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ABSTRACT: Attempts to reduce blackbird numbers by spraying roosts have created considerable controversy. Opinions and suppositions fuel this controversy; yet, until now, decision makers have had no quantitative tools to predict the impacts of population reduction or to aid in formulating management strategies. To improve the predictive ability, we have synthesized data on red-winged blackbird (*Agelaius phoeniceus*) populations into a computerized system, BIRDS (Blackbird Information Retrieval and Data System). Grackles (*Quiscalus quiscula*), cowbirds (*Molothrus ater*), and starlings (*Sturnus vulgaris*) will be added to the system later. BIRDS is designed to estimate the number of redwings for any area of North America at the start of the nesting season, to simulate the annual cycle of numbers for the population, and to trace the general movements of the population. BIRDS, when complete, will give us the ability to estimate the immediate numerical effect on a population for any management operation involving lethal control. Two examples of hypothetical management strategies demonstrate the output generated by BIRDS and how this information can be used in making management decisions.

INTRODUCTION

Conflicts between man and certain species of wildlife have increased greatly in recent years. Our society is demanding that agricultural production and resource exploitation be increased and that the integrity of the environment be maintained. Thus, natural resource agencies increasingly are confronted with difficult decisions requiring much more precision and understanding than previously have been needed or expected.

An excellent example of this situation is the controversy over the killing of millions of roosting blackbirds and starlings (hereafter referred to collectively as blackbirds) in the eastern United States (Meanley, 1975)--killing made possible by EPA registration, in 1974, of a technique for spraying roosting birds with a wetting agent (Lefebvre and Seubert, 1970).The conflict is between people who are adversely affected by nearby roosts containing up to 10 million blackbirds, and who want populations reduced, and other people, oftentimes far removed from problem sites, who believe that lethal control is not a proper solution to these problems. These strongly divergent factions appeal to the Federal Agencies concerned for support for their respective views.

In spite of numerous studies on blackbirds (e.g., see Meanley and Mitchell, 1966), information required to make intelligent predictions of the impact that such population reductions will have on total numbers of birds is not available. This is mainly because most studies have been considered as separate entities, with little effort made to integrate the myriad data into a form suitable for use by decision makers. Thus, policy makers, managers, and their research advisors have been forced to "make-do" with intuitive judgments based on experience, and limited knowledge of particular aspects of blackbird ecology in formulating decisions on population reductions.

We believe data that can provide needed management information on blackbird populations are available; but they are in such diffuse or inappropriate forms that they are not being used. Our objective is to synthesize these data into Information Retrieval Systems and a Population Dynamics Model for North American blackbirds. This system is hereafter referred to as BIRDS (Blackbird Information Retrieval and Data System). BIRDS is basically designed to estimate the numbers of blackbirds for any degree block of latitude and longitude in North America (excluding Mexico) at the start of the nesting season, to simulate the annual cycle of numbers for that population and to trace the general movements of the population. BIRDS, when completed, will give us the ability to predict the immediate numerical effect on a population for any management operation involving lethal control and will give us insight into long-term(several years)effects of such control. Thus, BIRDS is an attempt to provide a sorely needed overview of the continental populations of blackbirds and to put into proper perspective the impact that various management strategies will have on these populations.

METHODS

In developing BIRDS, we have worked almost exclusively with the red-winged blackbird because (1) there is a greater data base for this species than for other blackbirds, and (2) it is the most numerous and widespread blackbird species in North America (Webb and Royall, 1970). Thus, our discussion of population data and the simulation examples will concern only the redwing. Grackles, cowbirds, and starlings eventually will be included in the system.

BIRDS have three basic components: (1) Breeding Density Information Retrieval System, (2) Population Dynamics Model, and (3) Movement Information Retrieval System. These components are discussed separately below. The basic structure of BIRDS is depicted in Fig. 1.

Breeding Density Information Retrieval System (BDIRS)

BDIRS is a data system on magnetic tape that provides, for each degree block of latitude and longitude in North America within the breeding range of the redwing, the land area (in km^2), the ecological region (e.g., piedmont, short-grass prairie), and an index of the number of territorial male redwings. The range of the redwing was determined from the AOU checklist (1957) and numerous regional publications. Land area for each degree block was estimated by calculating total surface area and subtracting from this the area of all large bodies of water.

The indices of territorial male densities and the ecological regions were obtained from Breeding Bird Survey data (Robbins and Van Velzen, 1969). This survey has been run annually in the eastern United States and Maritime Provinces of Canada since 1966, and over the entire continent since 1969. Approximately 1, 500, 25-mile routes are now run annually. For each degree block, BDIRS gives total number of routes run and total number of redwings recorded for each year since 1966, along with grand totals for all years. For a degree block with no routes run, average values for the ecological region in which the block lies are used.

Population Dynamics Model (PDM)

There is a broad continuum in the approach to model building for populations (May 1974:10). At one end are general, theoretical models developed to examine abstract population characteristics (e.g., stability, cyclic fluctuations). At the other end are empirical, pragmatic models developed to realistically describe a specific system or population. Our model (PDM) is of this latter type. It is management oriented, having as its foundation real-world data on avian populations. The basic concept is simple; however, the masses of data processed and variety of biological relationships integrated make the actual model structure complex. Fortunately, a computer handles the myriad of calculations and bookkeeping chores expeditiously.

PDM is a computer program that, starting with initial population density indices obtained from BDIRS, simulates the numerical responses of a population of redwings in North America during an annual cycle(Fig. 1). The annual cycle runs from the initial week of nesting season until the initial week of the following year's nesting season. The output provides a weekly account of population numbers, by age and sex classes. Geographically, the minimum population simulated is the population contained within any 1-degree block of latitude and longitude. The maximum population simulated is the continental population (excluding Mexico).

PDM has as its cornerstone the relationship between population numbers, reproductive rates, and mortality rates of the sex and age classes. Relevant life-history and demographic data on redwings have been gleaned from the literature. This information either has been converted into mathematical and logical relationships and incorporated into the computer program or has been utilized as input data to initialize certain variables. The model structure is open-ended; as additional information is obtained, it easily can be incorporated.

Population parameters requiring initial values (supplied as input data) for each population simulated in PDM are listed in Table 1 along with values used in routine simulations. These values and some details on the structure of PDM are discussed in the following sections. These sections are not intended as a general review of life-history parameters of redwings; rather, they are presented to show the type and quality of data we are using and to point out where additional data are needed.

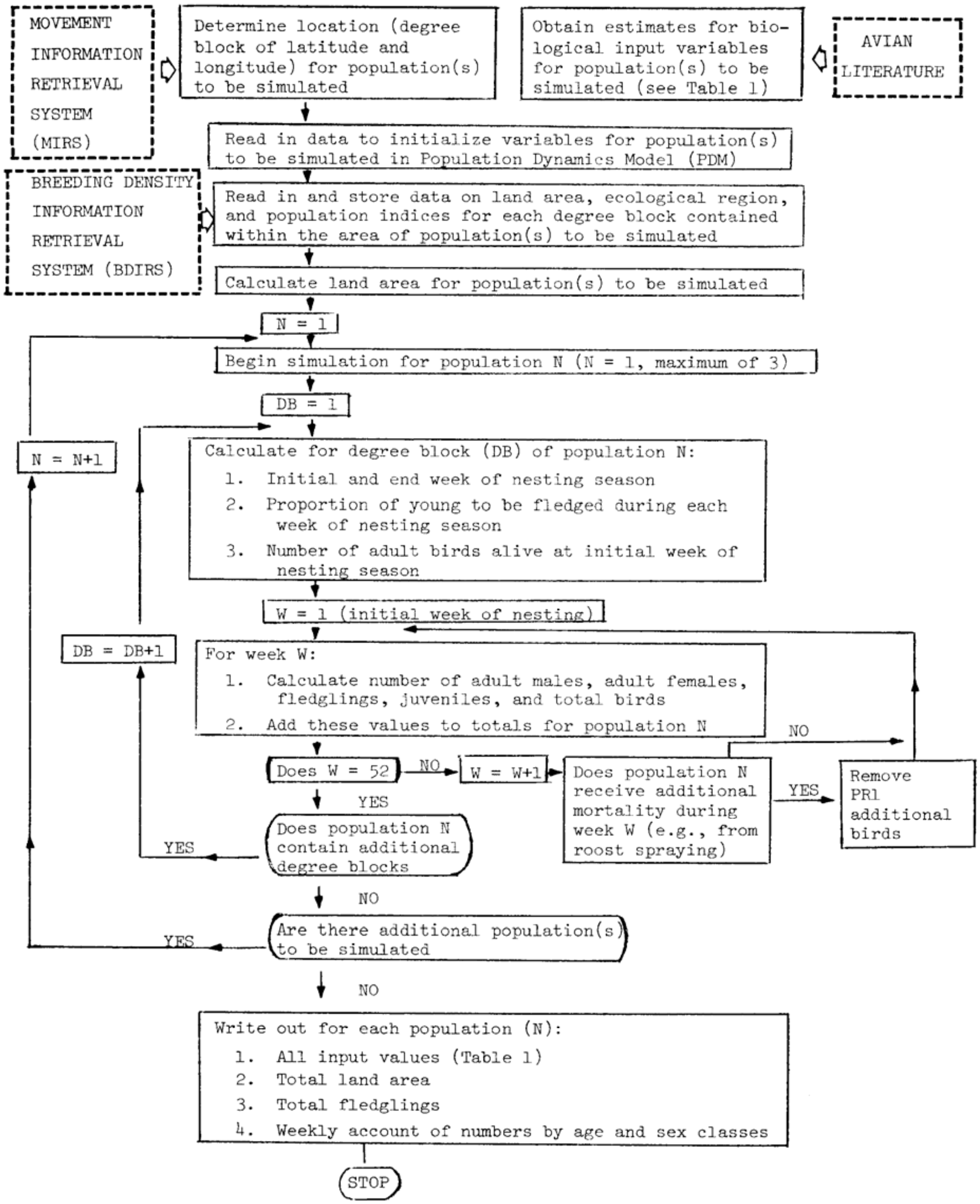

Figure 1. Flowchart of Blackbird Information Retrieval and Data System (BIRDS). BIRDS consists of three components: (1) Movement Information Retrieval System (MIRS), (2) Breeding Density Information Retrieval System (BDIRS), and (3) Population Dynamics Model (PDM).

Table 1. Parameters that require initial values (supplied as input data) for each population simulated in Population Dynamics Model.

Parameter name	Typical values for redwing population	Description of parameter
L1	43	Minimum latitude (°) of population
L2	46	Maximum latitude (°) of population
L3	75	Minimum longitude (°) of population
L4	81	Maximum longitude (°) of population
PRATIO	2.0	Average nesting females/territorial male
IDEV	4	Weeks required between laying of first egg in nest and fledging of young
NP1	2	Weeks between first young fledged and first peak in young fledged
NP2	4	Weeks between first young fledged and second peak in young fledged
AFRR	2.6	Annual fledging rate per adult female
AWSRM	0.99022	Adult male weekly survival rate
AWSRF	0.99022	Adult female weekly survival rate
VAR	0.00850	Amount by which AWSRM and AWSRF can vary
JWSR	0.94100	Initial juvenile weekly survival rate
WK1	40	Initial week for additional mortality
WK2	50	Second week for additional mortality
PR1	3,600,000	Number of birds killed during WK1
PR2	0	Number of birds killed during WK2

Initial Population Density.--For any degree block, the density index from BDIRS is converted into a density estimate of territorial males by the relationship depicted in Fig. 2 (see APPENDIX A). This conversion can be done for any year since 1966 or for the average of all years since 1966. The density estimate is then multiplied by the land area of the degree block (also found in BDIRS) to obtain an estimate of the total population of territorial males at the start of the nesting season. These relationship have been incorporated into PDM so that the number of territorial male redwings is calculated for each degree block included in a population to be simulated. The method of estimating the number of adult females and non-territorial males at the start of the nesting season is described below.

Ratio of Nesting Females to Male Territories.--The estimated number of females nesting per male redwing territory ranged from 1.6 to 3.7 for 10 studies reviewed by Dolbeer (1976). No discernible geographic or density-related pattern was apparent. The majority of studies indicated a ratio of about 2.0, and this value has been used (Table 1) in simulations to date; additional and more accurate estimates are needed for this parameter. The overall adult sex ratio has been assumed to be 1.0 (Laux 1970:51).

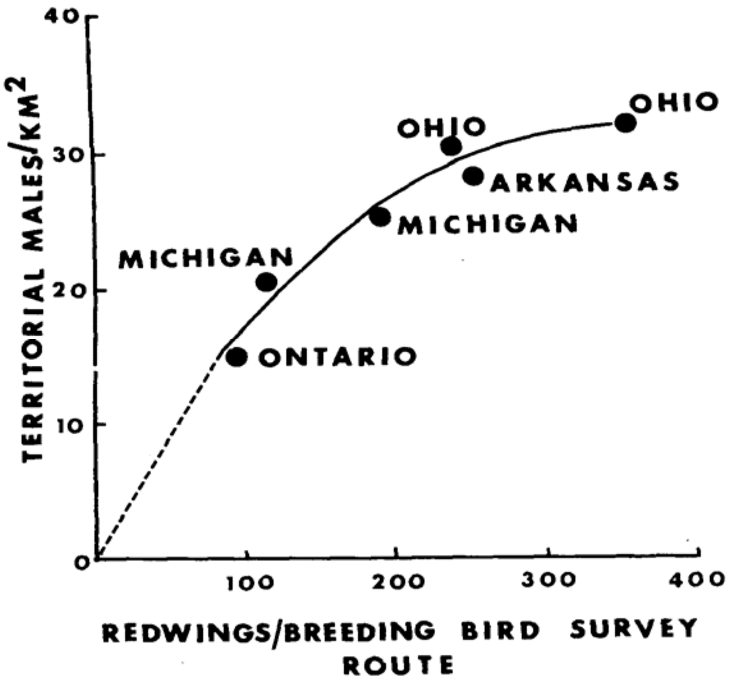

Figure 2. Relationship between Breeding Bird Survey indices for red-winged blackbirds and density estimates of territorial male red-winged blackbirds. Density estimates are from Dyer et al. (1973) for Ohio, Michigan, and Ontario and from Meanley (1971) for Arkansas.

Reproductive Rate.--Many data are available on clutch size, nesting success, and number of young fledged per successful nest for redwings and for many other passerine species; however, there are very few reliable estimates of the extent of renesting or double brooding or, most importantly, of the total young annually fledged per female or per territory. Dolbeer (1976) reports six studies of redwings in which the estimated number of young fledged per territory ranged from 2.6 to 8.1 (average 5.2). No geographic or density-related trend was apparent. The average ratio of nesting females to male territories is 2.0, indicating an average of about 2.6 young fledged per adult female. This value has usually been used as input (Table 1) in the initial simulations. Additional data are sorely needed on the reproductive rates of passerine species (Ricklefs, 1973:370).

Chronology of Nesting Season. --The time of initiation and duration of the nesting season varies considerably for the redwing throughout North America. Predictive equations were developed (e.g., Fig. 3) and incorporated into the model so that the correct timing of nesting can be estimated for the population in each degree block of latitude and longitude.

Temporal Distribution of Fledging.--Dolbeer (1976, plus unpublished data)determined that, in a redwing population in Ohio studies for 3 years, fledging occurred on the average over a nine-week period with peaks during the second and fifth week after first fledging. No other studies document the distribution of fledging; however, several studies (e.g., Case and Hewitt 1963, Robertson 1973) indicated that nesting effort and fledging were staggered in a somewhat similar pattern.

A series of equations was incorporated into PDM which, based on the pattern described by Dolbeer (1976), estimates the proportion of fledging during each week of the nesting season. Input values specifying when peak fledging occurs must be provided (Table 1). Thus, regardless of whether fledging occurs during a 2-week period (as near the northern limit of redwing range--Krapu 1973) or a 12-week period as in Louisiana (Meanley, 1971:23), the temporal distribution of fledging for the simulated populations is calculated to make it compatible with the limited real-world data available.

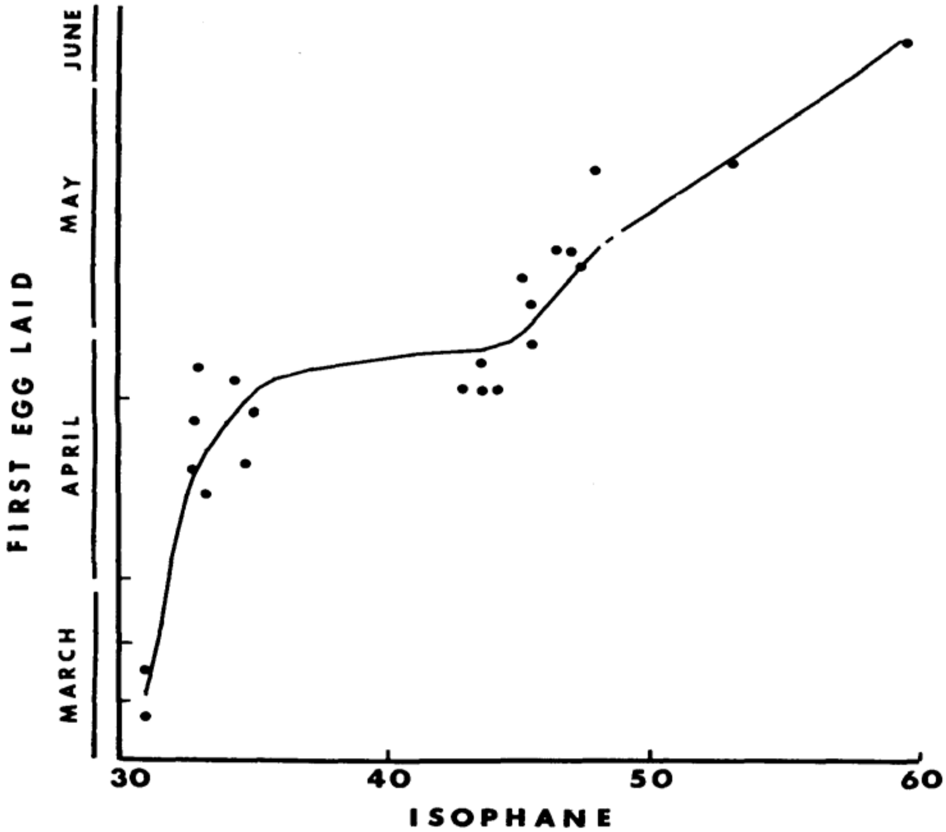

Figure 3. Initiation of nesting season (first egg laid in population) for red-winged blackbirds in relation to geographic location in North America. Data obtained from numerous publications; citations available from authors on request. [I sophane = ° latitude + (100- (° longitude × 0.2))]

Adult Survival.--Fankhauser (1967, 1971) estimated from banding data annual survival rates of 0.52-0.53 for adult redwings. Laux (1970:62-63) and Nero (1956) found that 56-65 percent of the adult males and females returned annually to breed in Michigan and Wisconsin study areas. The available data suggest no differences in survival rates between sexes; thus, they have been considered equal in all simulations (Table 1).

No data are available for redwings on survival-rate variability within a year. A review by von Haartman (1971) indicates adult survival rate does commonly vary within a year for many bird species, but the pattern of change differs widely among species. We hypothesize that adult redwing survival probably is highest in late summer-early fall and lowest in late winter. Thus, we have included a function in PDM that permits the survival rate to vary in this manner by an amount entered as an input value (Table 1).

Juvenile Survival--Almost no quantitative data are available on survival rates of juveniles for passerine species except that they are normally lower than adult survival rates during the first 6 months to 1 year after fledging (von Haartman, 1971 : 445-446). Thus, this is the one input value for which we must provide an "educated guess". We have included a linear function in PDM to increase the survival-rate value between the time of fledging and the initiation of breeding the following year.

Density-Dependent Functions.—PDM, in its present state, contains no density-dependent relationships. This obviously is unrealistic because the operation of density-dependent factors as regulatory mechanisms has been well-established for many bird populations (e.g., Jenkins et al., 1963; Carrick, 1963; Kluijver, 1966; Tanner, 1966). Important density-dependent factors probably operate on the juvenile segment of blackbird populations;

however, critical time(s) of year and quantitative relationships are unknown. Thus, at this stage of development, we have avoided the inclusion of hypothetical density-dependent functions. PDM, as depicted in Fig. 1, only simulates the average annual cycle of a population and estimates the immediate (within the same annual cycle) numerical impact of any population reduction. The inclusion of density-dependent relationships permitting biologically-realistic long-term (several years) simulations, is a major goal in the future expansion of PDM.

Movement Information Retrieval System (MIRS)

MIRS is designed to eventually trace the general location, during the late-summer crop-damage period, fall and spring migration periods, and winter roosting period, of the population indigenous (i.e., present during nesting season) to each degree block or group of blocks. This information is necessary to determine the locations of indigenous populations that will be affected (and thus which degree block(s) to enter in PDM for simulations) whenever lethal control operations are planned.

MIRS is being developed from a comprehensive analysis of all band return and recovery data for redwings. Banding data are presently insufficient to delineate the movements of populations indigenous to each degree block; however, enough recoveries are available, especially in the eastern United States, to predict the general location throughout the year of most populations. MIRS is incomplete at present.

RESULTS

The following examples of hypothetical management strategies demonstrate output generated by BIRDS and how this information can be used in making management decisions.

Example 1

Fifteen blackbird roosts creating health and agricultural problems are to be sprayed in the southeastern United States during the week of 25 January. U.S. Fish and Wildlife Service personnel estimate that these roosts contain 50 million birds, 35 percent of which are redwings. The Province of Ontario, which considers the redwing a desirable song bird, requests information on the impact that this killing will have on the redwing population nesting in the southeastern section of the Province the following spring.

First, assume MIRS is completed and it indicates a maximum of 15 percent of the redwings in these roosts come from the southeastern Ontario-southwestern Quebec region. Thus, if a total kill is achieved at these 15 roosts, a maximum of 2.6 million redwings from this region of Canada will die.

Second, using PDM, two simulations (one with normal mortality and one with an additional 2.6 million birds removed on 25 January) are run for the southeastern Ontario-southwestern Quebec redwing breeding population (latitude 43-46°N, longitude 75-81°W). These simulations (Fig. 4) indicate that a 2.6-million-bird removal would probably reduce the breeding population by a maximum of 20 percent. Ontario environmental groups then might state that the maximum population reduction they would approve is 10 percent. Thus, the U.S. Fish and Wildlife Service might approve only 7 of the 15 planned roost sprayings.

Example 2

Something similar to the following question is frequently asked by agricultural groups in the mid-western United States where redwing damage to maturing corn crops is oftentimes a problem (Stone et al., 1972). "How many redwings would have to be killed in winter roosts in January in the southeastern United States to reduce the breeding population of redwings in mid-western States (e.g., Indiana through western Pennsylvania) by 33 percent?" BDIRS can quickly provide a crude estimate.

First, using PDM, the redwing population breeding in these mid-western States (latitude 39-42°N, longitude 79-90°W) is simulated through an annual cycle. The results (Fig. 5) indicate this population probably contains about 48 million redwings in January, and a minimum of about 16 million of these birds would have to be killed to reduce the breeding population by 33 percent the following May.

Second, MIRS (assuming it is completed) is consulted and it indicates that the greatest winter-roosting concentration of redwings from the midwest occurs in Tennessee

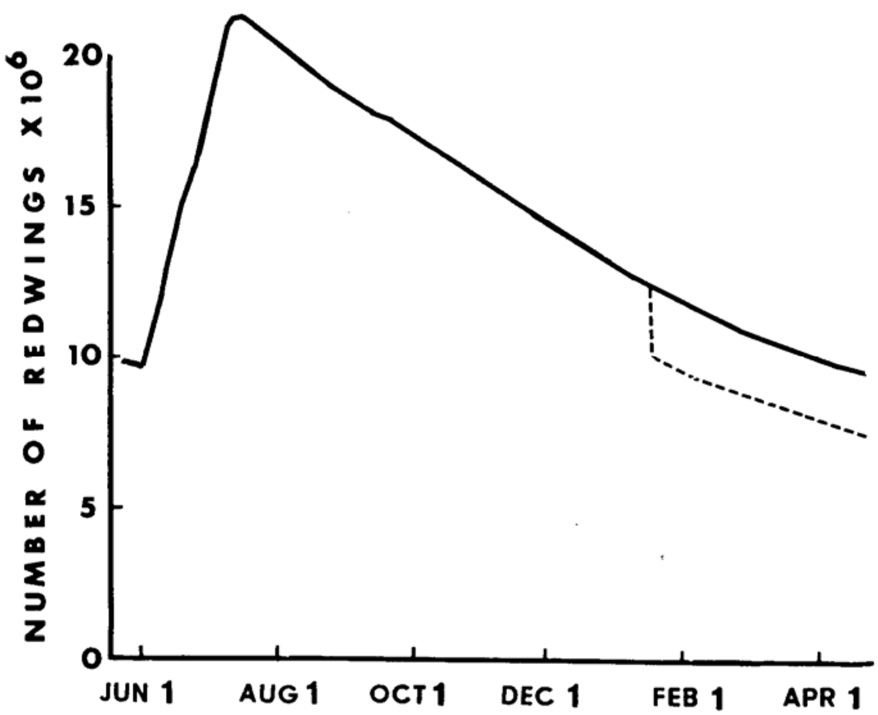

Figure 4. Annual cycle of red-winged blackbird population breeding in southeastern Ontario-southwestern Quebec region (latitude 43-46°N, longitude 75-8l°W). The dashed line represents the projected decline in the population, assuming no compensatory increase in survival of the remaining birds, if 3.6 million of these birds were killed in southern United States roosts during January.

and the northern halves of Mississippi, Alabama, and Georgia. However, even in these areas, mid-western redwings represent only about 60 percent of the roosting redwings, and redwings constitute only about 35 percent of the blackbirds in these roosts.

Thus, actually at least 27 million redwings would have to be killed in these winter-roost areas to reduce by 33 percent the breeding population of redwings in the mid-western States the following May. Moreover, since we have no selective means to kill redwings at these roosts, at least 76 million blackbirds would have to be killed to remove 27 million redwings. Furthermore, if the density-dependent relationships in blackbird populations (e.g., decreased mortality rate of the surviving birds) were known and included in PDM, we might find that a considerably higher number of birds would have to be killed than indicated above to bring about this 33-percent reduction in the breeding population.

DISCUSSION AND CONCLUSIONS

The examples of output presented above indicate three valuable management functions served by BIRDS. First, we obtain a clearer overview or perspective of the total number of birds in any problem situation. Second, BIRDS allows us to quickly and inexpensively examine the consequences of various management strategies, thereby permitting objective decisions that can be scientifically justified and defended. Third, BIRDS synthesizes a vast accumulation of biological data on blackbirds heretofore ignored in many decision-making processes of management involving lethal control.

The components of BIRDS (BDIRS, PDM, MIRS) are also excellent assets to research by serving as guideposts for new studies and as frameworks for the storage and/or integration of new findings. An advantage of the structure of BIRDS is that the system is flexible and open ended. When assumptions built into the components are proven inaccurate, they can easily be modified to conform to the new findings. As new or more accurate data become available, they can easily be incorporated. Thus, BIRDS will be continually upgraded as our understanding of blackbird populations improves.

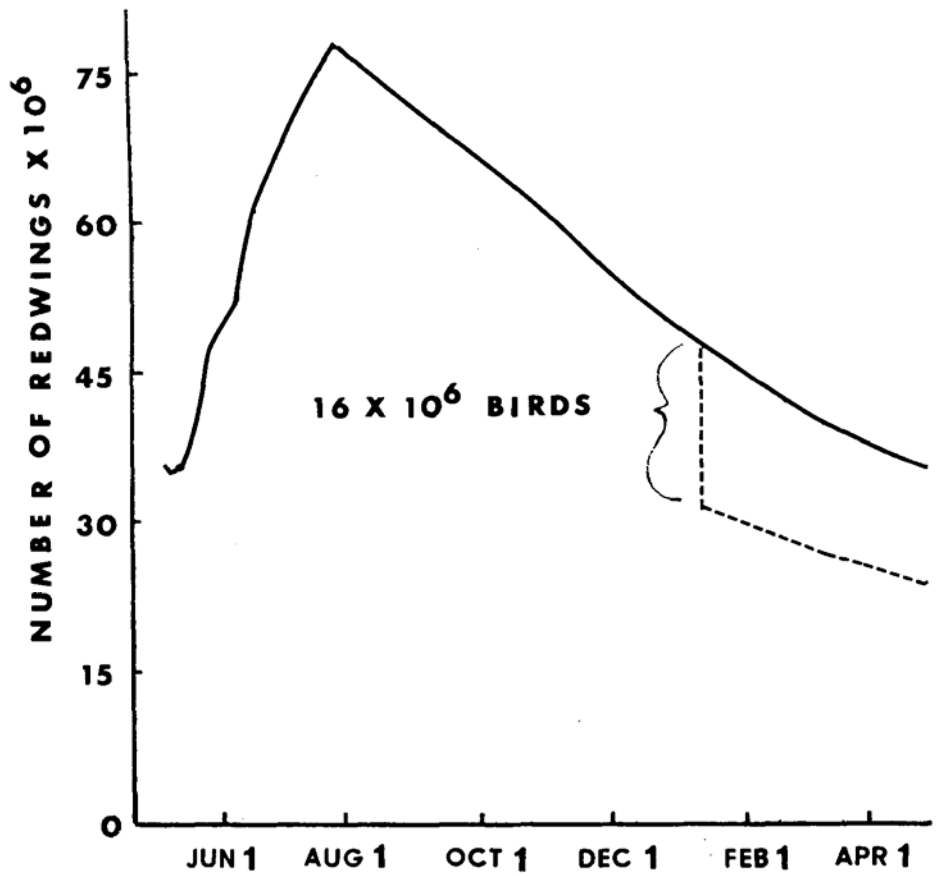

Figure 5. Annual cycle of red-winged blackbird population breeding in mid-western United States (latitude 39-42°N, longitude 79-90°W). The dashed line represents kill needed in January to reduce the breeding population by 33 percent, assuming there is no compensatory increase in survival of the remaining birds.

A likely criticism to be leveled at BIRDS is that the structure is too crude and thus the accuracy of the output is too uncertain to be trusted. However, BIRDS is not a hodge-podge of theoretical notions; the system is based on biological realism using available data on blackbird populations and avian population dynamics. To be sure, many relationships depicted and some data utilized in BIRDS are, at best, crude approximations. Still, we should utilize them, carefully take into account their limitations (e.g., our lack of knowledge of density-dependent factors), and work to improve them in the future.

As a final word of caution, we wish to emphasize that the system, BIRDS, is a novel concept that is still in its infancy of development. We also feel that BIRDS, regardless of future refinements and expansions, will never be a panacea for management, providing absolute answers on blackbird population reductions or on management strategies. We do believe, however, that BIRDS can serve in the future as a valuable management and research tool in our efforts to intelligently manage the continental populations of blackbirds. At the very least, BIRDS should improve the fuzzy "mental models" presently used in formulating many management decisions on blackbird population reductions.

APPENDIX A

Population Estimates of Territorial Male Redwings

The cornerstone of the entire system (BIRDS) is an ability to estimate the adult population numbers of redwings in each degree block in North America (excluding Mexico) at the start of the nesting season. Detailed censuses of territorial male redwings have been conducted in the western Lake Erie basin (Dyer et al., 1973) and in the Arkansas Grand

Prairie region (Meanley, 1971). Censuses of breeding populations have not been conducted in most parts of North America. Indices of breeding populations have been obtained throughout the United States and Canada since 1966 through the Breeding Bird Survey (Robbins and Van Velzen, 1969). The relationship between indice values and territorial male densities for the Lake Erie and Arkansas areas, where both surveys have been run, indicates the feasibility of estimating densities from the indices (Fig. 2).

There are at least two potential sources of error in estimating densities from this relationship. First, both survey methods sample roadside habitats which in some parts of North America may not be representative of habitat in general. This bias may inflate estimates of density in areas where considerable ditching and diking have been done along roadsides [e.g., eastern Arkansas (Meanley, 1971)] or deflate estimates where roads are absent from small and numerous marshy tracts. Second, the census method used to estimate territorial male densities (Y axis, Fig. 2) tends to underestimate the actual population (Dyer et al., 1973; Francis, 1973), causing the relationship in Fig. 2 to perhaps underestimate the density. Certainly, more work is needed to increase the accuracy of territorial male estimates; however, we feel estimates now being obtained are reasonable for the present purposes of BIRDS. The following two tests of the accuracy of the relationship in Fig. 2, using independent data, support this optimism.

Stewart and Kantrud (1972) estimated the territorial male redwing population in North Dakota to be 2.1 million birds in 1967. We estimated the population to be 3.0 million birds using the relationship in Fig. 2 and the 1968 Breeding Bird Survey data for North Dakota (1968 was first year for full coverage by the Survey in North Dakota). Stewart and Kantrud's (1972) census method would quite likely underestimate the true population--a study by Francis (1973) on the frequency of sighting territorial male redwings indicates an underestimation by as much as 34 percent. Thus, we feel our population estimate is quite reasonable.

Graber and Graber (1963:491) estimated the adult (1 year and older) population of redwings during the nesting season in Illinois in 1957 and 1958 at 8.4 million and 11 million birds, respectively. We estimated the adult population (using average indices for 1966-74 from Breeding Bird Survey) to be 13.5 million birds. The strip census used by Graber and Graber (1963:391-392) probably underestimated the total population. Also their study (p. 491) indicated that the redwing population was "probably still expanding" in Illinois in 1957-58. Thus, we feel our population estimate of 13.5 million birds for 1966-74 in Illinois is reasonable.

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