
El Toro	1	156	169	338	9	7	42	42
	2	99	131	148	18	8	48	26
	3	70	132	363	26	17	37	20
Fallon	1	68	82	354	16	7	65	12
	2	53	24	121	2	15	83	0
	3	55	87	484	13	38	42	7
Imperial Beach	1	316	307	788	7	5	45	43
	2	155	167	1617	10	8	43	39
	3	116	146	630	15	8	49	28
Lemoore	1	99	155	2199	15	25	40	20
	2	154	204	798	26	10	18	46
	3	43	84	756	34	28	30	8
Miramar	2	91	242	10	40	40	10	10
	3	114	179	91	30	26	18	26
Moffett Field	1	128	227	762	46	23	9	22
	2	328	223	3560	2	3	10	85
Point Mugu	1	349	265	347	2	5	17	76
	2	115	140	273	41	11	9	39
Tustin	1	117	51	1368	7	3	13	77
	2	214	198	1139	13	10	15	63
	3	67	126	314	40	10	35	15
Yuma	1	48	85	913	19	48	25	8
	2	74	141	1198	32	11	46	11
	3	62	111	1215	38	22	24	16

[1]Seasons: 1 = late summer-fall; 2 = late fall-winter; 3 = spring-summer.

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