A Simulation Model for Ring-Necked Pheasants

Melvin W. Taylor
Wildlife Research Biologist
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Nebraska Game and Parks Commission
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A contribution of Federal Aid in Wildlife Restoration
Project W-38-R Nebraska
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Introduction

One of the most important game birds in the United States is the ring-necked pheasant (Phasianus colchicus). This Asian refugee has provided recreation for untold numbers of sportsmen. Its presence has meant millions of dollars for state game agency coffers, not to mention its impact on local economies.

Pheasant populations have fluctuated widely in past years, but the overall trend since the early 1960’s has been downward over most of the pheasant range. This decline was caused primarily by loss of habitat due to change in agricultural land use (Mohlis 1974, Dahlgren 1963, Kobriger 1972, Taylor et al. 1976).

Limited attempts have been made by resource agencies to offset this trend and restore pheasant populations. However, insufficient budgets have prohibited a concerted attack on the problem. The only government programs which have had a positive impact on pheasant numbers were those involving cropland retirement, none of which were directed toward increasing pheasant numbers. It is generally agreed among pheasant biologists that these programs, given input from wildlife personnel, could have had an even greater impact on pheasant populations.

Since the pheasant is such an important part of the management programs of many agencies, additional attempts will undoubtedly be made to increase pheasant numbers. With grain surpluses now appearing to be a reality once again, federal cropland retirement programs are not entirely unlikely. Resource managers must maximize the effect of any future programs on pheasant numbers. This requires a priori quantitative predictions of the effect of a proposed program on pheasant populations. State agencies need methods to evaluate the effect of several alternative programs to permit selection of the most feasible approach to increasing pheasant numbers.

At the federal level, prior knowledge of the effect of proposed farm programs would allow wildlife officials close to the legislative process to request changes in programs that would most significantly affect wildlife densities. Often these changes could be made at no additional cost or even at a reduced cost. A procedure is needed, therefore, which will allow quantitative prediction of the effect of proposed programs on wildlife densities. Quantitative prediction has always been a problem for wildlife biologists, and lack of this predictive capability has resulted in poor acceptance of proposed wildlife programs by people not experienced in wildlife biology.

Recently an approach to resource management called computer simulation modeling has been applied to such problems. Several investigators have described practical modeling techniques for use by resource managers (Walters et al. 1974, Walters and Gross 1972, Watt 1968). Useful and reasonably realistic models have been developed and used in the management of fish and big game
The above models simply apply computer technology to existing methods used by population biologists. The procedure normally involves iteration through life tables much as a biologist could do with a calculator. Use of the computer, however, allows more rapid calculations and the incorporation of more complex and realistic features. For instance, age and sex specific parameters and density dependent functions to alter these parameters are easily included in a computer simulation but would be very laborious to include when using a calculator. There is really nothing mystical about computer simulation. It is simply a rapid method of applying existing technology which could not be utilized prior to the computer age.

To date, most reported attempts to model upland game populations have been frustrating and generally unsuccessful (Gross, personal communication). Failures are blamed on lack of knowledge concerning mechanisms controlling populations or lack of data quantifying these mechanisms. A shortage of properly trained modeling personnel and of funding for agencies to hire such personnel has also been a problem. These are legitimate limitations to small game modeling. They will likely remain so, given the budgetary and technological limits of resource management agencies. These circumstances, for the present, preclude obtaining the same precision and accuracy in an upland game model as is found in some big game models. Still, they should not mask the potential usefulness of models in small game management.

These problems notwithstanding, a project was initiated to develop a simulation model of a ring-necked pheasant population. A procedure was needed in Nebraska to evaluate the effect of alternative programs to be instituted with funds acquired from a recently established habitat program. A modeling approach was chosen to solve this problem. The generalized model for pheasant populations described in this paper will also be useful to wildlife officials involved in drafting future land retirement programs, to resource managers in other states, and to wildlife planning personnel.

**Materials and Methods**

Data and findings related to pheasant ecology were obtained from former pheasant research studies in Nebraska (Linder et al. 1960, Linder and Agee 1963, Baxter and Wolfe 1973) and other states (Wagner et al. 1965, Labisky 1968, Wiegand and Janson 1976). Statewide pheasant survey data for past years were obtained from files maintained by management personnel. Specific surveys used were the Rural Mail Carrier Survey (RMCS) (Mohler 1945), Hunter Report Card Survey (Miller and Schildman 1955), and Hunter Check Stations (Johnson 1959).
Agricultural land use data were obtained from Nebraska Agricultural Statistics (1945-1975). Acreages were recorded for winter wheat, oats, alfalfa, sorghum, corn and soybeans.

Acreages along county roadsides were obtained from Highway Statistics (1974). The miles of road in the pheasant range were multiplied by 5.0 acres per mile to estimate potential roadside nesting cover. Acreage was corrected downward at a rate of 2.5 percent per year after 1965 as a result of road reshaping and agricultural encroachment.

Weather information was obtained from a data bank maintained by the Nebraska Natural Resources Commission and originally collected by the National Weather Service. Weather parameters obtained for the years 1944-1974 were (1) mean weekly high temperature, (2) mean weekly low temperature, (3) total weekly precipitation, (4) total weekly snowfall; and, (5) total weekly evaporation. From this data, monthly averages and totals were calculated for use in some analyses and in the simulation.

**Model Development**

The work of past investigators was used to construct a conceptual model of a ring-necked pheasant population (Linder et al. 1960, Baxter and Wolfe 1973, Wagner et al. 1965, Labisky 1968). Nearly all investigators agree that lack of suitable nesting cover is the primary limiting factor in Plains and Midwest pheasant populations.

Winter mortality may be an important factor in some cases, particularly in the blizzard-prone areas of the northern and western plains (Wiegand and Janson 1976, Wagner et al. 1965, Dahlgren 1963, Kopishke and Chesness 1967). Weather also exerts its force in other ways, with the effects varying from one part of the range to another (Wagner et al. 1965, Francis 1968, Russell 1968, Buss 1950, Kozicky et al. 1955, Martinson and Grondahl 1966).

Hunting, although not considered limiting by most investigators, was included in the model, because it is an important part of the life history of the pheasant and it is the primary reason for management by resource agencies. Factors other than nesting cover, weather, and hunting were assumed to be non-limiting to the population. Using this concept, a flow chart representing a model pheasant population was constructed (Figure 1).

Mathematical relationships, equations, and parameters used to describe the conceptual model were derived in a variety of ways. Descriptions of the derivations and relationships used are given below. Symbols used to represent variables are the same as those used in the FORTRAN coding (Appendix I). Graphical representations were drawn using parameter values from the Nebraska simulation.
Effects of Weather

Although most investigators agree that weather has a pronounced effect on pheasant populations, both directly and indirectly (Wagner et al. 1965, Martinson and Grondahl 1966), the effects of weather vary across the pheasant’s range. For instance, drought was found to be detrimental to pheasant production in North Dakota (Martinson and Grondahl 1966), but dry conditions were beneficial in Wisconsin. Blizzards are a hazard in the plains, but they are a less significant problem further east (Wagner et al., 1965).

The impact of weather on Nebraska pheasants has never been adequately described, but most biologists readily agree that weather has an effect. For modeling purposes, some quantitative relationships were needed between pheasant population parameters and weather. To gain some insight into the major effects of weather, a series of correlation analyses were made relating pheasant population parameters to weather factors. The analyses implied several
relationships: (1) Precipitation from the previous year and early spring precipitation determine the quality of nesting cover available. This affects the number of successful nests produced in a given year (Linder et al. 1960); (2) Heavy precipitation during peak of hatch and extremely warm summer temperatures appear to have a negative impact on juvenile survival; (3) Cold temperatures and heavy precipitation (snow) in December and January adversely affected population density, presumably through increased winter mortality (Kozicky et al. 1955).

Variation in the effects of weather made it difficult to develop a generalized procedure for including the effect of weather as a part of the model. However, a system was developed to accomplish this to some degree. Monthly weather data (temperature and precipitation) were provided for all years to be simulated plus one year prior to the start of simulation. Mean values and standard deviations were calculated for each month over the period of years. In the simulation, each month of each simulated year is then rated as to the deviation from normal of its mean temperature and precipitation. The rating used was:

\[ RF = \frac{X - X}{SD} \]

Where: 
RF = weather rating factor 
X = average monthly temperature or precipitation 
\( X \) = long term mean temperature or precipitation for a particular month 
SD = standard deviation of long term mean

A value which falls between -2.0 and 2.0 is thus obtained except in unusual situations when a monthly mean falls more than two standard deviations away from the long-term mean. In the model, ratings are calculated for each month for a three-year period, the simulated year plus one prior and one succeeding year. In using the model, each month in the three-year period is assigned a weight reflecting the importance of that month’s weather in the life cycle of the pheasant. This allows inclusion of some months, exclusion of others by assigning a zero weight, and heavier weighting of important periods. Rating for precipitation and temperature are averaged to produce one weather rating value for each period of the year. In the model of Nebraska’s population, three critical periods were defined and a factor calculated for each. The periods were (1) Nesting Season—12 months of the previous year and the first five months of the year being simulated; (2) Summer—June through September of simulated year, and (3) Winter—December
of simulated year and January of the following year.

Provisions are made in the model so that these periods, both number and length, can be altered with relatively simple changes in FORTRAN coding. This would allow modeling the ideas of any investigator concerning the presumed effects of weather and their suggested period of importance.

Once a rating factor is obtained specifying what effect the weather might have, it is used in other relationships to alter population responses as a result of weather. Examples include the alteration of nest success as a function of precipitation in the previous year or the augmentation of winter mortality as a result of adverse winter weather.

Availability of Nesting Cover

The most important nesting cover types in Nebraska are road-sides, small grains, and alfalfa (Baxter and Wolfe 1973). Other cover that assumed importance during some years was land in federal retirement programs such as soilbank, Cropland Adjustment Program lands, and diverted acres. The value of various cover types was not equal, so total acreage of potential nesting cover was not a true reflection of the availability of good nesting cover. To solve this problem, each cover type was assigned a weight based on its relative value as nesting habitat. Weights used for Nebraska were derived from nest densities and success rates in various cover types (Baxter and Wolfe 1973). Winter wheat and oats were assigned a weight of one, road-sides three, and soilbank two. Considering nest densities and nest success rates, this simply means that three times as many chicks would be produced in an acre of roadside as in an acre of wheat or oats. Production in soilbank fell between road-sides and small grains, hence a weight of two was used.

Although very attractive as nesting cover, alfalfa produces practically no chicks, and a considerable number of hens are lost during harvest. A weight of \( -1 \) was assigned alfalfa to reflect its negative contribution to production. A weight of 0.2 was given land classified as diverted acres, based on an unpublished survey which indicated that about 20 percent of the diverted acres were in cover similar to small grains.

Using the above assigned weights, a nesting cover availability index was calculated for each year:

\[
ANSTCV = \sum_{i=1}^{NCT} WCT_i \cdot COV_i
\]
Where: ANSTCV = nesting cover availability index
    WC_i = weight of ith cover type
    COV_i = acreage of ith cover type
    NCT = number of cover types

For pheasant populations in other areas, nesting cover types may vary considerably in quantity and quality from those discussed here. For that reason, the model is constructed to accept acreages of up to 10 different cover types with corresponding weights for each.

**Nest Success**

Nesting success was based on the premise that nesting cover quality and quantity determine the number of successful nests (Linder et al. 1960). Nesting cover quantity was represented by the nesting cover availability index (ANSTCV). Quality was represented by altering ANSTCV as a straight line function of precipitation in the previous 12 months (weather rating factor). The degree of the effect of weather can be altered by changing the value of CVSLP, a parameter in the model. The number of successful nests each year then became a simple formulation (Figure 2):

\[
SUC = \frac{ANSTCV}{ACPN}
\]

Where: SUC = Total number of successful nests
    ACPN = average acres of cover per successful nest
    ANSTCV = nesting cover availability index adjusted for quality

SUC is never allowed to exceed the post-nesting season hen population. If the pre-breeding cocks per hen ratio falls below a specified value, the pre-breeding hen population is adjusted downward to allow the correct ratio. This ultimately lowers the value of SUC.

**Juvenile Mortality**

The number of chicks hatched was determined by multiplying SUC by average clutch size (EGSPN). Juvenile survival was calculated using an average survival rate adjusted by weather factors (Figure 3):

\[
SURV = ASURV + SRV1 \cdot C \text{ when } C \\
SURV = ASURV + SRV2 \cdot C \text{ when } C \leq 0
\]
Figure 2. Representation of successful nests as a function of the nesting cover availability index.

Figure 3. Generalized relationship of juvenile survival rate with the summer weather factor.
Where: SURV = survival rate of chicks from hatching to fall
   ASURV = average chick survival as measured in field experiments
   C = weather factor for months selected as affecting juvenile survival
   SRV1 = slope of weather-survival relationship when weather factor is greater than 0
   SRV2 = slope of weather-survival relationship when weather factor is less than or equal to 0

The relationship shown allows a more drastic reduction in numbers due to poor conditions than would be added if conditions were above average. This relationship can be altered by changing SRV1, SRV2, ASURV, or the period or weighting factor used in calculating weather effects.

**Adult Mortality**

Except for winter mortality, adult mortality rates (AMORT_ij — where i specifies sex and j represents period in the year) were maintained at a constant level for all years. Annual mortality was applied in four different periods: (1) Pre-nesting to post-nesting, (2) post-nesting to pre-hunt, (3) pre-hunt to post-hunt, and (4) winter. Provision is made in the model to specify the sex and period specific mortality rates a model-user wishes to incorporate. Rates used are printed in each simulated year.

Winter mortality was a variable and was derived from an average mortality plus an adjustment for severe weather (Figure 4):

\[
\text{WINMRT} = \begin{cases} 
\text{WMIN} & \text{when } B \geq 0 \\
\text{WMIN} - B \cdot \text{WINFCT} & \text{when } B < 0 
\end{cases}
\]

Where: WINMRT = winter mortality rate
       WMIN = minimum winter mortality under ideal conditions
       WINFCT = slope of winter mortality-weather relationship
       B = weather factor for specified months

Using this function, mortality is maintained at an average figure in normal or better than average years. For poorer winter conditions, as shown by the calculated winter weather rating factor (B), mortality is adjusted upward in a straight line fashion. The slope (WINFCT) of the severity line is a user-supplied model parameter and can be adjusted to reflect winter cover conditions or any other factor which may alter the effect of severe winter weather.

**Hunting**

Hunting mortality and hunter success is represented by several
Figure 4. Generalized relationship of winter mortality rate with the winter weather factor.

functions in the model. The number of hens accidentally shot is calculated as a function of season length, using a modeler-supplied value for proportion of hens shot per day of season (PHNKL). This may not be correct, but it was used for lack of a better defined relationship. It can easily be altered if a better relationship is found. Crippling loss of cocks (CSBNR) is a user-supplied constant.

Total cock harvest was based on a regression equation developed from 30 years of hunting season data:

\[ AKILL = 1000 \cdot (C0 + C1 \cdot BGL + C2 \cdot HNTRS + C3 \cdot SL + C4 \cdot TBRDS) \]

Where:  
AKILL = total harvest  
SL = season length (days)  
BGL = daily bag limit  
TBRDS = total number of birds prior to season (millions)  
HNTRS = number of hunters (thousands)  
C0-C4 = coefficients of regression equation (values for Nebraska given in Table 1).
In deriving this equation for Nebraska, a significant $R^2$ of .93 ($p < .01$) was obtained with a standard error of estimate of 109,000 on a mean of 1,070,000. A similar relationship could be developed for any area to be modeled for which suitable data is available. A major drawback of this equation is the present lack of sufficient data to predict the number of hunters in future simulated years. Such a function should be developed and could easily be added.

Hunter success in birds per hunter day was calculated from a straight line relationship with total population (Figure 5):

$$BDPDAY = BD1 + BD2 \cdot TBRDS$$

Where: $BDPDAY =$ birds per hunter day  
$TBRDS =$ total population in millions  
$BD1 =$ intercept of equation  
$BD2 =$ slope in equation

Provisions are made for the user to supply the maximum attainable birds per day (BDPM), BD1, and BD2. Similar relationships could be developed for other regions.

A routine is included which will predict the result of various regulatory strategies based on varying season lengths and bag limits for past years. The same routine, along with a specified rate of cock harvest (PCH) is used to select the most appropriate seasons for simulated years. This was included to show the effects of various regulatory strategies on the population and can be used to help maximize use of the resource without endangering its well-being.

**Table 1. Values of model parameters used in simulating the Nebraska pheasant population.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACPN</td>
<td>3.5000</td>
<td>CSBNR</td>
<td>0.1000</td>
</tr>
<tr>
<td>EGSPN</td>
<td>10.0000</td>
<td>CPHM</td>
<td>0.1000</td>
</tr>
<tr>
<td>ASURV</td>
<td>0.6500</td>
<td>CVSLP</td>
<td>0.5000</td>
</tr>
<tr>
<td>SRV1</td>
<td>0.7500</td>
<td>C0</td>
<td>-737.4000</td>
</tr>
<tr>
<td>SRV2</td>
<td>0.2250</td>
<td>C1</td>
<td>99.6000</td>
</tr>
<tr>
<td>WMIN</td>
<td>0.1000</td>
<td>C2</td>
<td>5.5000</td>
</tr>
<tr>
<td>WINFCT</td>
<td>0.3000</td>
<td>C3</td>
<td>5.5000</td>
</tr>
<tr>
<td>BD1</td>
<td>0.2500</td>
<td>C4</td>
<td>35.9000</td>
</tr>
<tr>
<td>BD2</td>
<td>0.1000</td>
<td>BDPM</td>
<td>2.5000</td>
</tr>
<tr>
<td>PHNKL</td>
<td>0.0015</td>
<td>PCH</td>
<td>0.5000</td>
</tr>
</tbody>
</table>
Implemention of the Model

The relationships discussed in preceding paragraphs were combined into a life table model similar to that developed for mallards (Anas platyrhynchos) by Walters et al. (1974). Normal life table calculations involving age and sex specific natural mortality rates, hunting season losses, and production were included. The model was implemented in FORTRAN IV on an IBM 360/65 computing system. A listing of the FORTRAN coding and appropriate comments is included in Appendix I. Card decks are available from the author.

The model is implemented in two phases. Given an initial population size, the first phase simulates the population for past years. In this process actual weather and nesting cover data are used. Season lengths, bag limits, and the number of hunters are known. Model output includes simulated mortality rates, population densities, and sex ratios for four periods in each year (Appendix II-1). Graphic output is produced which compares the simulated population to that actually measured (Appendix II-2). Predicted results of the given regulatory strategies on hunting statistics are produced. In addition, a table is printed showing the predicted harvest, if other regulatory strategies had been followed. This phase of the simula-

---

Figure 5. Representation of the relationship between hunter success and the total number of birds available.
tion is used primarily for validation of the model.

The second phase simulates a given number of future years. As in any prediction of future events, certain assumptions have to be made. This includes specifying the weather factors to be used and expected acreage of each nesting cover type. Estimates of hunter numbers and a desired harvest rate on cocks must be supplied. Given this future information, the simulation continues from the past years into the future.

Output is similar to that of Phase I except for harvest information and includes population size, sex ratios, and calculated juvenile and winter mortalities. A table is printed showing predicted harvest given various regulatory strategies. Using the specified harvest rate, values are generated showing the regulations which would achieve the desired harvest. A printout also gives the predicted results of each of the selected seasons (Appendix II-3).

After the FORTRAN coding was completed and debugged, several runs were made to validate the model. The Nebraska pheasant population was used in this process. Adjustments were made in unknown mortality rates, weather effects, and other model parameters to improve the fit of simulated values with actual population estimates. This method of validation has been criticized by Walters, et al. (1974) as being nothing more than another method of expressing the data. This criticism is valid when data used as input to the model were used to derive relationships used in the model.

In the model being described, however, this was the case only with respect to the relationship used to predict harvest. The remainder of the relationships were developed apart from data used as input to the model. In a sense, the model produces information independent of that collected in past surveys. In this situation, the author feels it is justifiable to validate the model using past data. By following this procedure, validation was accomplished without waiting for future data or necessitating collection of additional data. Additional data should be collected, however, to ultimately validate the model’s performance.

In the validation runs, little adjustment in parameter estimates was needed to achieve the relationship between simulated and actual values shown in Figure 6. The ease with which a fit was found appeared to indicate that the conceptual model is reasonably accurate and that field data collected by past investigators are adequate. It was concluded that use of the parameters and input in the final validation run would provide a realistic simulation. Therefore, these values (Table 1) were used in all the simulations discussed in the remainder of the paper.
Use of the Model

After validation, the model was in a form to provide useful insight into pheasant management. A number of simulation runs were made to show the capability and usefulness of the model. These are described along with other suggested uses for the simulation.

Man affects a pheasant population primarily through habitat manipulation. A series of simulations were made to show the effects of a program typical of what many wildlife agencies might initiate, if funded. Using the Nebraska pheasant population as an example, projections were made assuming a program would provide for the establishment of 100,000 acres of soilbank quality nesting cover on private and/or newly purchased lands. In each run, weather was assumed to be normal. Obviously, weather is seldom normal, so the absolute numbers obtained from the simulation may be in error, but the relative change in the population given various habitat conditions will remain nearly the same, regardless of weather conditions. With the above assumptions concerning weather in mind, the following simulations were made:

1. A program was initiated to establish an additional 100,000 acres of nesting cover with a weighted value of
2. Habitat conditions on private land were held constant.
3. No program was initiated. Conditions on private land were held constant.
4. A program was initiated as in No. 1. The equivalent of 500,000 acres of small grain nesting cover (weighted value of 1) was removed from private lands.
5. Loss of habitat remained the same as No. 3, while no program was implemented to replace any nesting cover.

The results of the above simulations are shown in Figure 7. Tables 2-5 give the numerical output in the 10th year of each simulation for the four runs. Both the effect on the population and the effect on hunting season results are shown. Information from this series of simulations could be used to perform an economic evaluation of the proposed program. The cost of the program should be available and the increase in population size or harvest can be obtained from the simulation output. Cost per bird produced or harvested can easily be calculated.

In addition to using the model to evaluate a habitat program versus no program, it can be used to compare one program to another. This can be tremendously useful when an agency has been provided a limited sum of money and desires to extract maximum benefit from the program initiated with such funds. Utilization of the model can often provide needed insight into the value

Figure 7. A comparison of the predicted fall populations resulting from four various habitat changes described in text.
of various programs and allow choosing of the one with the most attractive cost-benefit ratio. A comparison of one program with another was made using the Nebraska data.

Roadsides are an important nesting area for pheasants (Baxter and Wolfe 1973). Improvement of this cover could provide the habitat needed to increase populations. To test the effect of a roadside vegetation management program, roadside acreage was increased to reflect both improved cover and increased acreage of suitable cover. Other parameters and inputs remained the same as in simulation No. 2.

The effectiveness of a roadside program compared to the described private land retirement program can be compared by examining the results of the respective simulations (Figure 8 plus Tables 2 and 6). Given the cost of each program, a cost/bird produced figure can be calculated for each. Similar comparisons can be made with a variety of programs given the cover conditions to be produced, their value as nesting cover, and their cost.

Harvest information produced can also be used for evaluating regulatory strategy. As reported by many previous investigators, high harvest rates (cocks only) showed no adverse effect on future populations in any of the simulations made thus far. The most significant use of the harvest information appears to be comparing total kill under various habitat improvement programs and harvest achieved under various regulatory strategies.

**Figure 8. A comparison of predicted fall population size given a cropland retirement program versus a roadside management program.**
For instance, by studying Table 2, it can be determined that if harvest or recreational opportunity is the primary objective, more days of recreation and a higher harvest can be provided in Nebraska by liberalizing regulations than by improving habitat. This would be a more economical approach than full-scale habitat improvement that provides a fraction of what has been lost or what is needed. Regulatory agencies need to recognize this fact and promote liberalization of regulations. It must be understood by sportsmen, legislators, and administrators that without properly formulated regulations, the effect of any habitat improvement program will be minimized.

If birds produced are to be utilized by sportsmen, liberal regulations should be implemented to allow the desired harvest. This does not mean that an agency should set regulations without regard for the well-being of the pheasant population. However, through use of the simulation model, regulations can be set which provide more than adequate protection for the resource while maximizing recreational opportunity.

Up to now, discussion has centered on a cocks-only season. This is the most common and most popular approach. Some states, based on sound biological knowledge, have tried hen seasons with no apparent detrimental effects on the resource. Publicly, however, a hen season is unpopular and most states have discontinued such seasons. No simulations were made which incorporated a legal hen season. Evaluation of the effects of a hen season would be a valid use of the model, although some minor changes in FORTRAN coding and model output would be necessary.

Perhaps a model of this nature can most effectively be used in the formulation of future farm programs that include idled cropland. Use of the model would allow quantitative predictions of the effect of alternative programs on pheasant numbers. Data of this nature, accompanied by the economic benefits of pheasants to various states, would be very helpful in providing legislators with the necessary information to incorporate pheasant-benefiting management in any cropland retirement program. Often this could be accomplished at no additional cost to the government, if the legislators only knew the effects of proposed management practices.

Wildlife agencies in those states where the pheasant is a major game bird are greatly concerned about the drastic changes occurring on agricultural land (Taylor et al. 1976, Mohlis 1974, Kobriger 1972). Changes in land use have brought quite significant declines in pheasant densities. In states like Nebraska, which depend heavily on revenue from the pheasant hunter, these uncontrollable changes will significantly affect the resource and hence lower the income of the agency. The simulation described here could be useful in com-
Table 2. Results of simulation Number 1.

| NESTING COVER, THOUSANDS OF ACRES (WT.) | WHET 3070.1 1.0 | OATS 570.1 1.0 | ALF 1703.1 1.0 | ROAD 170.1 3.0 | SB 100.1 2.0 | DWAC 0.1 0.2 |
| WEATHER INDICES | NESTING SEASON 0.0 | SUMMER 0.0 | WINTER 0.0 |

<p>| NATURAL MORTALITY RATES | SIMULATED POPULATION |</p>
<table>
<thead>
<tr>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS/100 HENS</th>
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<tbody>
<tr>
<td>PRENESTING TO 0.30 0.35</td>
<td>1055470. 2369961.</td>
<td>44.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTNESTING TO 0.30 0.30 0.35</td>
<td>738829. 1540474.</td>
<td>4865713.</td>
<td>47.96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREHUNT TO 0.10 0.10</td>
<td>2950036. 3511187.</td>
<td>84.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POSTHUNT 0.10 0.10</td>
<td>1172844. 2633390.</td>
<td>44.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Predicted Kill Under Various Regulatory Strategies Assuming 117,000 Hunters

#### Season Length (Days)

<table>
<thead>
<tr>
<th>Bag Limit</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>338441</td>
<td>393441</td>
<td>448441</td>
<td>503441</td>
<td>558441</td>
<td>613441</td>
<td>668441</td>
<td>723441</td>
<td>778441</td>
<td>833441</td>
</tr>
<tr>
<td>3</td>
<td>438041</td>
<td>493041</td>
<td>548041</td>
<td>603041</td>
<td>658041</td>
<td>713041</td>
<td>768041</td>
<td>823041</td>
<td>878041</td>
<td>933041</td>
</tr>
<tr>
<td>4</td>
<td>537641</td>
<td>592641</td>
<td>647641</td>
<td>702641</td>
<td>757641</td>
<td>812641</td>
<td>867641</td>
<td>922641</td>
<td>977641</td>
<td>1032641</td>
</tr>
<tr>
<td>5</td>
<td>637241</td>
<td>692241</td>
<td>747241</td>
<td>802241</td>
<td>857241</td>
<td>912241</td>
<td>967241</td>
<td>1022241</td>
<td>1077241</td>
<td>1132241</td>
</tr>
</tbody>
</table>

Assuming 117,000 hunters, to obtain the specified harvest level of approximately 50,000% of the fall cock population or 113,500 birds in this case, one of the following seasons would be most appropriate. The predicted results of each season are given. Initial populations for the succeeding year’s simulation are based on implementation of the most liberal season listed.

<table>
<thead>
<tr>
<th>Season Length</th>
<th>Bag Limit</th>
<th>Cock Harvest</th>
<th>Hen Kill</th>
<th>Birds/day</th>
<th>Post Season Sex Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>5</td>
<td>1132241</td>
<td>426173</td>
<td>0.81</td>
<td>32.09</td>
</tr>
</tbody>
</table>

---
Table 3. Results of simulation Number 2.

<table>
<thead>
<tr>
<th>PHEASANT SIMULATION</th>
<th>YEAR 1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 2 - THIS RUN SIMULATES THE EFFECT OF ESTABLISHING 100,000 ACRES OF WEIGHT TWO NESTING COVER WHILE AT THE SAME TIME THE EQUIVALENT OF 500,000 ACRES OF WEIGHT ONE NESTING COVER IS LOST. THE NUMBER OF HUNTERS IS MAINTAINED AT THE 1975 LEVEL OF 117,000.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NESTING COVER, THOUSANDS OF ACRES (WT.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHET 2570. (1.0) OATS 570. (1.0)</td>
</tr>
<tr>
<td>ALF 1730. (1.0) ROAD 170. (3.0)</td>
</tr>
<tr>
<td>SB 100. (2.0) OYAC 5. (0.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WEATHER INDICES</th>
<th>NESTING SEASON</th>
<th>SUMMER</th>
<th>WINTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATURAL MORTALITY RATES SIMULATED POPULATION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COCKS</td>
<td>HENS</td>
<td>YOUNG</td>
<td>COCKS</td>
</tr>
<tr>
<td>PRENESTING TO</td>
<td></td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>POSTNESTING TO PREHUNT</td>
<td>0.30</td>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>TO POSTHUNT</td>
<td>0.10</td>
<td>0.10</td>
<td>2270161.</td>
</tr>
<tr>
<td>0.10</td>
<td>0.10</td>
<td>683888.</td>
<td>2130865.</td>
</tr>
</tbody>
</table>
Assuming 117,000 hunters to obtain the specified harvest level of approximately 50.0% of the fall cock population or 147,501 birds in this case, one of the following seasons would be most appropriate. The predicted results of each season are given. Initial populations for the succeeding year's simulation are based on implementation of the most liberal season listed.

The specified harvest of 147,501 birds cannot be reached within the framework of reasonable regulations with the given number of hunters. In this case, the maximum season of 100 days with a bag limit of 5 cocks is recommended. The predicted results of this season are:

<table>
<thead>
<tr>
<th>Cock Harvest</th>
<th>Illegal Hen Kill</th>
<th>Birds/Day</th>
<th>Post Season Sex Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>118,718</td>
<td>526,678</td>
<td>0.96</td>
<td>44.54</td>
</tr>
</tbody>
</table>

**Predicted Kill Under Various Regulatory Strategies Assuming 117,000 Hunters**

<table>
<thead>
<tr>
<th>Season Length, Days</th>
<th>Bag Limit 2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>39,386</td>
<td>49,298</td>
<td>59,258</td>
<td>69,218</td>
</tr>
<tr>
<td>20</td>
<td>50,338</td>
<td>60,298</td>
<td>70,258</td>
<td>80,218</td>
</tr>
<tr>
<td>30</td>
<td>55,836</td>
<td>65,798</td>
<td>75,758</td>
<td>85,718</td>
</tr>
<tr>
<td>40</td>
<td>61,336</td>
<td>71,298</td>
<td>81,258</td>
<td>91,218</td>
</tr>
<tr>
<td>50</td>
<td>66,836</td>
<td>76,798</td>
<td>86,758</td>
<td>96,718</td>
</tr>
<tr>
<td>60</td>
<td>72,336</td>
<td>82,298</td>
<td>92,258</td>
<td>102,218</td>
</tr>
<tr>
<td>70</td>
<td>77,836</td>
<td>87,798</td>
<td>97,758</td>
<td>107,718</td>
</tr>
<tr>
<td>80</td>
<td>83,336</td>
<td>93,298</td>
<td>103,258</td>
<td>113,218</td>
</tr>
<tr>
<td>90</td>
<td>88,836</td>
<td>98,798</td>
<td>108,758</td>
<td>118,718</td>
</tr>
</tbody>
</table>

---
Table 4. Results of simulation Number 3.

PHEASANT SIMULATION YEAR 1985

RUN 3 – THIS RUN SIMULATES THE EFFECT OF NOT ESTABLISHING ANY NEW NESTING COVER WHILE OTHER EXISTING NESTING COVER ACREAGES ARE HELD CONSTANT. THE NUMBER OF HUNTERS IS MAINTAINED AT THE 1975 LEVEL OF 117,000.

NESTING COVER, THOUSANDS OF ACRES

<table>
<thead>
<tr>
<th>Wheat</th>
<th>Oats</th>
<th>SB</th>
<th>Oats</th>
<th>Road</th>
<th>Oats</th>
<th>NW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3070</td>
<td>570</td>
<td>42</td>
<td>1730</td>
<td>170</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>-1</td>
<td>-1.0</td>
<td>2</td>
<td>-1.0</td>
<td>3.0</td>
<td>2.0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

WEATHER INDICES

<table>
<thead>
<tr>
<th>Nesting Season</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

NATURAL MORTALITY RATES

<table>
<thead>
<tr>
<th>Cock Mortality Rates</th>
<th>Simulated Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Nesting</td>
<td>Cock</td>
</tr>
<tr>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>Post-Nesting</td>
<td>0.30</td>
</tr>
<tr>
<td>Pre-Hunt</td>
<td>0.10</td>
</tr>
<tr>
<td>Post-Hunt</td>
<td>0.10</td>
</tr>
<tr>
<td>SEASON LENGTH DAYS</td>
<td>10</td>
</tr>
<tr>
<td>--------------------</td>
<td>------</td>
</tr>
<tr>
<td>BAG LIMIT</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>371408</td>
</tr>
<tr>
<td>3</td>
<td>471008</td>
</tr>
<tr>
<td>4</td>
<td>570608</td>
</tr>
<tr>
<td>5</td>
<td>670208</td>
</tr>
</tbody>
</table>

Assuming 117000 hunters, to obtain the specified harvest level of approximately 50,000 of the fall cock population or 1339043 birds in this case, one of the following seasons would be most appropriate. The predicted results of each season are given. Initial populations for the succeeding year's simulation are based on implementation of the most liberal season listed.

The specified harvest of 1339043 birds cannot be reached within the framework of reasonable regulations with the given no. of hunters. In this case, the maximum season of 100 days with a bag limit of 5 cocks is recommended. The predicted results of this season are:

- Cock Harvest: 1165208
- Illegal Hen Kill: 486476
- Birds/day: 0.90
- Post season Sex Ratio: 40.18

*******************************************************************************
Table 5. Results of simulation Number 4.

PHEASANT SIMULATION YEAR 1985

RUN 4 - THIS RUN SIMULATES THE EFFECT OF NOT ESTABLISHING ANY NEW
NESTING COVER WHILE THE EQUIVALENT OF 500,000 ACRES OF WEIGHT ONE
NESTING COVER IS LOST. THE NUMBER OF HUNTERS IS MAINTAINED AT THE
1975 LEVEL OF 111,000.

NESTING COVER, THOUSANDS OF ACRES (WT.)

| WHET | 2570. (1.0) | OATS | 570. (1.0) |
| ALF  | 1730. (-1.0)| ROAD | 170. (1.0) |
| SB   | 0. (2.0)   | DWAC | 0. (0.2)   |

WEATHER INDICES

<table>
<thead>
<tr>
<th>NESTING SEASON</th>
<th>SUMMER</th>
<th>WINTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

WEATHER INDEXES NESTING SEASON 0.0 SUMMER 0.0 WINTER 0.0

NATURAL MORTALITY RATES SIMULATED POPULATION

<table>
<thead>
<tr>
<th>PRENESTING TO</th>
<th>POSTNESTING TO</th>
<th>PREMUN TO</th>
<th>POSTMUN TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>COCKS</td>
<td>HENS</td>
<td>YOUNG</td>
<td>COCKS</td>
</tr>
<tr>
<td>0.30</td>
<td>0.35</td>
<td>0.35</td>
<td>513343.</td>
</tr>
<tr>
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<td>0.30</td>
<td>0.35</td>
<td>359340.</td>
</tr>
<tr>
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<td>0.30</td>
<td>0.10</td>
<td>2034394.</td>
</tr>
<tr>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>570376.</td>
</tr>
<tr>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>570376.</td>
</tr>
</tbody>
</table>
Predicted Kill Under Various Regulatory Strategies Assuming 117,000 Hunters

<table>
<thead>
<tr>
<th>Season Length (Days)</th>
<th>Bag Limit 2</th>
<th>Bag Limit 3</th>
<th>Bag Limit 4</th>
<th>Bag Limit 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>31839.17</td>
<td>41753.96</td>
<td>51753.96</td>
<td>61713.95</td>
</tr>
<tr>
<td>20</td>
<td>37339.17</td>
<td>47293.96</td>
<td>57293.96</td>
<td>67213.95</td>
</tr>
<tr>
<td>30</td>
<td>42839.17</td>
<td>52793.96</td>
<td>62793.96</td>
<td>72713.95</td>
</tr>
<tr>
<td>40</td>
<td>48339.17</td>
<td>58293.96</td>
<td>68293.96</td>
<td>78213.95</td>
</tr>
<tr>
<td>50</td>
<td>53839.17</td>
<td>63793.96</td>
<td>73793.96</td>
<td>83713.95</td>
</tr>
<tr>
<td>60</td>
<td>59339.17</td>
<td>69293.96</td>
<td>79253.96</td>
<td>89213.95</td>
</tr>
<tr>
<td>70</td>
<td>64839.17</td>
<td>74793.96</td>
<td>84753.96</td>
<td>94713.95</td>
</tr>
<tr>
<td>80</td>
<td>70339.17</td>
<td>80293.96</td>
<td>90253.96</td>
<td>100213.95</td>
</tr>
<tr>
<td>90</td>
<td>75839.17</td>
<td>85793.96</td>
<td>95753.96</td>
<td>105713.95</td>
</tr>
<tr>
<td>100</td>
<td>81339.17</td>
<td>91293.96</td>
<td>101253.95</td>
<td>111213.95</td>
</tr>
</tbody>
</table>

Assuming 117,000 hunters, to obtain the specified harvest level of approximately 50.00% of the fall cock population or 101,719.7 birds in this case, one of the following seasons would be most appropriate. The predicted results of each season are given.

Initial populations for the succeeding year's simulation are based on implementation of the most liberal season listed.

<table>
<thead>
<tr>
<th>Season Length</th>
<th>Bag Limit</th>
<th>Cock Harvest</th>
<th>Hen Kill</th>
<th>Birds/Gay</th>
<th>Post Season Sex Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4</td>
<td>101253.95</td>
<td>38597.1</td>
<td>0.76</td>
<td>31.87</td>
</tr>
<tr>
<td>80</td>
<td>5</td>
<td>100213.95</td>
<td>30877.7</td>
<td>0.76</td>
<td>31.16</td>
</tr>
<tr>
<td>90</td>
<td>5</td>
<td>105713.95</td>
<td>34737.4</td>
<td>0.76</td>
<td>28.90</td>
</tr>
</tbody>
</table>
Table 6. Results of simulation Number 5.

PHEASANT SIMULATION       YEAR 1985

RUN 5 - THIS RUN SIMULATES THE EFFECT OF IMPROVING ROADSIDE VEGETATION FOR NESTING COVER. THE COVER IS ESTABLISHED AT 15,000 ACRES PER YEAR. NOT ALL ROADSIDES IN PHEASANT RANGE ARE SEEDED BY THE END OF THE SIMULATION IN 1985. THE NUMBER OF HUNTERS IS MAINTAINED AT THE 1975 LEVEL OF 117,000, A LOW ESTIMATE IF PHEASANT NUMBERS INCREASE.

NESTING COVER, THOUSANDS OF ACRES(WT.)

<table>
<thead>
<tr>
<th>WHET</th>
<th>OATS</th>
<th>ROAD</th>
<th>Dvac</th>
</tr>
</thead>
<tbody>
<tr>
<td>3070.1</td>
<td>570.1</td>
<td>650.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1.01</td>
<td>1.01</td>
<td>3.01</td>
<td>3.21</td>
</tr>
</tbody>
</table>

WEATHER INDICES NESTING SEASON 0.0     SUMMER 0.0     WINTER 0.0

NATURAL MORTALITY RATES SIMULATED POPULATION

<table>
<thead>
<tr>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS/100 HENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRENESTING TO</td>
<td>0.30</td>
<td>0.35</td>
<td>191781.</td>
<td>3256741.</td>
<td>58.89</td>
<td></td>
</tr>
<tr>
<td>POSTNESTING TO</td>
<td>0.30</td>
<td>0.30</td>
<td>0.35</td>
<td>0.30</td>
<td>0.35</td>
<td>1342467.</td>
</tr>
<tr>
<td>PREHUNT</td>
<td>0.10</td>
<td>0.10</td>
<td>4524012.</td>
<td>5066102.</td>
<td>89.30</td>
<td></td>
</tr>
<tr>
<td>POSTHUNT</td>
<td>0.10</td>
<td>0.10</td>
<td>2306988.</td>
<td>3799577.</td>
<td>60.72</td>
<td></td>
</tr>
</tbody>
</table>
PREDICTED KILL UNDER VARIOUS REGULATORY STRATEGIES ASSUMING 117000. HUNTERS

<table>
<thead>
<tr>
<th>SEASON LENGTH, DAYS</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAG LIMIT</td>
<td>2</td>
<td>518422</td>
<td>573422</td>
<td>628422</td>
<td>683422</td>
<td>738422</td>
<td>793422</td>
<td>848422</td>
<td>903422</td>
<td>958422</td>
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<tr>
<td></td>
<td>3</td>
<td>610022</td>
<td>675022</td>
<td>730022</td>
<td>785022</td>
<td>840022</td>
<td>895022</td>
<td>950022</td>
<td>1005022</td>
<td>1060022</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>711622</td>
<td>776622</td>
<td>831622</td>
<td>886622</td>
<td>941622</td>
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<td>1106622</td>
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<tr>
<td></td>
<td>5</td>
<td>813222</td>
<td>878222</td>
<td>933222</td>
<td>988222</td>
<td>1043222</td>
<td>1098222</td>
<td>1153222</td>
<td>1208222</td>
<td>1263222</td>
</tr>
</tbody>
</table>

ASSUMING 117000. HUNTERS, TO OBTAIN THE SPECIFIED HARVEST LEVEL OF APPROXIMATELY 50,000 OF THE FALL COCK POPULATION OR 2262006. BIRDS IN THIS CASE, ONE OF THE FOLLOWING SEASONS WOULD BE MOST APPROPRIATE. THE PREDICTED RESULTS OF EACH SEASON ARE GIVEN. INITIAL POPULATIONS FOR THE SUCCEEDING YEAR'S SIMULATION ARE BASED ON IMPLEMENTATION OF THE MOST LIBERAL SEASON LISTED.

THE SPECIFIED HARVEST OF 2262006. BIRDS CANNOT BE REACHED WITHIN THE FRAMEWORK OF REASONABLE REGULATIONS WITH THE GIVEN NO. OF HUNTERS. IN THIS CASE, THE MAXIMUM SEASON OF 100 DAYS WITH A BAG LIMIT OF 5 COCKS IS RECOMMENDED. THE PREDICTED RESULTS OF THIS SEASON ARE:

<table>
<thead>
<tr>
<th>COCK HARVEST</th>
<th>1312221.</th>
<th>ILLEGAL HEN KILL</th>
<th>759915.</th>
<th>BIRDS/DAY 1.31</th>
<th>POST SEASON SEX RATIO 60.72</th>
</tr>
</thead>
</table>

---------------------------------------------------------------
prehensive planning. Given projected land-use changes based on present rates of change, it would be possible to predict future pheasant populations and their associated capability to attract hunters.

Conclusion

A simulation model for ring-necked pheasants has been developed. The model demonstrates potential in providing quantitative answers to management problems. It should be particularly useful for evaluating the effect on pheasants of agricultural land-use changes, habitat improvement programs, and federal farm programs.

Only a few applications of a pheasant modeling system have been discussed. Almost any question can be investigated. Some changes in FORTRAN coding and increased sophistication would be necessary, in some instances, but this is true of any simulation model. A finished product is never produced because there are always additions or changes which could improve a model's performance.

The simulation described lacks much of the mathematical sophistication characteristic of many models, but it provides adequate predictions and performs in an acceptable manner. The performance of the model demonstrates that development of simulation models is possible for upland game populations. With more sophisticated mathematical input, the model described could undoubtedly be improved. Hopefully, it can and will be used in its present or altered form to improve management of the ring-necked pheasant.
Literature Cited


Appendix I

FORTRAN IV G LEVEL 21  MAIN  DATE = 7/8/136  16/25/47  PAGE 0001

PROGRAM PHEASANT

THIS PROGRAM, GIVEN THE PARAMETERS DESCRIBED, WILL SIMULATE
A RING-NECKED PHEASANT POPULATION OVER A GIVEN PERIOD OF
YEARS. PROGRAM DEVELOPED BY MELVIN W. TAYLOR, NEBRASKA
GAME AND PARKS COMMISSION.

DIMENSION VARIABLES

*PRDKLI5.10l.SEASIIO),BAGI101,HNKI10I,SRI101,TITLEI100I

READ TITLE CARDS (5 CARDS MUST BE PROVIDED, SOME MAY BE BLANK)

READI5,751ITITLEIII,I=I,lOOI

READ SIMULATION CONTROL PARAMETERS

IYR = NO. OF PAST YEARS TO BE SIMULATED, PHASE 1
IYST - YEAR SIMULATION IS TO START
NYRSM - NO. OF FUTURE YEARS TO BE SIMULATED PAST THE RANGE OF
ACTUAL DATA, PHASE 2
IPRT = PRINT CONTROL 0 - COMPLETE OUTPUT 1 - GRAPHIC OUTPUT ONLY
ACPNN - AVERAGE ACRES OF NESTING COVER REQUIRED TO PRODUCE
ONE SUCCESSFUL NEST
ASURV - AVERAGE SURVIVAL RATE OF JUVENILES FROM EGG TO FALL
WINFCT = FACTOR CONTROLLING EFFECT OF WINTER WEATHER, ADJUST
TO REFLECT CONDITION OF WINTER COVER
PHNKL - PROPORTION OF HENS LOST TO ACCIDENTAL SHOOTING PER DAY OF SEASON
PCH - DESIRED PROPORTION OF COCKS TO BE HARVESTED
CSBNR = COCK CRIPPLING MORTALITY DURING HUNTING SEASON

READI5,311YR,IYST,MYRSM,IPRT,ACPNN,ASURV,WINFCT,PHNKL,PCH,CSBNR

3 FORMATI412,6F5.01
READ NATURAL MORTALITY RATES OTHER THAN HUNTING AND CRIPPLING LOSS FOR THE FOLLOWING PERIODS:
1 - PRE-NESTING TO POSTNESTING
2 - POST-NESTING TO PRE-HUNT
3 - PRE-HUNT TO POST-HUNT

READ COCK MORTALITIES

READ HEN MORTALITIES

READ NESTING COVER INFORMATIONAL PARAMETERS
NCT = NO. OF COVER TYPES
ANM - FOUR LETTER NAMES FOR EACH COVER TYPE
WCT - WEIGHT FACTOR FOR EACH COVER TYPE

C011 READ5(4)NCT,J(ANM(J),J=1,NCT)
C012 4 FORMAT(I2,16A4)
C013 READ5(1)NCT(J),J=1,NCT)

READ ACTUAL POPULATION IN MILLIONS AS ESTIMATED FOR EACH YEAR INCLUDED IN YEARS WITH DATA AVAILABLE

C014 READ5(13)ACTPOP(I),I=1,1NYR)
C015 13 FORMAT(16F5.0/16F5.0/16F5.0)

READ WEIGHTING FACTORS FOR TEMPERATURE AND PRECIPITATION DATA

C016 READ5(6)WTT(J),J=1,361,(WTP(J),J=1,36)
C017 6 FORMAT(36F2.0/36F2.0)

CALL WEATHER ROUTINE TO ESTABLISH WEATHER INDICES FOR YEARS WITH DATA

C018 CALL WEATH(A,B,C,WTT,WTP,YR)

READ WEATHER INDICES FOR YEARS TO BE SIMULATED AFTER SIMULATION OF THE YEARS WITH DATA AVAILABLE

C019 IK=IYR+1
C020 IK2=IYR+NYRSM
C021 DC 12 I=IK,IK2
C022 12 READ5(11)A(I),B(I),C(I)

WRITE OUT PARAMETERS USED IN THIS RUN

C023 WRITE(6,55)IYR,ISTS,NYRSM,IPRT,ACPN,ASURV,MINFT,PHNKL,ESBNR
C024 55 FORMAT(1PE8.51PE8.51PE8.51PE8.51PE8.51PE8.51PE8.51PE8.51PE8.51PE8.5)

**OAK, PAST YEARS REPRESENTED BY DATA=*15/
**YEAR SIMULATION IS TO START= 1992,
**FUTURE YEARS TO BE SIMULATED =*
**OPRINT CONTROL=*
**OACRES PER NEST=*14.2/
**JUVENILE SURVIVAL=*150,
**WINTER FACTOR=*1.2/
**PROPORTION OF HENS KILLED=*1.0,
**PROPORTION OF COCKS CRIPPLED=*1.0,
**MINIMUM NO. COCKS/HEN FOR BREEDING=*150,
**MINIMUM NO. COCKS/HEN FOR BREEDING=*150,
**COEFFICIENTS FOR HARVEST PREDICTION EQUATION**

- **REGRESSION CONSTANT**: F15.3
- **COEFFICIENT FOR BAG LIMIT**: F15.3
- **COEFFICIENT FOR NUMBER OF HUNTERS**: F15.3
- **COEFFICIENT FOR SEASON LENGTH**: F15.3
- **COEFFICIENT FOR NUMBER OF BIRDS**: F15.3

**WEATHER FACTORS**

- **TEMPERATURE**: 3X, 36F3.0
- **PRECIPITATION**: 36F3.0

**MULTIPLY INITIAL POPULATION BY 1000000 TO GET CORRECT POPULATION SIZE TO BEGIN WITH**

- **COCKS** = **COCKS** * 10.**6
- **HENS** = **HENS** * 10.**6

**ZERO REMAINING PART OF ARRAY FOR PLOTTING**

**START SIMULATION LOOP**

- **DO 99 NYR=1,IK2**
- **READ ACREAGE OF NESTING COVER IN THOUSANDS OF ACRES**
- **READ SEASON LENGTH, BAG LIMIT, AND NUMBER OF HUNTERS**

**ANSTCV=0.0**
SUBTRACT NESTING SEASON MORTALITY OF ADULT BIRDS

0040 COCKS(2)=COCKS(1)-COCKS(1)*AMORT(1,1)
0041 HENS(2)=HENS(1)-HENS(1)*AMORT(2,1)

CHECK SEX RATIO FOR BREEDING PURPOSES

0042 BRHNS=HENS(2)
0043 IF(COCKS(2)/HENS(2).LT.CPHM) BRHNS=COCKS(2)*(1.0/CPHM)

CALCULATE NESTING COVER INDEX

0044 DO 7 I=1,NCT
0045 7 ANSTCV=ANSTCV+COV(I)*WCT(I)

ADJUST NESTING COVER INDEX FOR WEATHER CONDITIONS AND CONVERT TO ACTUAL ACREAGE

0046 ANSTCV=ANSTCV*(1.0+IN(NYR)*CVSLP)*1000.

CALCULATE NO. SUCCESSFUL NESTS AS FUNCTION OF NEST COVER AVAILABILITY

0047 SUC=(1.0/ACPN)*ANSTCV

ADJUST SUCCESSFUL NESTS DOWNWARD IF NO. SUCCESSFUL NESTS GREATER THAN BREEDING HEN POPULATION

0048 IF(SUC.GT.BRHNS) SUC=BRHNS

CALCULATE JUVENILE SUMMER MORTALITY GIVEN WEATHER CONDITIONS

0049 IF(C(NYR).GT.0.0) SURV=ASURV+SRV1*C(NYR)
0050 IF(C(NYR).LE.0.0) SURV=ASURV+SRV2*C(NYR)

CALCULATE NO. OF YOUNG AND JUVENILE MORTALITY RATE

0051 YOUNG=SUC*EGSPN*SURV
0052 AJVMRT=1.0-SURV

SUBTRACT SUMMER MORTALITY, ADD YOUNG TO ADULT POPULATION

0053 COCKS(3)=COCKS(2)-COCKS(2)*AMORT(1,2)+.5*YOUNG
C HENS(3) = HENS(2) - HENS(2) * AMORT(2, 2) + .5 * YOUNG

C CALCULATE HUNTING STATISTICS

C N = 0

C CALCULATE HEN MORTALITY FROM ACCIDENTAL SHOOTING

C HNKL = PHNKL * HENS(3) * SL

C CALCULATE YOUNG/ADULT COCK IN THE HARVEST

C YNGPA = (.5 * YOUNG) / (COCKS(2) - COCKS(2) * AMORT(1, 2))

C CALCULATE NUMBER OF COCKS TO BE HARVESTED USING SPECIFIED HARVEST RATE

C CTBH = PCH * COCKS(3)

C CALCULATE TOTAL BIRDS IN SUMMER IN MILLIONS FOR USE IN HARVEST EQUATION

C TBRDS = (COCKS(2) + HENS(2) + YOUNG) / 10. ** 6

C CALCULATE HARVEST OF COCKS

C AKILL = (C1 * BGL + C2 * HNTRS / 1000. + C3 * SL + TBRDS * C4 + CO) * 1000.

C CALCULATE A PREDICTED HARVEST BASED ON VARIOUS REGULATORY STRATEGIES

C DO 120 I = 1, 4

C DO 120 J = 1, 10

C PRDKL(I, J) = (C1 * (I + 1) + C2 * HNTRS / 1000. + C3 * (J + 10.) + TBRDS * C4 + CO) * 1000.

C CHECK IF PREDICTED VALUE WITHIN 5% OF PREFERRED HARVEST RATE

C IF (NYR.LT.IK) GO TO 120

C FACT = (CTBH - PRDKL(I, J)) / CTBH

C IF (ABS(FACT) .LT. 0.05) GO TO 144

C GO TO 120

C 144  N = N + 1
CALCULATE STATISTICS FOR SEASON WHICH PROVIDES REQUESTED HARVEST RATE

HNK - HENS ACCIDENTALLY SHOT
SR - SEX RATIO, PREHUNT
CKS - COCKS IN POPULATION, PREHUNT
HNS - HENS IN POPULATION, PREHUNT

SEAS(N)=J*10
BAG(N)=I+1
HNK(N)=PHNKL*HENS(3)*SEAS(N)
CKS=COCKS(3)-PRDKL(I,J)-(AMORT(I,3)*CSBNR)*COCKS(3)
HNS=HENS(3)-HNK(N)-AMORT(2,3)*HENS(3)
SR(N)=(100./HNS)*CKS

ADJUST HEN MORTALITY AND HARVEST TO ALLOW FOR THE MOST LIBERAL SEASON SELECTED

IF(HNK(N)>HNKL)HNKL=HNK(N)
IF(PRDKL(I,J)>AKILL)AKILL=PRDKL(I,J)

CHECK FOR POSSIBILITY OF NO SEASON FIT WITH SPECIFIED HARVEST, ADJUST HEN MORTALITY AND HARVEST ACCORDINGLY

IF(N.EQ.0.AND.Nyr.GE.IK)HNKL=PHNKL*HENS(3)*100.
IF(N.EQ.0.AND.Nyr.GE.IK)AKILL=PRDKL(4,10)

CALCULATE BIRDS/HUNTER DAY, MAXIMUM IS BPDM

BDP DAY=BD1+BD2*TBRS
IF(BDP DAY.GT.BPDM)BDPDAY=BPDM

CALCULATE POST HUNT POPULATION

COCKS(4)=COCKS(3)-AKILL-(AMORT(1,3)*CSBNR)*COCKS(3)
HENS(4)=HENS(3)-HNKL-AMORT(2,3)*HENS(3)

CALCULATE SEX RATIOS

DO 16 I=1,4
16 RA(I)=(100./HENS(I))*COCKS(I)

CALCULATE WINTER MORTALITY
IF (B(NYR) .GE. 0.0) WINMRT = WINM
IF (B(NYR) .LT. 0.0) WINMRT = WINM - B(NYR) * WINFCT
AMORT(1,4) = WINMRT
AMORT(2,4) = WINMRT

C
C PRINT OPTION CHECK
C
IF (IPRT.EQ.1) GO TO 52

C
C WRITE RESULTS
C
IY = IY + 1
WRITE(6,21) TITLE(I), I = 1, 100
* YEAR 19*12/5/57, 204/12/5/57, 120(*-*)
WRITE(6,21) ANM(J), COV(J), WCT(J), J = 1, NCT
WRITE(6,31) (A(NYR), C(NYR), B(NYR))
* SUMMER, F8.2, 5X, WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,22)
WRITE(6,22)
WRITE(6,22)

C
C WRITERESULTS
C
IY = IYST + NYR - 1
WRITE(6,20) TITLE(I), I = 1, 100
* SIMULATED POPULATION, * SUMMER, F8.2, 5X, * WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100
* NATURAL MORTALITY RATES, 10X,
** SIMULATED POPULATION, ** SUMMER, F8.2, 5X, ** WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100

C
C WRITE RESULTS
C
IY = IY + 1
WRITE(6,21) TITLE(I), I = 1, 100
* YEAR 19*12/5/57, 204/12/5/57, 120(*-*)
WRITE(6,21) ANM(J), COV(J), WCT(J), J = 1, NCT
WRITE(6,31) (A(NYR), C(NYR), B(NYR))
* SUMMER, F8.2, 5X, WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,22)
WRITE(6,22)
WRITE(6,22)

C
C WRITERESULTS
C
IY = IY + 1
WRITE(6,20) TITLE(I), I = 1, 100
* SIMULATED POPULATION, * SUMMER, F8.2, 5X, * WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100
* NATURAL MORTALITY RATES, 10X,
** SIMULATED POPULATION, ** SUMMER, F8.2, 5X, ** WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100

C
C WRITE RESULTS
C
IY = IY + 1
WRITE(6,21) TITLE(I), I = 1, 100
* YEAR 19*12/5/57, 204/12/5/57, 120(*-*)
WRITE(6,21) ANM(J), COV(J), WCT(J), J = 1, NCT
WRITE(6,31) (A(NYR), C(NYR), B(NYR))
* SUMMER, F8.2, 5X, WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,22)
WRITE(6,22)
WRITE(6,22)

C
C WRITERESULTS
C
IY = IY + 1
WRITE(6,20) TITLE(I), I = 1, 100
* SIMULATED POPULATION, * SUMMER, F8.2, 5X, * WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100
* NATURAL MORTALITY RATES, 10X,
** SIMULATED POPULATION, ** SUMMER, F8.2, 5X, ** WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100

C
C WRITE RESULTS
C
IY = IY + 1
WRITE(6,21) TITLE(I), I = 1, 100
* YEAR 19*12/5/57, 204/12/5/57, 120(*-*)
WRITE(6,21) ANM(J), COV(J), WCT(J), J = 1, NCT
WRITE(6,31) (A(NYR), C(NYR), B(NYR))
* SUMMER, F8.2, 5X, WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,22)
WRITE(6,22)
WRITE(6,22)

C
C WRITERESULTS
C
IY = IY + 1
WRITE(6,20) TITLE(I), I = 1, 100
* SIMULATED POPULATION, * SUMMER, F8.2, 5X, * WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100
* NATURAL MORTALITY RATES, 10X,
** SIMULATED POPULATION, ** SUMMER, F8.2, 5X, ** WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,20) TITLE(I), I = 1, 100

C
C WRITE RESULTS
C
IY = IY + 1
WRITE(6,21) TITLE(I), I = 1, 100
* YEAR 19*12/5/57, 204/12/5/57, 120(*-*)
WRITE(6,21) ANM(J), COV(J), WCT(J), J = 1, NCT
WRITE(6,31) (A(NYR), C(NYR), B(NYR))
* SUMMER, F8.2, 5X, WINTER, F10.2/121(*-')/121(*-')/120(*-*)
WRITE(6,22)
WRITE(6,22)
WRITE(6,22)

60 WRITE(6,130)HNTRS,(K,K=10,100,10)
130 FORMAT(*OPREDICTED KILL UNDER VARIOUS REGULATORY STRATEGIES ASSUMING* NG*, 'F9.0', *, HUNTERS*', '10', '50X*, 'SEASON LENGTH; DAYS*', 'O*16X*', '10110*/', '5X*, 'BAG LIMIT')

132 WRITE(6,133)K,(PRDKL(I,J),J=1,10)
133 FORMAT('5X', '110', '9X', '10F10.0')
134 IF(NYR.LT.1)GO TO 52
135 PC=PCH*100.
136 WRITE(6,135)HNTRS,PC,CTBH

139 FORMAT('5X', 'SEASON LENGTH', 'BAG LIMIT', 'COCK HARVEST', 'HEN KILL', '5X*', 'BIKRS/DAY', 'POST SEASON SEX RATIO')

155 WRITE(6,136)SEAS(I),BAG(I),PRDKL(L2,L1),HNK(I),BDPDAY,SRI(I)
136 FORMAT('5X', 'F10.0', 'F14.0', 'F18.0', 'F14.0', 'F12.2', 'F18.2')

157 WRITE(6,138)CTBH,PRDKL(4,10),HNK,BDPDAY,RATIO(4)
138 FORMAT('5X*', 'THE SPECIFIED HARVEST OF', 'F10.0', '5X*', 'BIRDS CANNOT BE REACHED', '5X*', 'WITHIN THE FRAMEWORK OF REASONABLE', '5X*', 'REGULATIONS WITH THE GIVEN', '5X*', 'NO. OF HUNTERS. IN THIS CASE, THE MAXIMUM SEASON OF 100 DAYS', '5X*', 'WITH A BAG LIMIT OF 5 COCKS IS RECOMMENDED. THE PREDICTED RESULT', '5X*', 'OF THIS SEASON ARE:', '5X*', 'O*25X*', 'COCK HARVEST', 'F12.0', '5X*', 'ILLEGAL HEN KILL', 'F12.0', '5X*', 'BIRDS/DAY', 'F6.2', '5X*', 'POST SEASON SEX RATIO', 'F7.2')

STORE POPULATION STATISTICS FOR PLOTTING
52 CK(NYR)=(COCKS(3)+HENS(3))/10.**6
53 TK(NYR)=ACTPOP(NYR)

C SUBTRACT WINTER MORTALITY

C COCKS(1)=COCKS(4)-WINMRT*COCKS(4)
C HENS(1)=HENS(4)-WINMRT*HENS(4)

C WRITE(6,141)
C 141 FORMAT(' **,120(' _')/121(' _')/*',120('**'))

C 99 CONTINUE
C CHECK FOR PRINT OPTION
C IF(IPR.T.EQ.2)STOP
C WRITE HEADING FOR PLOT

C WRITE(6,30)TITLE(I),I=1,100
C 30 FORMAT('GRAPHIC REPRESENTATION OF ACTUAL(*) AND SIMULATED(**) POPULATION'S/5('/','20A4')/0',40X,'TOTAL PHEASANTS IN FALL, MILLIONS')

C CALL PLOTTING ROUTINE TO PLOT ACTUAL AND SIMULATED POPULATIONS
C CALL PLOT(IK2,CK,TK,IYST,IK)

C WRITE(6,32)
C 32 FORMAT(1H1)

STOP
END
SUBROUTINE PLOT(NrXrYrIYSTr1K)

C THIS ROUTINE PLOTS THE ACTUAL(Y) AND SIMULATED(X) POPULATIONS C FOR THE SPECIFIED SIMULATION PERIOD OF N YEARS. IYST DEFINES C THE STARTING YEAR. IK IS THE YEAR IN THE SIMULATION AFTER C WHICH ACTUAL DATA ENDS AND SIMULATION OF FUTURE YEARS BEGINS. C ONLY SIMULATED VALUES ARE PLOTTED AFTER YEAR IK. THE SCALE C OF THE GRAPH CAN BE CHANGED BY ALTERING XMAX.

DIMENSION X(50),Y(50),SCALY(11),IPLATE(101)
DATA IPrIPXrIPYrIPB/rH*rlHXrlHI/
XMAX=40.
DO J=1,11
SCALY(J)=(J-1)*(XMAX/10.)
WRITE(6,100)(SCALY(J),J=1,11)
100 FORMAT(1H0,6X,11F10.3/13X,10("V............"),"V")
KNT=4
DO 99 NO=1,N
DO 3 I=1,101
3 IPLATE(I)=IP
KNT=KNT+1
IX=X(NO)/(XMAX+.01)+1.5
IY=Y(NO)/(XMAX+.01)+1.5
IF(IX.EQ.IY.AND.NO.LT.IK)GO TO 10
IF(NO.GE.IK)GO TO 90
IPLATE(IX)=IPX
90 IPLATE(IY)=IPY
GO TO 90
IF(KNT.NE.5)GO TO 98
ISCALX=IYST+NO-1
WRITE(6,101)(IPLATE(I),I=1,101)
101 FORMAT(1H0,6X,19*,12*,101A1//)
KNT=0
GO TO 99
98 WRITE(6,102)(IPLATE(I),I=1,101)
99 CONTINUE
RETURN
END
SUBROUTINE WEATHR(A,B,C,WT,T,WTP,RTNG, IYR)

C
C CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C C
C THIS SUBROUTINE READS MONTHLY PRECIPITATION AND TEMPERATURE
C VALUES FOR ALL PAST YEARS SIMULATED PLUS ONE YEAR PRIOR TO
C SIMULATION START. A MEAN AND STANDARD DEVIATION IS CALCULATED
C FOR EACH MONTH OVER THE RANGE OF YEARS. A RATING IS THEN
C ASSIGNED EACH MONTH FOR TEMPERATURE AND PRECIPITATION BASED
C ON THE PROPORTION OF ONE STANDARD DEVIATION WHICH EACH DATUM
C FALLS AWAY FROM THE MEAN. A PROCEDURE IS THEN FOLLOWED WHEREBY C
C A SIMULATED YEAR IS AFFECTED BY THREE YEARS OF WEATHER, ONE C
C PRIOR YEAR, THE PRESENT YEAR, AND A FUTURE YEAR. WEATHER C
C EFFECTS ARE DIVIDED INTO THREE PERIODS:
C
1. PRENESTING AND NESTING WHICH INCLUDES THE PREVIOUS
   YEAR PLUS JAN-MAY OF THE SIMULATED YEAR.
2. HATCHING AND SUMMER PERIOD JUNE-SEPT.
3. WINTER PERIOD INCLUDING OCTOBER OF SIMULATED
   YEAR TO FEBRUARY OF FOLLOWING YEAR.

C THESE PERIODS CAN BE ALTERED IN LENGTH BY CHANGING THE LOOP
C INDICES FOR DO 12, 13, 14. PROVISIONS ARE MADE TO ALLOW THE
C INCLUSION OF ANY DESIRED WEATHER EFFECTS BY SPECIFYING C
C APPROPRIATE WEIGHTS IN THE WEATHER WEIGHTS OPTION IN THE MAIN
C PROGRAM. THE SUBROUTINE THEN RETURNS A WEATHER RATING BASED ON C
C A WEIGHTED AVERAGE EFFECT OF BOTH TEMPERATURE AND PRECIPITATION C
C THIS VALUE IS USED IN ALTERING POPULATION PHENOMENON.
C
C CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
DIMENSION T(50,12),P(50,12),SSP(12),SST(12),TOTT(12),TOTP(12),
*SDT(12),SDP(12),XTT(12),XTP(12),A(50),B(50),C(50),WT(50),WTP(50),
*RTNGT(50,12),RTNPG(50,12),RP(50),RT(50)

C
DO 2 J=1,12
SSP(J)=0.0
SST(J)=0.0
TOTT(J)=0.0
2 TOTP(J)=0.0

DO 1 IY=IYR+2

DO 1 I=1,IY
A(I)=0.0
B(I)=0.0
C(I)=0.0
1 READ(T,10)
(T(I,J),J=1,12),P(I,J),J=1,12)
10 FORMAT(2X,12F3.1,12F3.2)
   DO 1 J=1,12
  1 TOTT(J)=TOTT(J)+T(I,J)
   TOTP(J)=TOTP(J)+P(I,J)
   SST(J)=SST(J)+T(I,J)*T(I,J)
   SSP(J)=SSP(J)+P(I,J)*P(I,J)
   DO 3 J=1,12
  3 XBP(J)=TOTT(J)/IY
   DO 5 I=1,Y
  5 SDT(J)=SQRT((SST(J)-(TOTT(J)*TOTT(J)/IY))/IY)
   SDP(J)=SQRT((SSP(J)-(TOTP(J)*TOTP(J)/IY))/IY)
   XBT(J)=TOTT(J)/IY
   DO 7 J=1,12
  7 RTNGT(I,J)=(T(I,J)-XBT(J))/SDT(J)
   RTNGP(I,J)=(P(I,J)-XBP(J))/SDP(J)
   DO 99 I=1,YR
  99 CONTINUE
RETURN
END
Appendix II

Pheasant Simulation Year 1960

Run 1 - This run simulates the effect of establishing 100,000 acres of weight two nesting cover while other nesting cover acreages are held constant. The number of hunters is maintained at the 1975 level of 117,000.

Nesting Cover, Thousands of Acres (wt.)

<table>
<thead>
<tr>
<th></th>
<th>WHET</th>
<th>OATS</th>
<th>ALF</th>
<th>ROAD</th>
<th>SB</th>
<th>DWAC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3011.1</td>
<td>1213.0</td>
<td>1764.1</td>
<td>220.1</td>
<td>876.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Weather Indices

<table>
<thead>
<tr>
<th>Nesting Season</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.43</td>
<td>-0.17</td>
<td>0.61</td>
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</tbody>
</table>

Natural Mortality Rates

<table>
<thead>
<tr>
<th></th>
<th>Cocks</th>
<th>Hens</th>
<th>Young</th>
<th>Cocks</th>
<th>Hens</th>
<th>Young</th>
<th>Cocks/100 Hens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prenesting to</td>
<td>0.30</td>
<td>0.35</td>
<td></td>
<td>3032686</td>
<td>4565692</td>
<td></td>
<td>66.42</td>
</tr>
<tr>
<td>Postnesting to</td>
<td>0.30</td>
<td>0.30</td>
<td>0.39</td>
<td>2122880</td>
<td>2967700</td>
<td>10328456</td>
<td>71.53</td>
</tr>
<tr>
<td>Prehunt</td>
<td>0.30</td>
<td>0.30</td>
<td>0.39</td>
<td>6650244</td>
<td>7241618</td>
<td></td>
<td>91.83</td>
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</table>
HUNTING STATISTICS

<table>
<thead>
<tr>
<th>SEASON LENGTH</th>
<th>BAG LIMIT</th>
<th>NO. OF HUNTERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>5</td>
<td>150000</td>
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</tbody>
</table>

PREDICTED RESULTS

<table>
<thead>
<tr>
<th>COCK HARVEST</th>
<th>ILLEGAL HEN KILL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1543622</td>
<td>858131</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BIRDS/DAY</th>
<th>YOUNG/ADULT IN KILL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.79</td>
<td>3.48</td>
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</tbody>
</table>

PREDICTED KILL UNDER VARIOUS REGULATORY STRATEGIES ASSUMING 150000 HUNTERS

<table>
<thead>
<tr>
<th>BAG LIMIT</th>
<th>SEASON LENGTH DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

| 2  | 865323. | 920323. | 975323. | 1030323. | 1085322. | 1140322. | 1195322. | 1250322. | 1305322. | 1360322. |
| 3  | 964923. | 1019923. | 1074922. | 1129922. | 1184922. | 1239922. | 1294922. | 1349922. | 1404922. | 1459922. |
| 4  | 1064522. | 1119522. | 1174522. | 1229522. | 1284522. | 1339522. | 1394522. | 1449522. | 1504522. | 1559522. |
| 5  | 1164122. | 1219122. | 1274122. | 1329122. | 1384122. | 1439122. | 1494122. | 1549122. | 1604122. | 1659122. |
GRAPHIC REPRESENTATION OF ACTUAL(*) AND SIMULATED(#) POPULATIONS

RUN 1 - THIS RUN SIMULATES THE EFFECT OF ESTABLISHING 100,000 ACRES OF WEIGHT TWO NESTING COVER WHILE OTHER NESTING COVER ACREAGES ARE HELD CONSTANT. THE NUMBER OF HUNTERS IS MAINTAINED AT THE 1975 LEVEL OF 117,000.

TOTAL PHEASANTS IN FALL, MILLIONS

<table>
<thead>
<tr>
<th>Year</th>
<th>0.0</th>
<th>4.000</th>
<th>8.000</th>
<th>12.000</th>
<th>16.000</th>
<th>20.000</th>
<th>24.000</th>
<th>28.000</th>
<th>32.000</th>
<th>36.000</th>
<th>40.000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>*</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td>X</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>X</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
PHEASANT SIMULATION YEAR 1977

RUN 1 - THIS RUN SIMULATES THE EFFECT OF ESTABLISHING 100,000 ACRES OF WEIGHT TWO NESTING COVER WHILE OTHER NESTING COVER ACREAGES ARE HELD CONSTANT. THE NUMBER OF HUNTERS IS MAINTAINED AT THE 1975 LEVEL OF 117,000.

NESTING COVER, THOUSANDS OF ACRES (WT.)

<table>
<thead>
<tr>
<th>Type</th>
<th>WHET</th>
<th>OATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>3.070</td>
<td>0.570</td>
</tr>
</tbody>
</table>

ALF 1730 (-1.0) ROAD 170 (-3.0)
SB 0.1 (2.0) DWAC 0.4 (0.2)

WEATHER INDICES
- NESTING SEASON -0.30
- SUMMER 0.0
- WINTER 0.0

NATURAL MORTALITY RATES

<table>
<thead>
<tr>
<th>Category</th>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS</th>
<th>HENS</th>
<th>YOUNG</th>
<th>COCKS/100 HENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRENESTING</td>
<td>0.30</td>
<td>0.35</td>
<td></td>
<td>59935</td>
<td>187413</td>
<td>31.98</td>
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<tr>
<td>POSTNESTING</td>
<td>0.30</td>
<td>0.30</td>
<td>0.35</td>
<td>41955</td>
<td>121818</td>
<td>382014</td>
<td>34.44</td>
</tr>
<tr>
<td>PREHUNT</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
<td>220375</td>
<td>276280</td>
<td>79.77</td>
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</tr>
<tr>
<td>POSTHUNT</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
<td>636390</td>
<td>207210</td>
<td>30.71</td>
<td></td>
</tr>
</tbody>
</table>