A STUDY DESIGN TO PROVIDE INFORMATION FOR BIRD-AIRCRAFT STRIKE HAZARD PROGRAMS

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Abstract: Bird-aircraft strikes are a major concern to the entire aviation community. We developed a study to provide the Navy with information concerning avian use of agricultural lands on and near selected Naval bases in Arizona, California, and Nevada. With this knowledge a management program can be implemented to reduce hazardous bird-aircraft stikes. Permanent census points were established for observing flight patterns of birds at each base. In addition, transect lines were used to observe habitat use by birds in and around agricultural fields on each base. Habitat types and an estimated percent of that habitat within a 200-m-radius were recorded. Habitat classifications that were more specific than those used in the current Wildlife Habitat Relationships (WHR) system (data base) were given. Percent usage of habitats was estimated for 2 study sites and compared with the WHR system. Habitat use differed by species and crop type. These differences tended to be overlooked when using the WHR classifications. Our study design can be used for determinining the species composition and abundance of birds on a seasonal basis and relating that to crop types and crop phenology. Expansion of the current Wildlife Habitat Relationship (WHR) Data Base to include more specific agricultural habitat classifications is suggested.

Aircraft and bird collisions are a major concern to the aviation community. Since the first recorded human fatality in 1912, incidents involving bird collisions have increased as both the speeds and the number of aircraft flying have increased. Problems due to bird strikes have also increased since turbine engines began to replace piston engines in the 1950s (Blokpoel 1976). The rotating propeller blades on piston-engined aircraft tended to protect the engine before birds could do much damage. Turbine engines, however, are more exposed and vulnerable to bird strikes.

Military aircraft are especially prone to strikes because they fly at high speeds and at low altitudes where birds are most abundant. The Department of the Navy responded to this problem by implementing its present mandatory bird-aircraft strike hazard (BASH) reporting system in 1981 to document collisions when they occur and to develop management plans for avoiding bird-aircraft interactions. Once implemented the efficiency of BASH management programs is apparent almost immediately. Four naval air stations that started BASH programs in 1984 reported 57-78% fewer strikes in 1984 than in 1983 (Walker and Bennet 1985).

Three-fourths of all strikes occur at or near airports, usually during take-offs and landings (Solman 1971). Technical modifications to aircraft can only make a minor contribution to reducing strike hazards (Blokpoel 1976). Because of this, numerous methods have been employed to reduce bird populations and bird-strikes on and around airfields. These methods include reduction of overall bird populations, dispersal of birds, habitat manipulation, and the warning of pilots so they can take evasive action.

This project, which is a two year cooperative research effort between the University of California at Berkeley and the Department of the Navy, was instigated to provide the Navy with information concerning avian use of agricultural fields on and around Naval airfields.

The Navy currently participates in an agricultural outlease program where Navy land is leased to local farmers. Knowledge of bird use of this agricultural land is important information that must be incorporated into the Navy's BASH program.

This paper presents methods that can be used in the future by the Navy and other members of the aviation community, to obtain information needed to set up BASH management programs. We also present examples of results obtained using these methods and a brief evaluation of the California Wildlife Habitat Relationships (WHR) System.

STUDY AREA

Our study areas were located in Arizona, California, and Nevada. The Arizona study area was the Marine Corps Air Station at Yuma located in Yuma County in the southwestern corner of Arizona. The seven California study areas were the Naval Auxiliary Landing Field, Crow's Landing (Stanislaus Co.), and the Naval Air Station at Lemoore (Fresno Co.), both located in the San Joaquin Valley; the Naval Air Station at Point Mugu (Ventura Co.) on the southern coast of California; the Marine Corps Air Stations El Toro and Tustin, located in Santa Ana (Orange Co.) south of Los Angeles; the outlying Landing Field at Imperial Beach (San Diego Co.) on the southwestern coast of California near the Mexican border; and the Naval Air Field at El Centro (San Diego Co.) in the Imperial Valley south of the Salton Sea. The Nevada study area was the Naval Air Station at Fallon (Churchill Co.) located east of Reno. The study areas included the installations and adjacent agricultural areas.

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METHODS

BIRD FLIGHT PATTERNS

Permanent census points were established for observing flight patterns of birds at each base. If consistent non-random flight patterns are found, they can possibly be traced to off site factors influencing birds present on base. This information can also be used for recommendations on future management strategies. Flight patterns of aircraft can be changed to compensate for movements of birds over the airfield at certain times.

Between 3 and 6 points approximately 1,000-1,500 m apart were established around the airfield. The number of points established depended upon the size of the base. Distance between points was such that it reduced the probability of double counting birds. Data were collected in the morning for 30 min at each point from sunrise until approximately 2-3 hours after sunrise, and in the afternoon from 2-3 hours before sunset until sunset. Morning and afternoon points were run in the same order, than reversed the following day. All birds observed or heard within a 500-m-radius were recorded. Distance to the bird was estimated in meters, and a clinometer was used to measure the angle from the observer to the bird. The direction a bird was observed in and its direction of flight was noted using a compass. Weather variables including cloud cover, temperature, precipitation, wind, and wind direction were recorded at each point.

The total number of birds observed flying in a specific direction during the stationary census points were recorded into north, south, east, west, northeast, northwest, southeast, and southwest categories. These totals were then combined for each morning and afternoon over a season. Chi-square analysis was used to determine if flight direction at each base was random on a morning and afternoon basis, over each season. A significance level of $P < 0.05$ was used throughout the analysis.

Altitude of flight was estimated using the formula for a right triangle from the distance and angle measurements collected. Mean flight altitude was calculated for the bases which were found to have consistent non-random seasonal flight patterns.

BIRD HABITAT USE

In addition to the permanent census points, transect lines were established at each base. The purpose of these transects was to observe habitat use by birds in and around the agricultural outleases (located on base or in adjacent areas). With this knowledge habitats can be manipulated to attract fewer birds or to attract birds that are not a problem in bird-aircraft strikes. We used a modified variable circular plot method. Data were collected at designated points along a transect greater than 400 m apart. This distance was choosen so overlap of birds between points would be minimized. Transect length varied between 7 to 12 points depending upon the size of the agricultural outleases. The transects were walked in the morning beginning 15 min after sunrise and ending with the completion of the transect. This process was repeated in the afternoon with the last point concluding approximately 15 min 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. It was also short enough to reduce the probability of double counting (See Reynolds et al. 1980) One min prior to the 7 min was allowed to let the birds habituate to the observers presence. All birds seen or heard within a 200-m radius were recorded. Distance to the bird in meters, the bird's behavior and the habitat being used were also recorded.

Birds in flight were considered between habitats. Habitat types and an estimated percent of that habitat within a 200-m radius were made for each point recorded. Estimating habitat percentages each time a point was censused was important because the habitats could change over the course of a few days. Crops could be harvested, cut, or plowed. Habitats were classified by the vegetation present and the phenology of the vegetation (Appendix 1). Percent use of habitat types by major species was calculated for each base and season.

To facilitate data collection we divided the year into the following seasons. Season 1: late summer-fall, August through November; Season 2: late fall-winter, December through March; Season 3: Spring-summer, April through July. Data were collected at each base for 3 days per season.

COMPARISON WITH THE WHR SYSTEM DATA BASE

The California Wildlife-Habitat Relationships (WHR) System (Airola 1988) puts agricultural land into three categories: cropland, pasture, and orchard/vineyard. These categories were not specific enough for our needs. To illustrate this, we combined the five most common agricultural crops found at Marine Corp Air Stations Tustin and El Toro. We determined the percent usage of these combined crops by some common species. These results were then compared with percent usage of specific crops by the same species.

Table 1. The species and number of birds recorded during late summer-fall (season 1) at 2 Naval bases in California.

Species[1]	Number of birds	
	Crow's Landing	Lemoore
American Crow	445	1
American Goldfinch	34	28
American Kestrel	17	20
Blackbirds[2]	63	293
Black-shouldered Kite	3	47
Dark-eyed Junco	3	23
House Finch	4	707
Horned Lark	991	574
House Sparrow	4	8
Killdeer	77	26
Long-billed Curlew	185	1
Loggerhead Shrike	1	19
Mourning Dove	16	60
Northern Harrier	13	13
Redtail Hawk	9	11
Savannah Sparrow	168	23
Song Sparrow	0	66
Water Pipit	1	248
White-crowned Sparrow	41	102
Western Meadowlark	110	166
Yellow-billed Magpie	14	0
Yellow-rumped Warbler	0	85

[1]Scientific names can be found in Appendix 2.
[2]Includes: Red-winged blackbirds; Brewer's blackbirds; and European starlings.

RESULTS

A wide variety of birds were observed at the study sites over the different seasons. The numbers for major species of birds recorded at Naval Air Field Lemoore and Auxillary Landing Field Crow's Landing during two seasons are presented here as examples (Tables 1 and 2). Flight patterns were found to exist at several of the bases studied. One of these bases, Imperial Beach had 48.4 % of all birds observed flying west in the afternoon during the late fall-winter. In the afternoon during the spring-summer, 60.1 % of birds observed were flying north. The majority of birds flying directionally during these seasons were gulls (*Larus* sp.), 77% during the late fall-winter and 89% during the spring-summer.

The percent usage of specific crops by common species was calculated for MCAS Tustin and El Toro during the late fall-winter (Table 3). We found that House finches (*Carpodacus mexicanus*),were mainly using the strawberry and cabbage fields. They were using cauliflower fields in small numbers and they were not using lettuce or fallow fields. Conversely, Horned larks (*Eremophila alpestris*) and Water pipits (*Anthus spinoletta*), used the lettuce and cauliflower fields in high numbers but few were located in the strawberry and cabbage fields.

When the habitat types in table 3 were lumped, as with the WHR classification, we obtain different results (Table 4). House finches, Horned larks and Water pipits made up the highest percentages of birds using the combined crops, but we know they did not use the same crops (Table 3). Blackbirds which made up only 8% of birds when we combined crops, were one of the main birds found using fallow fields, a habitat that was very common during this season.

DISCUSSION

The local environment surrounding Imperial Beach is an important factor in explaining the patterns of directional flight found to exist there. OLF Imperial Beach is located near the Tijuana River and the Pacific

Table 2. The species and number of birds recorded during the late fall - winter (season 2) at 2 Naval base in California.

Species[1]	Number of birds Crow's Landing	Lemoore
American Crow	2,167	8
American Goldfinch	46	0
American Kestrel	15	37
American Robin	25	7
Blackbirds[2]	0	2,979
Black-shouldered Kite	10	6
Canada Goose	23	0
Cliff Swallow	280	103
Dark-eyed Junco	0	5
Great Egret	6	1
House Finch	144	304
Horned Lark	933	1,186
House Sparrow	0	5
Killdeer	64	200
Long-billed Curlew	193	57
Loggerhead Shrike	1	18
Mallard	15	22
Mourning Dove	42	71
Mountain Plover	0	71
Northern Harrier	30	27
Northern Pintail	43	0
Rock Dove	25	0
Redtail Hawk	26	12
Say's Phoebe	0	2
Savannah Sparrow	439	250
Song Sparrow	1	111
Tree Swallow	21	2
Turkey Vulture	6	0
Water Pipit	109	1,337
White-crowned Sparrow	251	355
Western Meadowlark	76	484
Yellow-billed Magpie	*30*	*0*
Yellow-rumped Warbler	6	15

[1]Scientific names can be found in Appendix 2.
[2]Includes: Red-winged blackbirds; Brewer's blackbirds; and European starlings.

Table 3. The percent usage of individual crops by common species at Marine Corps Air Stations Tustin and El Toro during late fall-winter.

Species[1]	Crops (%) Strawberries	Lettuce	Cauliflower	Fallow field	Cabbage
Goldfinches (*Carduelis sp.*)	28	0	0	0	0
House finches	41	0	8	0	61
Horned larks & Water pipits	13	70	88	26	6
Western meadowlarks	<1	2	0	11	0
Blackbirds[2]	2	2	0	5	0

[1] Scientific names given in Appendix 2.
[2] Includes: Red-winged blackbirds; Brewer's blackbirds; and European starlings.

Table 4. The percent usage of combined crops by common species at Marine Corps Air Stations Tustin and El Toro during late fall-winter.

Species[1]	Combined crops (%)
Goldfinches (*Carduelis sp.*)	13
House finches	25
Horned larks & Water pipits	35
Western meadowlarks	*2*
Blackbirds[2]	*8*

[1]*Scientific names given in Appendix 2.*
[2] Includes: Red-winged blackbirds; Brewer's blackbirds; and European starlings.

Ocean. A large lagoon to the west of the base usually contains large numbers of gulls (*Larus* sp.), both feeding and resting. The Tijuana Estuary is located northwest of OLF Imperial Beach. Salt evaporation ponds and San Diego Bay are located north of the base.

Gulls account for about 40% of the world's reported bird-aircraft strikes (Seubert 1976), and are considered by many to be the most serious avian threat to aircraft. Gulls tend to follow predictable daily movements (Forsythe 1976). The methods we have established can be used to determine flight patterns of gulls, and other birds. Off-site factors that may be influencing these flight patterns can be determined (e.g., rivers, garbage dumps, roost sites). This knowledge can then be incorporated into BASH management programs. In some situations, it might be possible to manipulate off-site factors and disrupt flight patterns. Take-offs and landings can also be modified to avoid these birds.

In order to develop an effective BASH management plan, the species composition and abundance of birds on a seasonal basis in relationship to crop types and crop phenology must be determined. Our study design can be used to obtain this information. This information should then be compared with bird collision reports. Once it is determined what bird species are involved in collisions and what habitats they are using, management plans can be implemented. Habitats that attract large numbers of birds can be manipulated to make them less attractive to problem species. Since the Navy has control over what crops are grown on naval land, restrictions can be placed on what should and should not be grown.

In addition, the information collected on avian usage of specific crops can be used to fill gaps in the WHR system. The agricultural categories in the current WHR system are much too general. Agricultural crops vary in the amount of cover and food they provide. Preferences for certain crops are overlooked when all crops are combined. Information about crop preference is extremely important in situations like the Navy's BASH program. By developing a more specific classification scheme, better information on avian usage of specific habitats cans be determined and incorporated into the WHR data base, thus improving its predictive ability.

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Appendix 2. Common and scientific names of the birds found in Tables 1-4.

COMMON NAME	SCIENTIFIC NAME
American Crow	*Corvus brachyrhynchos*
American Goldfinch	*Carduelis tristis*
American Kestrel	*Falco sparverius*
American Robin	*Turdus migratorius*
Brewer's Blackbird	*Euphagus cyanocephalus*
Black-shouldered Kite	*Elanus caeruleus*
Canada Goose	*Branta canadensis*
Cliff Swallow	*Hirundo pyrrhonota*
Dark-eyed Junco	*Junco hyemalis*
European Starling	*Sturnus vulgaris*
Great Egret	*Casmerodius albus*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
Horned Lark	*Eremophila alpestris*
Killdeer	*Charadrius vociferus*
Long-billed Curlew	*Numenius americanus*
Loggerhead Shrike	*Lanius ludovicianus*
Mallard	*Anas platyrhynchos*
Mourning Dove	*Zenaida macroura*
Mountain Plover	*Charadrius montanus*
Northern Harrier	*Circus cyaneus*
Northern Pintail	*Anas acuta*
Rock Dove	*Columba livia*
Red-tailed Hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Say's Phoebe	*Sayornis saya*
Savannah Sparrow	*Passerculus sandwichensis*
Song Sparrow	*Melospiza melodia*
Tree Swallow	*Tachycineta bicolor*
Turkey Vulture	*Cathartes aura*
Water Pipit	*Anthus spinoletta*
White-crowned Sparrow	*Zonotrichia leucophrys*
Western Meadowlark	*Sturnella neglecta*
Yellow-billed Magpie	*Pica nutalli*
Yellow-rumped Warbler	*Dendroica coronata*