# THE U. S. AIR FORCE BIRD AVOIDANCE MODEL FOR LOW-LEVEL TRAINING FLIGHTS

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*Abstract:* Since 1986, bird strikes have caused nearly $500 million in damage to United States Air Force (USAF) aircraft as well as the loss of 33 lives. To reduce these losses, the USAF developed a Bird Avoidance Model (BAM) to evaluate low-level training routes for bird strike hazards throughout the contiguous United States. Through an interagency agreement, I have provided BAM evaluations to USAF personnel since April 1996. From April 1996 - March 1997, 1,654 routes were evaluated for bird strike hazards. The current BAM, developed during the 1980s, incorporates waterfowl and raptor species, which account for the majority of damaging bird strikes to military aircraft. Because major changes have occurred to bird populations of relevant species throughout North America (e.g., Canada geese (*Branta canadensis*), double-crested cormorants (*Phalacrocorax auritus*), gulls (*Larus* spp.), there is need for an updated model that contains current population data for a larger array of bird species. The USAF is in the process of developing a geographic information system (GIS)-based BAM that will contain current population data on an expanded diversity of species that pose strike threats along low-level training flights.

**Pages 162-170 *in* C. D. Lee and S.E. Hygnstrom, eds. Thirteenth Great Plains Wildl. Damage Control Workshop Proc., Published by Kansas State University Agricultural Experiment Station and Cooperative Extension Service.**

**Key Words:** bird strike, GIS, migration, military, raptor, waterfowl

## INTRODUCTION

### Bird Strike History

Aircraft collisions with birds (bird strikes) have occurred since the beginning of aviation. In the spring of 1912, C. Rogers was the first man to fly across North America. Later that same year, a gull (*Larus* sp.) became tangled in the control wires of C. Rogers' plane, causing the plane to crash off the Pacific Coast, killing Rogers (Solman 1978). Since then, a multitude of bird strikes have damaged and downed civil and military aircraft (Richardson 1994, Thorpe 1996, Cleary et al. 1996). Additionally, bird strikes appear to be increasing (Solman 1978, 1981; Donoghue 1996).

Since 1986, bird strikes have caused nearly $500 million in damage to United States Air Force (USAF) aircraft as well as 33 fatalities (P. Windler, Maj., USAF BASH Team, Kirtland AFB, N.M., pers. commun.). On average, USAF aircraft incur 2,500 bird strikes per year, most of which occur during fall and spring migration (Figure 1). About 69% of all USAF bird strikes are below 1,000 feet (305 m) above ground level (AGL) (Figure 2) and 26% of known USAF bird strikes occur along low-level training routes and ranges (C. Atkins, Capt., USAF BASH Team, Kirtland AFB, N.M., pers. commun.). In addition to USAF losses, the U. S. Navy has reported 7,761 bird strikes causing <$10,000 in damage per strike and 4,612 bird strikes causing >$10,000 in damage per strike, totaling 12,373 bird strikes and $217 million in damages since 1986 (L. Stella, LCDR, U. S. Navy, Norfolk, Va., pers. commun.). Primary reasons for increasing bird strikes include: an increase in the number of aircraft; faster, larger, and quieter aircraft; adaptation of certain bird species to urban environments; and an increase in many bird populations.

### Low-level Flights

Bird strikes have been reported during all phases of flight. Low-level military flights, however, experience a large number (26% of known USAF bird strikes) of strikes because these flights are typically at high speed (e.g., 350-600 nautical miles [nm] per hr) and altitudes (e.g., 30-300 m AGL) where birds commonly fly (DeFusco 1993). These low-level strikes represent 65% of the damage caused by bird strikes to USAF aircraft (R. DeFusco, Maj., USAF Academy, Colorado Springs, Colo., pers. commun.).

As examples, in September 1987 a USAF B-1 bomber struck an American white pelican (*Pelecanus erythrorhynchus*) near LaJunta, Colorado, causing the plane to crash and killing 3 of 6 crew members. Damages exceeded $215 million (DeFusco 1993). In May 1992, a turkey vulture penetrated the windshield of a U. S. Navy FA-18 Hornet, causing the jet to crash into the Santa Fe River and killing the pilot (Gainesville, Fla. Sun, 24 June 1993). In September 1992, a turkey vulture (*Cathartes aura*) penetrated the windshield of a USAF trainer near Dyess AFB, Texas, killing the pilot. An instructor in the back seat landed the aircraft safely (DeFusco 1993).

### Increase and Urbanization of Bird Populations

Populations of many bird species involved in bird strikes have increased in the last few decades. Restrictions in pesticides and other chemicals that affected reproduction, enhanced management and protection programs, and adaptation by some of these species to human environments are all contributing factors to these increases.

For example, long term population trends from North American breeding bird survey (BBS) data show an increase of 3.1% per year ($P < 0.01$) for white pelicans and 1.1% per year ($P = 0.02$) for turkey vultures from 1966-1993 (Peterjohn et al. 1994). In addition, populations of double-crested cormorants (*Phalacrocorax auritus*) in the Great Lakes and northern prairie regions have grown at annual rates of 15 to 63% since the 1970s (Hatch 1995). Ring-billed gulls (*L. delawarensis*) nesting in the Great Lakes have increased from about 280,000 pairs in 1976 to 710,000 pairs in 1990 (Blokpoel and Scharf 1991). These gulls now frequently nest on rooftops in urban environments (Dwyer et al. 1996). Similarly, herring gulls (*L. argentatus*) on the Canadian side of the lower Great Lakes, excluding Lake Erie, have increased from 440 pairs at 23 colonies in 1976-77 to 1,304 pairs at 37 colonies in 1990 (Blokpoel and Tessier 1996). Numbers of giant Canada geese (*Branta canadensis maxima*), greater and lesser snow geese (*Chen caerulescens atlantica* and *C. c. caerulescens*, respectively), and Ross' geese (*C. rossii*) have increased dramatically during the last 30 years, requiring liberalized and extended hunting seasons (Ankney 1996).

## CURRENT BIRD AVOIDANCE MODEL

### History

The Bird Avoidance Model (BAM) in use today was developed in the early 1980s for the USAF's Bird Aircraft Strike Hazard (BASH) Team by the Aerospace Mechanics Division, University of Dayton Research Institute, Dayton, Ohio. The BAM is a DOS-based program written in FORTRAN that computes bird strike hazards for areas within the continental United States (CONUS) (Skinn et al. 1981). The purpose of the BAM is to reduce bird strikes to aircraft by determining locations and times of elevated bird activity based on historical data. After development, this model went through several changes during the 1980s.

The first BAM contained on'_ waterfowl population data. Distributions, migratory flyways, and populations of waterfowl within 18 regions of the CONUS as described by Bellrose (1980) were the primary source of data for the BAM. Additionally, waterfowl survey data from state and federal wildlife refuges were included in the BAM.

Although waterfowl constituted a large number of documented bird strikes, raptors (primarily vultures [*Cathartes aura* and *Coragyps atratus*.] and hawks [*Accipiter* spp. and *Buteo* spp.]) posed a greater hazard to USAF pilots because of their soaring habits at altitudes of low-level military routes. Therefore, in 1983 a population census of raptors was initiated in various regions of the CONUS for inclusion into the BAM. In 1985, raptor census data was incorporated into the BAM. Discussions took place to incorporate other bird species (e.g., gulls, shorebirds) but none were due to a lack of funding.

One shortcoming of the current BAM is that it is not user-friendly, requiring a trained individual to run the model and interpret the output. The output has to further be transformed into a readable and compressed format for distribution to those military personnel requesting BAM evaluations. Spectrum Science & Software, Inc., Ft. Walton Beach, Florida, modified and shortened the steps for running the BAM and transforming the output in the mid-1980s; however, these changes did little to make the program more user-friendly.

**BAM Output**

The BAM overlaps x and y coordinates (latitude and longitude) of low-level routes and areas of concern with bird hazards associated with those same x and y coordinates. The user is able to add routes, modify and edit routes already entered, and delete routes as necessary. After a route is entered or modified as desired, a number of executable expressions are entered which runs the program for the desired route. The output is in 2 forms. The first is the hazard output, which is broken down by month, time of day (dawn, mid-day, dusk, and night), and finally by waterfowl and raptors (Figure 3). There is 1 page of output for each segment along the route and 1 page for the entire route. Thus, a route with 5 segments will have 6 pages of output. The second output from the BAM presents the overall bird hazards for the entire route by month and time of day. The first output is transferred into a shortened, readable format presenting waterfowl and raptor hazards for each segment of the route, whereas the second output is exported into Harvard Graphics 3.0 to generate a graphic representation of total hazards for the route (Figure 4).

Hazards codes are organized into 3 categories: note, caution, and warning for waterfowl and raptors (Table 1). These hazards are associated with the number of expected bird strikes per 1 million nm of flight along a particular route or area. Raptor hazard codes appear more cautious than waterfowl codes because of the soaring habits raptors exhibit, increasing the probability of a bird strike.

**Table 1. Hazard codes for waterfowl and raptors from data output from the Bird Avoidance Model.**

| Species group | Hazard codes | # of expected bird strikes per 1 million nautical miles of flight |
|---|---|---|
| Waterfowl | Note | 30-99 |
| | Caution | 100-999 |
| | Warning | >999 |
| Raptors | Note | 3-9 |
| | Caution | 10-19 |
| | Warning | >19 |

After evaluating areas for bird hazards with the BAM, the output is organized into a simple format which includes a 2-page cover letter explaining the BAM and the evaluations received, a graph of the overall bird hazards for the route or area (Figure 4), a verbal explanation of bird hazards (using bird hazard codes) for raptors and waterfowl for specific areas along the route or area, and a questionnaire. The verbal explanation provides recommendations to reduce bird strikes by avoiding those areas along the route where bird hazards are more prevalent. In addition to the above information, current waterfowl population data are included upon request. Data on waterfowl for 1996 were obtained from Caithamer and Dubovsky (1996) and by contacting National Wildlife Refuge biologists and Flyway Representatives.

**Requests and Use of the BAM to Reduce Bird Strikes**

From April 1996 - March 1997, 1,654 routes were requested and evaluated for bird strike hazards using the BAM. Routes and areas evaluated include: low-level visual routes (VR) , instrument routes (IR), slow-speed routes (SR), military operational areas (MOAs), restricted areas, airfields, and other areas of interest (Table 2). Requests have been made by USAF commands (43%), USAF Reserve (2%), U. S. Air National Guard (11%), U. S. Navy (7%), U. S. Marine Corps (32%), U. S. Coast Guard (3%), and private consulting firms conducting Environmental Impact Statements on airfields (2%) (Table 2).

Table 2. **Source of Bird Avoidance Model requests for various route types from 1 April 1996 - 31 March 1997.**

| Requestor | # of requests | Route type[a] | | | | | Total routes |
|---|---|---|---|---|---|---|---|
| | | AB[b] | VR | IR | SR | Other | |
| US Air Force commands | 86 | 276 | 192 | 109 | 60 | 73 | 710 |
| US Air Force Reserve | 8 | 22 | 1 | 0 | 12 | 6 | 41 |
| US Air National Guard | 19 | 18 | 61 | 16 | 16 | 71 | 182 |
| US Navy | 5 | 0 | 64 | 21 | 1 | 23 | 109 |
| US Marines | 7 | 46 | 204 | 120 | 39 | 121 | 530 |
| US Coast Guard | 3 | 5 | 0 | 0 | 0 | 47 | 52 |
| Private | 9 | 13 | 9 | 1 | 6 | 1 | 30 |
| Total | 137 | 380 | 531 | 267 | 134 | 342 | 1,654 |

[a] AB = Air base; VR = Visual routes; IR = Instrument routes; SR = Slow speed routes; Other = Military Operational Areas, Restricted Areas, and other areas of concern.

[b] Includes Air Force Bases, Naval Air Stations, airports, Coast Guard ports, and other air bases.

## BIRD AVOIDANCE MODEL OF TOMORROW

### Species Included

The USAF is in the process of developing a geographic information system (GIS)-based BAM. This new BAM will combine the latest in computer technology with current bird population data and should provide a powerful management tool to military aviators and flight safety personnel. Species to be incorporated in the GIS-BAM include those frequently recorded in the USAF bird strike database (e.g., gulls, waterfowl, vultures), birds that are a threat to military aircraft because of their flocking behavior (e.g., blackbirds), and birds that pose a threat because of their large size (e.g., pelicans, swans [*Cygnus* spp.]). Population and migration data of waterfowl, raptors, blackbirds, horned larks (*Eremophila alpestris*), shorebirds, gulls, pelicans, and other flocking birds are to be included in the GIS-BAM. Hazards will be identified as the amount of avian mass/volume of air space, instead of by species occurrence and abundance.

### Data Layers

The use of GIS allows the input of multiple data layers. Data layers to be incorporated in the GIS-BAM include environmental data (e.g., mean annual temperatures and precipitation amounts), geographical data (e.g., topography, streams, roads, vegetation classifications), and bird population data (e.g., Breeding Bird Surveys, Christmas Bird Counts, USAF bird strike database, National Wildlife Refuge survey data, and miscellaneous migration and population data). All data will be scaled to a 1 $km^2$ resolution.

### Development

The GIS-BAM is being developed using ARC INFO (ESRI 1994) on a UNIX workstation and will be operated using ARC VIEW (ESRI 1994) on a Windows-run PC. Completion of the GIS-BAM is projected for January 1998. The program will be available on a CD-ROM and will include a user's manual. The capability to update current data and add new data will be developed into the program. Additionally, Next Generation Radar (NEXRAD) technology is planned as a source of data in future versions of the GIS-BAM. Once the U. S. GIS-BAM is completed, development of similar BAM's will begin for Alaska and other areas the USAF routinely flies (e.g., Africa, Europe).


## ACKNOWLEDGMENTS

I thank the USAF BASH Team at Kirtland AFB, NM: Maj. D. Arrington for assistance with BASH information, Capt. C. Atkins for providing USAF bird strike statistics and additional assistance, G. LeBoeuf for assistance with BASH information, and Maj. P. Windler for providing assistance with low-level routes and military information and data. LCDR L. Stella provided U. S. Navy bird strike statistics. R. A. Dolbeer reviewed an earlier draft of this manuscript. E. Riegelmann provided information about the GIS-BAM and its development.


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**Figure 1. Percent of Bird Strikes (N = 26,475) by Month to USAF Aircraft, 1986-95. Data are from the USAF Bird Strike Database (C. Atkins, Capt. USAF BASH Team, Kirtland AFB, N.M., Pers. Commun.)**

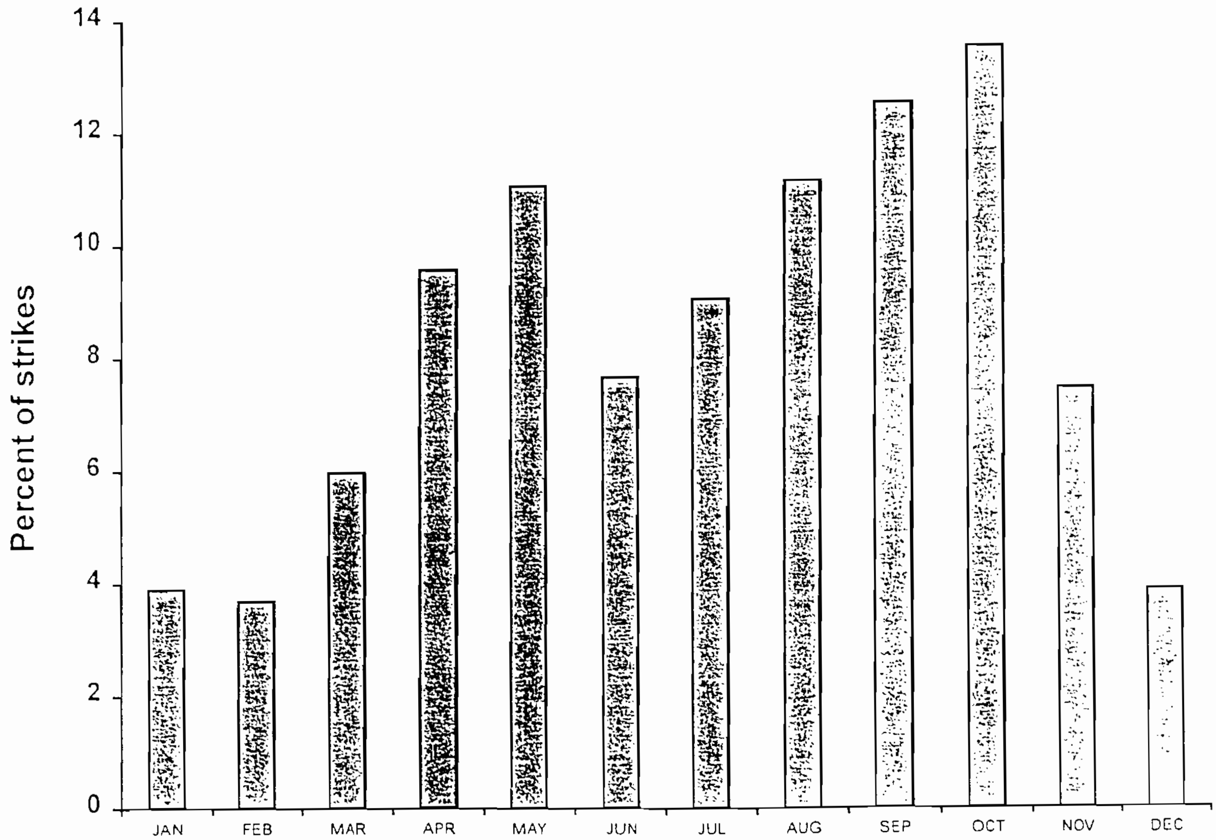

Figure 2. Percent of Bird Strikes (N = 26,475) by Altitude to USAF Aircraft, 1986-95. Data are from the USAF Bird Strike Database (C. Atkins, Capt., USAF BASH Team, Kirtland AFB, N.M., Pers. Commun.).

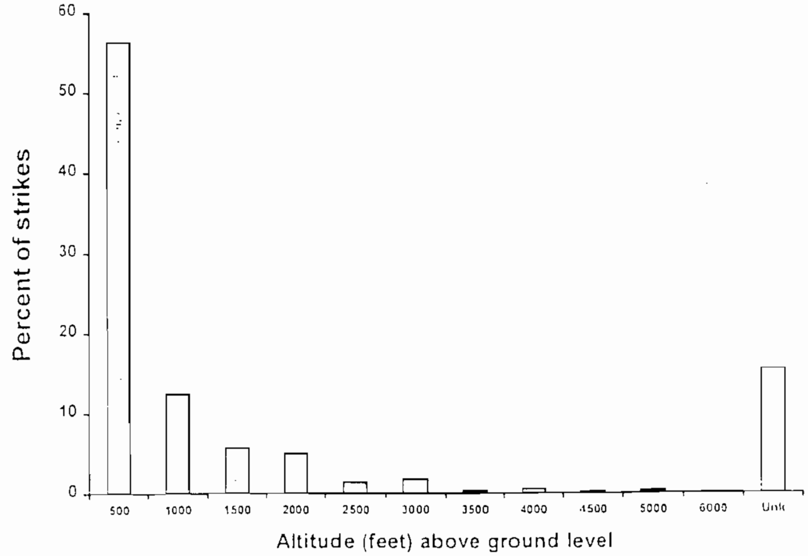


Figure 3. Example of the Bird Avoidance Model Output for the Low-Level Visual Training Route VR-094, Broken Down by Month, Time of Day, and Waterfowl and Raptors. Numbers Represent Mean Number of Expected Bird Strikes/1 Million Nautical Miles of Flight for Entire Route.

ROUTE NAME VR 94 AIRCRAFT TYPE USER FRONTAL AREA (SQ FT) 100.0 ROUTE LENGTH (NMI) 151.2

| | MORNING | | | MID-DAY | | | EVENING | | | NIGHT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | MIGRATORY THREAT | LOCAL THREAT | TOTAL THREAT | MIGRATORY THREAT | LOCAL THREAT | TOTAL THREAT | MIGRATORY THREAT | LOCAL THREAT | TOTAL THREAT | MIGRATORY THREAT | LOCAL THREAT | TOTAL THREAT |
| JANUARY | 1.40 | 20.02 | 21.42 | 4.89 | 5.92 | 10.82 | 1.40 | 20.02 | 21.42 | 9.09 | .00 | 9.09 |
| WATERFOWL | 1.40 | 17.78 | 19.18 | 4.89 | 1.98 | 6.87 | 1.40 | 17.78 | 19.18 | 9.09 | .00 | 9.09 |
| RAPTORS | .00 | 2.24 | 2.24 | .00 | 3.95 | 3.95 | .00 | 2.24 | 2.24 | .00 | .00 | .00 |
| FEBRUARY | 1.00 | 14.96 | 15.96 | 3.50 | 5.36 | 8.86 | 1.00 | 14.96 | 15.96 | 6.50 | .00 | 6.50 |
| WATERFOWL | 1.00 | 12.73 | 13.73 | 3.50 | 1.41 | 4.91 | 1.00 | 12.73 | 13.73 | 6.50 | .00 | 6.50 |
| RAPTORS | .00 | 2.24 | 2.24 | .00 | 3.95 | 3.95 | .00 | 2.24 | 2.24 | .00 | .00 | .00 |
| MARCH | .82 | 10.19 | 11.01 | 2.39 | 6.15 | 8.54 | .80 | 10.19 | 10.99 | 3.65 | .00 | 3.65 |
| WATERFOWL | .56 | 7.16 | 7.72 | 1.97 | .80 | 2.76 | .56 | 7.16 | 7.72 | 3.65 | .00 | 3.65 |
| RAPTORS | .25 | 3.04 | 3.29 | .42 | 5.36 | 5.78 | .24 | 3.04 | 3.27 | .00 | .00 | .00 |
| APRIL | .80 | 3.47 | 4.27 | 1.51 | 4.42 | 5.93 | .75 | 3.47 | 4.22 | .62 | .00 | .62 |
| WATERFOWL | .10 | 1.22 | 1.32 | .34 | .14 | .47 | .10 | 1.22 | 1.32 | .62 | .00 | .62 |
| RAPTORS | .70 | 2.25 | 2.95 | 1.17 | 4.29 | 5.46 | .66 | 2.25 | 2.91 | .00 | .00 | .00 |
| MAY | .02 | 2.84 | 2.86 | .03 | 5.41 | 5.44 | .02 | 2.84 | 2.86 | .00 | .00 | .00 |
| WATERFOWL | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| RAPTORS | .02 | 2.84 | 2.86 | .03 | 5.41 | 5.44 | .02 | 2.84 | 2.86 | .00 | .00 | .00 |
| JUNE | .00 | 2.84 | 2.85 | .01 | 5.41 | 5.42 | .00 | 2.84 | 2.85 | .00 | .00 | .00 |
| WATERFOWL | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| RAPTORS | .00 | 2.84 | 2.85 | .01 | 5.41 | 5.42 | .00 | 2.84 | 2.85 | .00 | .00 | .00 |
| JULY | .00 | 2.84 | 2.84 | .00 | 5.41 | 5.42 | .00 | 2.84 | 2.84 | .00 | .00 | .00 |
| WATERFOWL | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| RAPTORS | .00 | 2.84 | 2.84 | .00 | 5.41 | 5.42 | .00 | 2.84 | 2.84 | .00 | .00 | .00 |
| AUGUST | .11 | 2.84 | 2.95 | .18 | 5.41 | 5.59 | .10 | 2.84 | 2.94 | .00 | .00 | .00 |
| WATERFOWL | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| RAPTORS | .11 | 2.84 | 2.95 | .18 | 5.41 | 5.59 | .10 | 2.84 | 2.94 | .00 | .00 | .00 |
| SEPTEMBER | .86 | 3.53 | 4.39 | 1.37 | 4.43 | 5.80 | .81 | 3.53 | 4.34 | .90 | .00 | .90 |
| WATERFOWL | .10 | 1.28 | 1.38 | .10 | .14 | .24 | .10 | 1.28 | 1.38 | .90 | .00 | .90 |
| RAPTORS | .76 | 2.25 | 3.01 | 1.27 | 4.29 | 5.55 | .71 | 2.25 | 2.96 | .00 | .00 | .00 |
| OCTOBER | 1.19 | 16.51 | 17.70 | 1.29 | 6.36 | [illegible] | 1.19 | 16.51 | 17.69 | 9.54 | .00 | 9.54 |
| WATERFOWL | 1.06 | 13.47 | 14.53 | 1.06 | 1.50 | 2.56 | 1.06 | 13.47 | 14.53 | 9.54 | .00 | 9.54 |
| RAPTORS | .14 | 3.04 | 3.17 | .23 | 5.36 | 5.58 | .13 | 3.04 | 3.16 | .00 | .00 | .00 |
| NOVEMBER | 2.24 | 30.23 | 32.47 | 2.26 | 7.06 | 9.32 | 2.24 | 30.23 | 32.47 | 19.32 | .00 | 19.32 |
| WATERFOWL | 2.20 | 27.99 | 30.19 | 2.20 | 3.11 | 5.31 | 2.20 | 27.99 | 30.19 | 19.32 | .00 | 19.32 |
| RAPTORS | .04 | 2.24 | 2.27 | .06 | 3.95 | 4.01 | .03 | 2.24 | 2.27 | .00 | .00 | .00 |
| DECEMBER | 2.33 | 31.38 | 34.21 | 2.33 | 7.24 | 9.57 | 2.33 | 31.38 | 34.21 | 20.97 | .00 | 20.97 |
| WATERFOWL | 2.33 | 29.64 | 31.97 | 2.33 | 3.29 | 5.62 | 2.33 | 29.64 | 31.97 | 20.97 | .00 | 20.97 |
| RAPTORS | .00 | 2.24 | 2.24 | .00 | 3.95 | 3.95 | .00 | 2.24 | 2.24 | .00 | .00 | .00 |

Figure 4. Example of Harvard Graphics-generated Output from the Bird Avoidance Model Showing Overall Hazards (Waterfowl and Raptor) by Month and Time of Day for Low-Level Military Training Route VR-094. The nm Refers to Nautical Miles.