Evaluating the Bird Avoidance Model

by

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At BSCE 15, I discussed the development of a predictive model which could be used to predict relative levels of birdstrike risk during specific low-level operations.. This Bird Avoidance Model (BAM) is now operational and is loaded onto the Cyber 170 computer located at the Air Force Engineering and Services Center, headquarters of the USAF Bird/Aircraft Strike Hazard (BASH) Team. BAM is designed to determine the birdstrike potential while flying a low-level flight route in the continental United States. BAM was developed as a flight planning tool when creating or altering low-level routes or when scheduling missions or times of particular flights. The purpose of this paper is to report on progress made to verify the accuracy of the BAM computations with past birdstrike mishap data from low-level missions.

As a review, the model simulates low-level flights on a particular route structure throughout the contiguous United States. The potential birdstrikes from waterfowl for a particular aircraft are computed as a function of the aircraft's frontal area, flight distance along the route, and various other factors influencing the number of birds expected in the airspace at a certain time. When considered in terms of waterfowl migratory behavior, flight parameters such as date, time of day, altitude and nearby feeding and resting habitat directly influence the overall birdstrike risk.

As could be expected, a method of quantifying where and when to expect waterfowl was the most difficult aspect of designing BAM. Dr. Frank C. Bellrose, Jr, author of Ducks, Geese and Swans of North America, was the major consultant for properly depicting the corridors and chronology of waterfowl migration used in the model. The information is based on 35 years of personal observation by Dr. Bellrose, substantiated with national and state waterfowl refuge reports, banding records, annual kill reports and flight following using aircraft and radar. The waterfowl migration data identified migration corridors, concentration areas, and weekly accounts of population levels throughout eighteen regions in the US. Appendix I is an excerpt from the BAM programmer's guide which further discusses how the waterfowl count data was used.

BAM Application

BAM is "user friendly", meaning that very little familiarity is needed with either computers or programming to evaluate a low-level route for birdstrike potential. To use it, the user must input the following information:

(1)the specific route number or geographic coordinates of a new route;
(2)date (month and day);
(3)time of day (hour);
(4)type of aircraft or frontal area; and
(5)type of output desired.

All other information is stored ("canned") within the internal framework of the computer program. This method lessens the responsibility of the casual user but maintains critical ordering of the calculations which saves both time and money. Appendix II defines the processing flow-chart and four major functions performed by BAM.

BAM OUTPUT

The final BAM product consists of a tabularized summary of the number of birds which are to be expected along the low-level route. Four options are available for the final printout ranging from a summary of the overall risk for the entire route to a segment-by-segment analysis of the proportion of risk due to each waterfowl type (duck, goose or swan). There are over 600 different low-level routes in the US, some with over 50 segments. Clearly, it is virtually impossible to adequately compare birdstrike risk over 36 weeks of migration (1 Sept - 30 April) during three periods of day for each route while in tabular form. For this reason, I have prepared several graphs which illustrate the variety of birdstrike problems that can be expected (Figures 1-4).

Actual versus Predicted

Quantifying birdstrike risk during low-level flight operations is possible assuming (1) the total number of waterfowl in the airspace at a particular time is known; and, (2) these birds are distributed randomly throughout the airspace. Neither of these assumptions are completely true and certain trade-offs were made to accommodate the vast amounts of data to the basic program. BAM's approach to risk quantification is based on the accuracy of the bird counts as determined by the ability to estimate the annual total waterfowl population and the historical distributions of waterfowl movements and chronology within relatively broad geographical areas. The assumption that birds are distributed randomly ignores the natural tendencies to migrate in flocks or during certain times of the day. This results in conservative (larger) risk estimates. Basically, this means that BAM is somewhat more valid when comparing various routes or alternate flight dates than when calculating the potential birdstrike risk involved in flying a specific route in a certain type of aircraft.

Since 1978, the BASH Team has collected accounts of 846 birdstrikes that occurred during low-level flights in the United States. A little over one-fourth (27.4%) are located on or near a Department of Defense low-level route. Of these, approximately 15.1% (35) are known to involve waterfowl. Table 1 shows the monthly distribution of total birdstrikes and those occurring on low-level routes.

To check the reliability of the model to predict periods of increased bird activity along low-level routes two methods were used to collect frequency data on bird risk. First, the actual mishap data was compared with the graphic data on the respective low-level route. If the birdstrike occurred during a peak in waterfowl activity a plus (+) was recorded; otherwise, a minus (-) was recorded. This is a subjective method of collecting the frequency of occurrence data but it was necessary in the early stages of the project to be familiar with the mishap data in order to correctly locate some of the birdstrikes on specific routes. A second, and more objective approach to obtaining the frequency data was to have another BASH Team member review the low-level route graphs and annotate dates and times of day when they would not fly the various routes. After completion of this task, the individual reviewed the actual mishap data and recorded the number of times the model accurately predicted the birdstrikes (+) or did not (-). Depending on the method used, BAM was able to predict birdstrikes (from all types of birds) from 64.5% - 55% of the cases, respectively. BAM was more accurate at predicting birdstrikes involving waterfowl (68.5% and 74.2%, respectively). Based on Chi-square analysis there was no significant difference between methods.

Figures 1-4 are graphic representations of tabular data produced by the Bird Avoidance Model. A different birdstrike risk is calculated for each week of waterfowl migration from September through April yielding 36 separate points. Limitations on the computer plotter used to produce these plots restrict the number of points to nine. The numbers on the ordinate (y-axis) refer to the number of birds expected for a flight with an aircraft with a frontal area of 100 square feet flying at a certain time of day (on right side). Basically, nighttime involves active migratory activity from about 1800-0600 hours; dawn/dusk involves migratory arrival and departure activity from refuges and stopover points (0600-0900 and 1500-1800); and daytime refers to reduced flight activity with occasional sorties to local feeding areas within 30 miles (0900-1500 hours). A value on the ordinate of 0.05 means 5 birds per every 100 flights. These numbers are symbolic allowing comparison of routes or times of flight. The following figures are good examples of the variety and complexity of birdstrike problems on low-level routes.

Figure 1. Birdstrike hazards on IR203 are greatest during the evening hours from early October through early February indicating a large stagnant population along the route during that period. Moderate daytime hazards exist from November through January. A review of the routing of IR203 indicates that the model is relatively valid since it passes close to some of the densest winter waterfowl concentrations in the US just east of San Francisco, California.

Figure 2. High birdstrike risk is typical of early and late migration on northern tier routes. Daytime is the best time to fly IR403 year-round. Birdstrike risk drops sharply in late December, flattens out, and does not rise significantly until late March. Birds departing refuges and feeding areas present the most risk.

Figure 3. Two extremely intense, but short-lived migrations occur on IR800. The bird hazard is limited to fall and early winter in this northeastern region with little significant movement (relatively) in the spring.

Figure 4a-4e. Bird hazards can be depicted before the routes are approved. A segment-by-segment look at the birdstrike risk can be used to avoid significant concentration areas of birds. Although the timing of the bird activity is about the same, segment D has a birdstrike potential one order of magnitude lower than A,B,or C.

FIGURE 1

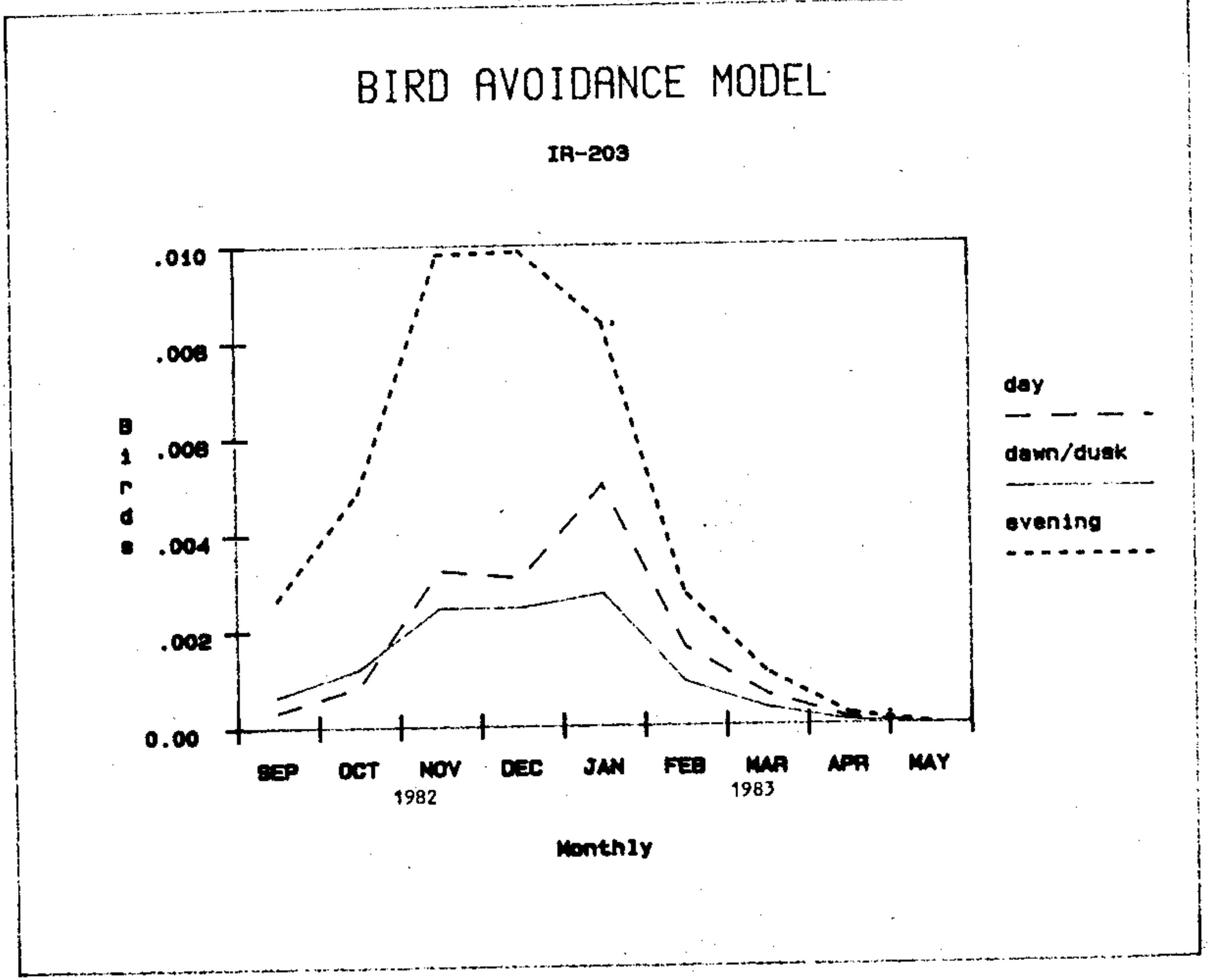

BIRD AVOIDANCE MODEL
IR-203
Birds
.010
.008
.006
.004
.002
0.00
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1982
1983
Monthly
day
dawn/dusk
evening

FIGURE 2

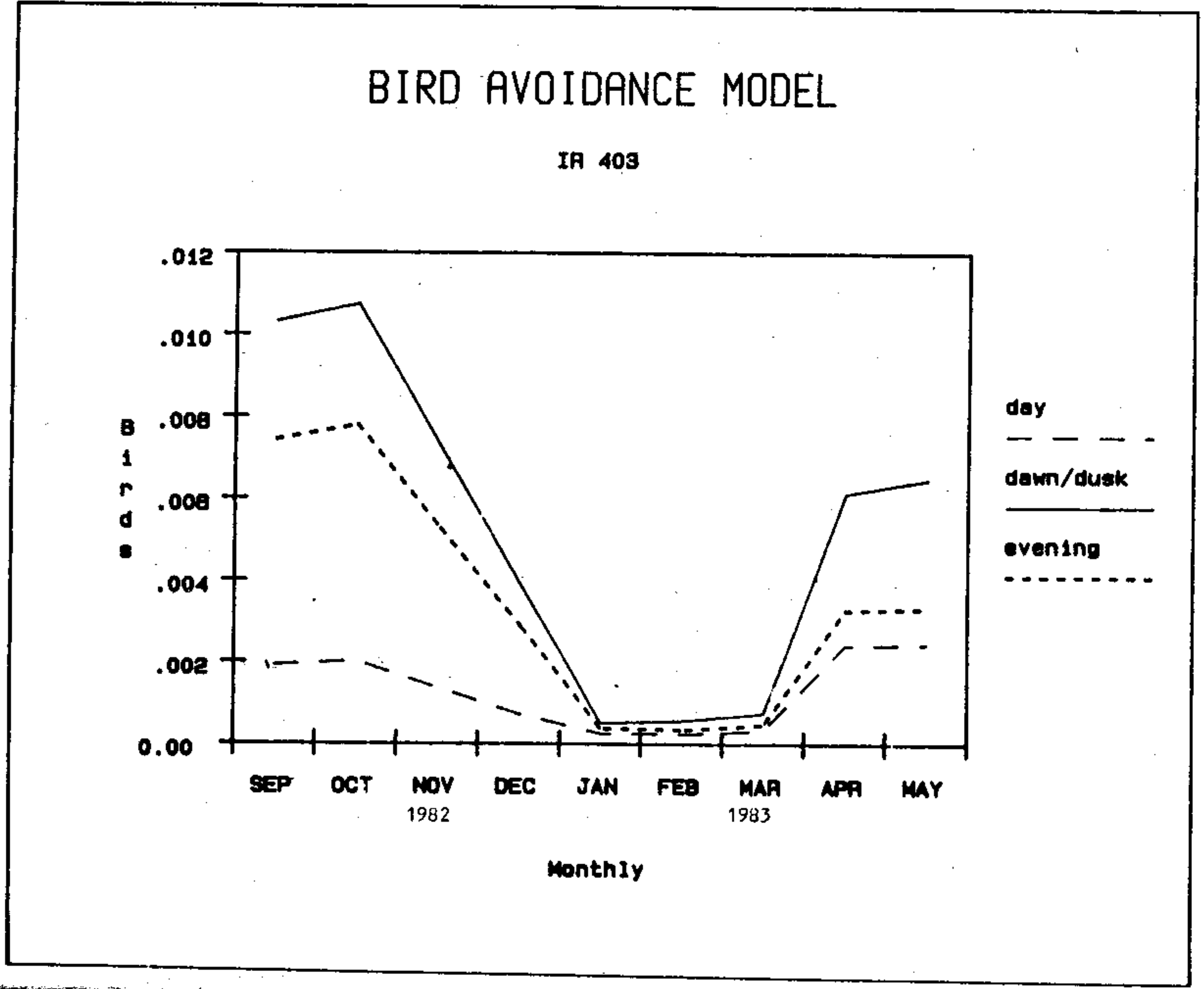


FIGURE 3

FIGURE 3

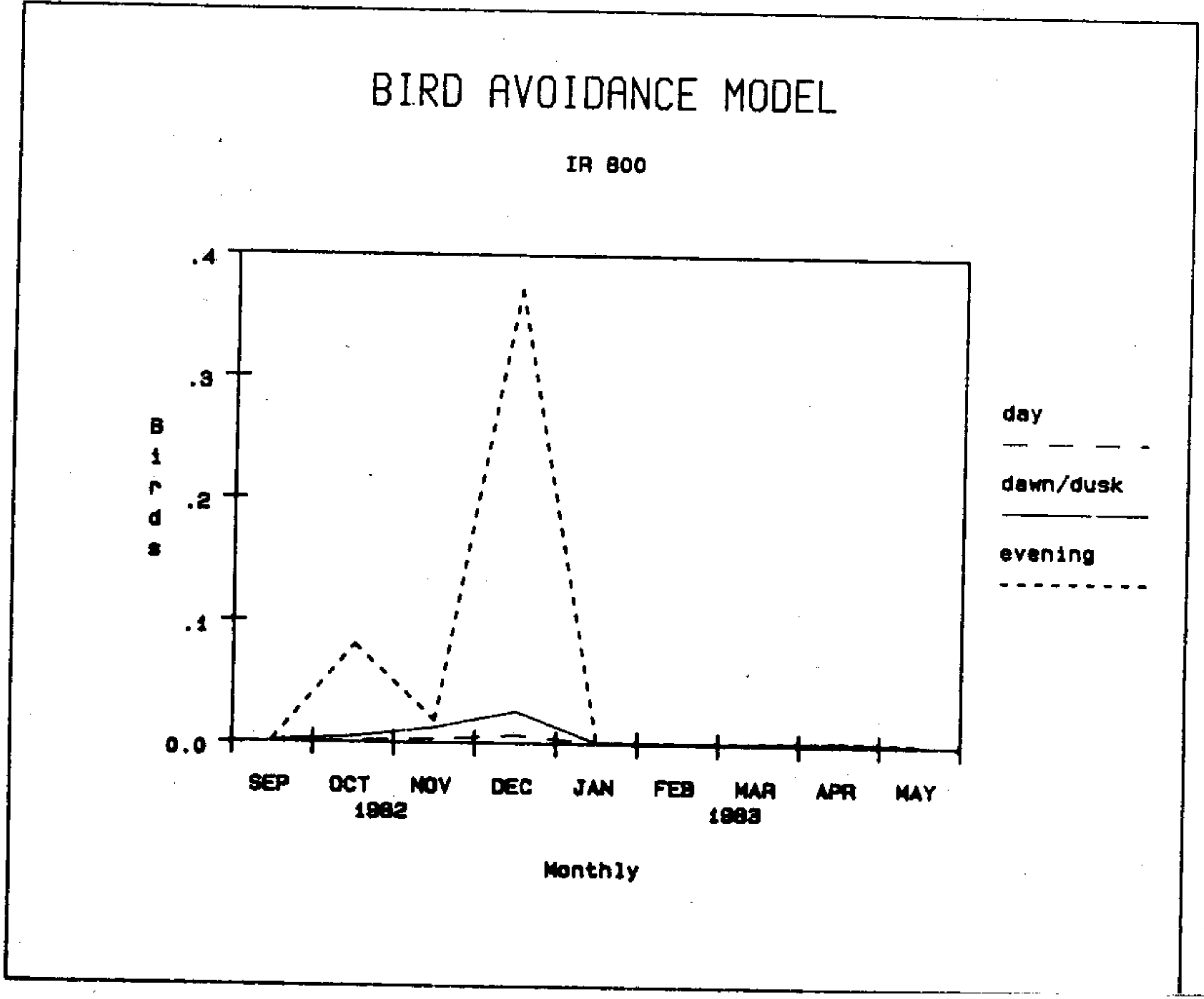
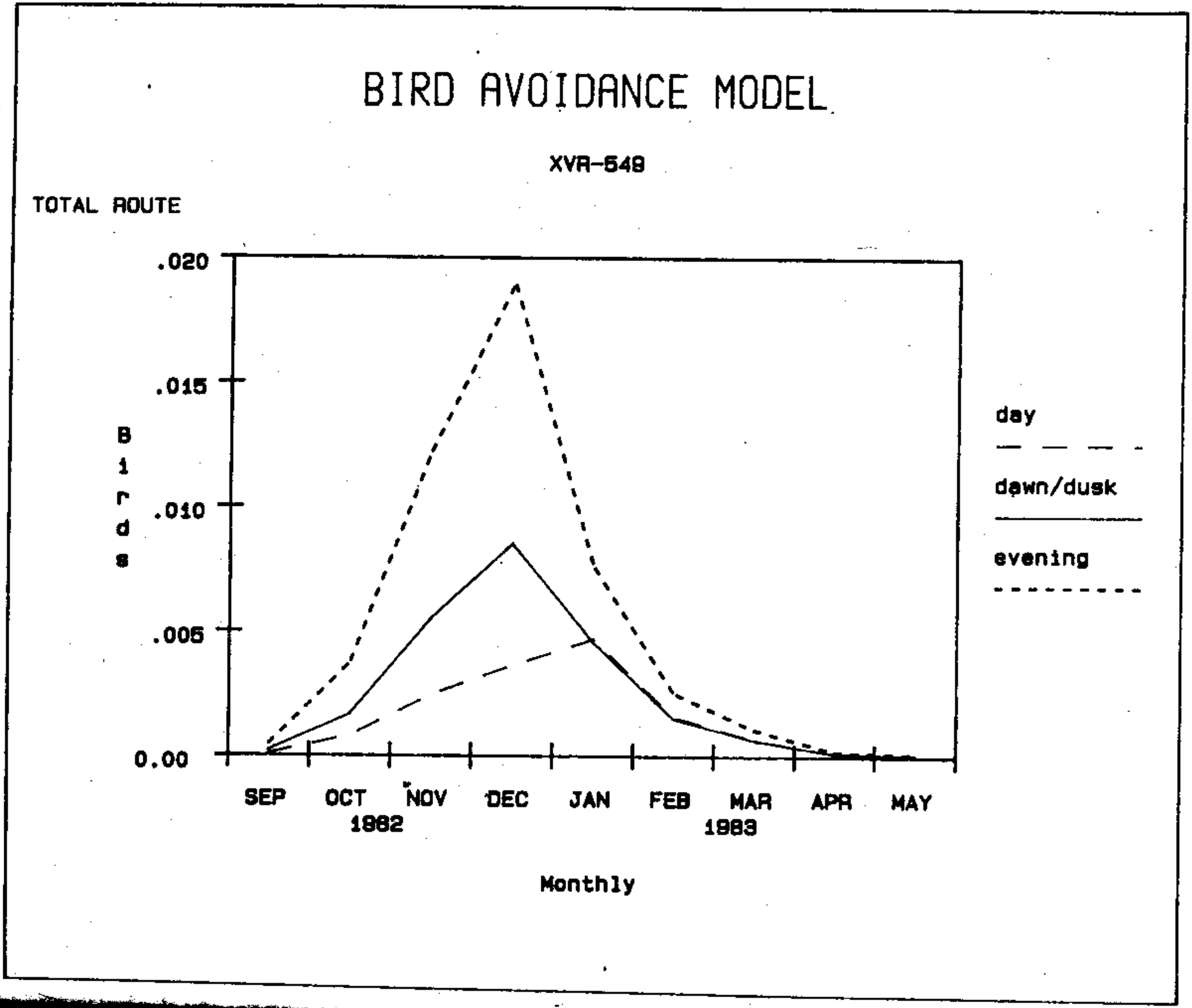

BIRD AVOIDANCE MODEL
IR 800
Birds
.4
.3
.2
.1
0.0
SEP
OCT
1982
NOV
DEC
JAN
FEB
MAR
1983
APR
MAY
Monthly
day
dawn/dusk
evening

FIGURE 4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XVR-549
TOTAL ROUTE
Birds
.020
.015
.010
.005
0.00
SEP
OCT
1982
NOV
DEC
JAN
FEB
MAR
1983
APR
MAY
Monthly
day
dawn/dusk
evening

FIGURE 4a

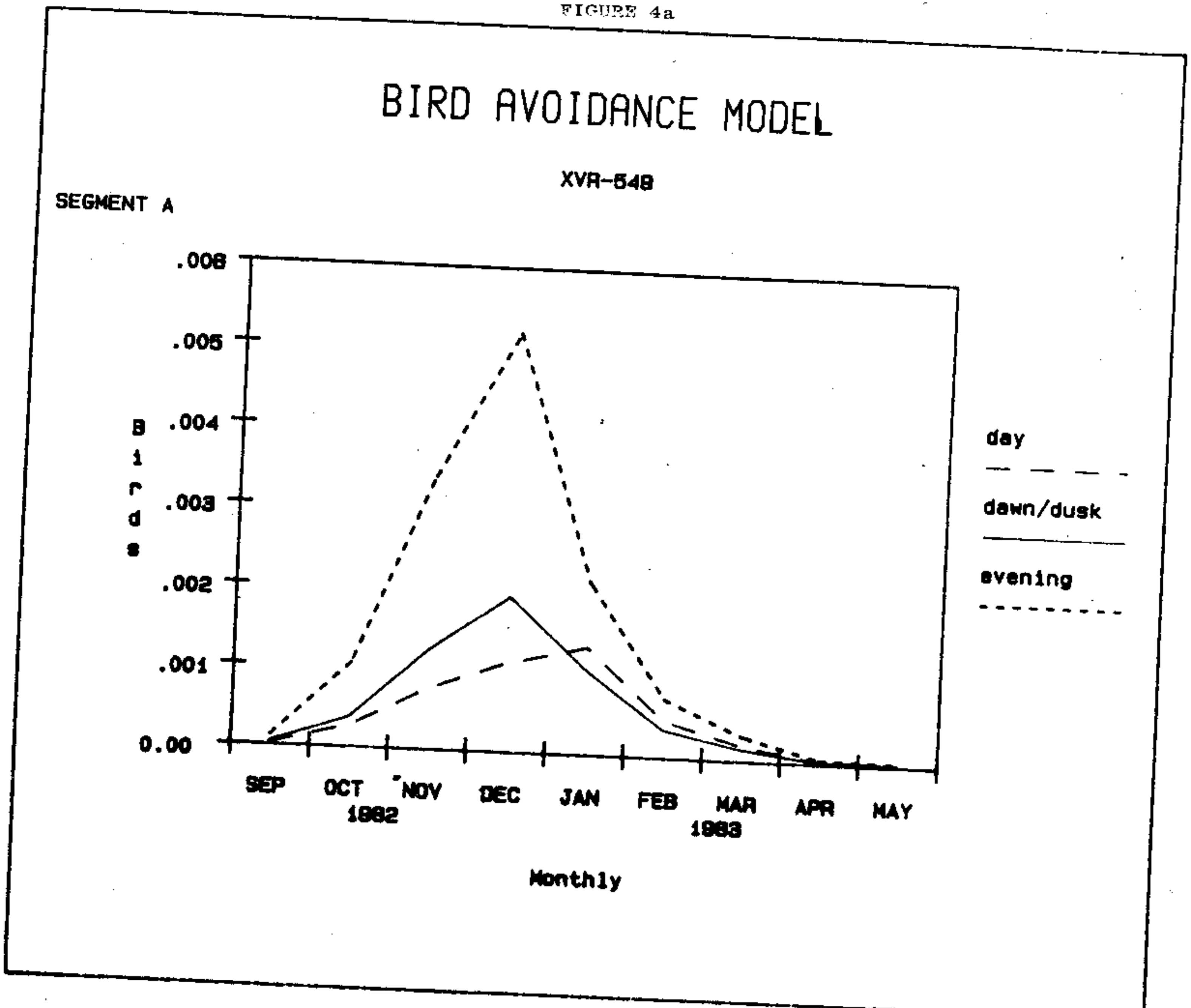

BIRD AVOIDANCE MODEL
XVR-548
SEGMENT A
Birds
.006
.005
.004
.003
.002
.001
0.00
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1982
1983
Monthly
day
dawn/dusk
evening

FIGURE 4b

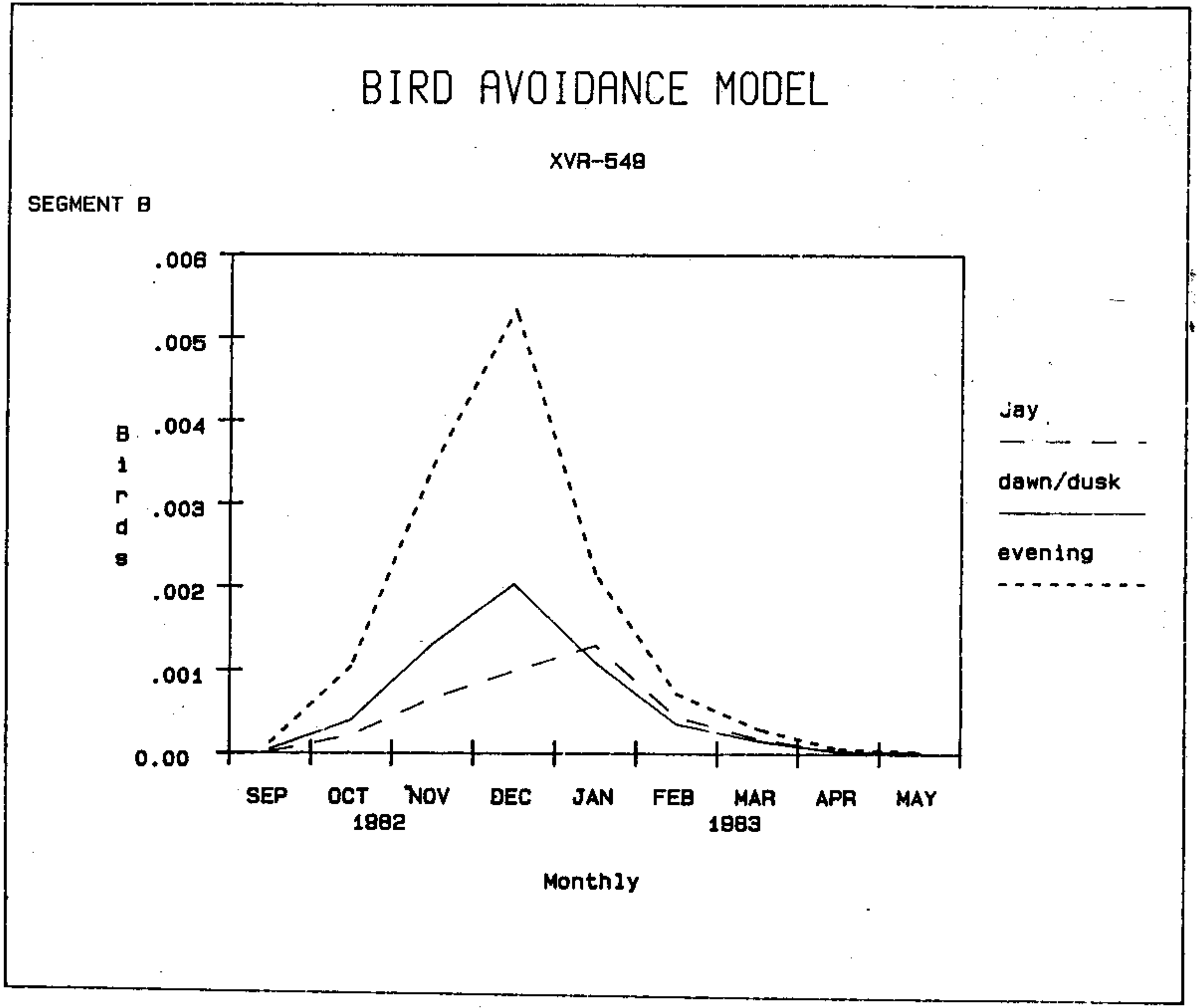

BIRD AVOIDANCE MODEL
XVR-548
SEGMENT B
Birds
.006
.005
.004
.003
.002
.001
0.00
SEP
OCT
1982
NOV
DEC
JAN
FEB
MAR
1983
APR
MAY
Monthly
Jay
dawn/dusk
evening

FIGURE 4c

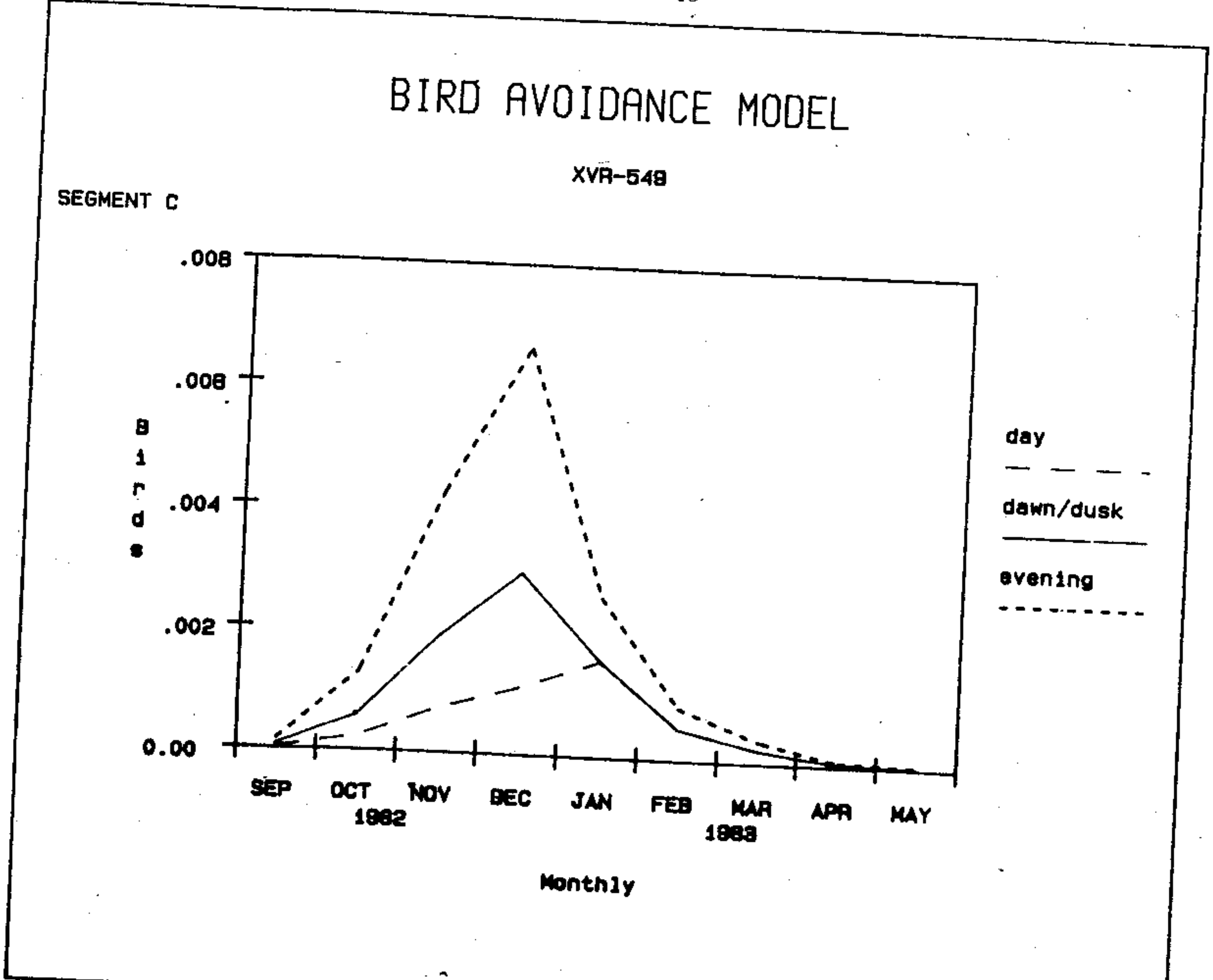
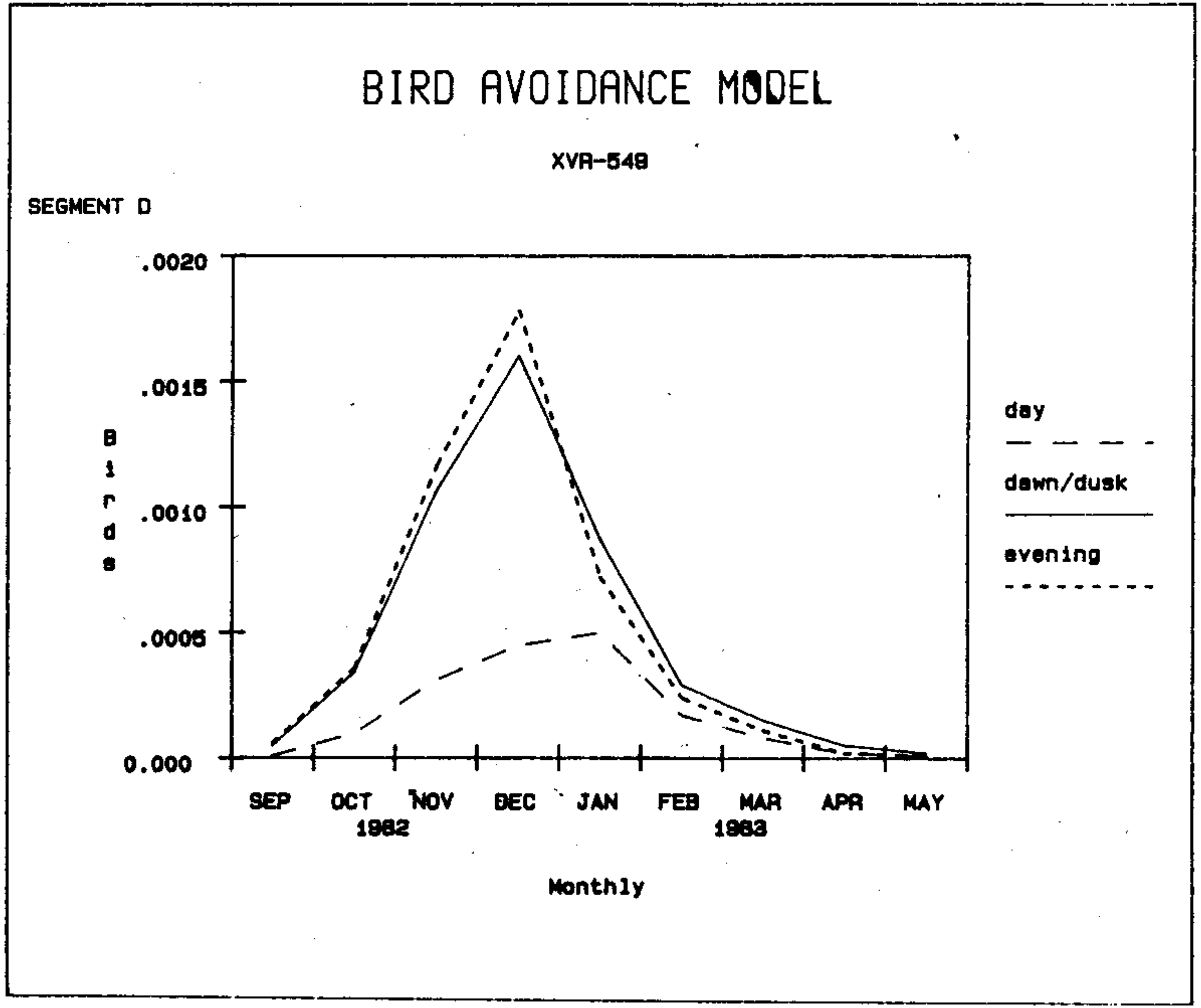

BIRD AVOIDANCE MODEL
XVR-549
SEGMENT C
Birds
.008
.006
.004
.002
0.00
SEP
OCT
1982
NOV
DEC
JAN
FEB
MAR
1983
APR
MAY
Monthly
day
dawn/dusk
evening

FIGURE 4d


BIRD AVOIDANCE MODEL
XVA-549
SEGMENT D
Birds
.0020
.0015
.0010
.0005
0.000
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1982
1983
Monthly
day
dawn/dusk
evening

	TOTAL BIRD STRIKES	BIRD STRIKES ALONG LOW-LEVEL ROUTES
JANUARY	34	19
FEBRUARY	37	9
MARCH	83	41
APRIL	105	43
MAY	96	19
JUNE	45	6
JULY	49	6
AUGUST	68	9
SEPTEMBER	82	27
OCTOBER	134	54
NOVEMBER	71	29
DECEMBER	42	11

Table 1. Distribution of birdstrike mishaps and those associated with low-level routes. There was no significant difference between the frequencies when the months May-August were dropped from the analysis. BAM covers only the months of migration (September-April) in the United States.

BAM appeared more reliable when predicting birdstrike risk in the fall than spring seasons. Chi-square analysis was performed on subsets of the frequency data concerning the ability of the model to accurately predict periods of potentially hazardous waterfowl activity which would interfere with normal low-level operations. The probability distribution function of the Chi-square statistic was highly significant $[P(\chi^2)=0.999]$ indicating that the fall birdstrike hazards were more predictable than those in the spring. This is probably due to the historically rapid influx of migrants in the fall as compared with the relatively more constant exodus in the spring. There is also more comprehensive data on the fall migration because of the additional information provided by hunters and the keen interest around waterfowl refuges during that period. Although there was no significant difference between the frequency of all birdstrikes and those occurring on low-level routes (during the eight month migratory period) further analysis of the mishap data may elucidate differences between early and late periods each season.

Future Validation Efforts

To "fine tune" BAM to more accurately predict birdstrike potential, additional sources of information are necessary as well as a more complete analysis of the mishap data. For example, extensive documentation concerning the number of times and when a low-level route was flown is being sought. This type of data can be used to generate a birdstrike rate for a particular route which can then be compared with the value predicted by BAM. These comparisons will form the basis for modifications to BAM to increase its reliability and enhance its acceptance by the field. Currently, about 50 operational units have requested graphs of low-level routes that they conduct flight training on. Their experiences in applying the information that BAM can provide will ultimately provide the yardstick (or meterstick) to evaluate the model's efficacy.

APPENDIX I

A.3 REGIONAL WATERFOWL COUNTS

The continuous United States has been divided into 18 migration tracking regions. The migratory pattern of ducks, geese, and swans were derived from weekly bird counts compiled for each region. The weekly counts were statistically smoothed to eliminate obvious inconsistencies in the counts.

Bird counts were provided for the spring and fall migration seasons for each region. The Fall season begins in September and ends the last week of December. The Spring tracking season begins the first week in January and runs into the middle of May. A problem arose in that the spring and fall counts were taken in the same calendar year which means that the counts were not continuous through the two seasons. The counts were manipulated in such a way that the counts would appear continuous across the two seasons in most cases.

We made the following assumptions in our approach to the problem of inconsistent counts.

(a) The methods of counting the birds each week is the same in both seasons,

(b) the counts obtained each week are a fixed percent of the total regional population for the week, and

(c) miscounts may have occurred due to sporatic reporting, duplication of counts, etc.

The first assumption relates the fall and spring season and allows us to use the same smoothing technique for both seasons. The second assumption implies that each weekly value of a region has a factor in common (percent of total weekly population) and, therefore, a relationship exists from week to week. The third assumption allows us to smooth the raw counts into a curve consistent with actual migration behavior.

From the assumption above, we developed a data file of weekly bird populations for each region based on a projected annual population. Using assumption 2 above, we know that some percentage (P_{ik}) for region i in season k exists which applies to each week in season k.

P_{ik} is defined as the ratio of the estimated number of waterfowl passing through region i (O_i) based on counts of observed waterfowl to the estimated number of waterfowl passing through region i (A_i) based on the population assignment of the migration corridors in region i. O_i was manually derived from the observed counts to more accurately reflect the migration patterns in region i.

For regions through which waterfowl tend to migrate, O_i was estimated as the sum of the weekly counts. For regions in which waterfowl tend to accumulate, the largest weekly count was used to determine O_i. A_i was determined by summing the assigned populations of corridors which pass through region i.

The weekly waterfowl counts were inconsistent at times and were subsequently statistically smoothed. Values which deviated greatly from the general curve of the data were discarded and replaced by linearly interpolated values. A three-point average technique was applied to the data to achieve an even smoother curve. The resulting counts (C_{ijk}) for region i, week j, and season k together with P_{ik} are used to estimate the regional weekly counts (N_{ijk}) used by the computer model.

Since C_{ijk} and P_{ik} are known, the equation

$$C_{ijk} = (N_{ijk}) * (P_{ik}) \tag{A.17}$$

can be algebraicly transformed into

$$N_{ijk} = \frac{C_{ijk}}{P_{ik}} \tag{A.18}$$

The value of N_{ijk} provides a known population which is distributed across region k depending on the type of modeled waterfowl behavior. Population distribution is discussed in greater detail in the Sections A.4 and A.5.

A.4 WATERFOWL REFUGES/HABITATS

Waterfowl refuges and habitats are resting and feeding locations for waterfowl which are not in active migration. A threat to aircraft from waterfowl at these locations exists while the waterfowl are flying locally. The ceilings of local waterfowl flights vary from genus to genus. The area of a refuge is multiplied by the genus flight ceiling to determine the volume of airspace (V_r) over refuge r. The bird density (D_r) of refuge r is calculated by the equation

$$D_r = \frac{B_r}{V_r}\left(N_{ijk} \cdot F_i\right) \qquad (A.19)$$

where B_r is a population distribution factor assigned to refuge. B_r is calculated as $\frac{S_r}{\Sigma S_i}$ where S_r is an abundance score assigned to refuge r based on its observed population. ΣS_i is the sum of all refuge scores in region i. The S_r values were provided by Dr. Bellrose. F_i is a population distribution factor which assigns the percentage of the total bird population in region i to the refuges in region i.

F_i reflects the relative attractiveness of region i to waterfowl for resting and feeding. The more attractive a region is, the less important are the refuges within the region. We defined the attractiveness of a region in terms of the ratio of the area of defined migration corridors within a region to the total area of the region. When this ratio approaches one, it is implied that favorable feeding and resting grounds exist over a larger portion of the region and thereby the importance of the waterfowl refuges decreases. The refuges, however, are always weighted heavier than non-refuge areas.

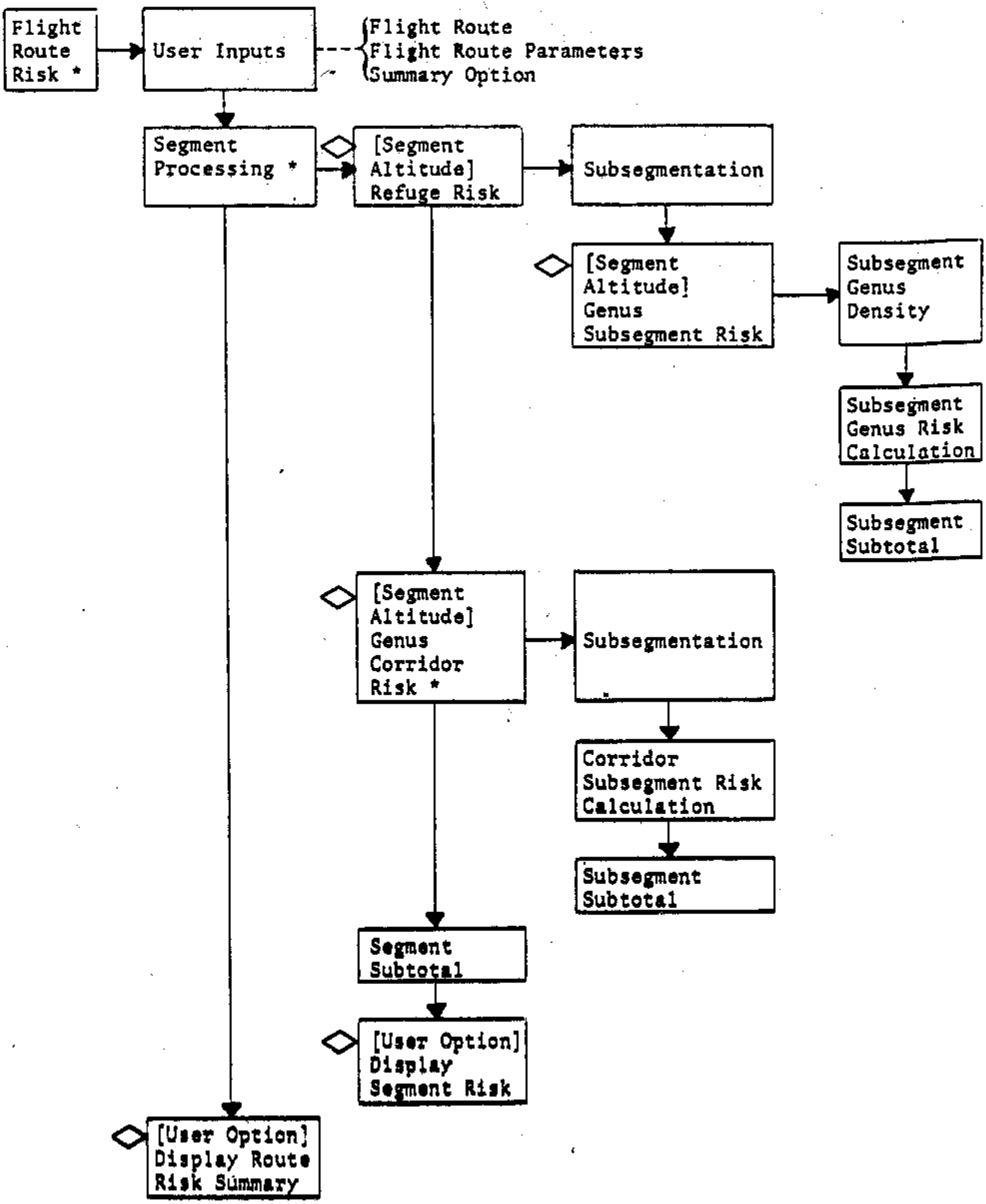


Figure 2.1. Logic Flow of Program BAM.

APPENDIX II

The processing hierarchy defined by the functional flowchart can be described as a binary tree with traversal to the right and then downward. Boxes connected by horizontal arrows have a superordinate - subordinate relationship from left to right, that is, the function of the box on the left is performed as a collective effort of all boxes to its right. The function of the superordinate box may be repeated until all iterations are complete. At this point processing continues downward to parallel functions if they exist. Boxes connected by vertical arrows are called parallel because their functions are performed independently of each other.

Program BAM performs four major functions given that the bird migration behavior information has been previously defined and stored. The four functions of program BAM are as follows:

1. User Definitions - user interface routine to define flight route and time of flight,
2. Flight Subsegmentation - subdivide flight route segments so that uniform bird densities can be established,
3. Waterfowl Density Assignments - retrieve stored waterfowl information for subsegments defined by function 2 to generate bird densities, and
4. Birdstrike Risk Presentation - calculate and display risks to user for selected route and route conditions.

The User Definitions function is a question and answer session between program BAM and the user which occurs once for each flight route execution. The user identifies the flight route, date of flight, time of day of flight, aircraft frontal area, and a print summary option. The flight route may be selected from recorded routes at an assigned above ground level (AGL) altitude which determines whether the risk of

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The flight route is originally defined as a series of flight segments. Function 2 is dependent on the flight altitude to determine the type of bird concentration zones which present a birdstrike risk. The concentration zones for non-migratory waterfowl refuges are the same for all genuses (ducks, geese and swans) which means the flight segment needs to be subsegmented only once because all genuses use the same subsegments in risk calculations. The risk calculation is performed for the subsegments only when the flight altitude falls below the genus-defined non-migratory waterfowl ceiling. The concentration zones for migrating waterfowl (migration corridors) are different for all genuses which means that a segment is subsegmented and risk is calculated for each genus provided the flight altitude falls beneath the migration ceiling.

The waterfowl density assigned to a flight subsegment (function 3) is dependent on the flight subsegment altitude. Subsegments which involve risk from non-migrating waterfowl are further dependent on whether the flight location coincides with a waterfowl refuge. Waterfowl are statistically distributed between refuge and non-refuge areas based on the importance of refuges in a given region. For flights over refuges the bird population is further proportioned based on the relative attractiveness of the refuge to other refuges in the region. The assigned population at a refuge is divided by the genus-dependent volume airspace over the refuge to generate the waterfowl density. For non-refuge areas, the apportioned bird population is distributed uniformly through the non-refuge airspace volume in the region to generate the bird density for the subsegment.

Subsegments which involve risk from migrating waterfowl are dependent on the type of migration corridor in which they reside. The number of waterfowl in a migration corridor is calculated as a corridor weighted percentage of the total region population. The derived population is uniformly distributed throughout the migration corridor to achieve the subsegment bird density. Subsegments at migration altitudes which are not in any corridor have no risk of birdstrike.

Several types of information used to determine the waterfowl distributions through corridors and refuges have been calculated external to program BAM and stored in the direct access file STATIC. When these values are required, program BAM calculates the record number where the information is stored, determines the pertinent word within the record, and calls the subroutine RDSTAT to retrieve the desired value. The file STATIC which contains the values is logically processed like a large data table.

The fourth function of Program BAM is to calculate the total route risk as a sum of segment risks. Each subsegment risk is calculated as the bird density identified by function 3 multiplied by the subsegment length which is derived from values established in function 2. The risk values are presented to the user in the form requested by the user in function 1 of Program BAM.

2.2 SYMBOLIC CONSTANTS AND DATA NAMES

The items described in this subsection are listed in the variable map of the Program BAM compilation listing