A DYNAMIC WHITE-TAILED DEER POPULATION SIMULATOR

AND

LESSONS FROM ITS USE

by

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INTRODUCTION

This study had three major objectives. The first objective was to develop a computer simulation that can be used to study a white-tailed deer (*Odocoileus virginianus*) population. The simulator was designed so that discrete as well as stochastic modes could be used. Another objective was to determine an algorithm for achieving long-term population stability. The third objective was to develop a simulator that could be employed as a long-range management planning tool or as an educational medium.

Detailed study of a white-tailed deer herd requires a sizable staff working for many years. Most wildlife organizations can afford neither the men nor the time required to conduct such extensive studies. Even if such studies were conducted, there are few opportunities for statistical replicates. Because of high costs and the questionable results of unreplicated studies, an alternative is needed. Computer simulation provides such an alternative.

Simulation has a place in wildlife management because of the value of the wildlife resource. Experimenting with natural populations is not only time consuming and expensive but also can damage the wildlife resource. Simulation removes the possibility of such damage. A simulation allows managers to study management alternatives that he would not allow himself to use on an actual population because of a fear of how a deer population or hunters would react. Such alternatives could result in improved management of the wildlife resource. Also, simulation brings population dynamic studies well within the budget of wildlife organizations. Such studies, when conducted with a simulation, reduce expenditures and enable completion in a reasonable period, with available funds and manpower.

Many aspects of white-tailed deer biology have been researched. The results are often published but in many cases, the question of how a research conclusion relates to actual management of white-tailed deer remains unanswered. Many wildlife management organizations are collecting, at great expense, data on white-tailed deer. This information is collected but seldom used. Are enough data collected? Are too much collected? These questions can be asked but factual answers are difficult to achieve. What is needed is a means of determining what data will most aid management. With this information, data collection can be altered in order to increase the efficiency for management purposes.

There are many problems in the management of a wildlife species and a systems approach might be employed to aid in their solution (see Patten 1971, Van Dyne 1969). One aspect of a systems approach that could be considered, either to solve or aid in solving problems, would be to model the resource and use the model to simulate the resource over time. The model may be used to conduct population studies in a short period at a relatively low cost. Also, a population simulation could be used to conduct a sensitivity analysis (Taha 1968). A sensitivity analysis would give a great deal of information to the manager in the form of what data to collect and how to get the most information from it. A simulator could also be used to experiment with research findings. Research findings (e.g. fawn reproduction) could be placed in the simulator and alterations in management strategies resulting from this new information studied.

A deer population can be conceived as a system. The processes of the system include reproduction, survival, and mortality. Turner (1967) stated that every system must have an environment in which to operate. He defined the system's environment as the set of all objects outside the system, a change in which affects the system. For a deer population, the habitat, political situation, and economic climate are the system's environment. Changes in these environmental conditions have an effect on the deer population.

A system can be classified in a variety of ways. A system can be man-made or natural. A deer population is a natural system. A system can be classified as open or closed. Deer populations are open systems because of the interaction between the population and their environment. Systems can be classified as adaptive or not. Deer populations are adaptive systems because they respond to their environment in a positive manner (i.e. an increase in habitat condition will likely result in an increase in population size or deer condition).

Turner (1967) defined a model in general as an abstraction, idealization, and simplification of reality. Models may be categorized as conceptual or physical. Conceptual models may be categorized as:

a) verbal; a verbal description of reality,

b) graphical; a graphical display or description of reality,

c) mathematical; equations, algorithms, and probability distributions are used to describe reality,

d) computer; a model that could be used on a computer to provide a description of reality.

Physical models may be classified into several groups:

a) scale; a scaled-down replica

b) life size; replica of reality that is the same size as the real thing,

c) analog; a substitution of similar items and/or processes.

The deer population model to be described herein may be classified as a combination of the conceptual models: verbal, graphical, mathematical, and computer. Physical models of deer populations have been developed but the mathematical and computer models are used in conducting simulation studies.

Turner (1967) defined simulation as a process of building a dynamic model of a system. In simulation studies, the basic concept is to allow a system to function through time and determine how the system is affected by changes in the system or its environment. According to Riffe (1970), there are two essential ideas for simulation. First, there must be a similarity between the real thing being described and the descriptive algorithms, probability distributions, and various other aspects of the simulation. Second, there must be non-identity. The representation cannot be the "real thing" or it would not be a model. A model of a deer population is not identical to but describes the relationships in a deer population.

Simulation is being used to study many aspects of natural phenomenon. A great deal about a system and certain phenomenon can be learned by attempting to model it. Turner (1967) stated that an analyst can enhance his understanding of a system by abstracting the features of the real world system to form a model which will allow him to manipulate the system. A deer manager may be able to learn a great deal about deer populations by doing research and collecting research results from the literature. He may then model a deer population. Once developed, the model can be manipulated by the manager in order to understand better the population.

Simulation is being used in many studies of various systems and in determining management strategies for these systems. Also, management strategies can be tested using simulation to determine how the system reacts under different strategies. Stein and Bauske (1972) constructed a computer simulation of the combustion of wood and other cellulose fuels. The simulation is used to determine pollutant production in the combustion of improper mixtures of fuel. This simulation could aid in helping manufacturers improve combustion and reduce pollutants. In order to study and compare fire control strategies, Storey (1972) developed FOCUS, a model that can be used to simulate the entire sequence of fire prevention, occurrence, detection, spread, control, damage, and cost over time. The simulation was very helpful in determining the effectiveness of various fire control techniques.

Simulation is also being used to determine management strategies for different animal resources. Simulation studies are also being used to determine the efficiency of existing management plans. Simulation is being used to improve existing management practices or reinforce old ones. Miller et al. (1972) developed a population simulation for the sandhill crane (Grus canadensis). He concluded that the data being collected was not sophisticated enough to detect small changes in the trend of the crane population and that certain harvesting techniques could result in an undetected decline in the population. Southward (1968) used simulation to investigate different management strategies that might be applied to the Pacific halibut (Hippoglossus stenolepis) resource. His finding, using the simulation, were the same as those that had been determined over many years of actual management.

Simulation is being used to improve research technology and as a result improve research conclusions. This use of simulation was employed by Burnham and Overton (1968) in an attempt to improve population estimates from trapping data. They used a simulator to determine how population estimates were affected when the assumption of equal probabilities of animals being trapped was violated. When this assumption is not met, there is a great variability in the population estimates. Through the use of their simulation, methods of population estimates could be developed that are accurate regardless of the probability of each animal being trapped or sighted.

Simulation is a very useful education technique (see Zucherman and Horn 1973). Students can be placed in many different situations using a simulation and thereby learn how to cope with these situations. In wildlife management education, this is especially true because actual field experience in management may not be available to students.

The white-tailed deer is one of the most prized game species in North America. The public is often concerned about them. Under some circumstances, deer management is aided by public concern but when the public has insufficient information and actively influence management, some desirable activities may be hampered. As with all information, conclusions arrived at by the public can differ due to the processing of the information. Different attitudes may develop toward management strategies. As a result, the wildlife resource may suffer or potential resource benefits may not be achieved. The public's management ideas or plans could be placed in a simulator enabling them to evaluate the results of their proposals. The results might also be compared with the management plans of deer biologists. The public's concept of deer management may thus be altered with improved resource management resulting.

Effective management of any species requires a clear understanding of the population dynamics of that species. Detailed population studies are rarely conducted due to budgetary or manpower restrictions.

Simulation can be used to make population studies and such studies are relatively cheap and require a minimum of time. Also, simulators, once developed can be used often (replicates) and modified for improved results. Simulation is also a good educational medium. Students can learn management principles and study the effect of different management strategies. With this type of study, the student can enhance his comprehension of species management. The simulation described herein is a tool that can be used to study population dynamics of a deer herd, is easily modified to improve simulation results, and is an educational tool for students and the general public. Simulation is not the only tool to conduct population studies, but it is a viable alternative.

REVIEW OF LITERATURE

Davis (1968) modeled a deer population and used linear programming to obtain a solution to the problem of relating the controllable variables of deer harvest and land clearing to the objectives of maximizing a function of the controllable variables based on the wildlife manager's utility for each. One of the major assumptions was that utility is linearly related to the number of deer harvested and acres cleared. I have found no data to support this assumption and it has little intuitive appeal. Davis modeled natality and mortality as being independent of density and therefore remaining constant year after year. This assumption also appears to be weak because of reported significant fluctuations in natality and mortality (as well as their interdependence) from year to year.

Brennan et al. (1970) developed a digital simulation language for deer population dynamic studies. They were able to simulate a population while weather and carrying capacity of the range were varied according to seasonal probability distributions. Natality was determined during the simulation as a function of animal condition, age and the ratio of adult males to females. There is an explicit treatment of density dependent natality and mortality as well as density independent mortality in their simulation. Natality and mortality are considered as functions of the population level. These data must be supplied by the user. In many cases, supplying mortality and natality functions would limit the use of the simulation but would also make the simulation more specific for a particular population. The usefulness of this simulator is that various harvesting strategies can be tested and their effect on the population dynamics determined.

Gross (1970) constructed a model of a deer population from data provided for the Llano Basin deer herd (Colorado). The model accounted for density dependent natality and mortality. Using seasonal mortality data for the herd, the predictive ability of the simulation was determined. Once he had achieved a reasonable predictive ability with the simulator, the consequences of various harvesting techniques were examined.

Riffe (1970) constructed a model of a deer population using reproductive and mortality data obtained from the Pennsylvania Game Commission. He considered the basic unit of the population as a single deer and the basic time unit of the population as one month. In using the model to conduct a simulation, each deer was considered each month and the occurrence or non-occurrence of birth and death was randomly determined. The probability of birth and death were handled as age-specific data. The model was used to conduct simulation studies that investigated the effect of different harvest techniques on the dynamics of a deer population.

Walter et al. (1971) constructed a model to be used in a simulation study of different deer management strategies. His simulation results led to the conclusion that harvest yields may be increased 10-20% above yearly harvest by harvesting at intervals of 2 to 4 years. The reason for this increase is that the average

age of the does would be shifted upward to the optimal age of productivity.

Swartzman (1972) modeled a deer population and used non-linear programming techniques to obtain an optimal harvest with the following constraints: (1) permissible kill by area and age-sex classes; (2) minimum range condition to be maintained; and (3) limitations on the maximum number of kills per hunter. He first used the model to determine the maximum total deer kill for a state in a single hunting season.

Swartzman later approached the problem of maximization of kill for one hunting season subject to the constraint that a herd of a specified size and age-sex composition must be left at the end of the season. This problem was first solved using linear programming techniques but was later transformed to a non-linear problem. He felt that some of the relationships modeled could be more accurately described with non-linear equations resulting in better solutions.

Lomnicki (1972) modeled a roe deer (Capreolus capreolus) population and used the model to predict maximum meat production. Since deer meat can be sold in Europe, he attempted to maximize the production of meat over time. The problem was solved using non-linear techniques. The model was based on the amount of energy available; the energy required by the deer; age-specific natality, mortality, and meat production (weight); and the number of does that can be serviced by a single buck. The function to be optimized, meat production, was relatively easy to measure. To make this model functional in Virginia, the trophy value of the different age-sex deer would have to be determined in order to develop an optimization equation and this is a rather subjective measurement.

Rayburn (1972) developed a deer population and habitat model to determine the potential of land to support a deer population. He determined the energy requirements of deer based on basal metabolism, the climate, the terrain of the habitat and various other variables effecting energy flow in a deer population. The forage production was estimated using various successional parameters. The forage production parameters are the maximum expected production, the production age of the stand, the year in which maximum production is reached and the years of productive life remaining. The energy available to the deer was determined based on the digestibility of the forage and the amount of forage available. He employed the concept of a standard deer, a 50 kilogram doe, to determine the energy flow through a population.

By using the energy requirements of the deer and the energy that can be supplied by the habitat, the potential of an area to produce deer can be measured. Using this method, he developed a means of ranking areas on their potential to produce deer. The model was developed to give wildlife management agencies a means of choosing between areas to be purchased for deer management purposes.

Romesburg (1972) developed a model of a white-tailed deer population in Potter County, Pennsylvania. He used density dependent natality and mortality determined through data supplied by the Pennsylvania Game Commission. He attempted to construct a model that could be used to compare harvest strategies on the basis of specific objectives relative to forest products, automobile drivers, hunters, naturalists, wildlife managers and farmers. He used two approaches in attempting to find the optimum harvesting technique to achieve their objectives. He used the approach of least complaints and the approach of cost-benefit analysis. Using these two approaches, he was able to compare harvesting techniques of any of the above groups of people.

Dean and Galloway (1965) developed a computer program that can be used for population studies with a minimum of computer training. The parameters considered in the program include:

(1) age and sex distribution of the initial population,

(2) frequency of reproduction of females,

(3) birth rate,

(4) maturity limits for both sexes,

(5) proportion of females that breed,

(6) density independent and density dependent mortality,

(7) maximum length of life.

The program produced population size and accumulated totals over the years of the simulation.

Their simulator did not include interaction between the habitat and the population. Experimentation is possible assuming habitat conditions can be stabilized.

METHODS AND PROCEDURES

Often models used in simulation studies are developed using data collected in a specific area (e.g. Llano Basin Deer Herd). Various data and population processes reported in the literature are used to construct DEER, a general simulator useful for most deer populations.

Robert H. Giles, Jr. and Richard J. Lynn (unpublished memo.) developed STAGMAN, a deer population simulator. The purpose of the simulator was to achieve a stable population by manipulating the sex ratio of the population according to Quick's method (1963). The model determined the forage available to the population and calculated how many deer the habitat would support with a specified age and sex structure. With the known total population and the supportable population, a desired removal of deer was calculated. The simulator then removed the number of bucks and does (as in a permit system) that would achieve a desired sex ratio after the harvest. Once the sex ratio was achieved, the simulator reported a management strategy designed to stabilize the population under consideration.

Using STAGMAN as a starting point, DEER, a white-tailed deer population simulation, was constructed. DEER, a FORTRAN IV computer program, operates on the IBM 370 model 65 computer facilities at Virginia Polytechnic Institute and State University.

In order to describe the procedure used in developing the simulation, a chronological step-by-step explanation of DEER will be presented.

DEER

All of the variable names used in DEER have been indexed at either the beginning of the main program or the beginning of the subroutines. The program has also been documented so that various portions of the simulation can be readily identified.

Main Program

A general flow chart is shown in Fig. 1. Throughout the simulation, random determination of population characteristics are made by using the lower and upper limits for these characteristics that have been supplied as input data by the user. RANDU, a random number generator, supplies a rectangular (uniform) distribution of numbers between 0 and 1. This assumes equal probability of selection of a number within this range. Once this random number is received, the random characteristic of the population is determined as follows:

Random Aspect = [Upper Limit - Lower Limit] * Z + Lower Limit

where; Z is the random number between 0 and 1. A discrete simulation is achieved by setting the lower and upper limits equal in the input data. This achieves the objective of developing a discrete as well as a stochastic model.

The main program begins by reading in the data necessary to describe the deer herd and the habitat in which they survive. In order to allow the user to control habitat conditions to some extent, either (1) the maximum and minimum forage production per acre, or

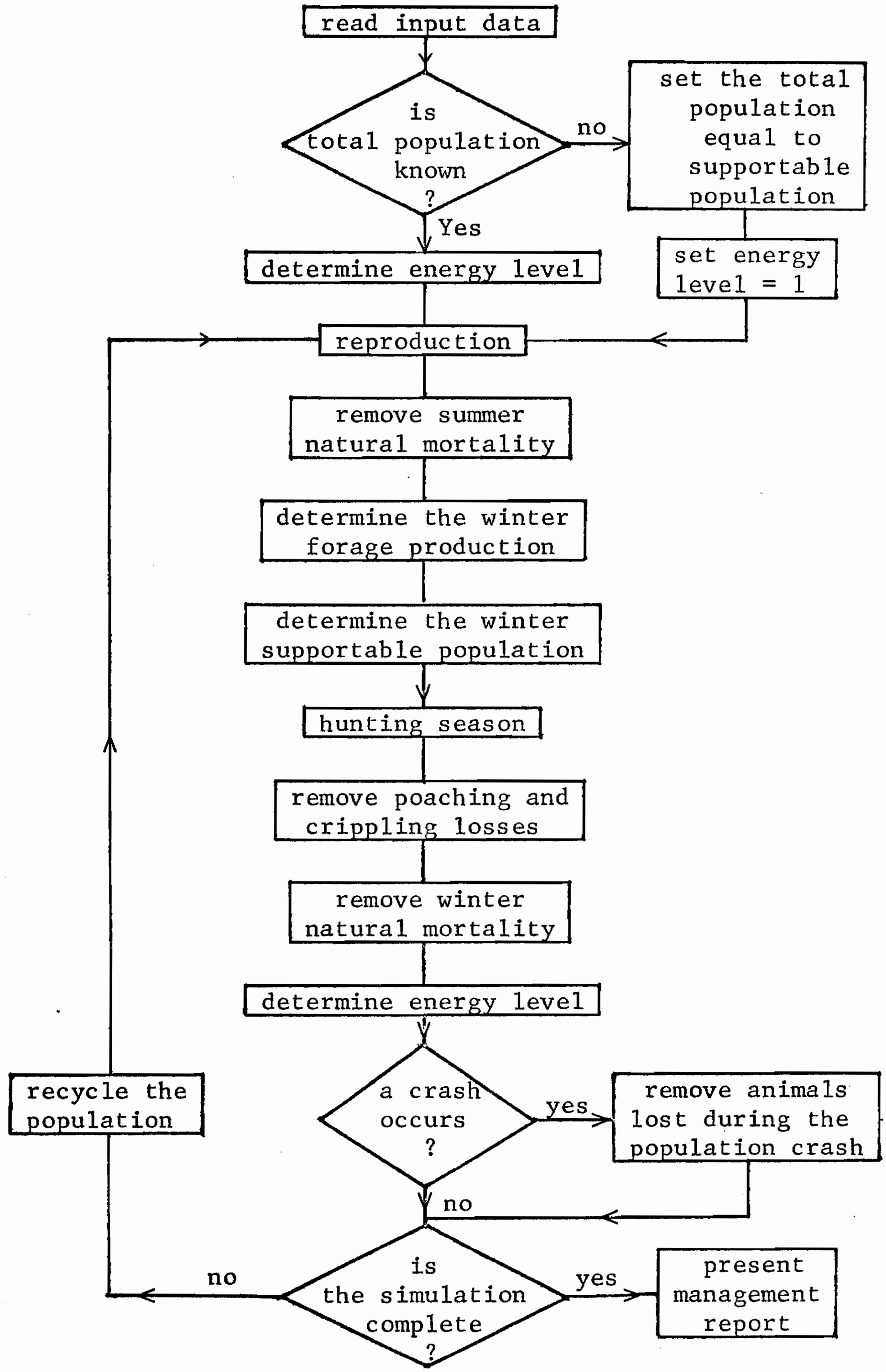

Fig. 1. Flow chart for DEER

(2) the maximum and minimum deer per acre the habitat will support can be specified. Both of these characteristics must be specified for the summer and winter. If the above values are provided in the form of forage per acre, the maximum and minimum forage production is determined by multiplying the forage per acre by the total number of acres. For example:

$$FMAXS = FMAX * ACRES$$

where; FMAXS is the maximum forage production during the summer;
FMAX is the maximum forage production per acre during the summer;
ACRES is the total number of acres in the habitat.

If the second option is chosen, the maximum and minimum deer per acre for the summer and winter are specified. Then the maximum and minimum forage production by the habitat is determined by calculating the maximum and minimum number of deer on the area and then determining the forage required by these deer. To determine the forage required by a deer, a relationship between the weight of a deer and the amount of forage required daily to sustain the deer is employed. The relation specifies that a buck of weight W (kg) requires 0.152 $W^{0.75}$ kilograms of forage per day and that a doe of weight W (kg) requires 0.141 $W^{0.75}$ kilograms of forage per day (Whelan; Penn. State data). Using this relationship, the maximum forage production for the summer is determined as follows:

$$FMAXS = \sum_{I=1}^{XQ} [(0.141 * DWD^{0.75} * D * S(J)) +$$

$$(0.152 * DWB^{0.75} * B * S(J))]$$

where; FMAXS is the maximum forage production during the summer;
XQ is the number of age classes;
DWD is the average weight of the does in each age class;
D is the maximum number of does expected in each age class;
DWB is the average weight of the bucks in each age class;
B is the maximum number of bucks expected in each age class;
S(J) is the number of days in the seasons, J = 1 for summer, J = 2 for winter.

Note; S(1) + S(2) = 365

The minimum summer forage production, the maximum winter forage production per acre and the deer per acre the habitat will support are specified by the user, the simulation is programmed to use the forage production per acre only.

Carrying Capacity

In order to determine the carrying capacity of the habitat at the beginning of the simulation, an estimate of the forage available to the deer during the summer and winter must be made. This task is accomplished by two methods.

If for each area the available forage per acre for the summer and winter herds are known, the total forage is determined by addition of all areas. In other words:

$$TOT(J) = \sum_{I=1}^{JAREA} (AREA(I) * PROD(J,I))$$

where; TOT(J) is the total forage available, J = 1 for summer, J = 2 for winter;
AREA(I) is the acreage of area I;

PROD(J,I) is the forage production per acre on area I, J = 1 for summer, J = 2 for winter;

JAREA is the number of areas considered.

If an estimate of the available forage per acre is not available, an estimate of the deer density the habitat will support during the summer and winter must be available. With this type of data, an estimate of the supportable population can be determined as follows:

$$SP(J) = \sum_{I=1}^{JAREA} (AREA(I) * DAREA(J,I))$$

where; SP(J) is the supportable population, J = 1 for summer, J = 2 for winter;

AREA(I) is the acreage of area I;

DAREA(J,I) is the deer per acre on area I the habitat will support, J = 1 for summer, J = 2 for winter;

JAREA is the number of areas considered.

Using the supportable population for the summer or winter as determined above, an estimate of the forage required by this population can be determined. Using the relationship of deer weight to forage requirements per day, the average weight of the deer in each sex and age class and the number of deer in the supportable population for the summer and winter, the simulator calculates the forage that must be available. An estimate of the number of deer in each age class of the supportable population is determined in the following manner:

$$ID = SP(J) * AR(I) * PCTF$$

$$IB = SP(J) * AR(I) * PCTM$$

where; ID is the number of does in each age class;

IB is the number of bucks in each age class;
SP(J) is the supportable population, J = 1 for summer, J = 2 for winter;
AR(I) is the proportion of the population in each age class;
PCTF is the proportion of the population that is female;
PCTM is the proportion of the population that is male.

Using the supportable population in each age class and the average weight of the deer in each age class that was provided in the input data, the total forage available to the deer is determined by summing all the forage requirements of the deer in the supportable population as follows:

$$\mathrm{TOT(J)} = \sum_{\mathrm{I=1}}^{\mathrm{XQ}} [0.141 * \mathrm{DWD(I)}^{0.75} * \mathrm{ID} * \mathrm{S(J)} + 0.152 * \mathrm{DWB(I)}^{0.75} * \mathrm{IB} * \mathrm{S(J)}]$$

where; TOT(J) is the forage available to the deer, J = 1 for summer, J = 2 for winter;
XQ is the number of age classes;
DWD(I) is the average weight of the does in age class I;
ID is the number of does in each age class;
DWB(I) is the average weight of the bucks in each age class;
IB is the number of bucks in each age class;
S(J) is the number of days in the season, J = 1 for summer, J = 2 for winter.

Either of the above methods may be used to calculate the forage available to the deer herd during the summer or winter.

Standard Deer

To determine the supportable population of an area, the concept of a standard deer is utilized. The forage required by a standard deer is estimated by weighing the forage required by a deer of a given sex and age by the proportion of the total population that is represented by such a deer. These weighed forage requirements are then summed. The forage required by a standard deer is determined by two methods in the simulation. One method is used to begin the simulation when no estimate of the population is available. Another method is used when the simulation is running and the total population is known.

In the first case, there being no estimate of the population, the simulator uses the proportion of the population in each age class and the sex ratio of the population to determine the proportion of the population represented by a deer of a given age and sex in determining the forage required by a standard deer. The proportion of the total population represented by a deer of a given age and sex is equal to the proportion of the population in that age class times the proportion of the population that is male or female. This proportion is used in the calculation of the forage requirements of a standard deer as follows:

$$\mathrm{TCONS} = \sum_{I=1}^{XQ} [(0.141 * \mathrm{DWD}(I)^{0.75} * \mathrm{PCTF} * S(J) + 0.152 * \mathrm{DWB}(I)^{0.75} * \mathrm{PCTM} * S(J)) * \mathrm{AR}(I)]$$

where; TCONS is the forage required to sustain a standard deer;
XQ is the number of age classes;
DWD(I) is the average weight of the does in age class I;
PCTF is the proportion of the population that is female;
DWB(I) is the average weight of the bucks in age

class I;
PCTM is the proportion of the population that is male;
AR(I) is the proportion of the population in age class I;
S(J) is the number of days in the season, J = 1 for summer, J = 2 for winter.

Once the simulation is running, the forage required by a standard deer is determined by using the number of deer in each age and sex class to determine what proportion of the total population is represented by each class. This proportion is then used as follows:

$$TCONS = \sum_{I=1}^{XQ} [0.141 * DWD(I)^{0.75} * S(J) * (DXK(I)/TOTPOP) + 0.152 * DWB(I)^{0.75} * S(J) * (BXK(I)/TOTPOP)]$$

where; TCONS is the forage required by a standard deer;
XQ is the number of age classes;
DWD(I) is the average weight of the does in each age class;
DXK(I) is the number of does in each age class;
TOTPOP is the total population;
DWB(I) is the average weight of the bucks in each age class;
BXK(I) is the number of bucks in each age class;
S(J) is the number of days in the season, J = 1 for summer, J = 2 for winter.

Supportable Population

With the forage required by a standard deer, an estimate of the number of deer the habitat will support with the specified structure is determined by dividing the total available forage by the forage required by a standard deer. This calculation is carried out as follows:

$$SP(J) = TOT(J)/TCONS$$

where; SP(J) is the supportable population, J = 1 for summer, J = 2 for winter;
TOT(J) is the available forage, J = 1 for summer, J = 2 for winter;
TCONS is the forage required by a standard deer.

If no estimate of the winter population is available, the total population is set to what the habitat will support. The supportable population is estimated by using the forage available during the winter along with the forage requirements of a standard deer determined by using the age ratios and sex ratio supplied by the user. This section of the simulation is provided to allow the use of the simulator without knowing the total population on the area under study, a typical condition. The concept being developed is one for a potential population. Whether that potential is ever achieved is a later question.

<u>Determine Energy Level</u>

During the initiation of the simulation, an energy level for the population is determined so that reproduction can be varied according to an energy level. Verme (1965, 1969) reported the differences in reproductive attainment of white-tailed does that were provided with different levels of nutrition. If an estimate of the total winter population is available, subroutine LEVELS is called to determine the energy level of the population. If no estimate of the winter population is available, the energy level is set equal to 1 because the total population is determined to be what the habitat will support, as described above.

Initiation of Annual Cycle

Once all portions of the simulation are initiated, the simulation goes into an annual cycle. Each year is broken into two periods, initially set at 183 days each. The period containing reproduction is referred to as summer, the period containing the harvest, winter. The cycle begins during the start of the summer period prior to reproduction.

Natality

To carry out reproduction, the use of subroutine NATAL is employed. Cheatum and Severinghaus (1950) reported on the reproductive capacity of female white-tailed deer of various ages and in different habitats. The habitats were listed as good, medium, and poor ranges. They reported the number of embryos per pregnant doe and the proportion of the different age does that were pregnant. Ransom (1967) also reported on the reproductive capabilities of does that were on different range conditions. He also reported the fetuses per pregnant doe and the proportion of different age does that were pregnant. Roseberry and Kilmstra (1970) conducted research indicating the differences in reproductive attainment for fawns, yearlings, and adult white-tailed does. Hesselton (1965) reported from the Seneca deer herd the differences between the proportion of the fawn does and the proportion of adult does that were pregnant. NATAL was structured to conform with these reported ideas and data.

The main program, operating with energy determined by LEVELS, determines: (a) the proportion of fawn does that fawn successfully; (b) the proportion of adult does that fawn successfully. These values are selected at random by RANDU within prespecified limits. Also, there is a random determination of the proportion of the fawns that are to be male. Then NATAL is called. The number of age classes, the number of does in each age class, the natality of the does in each age class, the proportion of the fawns that are male, the proportion of fawn does that fawn successfully, the proportion of adult does that fawn successfully and the energy level of the population are fed to the subroutine. The number of doe and buck fawns born are returned to the main program. In order to add the fawns to the population, all the other deer are moved up one age-class and the fawns are placed in the first age-class.

In order to develop a clearer understanding of the reproductive attainment of the population, the following characteristics are calculated: the number of doe fawns per adult doe, the number of fawns per adult deer, the number of fawns per adult doe, the proportion of the population that is made up of fawns and the number of fawns per female deer. These characteristics are useful in comparing the simulated population with data collected on an actual population.

Summer Supportable Population

The fawns are added to the population to determine the summer population. The forage required by a standard deer is calculated using the summer population and the method described earlier. By dividing the forage available during the summer by the forage requirement of a standard deer, the supportable population for the summer is obtained. In other words,

$$SP(1) = TOT(1)/TCONS$$

where; SP(1) is the supportable population during the summer;
TOT(1) is the forage available during the summer;
TCONS is the forage required by a standard deer.

Summer Mortality

During the summer months, some animals are removed from the population by natural mortality. For example, some deer are killed by automobiles, lost due to accidents, or starvation. These summer losses are specified by the user as lower and upper limits for the proportion of the population to be lost to summer mortality. A random determination is made of the minimum and maximum mortality. This mortality along with the vulnerability (to be discussed later) of each age-sex class and the summer supportable population are supplied to subroutine MORT which removes the summer mortality from each age class. Subroutine MORT attempts to reduce the population to the supportable population but the minimum and maximum summer mortality is maintained.

Forage

Using the population surviving the summer, the amount of unused forage or the amount of over-browsing is determined by using subroutine LEVELS. Using a random fluctuation of the winter forage, a random proportion of unused summer forage that is available during the winter, and the proportion of over-browsing that the habitat is unable to replace for the winter population, the forage available to the population during the winter is determined using subroutine HABTAT. The average available winter forage, the proportion of unused summer forage that is available during the winter, and the proportion of summer over-browsing the habitat is unable to replace during the winter are supplied to HABTAT, and the forage available during the upcoming winter is returned to the main program.

Stability

Giles and Lynn (unpublished memo) used Quick's Method to stabilize a deer population in STAGMAN. Using Quick's Method, a desired proportion of the population to be female is determined so that a population will stabilize when this desired proportion of females is achieved. The desired proportion female is calculated as follows:

$$SXX = \frac{1}{E * BORN}$$

where; SXX is the desired proportion of females;
E is the mean life expectancy of the does in age class 1;
BORN is the number of fawns per doe.

Attempting to achieve stability in this manner is an alternative that can be specified by the user.

Winter Supportable Population

Using the population surviving the summer, the forage required by a standard deer is calculated. With the forage available during the winter and the forage required by a standard deer, the winter supportable population is calculated as follows;

$$SP(2) = TOT(2)/TCONS$$

where; SP(2) is the winter supportable population;
TOT(2) is the forage available during the winter;
TCONS is the forage required by a standard deer.

Desirable Harvest

To maintain the habitat, the desirable harvest is determined by subtracting the supportable winter population from the total winter population. The calculation is made as follows:

$$DEZRE = TOTPOP - SP(2)$$

where; DEZRE is the desired harvest;
TOTPOP is the total fall population;
SP(2) is the winter supportable population.

This desirable harvest is the number of deer to be removed by harvesting, poaching, crippling, or natural mortality in order to maintain a healthy habitat condition.

The proportion of this desirable harvest that is to be removed by hunting is determined by predicting the winter mortality due to poaching, crippling, and natural causes. The proportion of the population to be harvested as antlered deer and the proportion of the population to be harvested as antlerless deer are determined according to the limitations placed on the harvest by the user of the simulator.

Harvest Strategies

There are six methods of harvesting that the user can specify. First, the user can specify a constant proportion of the population to be harvested as antlered and antlerless deer. If this type of harvest is desired, the kill remains constant year after year. The user's second alternative is to specify a constant proportion of the population to be removed as antlered deer. If this alternative is chosen, the simulation uses population characteristics and statistics to determine what proportion of the population should be removed as antlerless deer so as to prevent overbrousing of the habitat. The third alternative is to specify a constant proportion of the population to be removed as antlerless deer. With this alternative, a determination is also made of the proportion of the population to be removed as antlered deer to maintain a healthy habitat condition. The fourth alternative enables the simulator to manipulate the proportion of the population to be removed as antlered and antlerless deer so as to achieve a desired proportion of females as determined by Quick's Method. The fifth alternative enables the simulator to manipulate the proportion of the population to be harvested as antlered and antlerless deer so as to achieve a desired proportion of females as specified by the user. The sixth alternative is a combination of all five of the above alternatives. When this alternative is selected, the proportion of the population to be harvested as antlered and antlerless deer is read in each year along with a control variable to select one of the above five methods of harvest. This alternative has been added to give the user almost unlimited control over harvest strategies. These alternatives can be achieved in the field in many ways (see Giles 1969) but are available to the user by his selection of a control variable in the input data.

Once the antlered and antlerless kill have been determined, a random determination of the kill for a given year is made. The kill determined by the simulator and the difference in the lower and upper limits for the proportion of the population to be harvested as antlered and antlerless deer specified in input data are used to make the random determination. The random determination is made as follows for the antlered kill:

$$PBD = C2 * Z + (PBD1 - C2/2)$$

where; PBD is the proportion of the population to be harvested as antlered deer;
C2 is the difference in the upper and lower limits of the antlered harvest specified in input data;
PBD1 is the desired proportion of the population to be harvested as antlered deer;
Z is a random number between 0 and 1.

In order to provide a means of limiting the harvest, a random determination of the maximum proportion of the antlered or antlerless deer to be harvested is made by using lower and upper limits specified in input data. The simulator will not allow a harvest of antlered or antlerless deer greater than this maximum. This component of the simulator gives the user the alternative of limiting the proportion of the antlered or antlerless deer to be harvested in any type season.

Hunting Season

Once the desired harvest has been determined, a hunting season is held and deer are removed from the population. The antlered harvest is determined by taking the proportion of the population to be harvested as antlered deer and multiplying by the total population. The antlerless kill is determined in the same manner by using the proportion of the population to be harvested as antlerless deer. In the simulation, the bucks that are 1 1/2 years and older are referred to as antlered deer and the antlerless deer are the buck fawns and all-age does.

Vulnerability

In attempting to remove the deer from each age class, a concept of vulnerability is employed. Vulnerability is used as a means of weighting the different age-sex deer according to how they are to be represented in the kill. An example of the concept could be characterized as follows. If all age classes were given an equal vulnerability (all set to 1), then each age class would be represented in the harvest in the same proportion that they are represented in the population. The formula is represented as follows:

$$\text{Number of Deer Harvested In Age Class I} = \frac{\mathrm{VUL(I)} * \mathrm{D(I)}}{\sum_{J=1}^{XQ} \mathrm{VUL(J)} * \mathrm{D(J)}} * \mathrm{HARVEST}$$

where; VUL(I) is the vulnerability or weighting factor for age class I;
D(I) is the number of deer in age class I;
XQ is the number of age classes;
HARVEST is the total number of deer harvested.

The deer harvested are removed from each age employing this concept as follows:

For antlered deer:

$$DB(I) = XBU * \frac{VUL(1,I) * BXK(I)}{\sum_{J=2}^{XQ} (VUL(1,J) * BXK(J))}$$

For I = 2,...,XQ;

For antlerless deer:

$$DD(I) = XDE * \frac{VUL(2,I) * DXK(I)}{VUL(1,1) * BXK\ (1) + \sum_{J=1}^{XQ} (VUL(2,J) * DXK(J))}$$

For I = 1,...XQ;

And for fawn bucks:

$$DB(1) = XDE * \frac{VUL(1,1) * BXK(1)}{VUL(1,1) * BXK(1) + \sum_{J=1}^{XQ} (VUL(2,J) * DXK(J))}$$

where; DB(I) is the number of bucks harvested in age class I;
XBU is the number of antlered deer harvested;
BXK(I) is the number of bucks in age class I;
VUL(1,I) is the vulnerability of the bucks in age class I;
XQ is the number of age classes;
DD(I) is the number of does removed from age class I;
XDE is the total antlerless harvest;
VUL(2,I) is the vulnerability of the does in age class I;
DB(1) is the number of bucks in age class 1 harvested;
VUL(1,1) is the vulnerability of the bucks in age class 1;
BXK(1) is the number of buck fawns in the population.

By harvesting the deer in the above manner, the manager is able to handle the problem of how each age class is represented in the antlered or antlerless harvest. The antlered harvest removes only the bucks that are 1 1/2 or older; the antlerless harvest removes both does and the fawn bucks. This section can also be used to experiment with how each age class is represented in the antlered or antlerless harvest and determine its effect on the dynamics of the deer herd. The simulation is designed only to remove a determined proportion of the population as antlered and antlerless deer. The type of season that should be used to achieve this type of harvest is beyond the scope of this study but has been discussed by Giles (1968) and Mechler (1970).

Crippling Losses

After the harvest, the deer lost due to crippling are removed from the population. Roseberry et al. (1968) reported that the crippling losses of white-tailed deer were 35% of the total kill (Crab Orchard National Wildlife Refuge). They conducted a representative survey of 12% of the area being studied to determine crippling losses. Using this method of reporting crippling losses, the simulation was programmed to calculate crippling losses as a proportion of the harvest. Crippling losses may be proportional to the harvest but proportional to the initial population. The user can specify in the input crippling losses as a proportion of the population or of the harvest. A random determination of crippling losses is made using the lower and upper limits that are specified by the user. Once the crippling loss is determined, subroutine CRIPL is employed. The subroutine requires the number of deer lost to crippling, the number of age classes, and the vulnerability of each age-sex class to crippling. Where such data are not available, a reasonable assumption is that vulnerability to crippling is like that to harvest. With this information, the losses are removed from each age class.

Illegal Kill

After crippling losses are removed, losses to poaching or illegal kill are determined and removed by the simulator. Taylor (1961) reported on the illegal kill on the George Reserve, western New York, Massachusetts, and Ohio. He reported that of the total loss, a high proportion was removed as legally killed deer during an either-sex season. A lower proportion was removed as legally killed deer when a "bucks only" season was held. He reported that the losses during a "bucks only" season were due mainly to the waste of deer through the kill of antlerless deer and death due to starvation. The simulation is designed to determine poaching losses as a proportion of the population or as a proportion of the harvest. The user chooses how illegal kill is determined in input data. A random determination of poaching losses is made using the lower and upper limits for poaching supplied in input data. The poaching losses are determined and subroutine POCHER is called. The number of deer lost to poaching, the number of age classes and the vulnerability of each age-sex class to poaching are supplied to POCHER and the poaching losses are removed from each age class.

Winter Natural Mortality

After poaching losses are removed, the simulation removes winter natural mortality. A random determination of the minimum and maximum proportion of the population lost to winter natural mortality is made using the lower and upper limits specified by the user in the input data. The minimum mortality, the maximum mortality, the vulnerability of each age and sex class to winter natural mortality and the winter supportable population are supplied to subroutine MORT and the winter mortality is removed from each age class.

Mortality Summary

The types of mortality have been summarized in Table 1. The table presents how the number of deer lost is determined and what variable is weighted by the vulnerability in determining how each age and sex class is represented in the mortality.

Energy Level

After winter natural mortality is removed, the energy level of the population is calculated so that reproduction can be affected by the energy available to the population during reproduction. Subroutine LEVELS is provided with the forage available to the population and the number of age classes. In return, an energy level is supplied to the main program.

Table 1. Summary of population mortality and method of removal

Type of mortality	Mortality is determined as a proportion of the	In removal, vulnerability is used to weight the
Harvest	Total Population	Number of deer in each age class
Poaching	Total Population Total Harvest	Number of deer in each age class
Crippling	Total Population Total Harvest	Number of deer harvested in each age class
Natural Mortality	Total Population	Number of deer in each age class

Summer Forage

The forage that is to be available during the summer is determined after winter mortality is removed. The random fluctuation in the summer forage, the proportion of unused winter forage that is available during the summer and the proportion of over-browsing that the habitat is unable to replace during the summer are determined using lower and upper limits supplied by the user as input data. Subroutine HABTAT takes the average amount of forage available during the summer and the variables above and returns the forage available during the upcoming summer.

Population Crash

White-tailed deer are unlike many animals in that they can expand their number to a point at which the habitat is degraded and the deer population will crash. To make this phenomenon a part of the simulation, the user specifies the lower and upper limits for the ratio of the actual population to the supportable population for a population crash to occur. If a population crash occurs, the population is reduced by a randomly determined proportion of the population. The user specifies through input data the proportion of the crash that is to be removed from each age class. To allow some control over the crash, the user can specify that a random determination be made of the proportion of the crash that is male and female. If this option is not specified, the simulator uses the proportion of the population that is male and female.

Life Tables

At the end of winter, the simulator takes the existing population and constructs a life table (Quick 1963) for the bucks and for the does. The life tables are calculated by use of subroutine LTB. Also various population characteristics such as average annual mortality, average rate of mortality, and turn over period are calculated (Deevey 1965) in order to provide insight into the dynamics of the white-tailed deer population under consideration.

Annual Cycle

With the completion of the life table calculations, the simulator has completed an annual cycle. The simulation returns to the reproductive segment of the simulator to begin another annual cycle. All population characteristics are carried over from one year to the next and the simulation runs for the number of years specified by the user.

The simulator gives the user an annual report on the population. All losses from the population are reported according to their age-sex classes, the population structure is specified by use of a sex-age pyramid, a harvest report is presented, population characteristics are provided, and a life table for bucks and for does is also presented.

After annual cycles have been completed, the simulator provides a population summary, a habitat condition summary, and a harvest that is designed to stabilize the population. If desired, the management plan can be run through the simulator to determine any changes that should be made in the management plan.

Subroutines in DEER

To make the simulation adaptable to changing conditions, various processes carried out in the population were programmed as subroutines. The main program calls the subroutines during the annual cycle so as to simulate best the deer population.

Subroutine LEVELS

This subroutine has been designed to determine the energy level for the population and either the amount of over-browsing or under-browsing during a season of the year.

Using the relationship of deer weight to forage requirements, the number of deer in each age-sex class, and the weight of the deer in each age and sex class, the total forage requirements are calculated. The total amount of forage available to the population is passed to LEVELS and the forage required is subtracted from the forage available to determine the amount of either over-browsing or under-browsing. Thus, the effect of the deer on the vegetation to be available the next season can be determined.

To determine the energy level, the ratio of available forage to forage requirements is calculated. If the ratio is greater than 0.90 the energy level is assigned a value of 1. If the ratio is greater than 0.70 but less than or equal to 0.90, the energy level is set equal to 2. If the ratio is less than or equal to 0.70, the energy level is set equal to 3.

The function of the subroutine is completed when the energy level and either the amount of over-browsing or under-browsing has been determined. Upon completion of these calculations, they are passed back to the main program.

Subroutine NATAL

This subroutine is designed to carry out the reproductive processes that occur in a deer population. To calculate the number of buck and doe fawns that are produced, the number of age classes, the number of does in each age class, the attained natality of the does that produce fawns successfully for each energy level, the proportion of the fawns that are bucks, the proportion of the doe fawns that produce fawns successfully, the proportion of adult does that produce fawns successfully, and the energy level of the population are supplied to NATAL. The number of does producing fawns for each age class is obtained by multiplying the number of does in each age class by the proportion of the does, fawns or adults, that successfully produce fawns. To obtain the number of fawns produced by each age class, the number of does successfully producing fawns in each age class is multiplied by the attained natality for the specified energy level of the does in each age class. The total number of fawns produced is obtained by summing the number of fawns produced by each age class. The number of buck fawns is determined by multiplying the total number of fawns by the proportion of the fawns that are buck. The number of doe fawns is calculated by subtracting the number of buck fawns from the total number of fawns.

Once the number of buck and doe fawns has been calculated, the task of the subroutine is complete and the two values are passed back to the main program.

Subroutine RANDU

This subroutine is programmed to produce a rectangular distribution of numbers between 0 and 1. The subroutine requires a random integer in order to produce a random real number and a random integer. The real number is used to make random determinations in the main program and the random integer is returned to the main program so that it can be used when RANDU is called again. A chi-square test (Dixon and Massey 1969) was used to test the distribution of numbers supplied by RANDU. There was no significant difference (0.01 level of significance) between the distribution produced by RANDU and a uniform distribution.

Subroutine MORT

This subroutine is designed to execute natural mortality during the summer and winter on each age and sex class. To do this it utilizes data passed to it on the minimum and maximum proportion of the population to be lost to natural mortality, the vulnerability of each sex and age class to the seasonal mortality, and the supportable population during a given season.

The vulnerability of each age and sex class to natural mortality (summer or winter) is a means of weighting the number of deer in each age class. Vulnerability is used to determine what proportion of the mortality is to be removed from a given age and sex class. Once determined, removal from each age class progresses as follows:

$$RDB(I) = SUM * \frac{VULN(1,J) * BXK(I)}{\sum_{J=1}^{XQ} (VULN(1,J) * BXK(J) + VULN(2,J) * DXK(J))}$$

$$RDD(I) = SUM * \frac{VULN(2,I) * DXK(I)}{\sum_{J=1}^{XQ} (VULN(1,J) * BXK(J) + VULN(2,J) * DXK(J))}$$

where; RDB(I) is the number of bucks lost to natural mortality for each age class;
RDD(I) is the number of does lost to natural mortality for each age class;
XQ is the number of age classes;
BXK(I) is the number of bucks in each age class;
DXK(I) is the number of does in each age class;
VULN(I,J) is the vulnerability of each sex for age class J for summer or winter, I=1 for bucks, I=2 for does;
SUM is the total natural mortality.

The number of deer lost to natural mortality is determined by the minimum and maximum mortality along with the supportable population. The first restriction that must be satisfied is that the minimum mortality is achieved. Once this restriction is satisfied, MORT attempts to remove enough deer to achieve the supportable population. In attempting to achieve the supportable population, if the maximum mortality is reached before the supportable population level is reached, the natural mortality is set to the maximum level. The method of achieving this mortality is shown in Fig. 2.

Once the total mortality is determined, the mortality is removed from each sex and age class and the control returns to the main program. The summer and winter mortality is removed in the same manner based

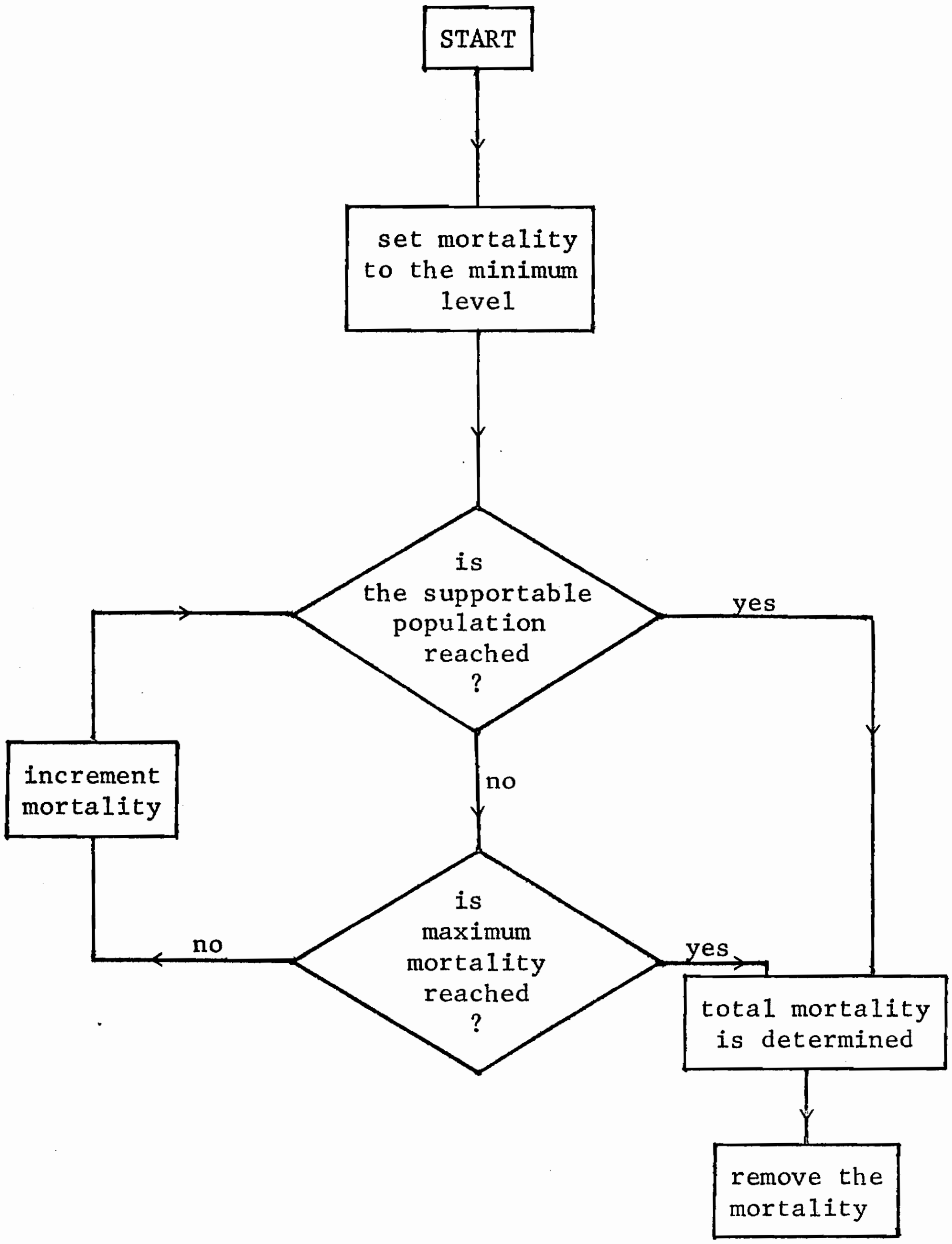

Fig. 2. Determination of natural mortality

on input data.

Subroutine CRIPLE

This subroutine is designed to remove crippling losses that occur during the harvest. The number of deer lost to crippling, the vulnerability to crippling of each age-sex class and the number of age classes are supplied to CRIPLE and the deer are removed from each age and sex class. In order to allow the user to manipulate the way in which the deer are removed from each class, a concept of vulnerability to crippling is employed. Assuming that crippling losses occur during the harvest, vulnerability is a mean of weighting each age class in the harvest according to their vulnerability to crippling. Crippling losses are then removed from each age and sex class. The crippling losses for each age and sex class is determined as follows:

$$CPB(I) = CLOS * \frac{VULC(1,I) * DB(I)}{\sum_{J=1}^{XQ} (VULC(1,J) * DB(J) + VULC(2,J) * DD(J))}$$

$$CPD(I) = CLOS * \frac{VULC(2,I) * DD(I)}{\sum_{J=1}^{XQ} (VULC(1,J) * DB(J) + VULC(2,J) * DD(J))}$$

where; CPB(I) is the number of bucks lost to crippling in age class I:
CPD(I) is the number of does lost to crippling in age class I;
CLOS is number of deer lost of crippling;
DB(I) is the number of bucks harvested in age class I;
DD(I) is the number of does harvested in age class I;
VULC(I,J) is the vulnerability of the deer in age class J to crippling, I = 1 for bucks, I = 2 for does;

XQ is the number of age classes.

The crippling losses are removed from each age-sex class and the control returns to the main program.

Subroutine POCHER

This subroutine is programmed to remove the poaching or illegal kill from the population. The number of animals lost to poaching, the number of age classes, and the vulnerability of each age-sex class to poaching are passed to POCHER and the poaching losses are removed from each age and sex class.

The vulnerability to poaching is a means of weighting the number of deer in each age-sex class in determining what proportion of the poaching losses are to be removed from a given age-sex class. The poaching losses are removed as follows:

$$CPB(I) = PLOS * \frac{VULP(1,I) * BXK(I)}{\sum_{J=1}^{XQ} (VULP(1,J) * BXK(J) + VULP(2,J) * DXK(J))}$$

$$CPD(I) = PLOS * \frac{VULP(2,I) * DXK(I)}{\sum_{J=1}^{XQ} (VULP(1,J) * BXK(J) + VULP\ (2,J) * DXK(J))}$$

where; CPB(I) is the number of bucks lost to poaching in age class I;
CPD(I) is the number of does lost to poaching in age class I;
PLOS is the number of deer lost to poaching;
BXK(I) is the number of bucks in age class I:
DXK(I) is the number of does in age class I;
VULP(I,J) is the vulnerability to poaching for the

deer in age class J, I = 1 for bucks,
I = 2 for does;
XQ is the number of age classes.

Once calculated, control is returned to the main program.

Subroutine LTB

This subroutine has been designed to perform all the calculation (Quick 1963) necessary to produce a time-specific life table. The age of the deer in each age class, the number of deer in each age class and the number of age classes are supplied to LTB and a life table is produced. Also the calculation (Deevey 1965) of average annual mortality, average rate of mortality and turnover are made to give a clearer impression of the dynamics of the population.

All calculations are performed and LTB passes the mean life expectancy of the deer in age class 1 to the main program as control returns to the main program.

Subroutine HABTAT

This subroutine is designed to allow deer numbers to have an effect on their habitat. The average forage production, the proportion of over-browsing the habitat is unable to replace, the proportion of unused forage that is available the following season, and the proportion of the average forage production that is available during the coming season, are provided to HABTAT and the subroutine calculates the available forage during the coming season.

The average forage production is multiplied by the randomly determined proportion of the forage that is available this season to determine the expected forage production. If there was over-browsing in the previous season, the amount of forage lost is determined by multiplying the deficit forage by the proportion of over-browsing the habitat is unable to replace. If the habitat was under-browsed, the forage gained due to under-browsing is determined by multiplying the surplus forage by the proportion of unused forage that is available the following season. The total forage production is then determined by adding the forage gained from last season to the expected forage production or subtracting the forage lost due to last season's over-browsing from the expected forage production. The estimation of forage available during a season is shown in Fig. 3. The forage available during the coming season is passed to the main program where it is used to determine how many deer the habitat will support.

Testing the Simulation

All operations and alternatives available to the user in DEER were tested by using many alternatives with all types of data taken from the literature. Also, AUTOFLOW, a system available at the Virginia Polytechnic Institute and State University computer facilities, was employed to flow chart the simulator to facilitate checks for logic errors.

Population Stability

For a measure of stability, the total summer population, the buck kill and doe kill were fitted to a straight line using linear

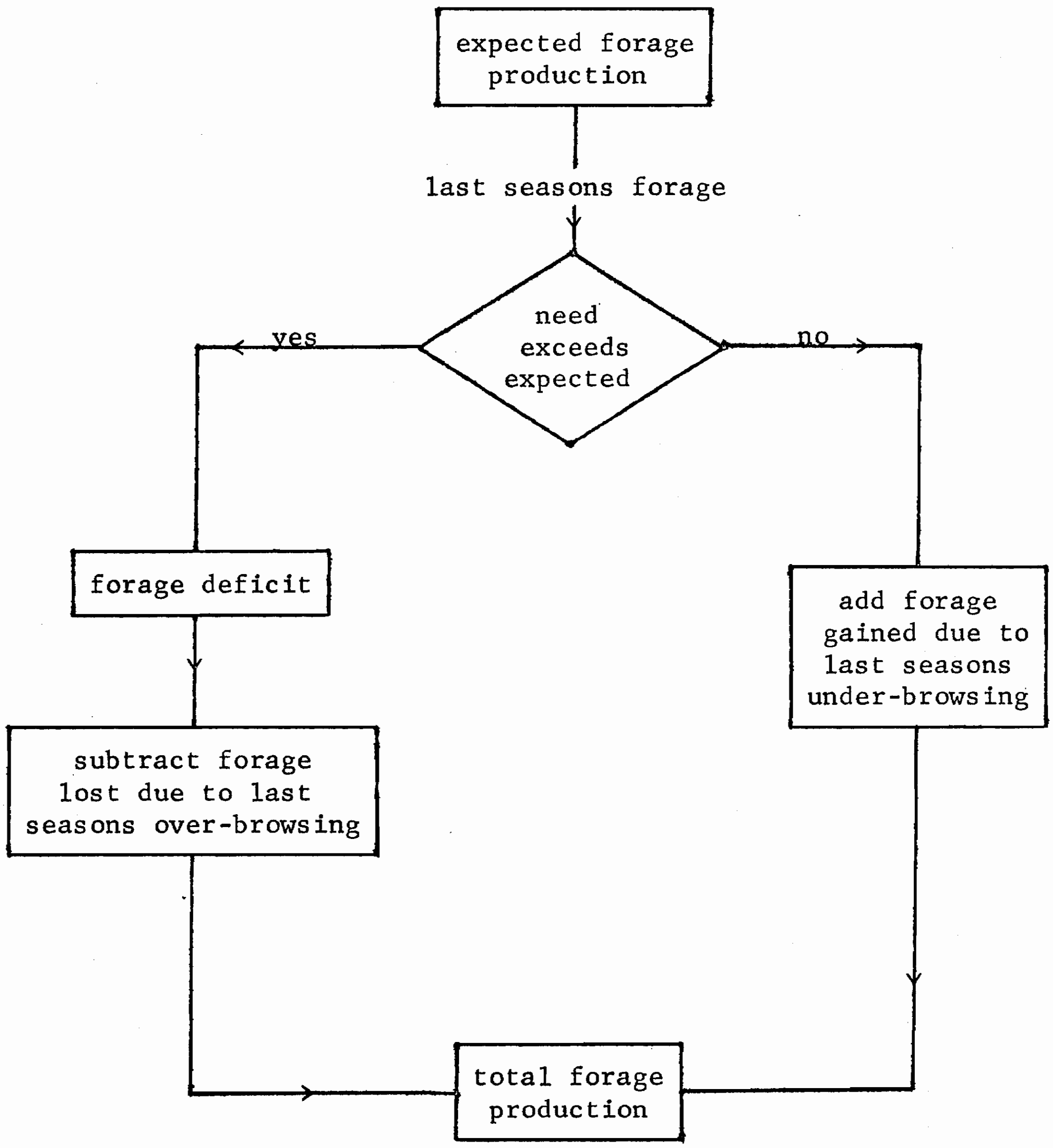

Fig. 3. Predicting forage production during a given season

regression techniques (Dixon and Massey 1969). An analysis of variance was used to test for a significant regression (slope $\neq 0$). In order to compare the population stability of different populations over time, an F-test (Dixon and Massey 1969) using an estimate of the variance about the regression was used to test for a significant difference in the stability of the two populations.

Another approach in determining the stability of a population is to apply the concept of a quality control chart for individuals (Duncan 1965). Basically, the process uses the range of successive values (population year after year) to determine the variance of the values and allows stability limits to be placed on the values. If a value happens to fall outside these limits something has happened to the system and the situation is unstable.

Using this same approach, stability limits can be placed on the total population, buck kill, doe kill, or other variables. When the value falls out of these limits something in the population has happened resulting in an unstable situation (by definition). The cause of instability has to be searched for by the user.

Sensitivity Analysis

In order to determine how sensitive the system is to changes in population characteristics and habitat changes, a stable population is developed by use of DEER and various changes are then made in the population characteristics. The effect on stability of the proportion of the fawn does that produce fawns, the proportion of adult does that produce fawns, the natality of the adult does, the harvest of deer, crippling losses, poaching losses, and sex ratio changes were investigated in an attempt to gain insight into which factors have the greatest effect on population stability.

RESULTS

DEER, a computer-based deer population simulation, was programmed in FORTRAN IV for an IBM 370. It requires 67256 bytes for the object code and 3580 bytes of array area, and employs only subroutines inherent to the program itself. It can be operated in both discrete or stochastic modes. Costs of operation (VPISU 1974) are about $6.71 for a 22 year "study". While developed especially for deer as a game resource, it can be readily adapted for other species or uses. The adaptions may be either simple programming or in the special use of inputs. For example, the user can make a particular assumption or translation of a variable. "Vulnerability" can be translated as "sightability" for non-consumptive or appreciative management of a herd. The model employs a fundamental bioenergetic approach to relating populations to available food supplies. It employs a dynamic sex and age specific algorithm, largely employing linear relationships. When the necessary inputs are supplied to the system, the processes of reproduction, mortality, and survival are performed and the simulation results (output) are presented to the user as annual reports and as a graph. DEER has no objective function; it is not an optimizing system, because the outputs are value free. However, the quest for population stability has influenced all decisions and design of the system. Results may be evaluated by the user in any way he sees fit. A means for evaluating stability was developed. No implications of the "goodness" of stability can be implied. This can only be evaluated on the basis of resource user's objectives. Stability is a functional basis for comparison and can be used, like the concept of "100% efficiency," to describe a desired increase or decrease.

Inputs for DEER

The inputs for DEER describe the population to be simulated and the habitat in which they survive. These requirements are presented in Table 2. The present system requires key punched cards of the data in Table 2.

Processes of DEER

The FORTRAN IV computer program for DEER is presented in Table 3. The execution time for a 22 year "study" is about 21 seconds.

The Outputs of DEER

Annual Report

The yearly reports that result from DEER are presented to provide the user with a detailed description of the population. The report includes:

a) the summer population and the supportable population,

b) the natality of does in each age class,

c) the number of deer in each age and sex class,

d) a sex and age pyramid,

e) the summer mortality by sex and age class,

f) the fall population and the winter supportable population,

g) the desired removal (to maintain the habitat),

Table 2. Input data for DEER

CARD	DATA	FORMAT
1	The age of the deer in each age class	11F7.0
2	The weight of the does in each age class	11F7.0
3	The weight of the bucks in each age class	11F7.0
4	The proportion of the population in each age class	11F7.0
5	The attained natality of the does in each age class with an energy level # 1	11F7.0
6	The attained natality of the does in each age class with an energy level # 2	11F7.0
7	The attained natality of the does in each age class with an energy level # 3	11F7.0
8	The proportion of the population crash that is to be removed from each age class	11F7.0
9	The vulnerability of the bucks in each age class to hunting	11F7.0
10	The vulnerability of the does in each age class to hunting	11F7.0
11	The vulnerability of the bucks in each age class to crippling	11F7.0
12	The vulnerability of the does in each age class to crippling	11F7.0
13	The vulnerability of the bucks in each class to winter natural mortality	11F7.0
14	The vulnerability of the does in each age class to winter natural mortality	11F7.0
15	The vulnerability of the bucks in each age class to summer natural mortality	11F7.0
16	The vulnerability of the does in each age class to summer natural mortality	11F7.0

Table 2. Input data for DEER (continued)

CARD	DATA	FORMAT
17	The vulnerability of the bucks in each age class to poaching	11F7.0
18	The vulnerability of the does in each age class to poaching	11F7.0
19	The lower and upper limits for the proportion of the population lost to poaching	2F7.0
20	The lower and upper limits for the proportion of the harvest lost to poaching	2F7.0
21	The lower and upper limits for the proportion of the harvest that is lost to crippling	2F7.0
22	The lower and upper limits for the proportion of the population that is lost to crippling	2F7.0
23	The lower and upper limits for the ratio of the actual population to the supportable population at which a population crash occurs	2F7.0
24	The lower and upper limits for the maximum proportion of the antlered or antlerless deer that can be harvested in any type of season	2F7.0
25	The lower and upper limits for the proportion of the population lost when a population crash occurs	2F7.0
26	The lower and upper limits for the proportion of the fawns that are male	2F7.0
27	The lower and upper limits for the proportion of the population lost to summer natural mortality regardless of the harvest	2F7.0
28	The lower and upper limits for the proportion of the population lost to winter natural mortality regardless of the harvest	2F7.0
29	The lower and upper limits for the maximum proportion of the population lost to summer natural mortality without a population crash	2F7.0

Table 2. Input data for DEER (continued)

CARD	DATA	FCRMAT
30	The lower and upper limits for the maximum proportion of the population lost to winter natural mortality without a population crash	2F7.0
31	The lower and upper limits for the proportion of the population crash that is male. If a blank card is read in, the proportion of the crash that is male equals the proportion of the population that is male.	2F7.0
32	The lower and upper limits for the proportion of the doe fawns that fawn successfully with an energy level # 1	2F7.0
33	The lower and upper limits for the proportion of the doe fawns that fawn successfully with an energy level # 2	2F7.0
34	The lower and upper limits for the proportion of the doe fawns that fawn successfully with an energy level # 3	2F7.0
35	The lower and upper limits for the proportion of adult does that fawn successfully with an energy level # 1	2F7.0
36	The lower and upper limits for the proportion of the adult does that fawn successfully with an energy level # 2	2F7.0
37	The lower and upper limits for the proportion of the adult does that fawn successfully with an energy level # 3	2F7.0
38	The lower and upper limits for the desired proportion of the population that is female: If a blank card is read in, the desired proportion female is determined by Quick's method given that a kill to achieve a desired sex ratio is requested.	2F7.0
39	The lower and upper limits for the proportion of summer over-browsing that the habitat is unable to replace during the winter	2F7.0

Table 2. Input data for DEER (continued)

CARD	DATA	FORMAT
40	The lower and upper limits for the proportion of winter over-browsing that the habitat is unable to replace during the summer	2F7.0
41	The lower and upper limits for the proportion of the forage that is not used during the summer that is available during the winter	2F7.0
42	The lower and upper limits for the proportion of the forage that is not used during the winter that is available during the summer	2F7.0
43	The lower and upper limits for the proportion of the forage that is available one summer that can be produced by the habitat the following summer	2F7.0
44	The lower and upper limits for the proportion of the forage that is available one winter that can be produced by the habitat the following winter	2F7.0
45	The lower and upper limits for the proportion of the population to be removed as antlered deer in the harvest	2F7.0
46	The lower and upper limits for the proportion of the population to be removed as antlerless deer in the harvest	2F7.0
47	The control variable for the type of kill desired: If 0, there is a constant antlered kill and as many antlerless deer needed to maintain the vegetation. If 1, there is a constant antlered and antlerless kill as specified. If 3, the kill is designed to achieve a desired sex ratio either specified by the user or determined by Quick's method. If 4, the desired kill and type of kill is read in annually. See comment after Card 56.	I2

Table 2. Input data for DEER (continued)

CARD	DATA	FORMAT
	If 2, there is a constant antlerless kill and as many antlered deer needed to maintain the vegetation	
48	The number of bucks per 100 does in the beginning population	F7.0
49	The total number of deer in the population; If unknown, read in a blank card.	F7.0
50	The allowable difference between the actual population after all mortality and the supportable population	I2
51	The number of years desired in the simulation	I2
52	The minimum forage production per acre and the maximum forage per acre (pounds) or the minimum number of deer per acre and the maximum number of deer per acre the habitat will support for the summer	4F7.0
53	The minimim forage production per acre and the maximum forage per acre (pounds) or the minimum number of deer per acre the habitat will support for the winter	4F7.0
54	The number of areas considered in the simulation (JAREA, Used below)	I2
55	The acreage of area 1, the summer forage production per acre (pounds), the winter forage production per acre, the number of deer per acre the habitat will support during the summer, the number of deer per acre the habitat will support during the winter; specify the forage per acre or the number of deer per acre	5F7.0
56	Area 2, same as above	5F7.0
⋮	⋮	
54 + JAREA	Area JAREA, same as above	5F7.0

The remaining data cards are required if the control card 47 equals 4.

Table 2. Input data for DEER (continued)

CARD	DATA	FORMAT
	One data card for every year of the simulation is required when the control variable equals 4. The cards contain the following information: the lower and upper limits for the proportion of the population to be harvested as antlered deer, the lower and upper limits for the proportion of the population to be removed as antlerless deer, and the control variable (see card 47).	4F7.0,I2

TABLE 3. COMPUTER PROGRAM FOR DEER

```
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++C
C++++++++++++++++++++++++++++++          ++++++++++++++++++++++++++++C
C++++++++++++++++++++++++++++++ DEER ++++++++++++++++++++++++++++++++C
C++++++++++++++++++++++++++++++          ++++++++++++++++++++++++++++C
C++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++C
C--------------------------------------------------------------------C
C-------------------------                ---------------------------C
C------------------------- VARIABLE INDEX ---------------------------C
C-------------------------                ---------------------------C
C--------------------------------------------------------------------C
C                                                                    C
C    ACRES     = THE TOTAL NUMBER OF ACRES IN THE HABITAT            C
C    ADULT(I,J) THE UPPER AND LOWER LIMITS FOR THE PROPORTION OF ADULT C
C               DOES THAT FAWN SUCCESSFULLY WITH AN ENERGY LEVEL J   C
C               I EQUALS 1 FOR THE LOWER LIMIT.                      C
C               I EQUALS 2 FOR THE UPPER LIMIT.                      C
C    AGA(I)    = THE AGE OF THE DEER IN AGE CLASS I                  C
C    AR(I)     = PROPORTION OF ANIMALS IN AGE CLASS I                C
C    AREA(I)   = ACRES IN UNIT I                                     C
C    BMORT     = BUCKS LOST WHEN THE POPULATION CRASHES              C
C    BOY       = NUMBER OF BUCK FAWNS                                C
C    BORN      = THE NUMBER OF FAWNS PER DOE                         C
C    BR        = PROPORTION OF ADULT DOES THAT BREED IN A GIVEN YEAR C
C    BSQ       = THE SUM OF THE PROPORTION OF THE POPULATION REMOVED AS C
C               ANTLERED DEER SQUARED FOR THE YEARS OF AN ANY DEER SEASONC
C    BUC       = THE NUMBER OF MALES IN THE POPULATION DURING THE HUNT C
C    BUCK      = BUCKS PER 100 DOES                                  C
C    BXB       = PROPORTION OF THE DOE FAWNS THAT FAWN IN A GIVEN YEAR C
C    BXK(I)    = NUMBER OF BUCKS IN AGE CLASS I                      C
```

TABLE 3. (CONTINUED)

```
----------------------------------------------------------------------
----------------------------------------------------------------------
C    C2         = DIFFERENCE IN THE UPPER AND LOWER LIMIT FOR THE          C
C                 PROPORTION OF THE POPULATION REMOVED AS ANTLERED DEER IN C
C                 AN 'ANY DEER' SEASON                                     C
C    C3         = DIFFERENCE IN THE UPPER AND LOWER LIMIT FOR THE          C
C                 PROPORTION OF THE POPULATION REMOVED AS ANTLERLESS DEER  C
C                 IN AN 'ANY DEER' SEASON                                  C
C    CLOS       = THE NUMBER OF DEER LOST TO CRIPPLING                     C
C    CON        = FOOD CONSUMPTION OF DEER FOR A GIVEN AGE CLASS           C
C    CP         = MEAN PROPORTION OF THE HUNTING KILL LOST TO CRIPPLING    C
C    CPB(I)     = NUMBER OF BUCKS THAT WERE CRIPPLED OR POACHED IN AGE     C
C                 CLASS I                                                  C
C    CPD(I)     = NUMBER OF DOES THAT WERE CRIPPLED OR POACHED IN AGE      C
C                 CLASS I                                                  C
C    CRIPL      = PROPORTION OF THE HARVEST LOST DUE TO CRIPPLING          C
C    CRIPL1     = LOWER LIMIT FOR THE PROPORTION OF THE HARVEST LOST TO    C
C                 CRIPPLING                                                C
C    DACRES     = THE MEAN NUMBER OF DEER PER ACRE THE HABITAT WILL        C
C                 SUPPORT DURING THE SUMMER                                C
C    DACREW     = THE MEAN NUMBER OF DEER PER ACRE THE HABITAT WILL        C
C                 SUPPORT DURING THE WINTER                                C
C    DAREA(I,J) THE DEER PER ACRE THAT AREA J WILL SUPPORT                 C
C                 I=1 FOR SUMMER                                           C
C                 I=2 FOR WINTER                                           C
C    DD(I)      = NUMBER OF DOES HARVESTED IN AGE CLASS I                  C
C    DB(I)      = NUMBER OF BUCKS HARVESTED IN AGE CLASS I                 C
C    DEER       = PROPORTION OF THE POPULATION REMOVED BY NATURAL CAUSES   C
C    DEZRE      = DESIRABLE HARVEST TO MAINTAIN A VEGETATION STABILITY     C
C    DIF        = DEER LOST DUE TO ALL CAUSES FOR A SINGLE YEAR            C
C    DMAXS      = THE MAXIMUM NUMBER OF DEER PER ACRE THE HABITAT WILL     C
----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
C                    SUPPORT DURING THE SUMMER                                 C
C    DMAXW      = THE MAXIMUM NUMBER OF DEER PER ACRE THE HABITAT WILL         C
C                    SUPPORT DURING THE WINTER                                 C
C    DMINS      = THE MINIMUM NUMBER OF DEER PER ACRE THE HABITAT WILL         C
C                    SUPPORT DURING THE SUMMER                                 C
C    DMINW      = THE MINIMUM NUMBER OF DEER PER ACRE THE HABITAT WILL         C
C                    SUPPORT DURING THE WINTER                                 C
C    DMORT      = DOES LOST WHEN THE POPULATION CRASHES                        C
C    DNX(I,J)   = THE ATTAINED NATALITY FOR DOES IN AGE CLASS J THAT FAWN      C
C                    SUCCESSFULLY WITH AN ENERGY LEVEL I.                      C
C    DOE        = THE NUMBER OF FEMALES IN THE POPULATION DURING THE HUNT      C
C    DSQ        = SUM OF DOE KILL SQUARED FOR THE YEARS OF AN ANY DEER         C
C                    SEASON                                                    C
C    DWB(I)     = WEIGHT FOR BUCKS IN AGE CLASS I                              C
C    DWD(I)     = WEIGHT FOR DOES IN AGE CLASS I                               C
C    DXK(I)     = NUMBER OF DOES IN AGE CLASS I                                C
C    E          = MEAN LIFE EXPECTANCY OF AGE CLASS 1                          C
C    FAWN(I,J)= THE UPPER AND LOWER LIMITS FOR THE PROPORTION OF THE DOE       C
C                    FAWNS THAT FAWN SUCCESSFULLY WITH AN ENERGY LEVEL J       C
C                    I EQUALS 1 FOR THE LOWER LIMIT.                           C
C                    I EQUALS 2 FOR THE UPPER LIMIT.                           C
C    FEMALE     = NUMBER OF FEMALES REMAINING IN THE POPULATION AFTER ALL      C
C                    MORTALITY                                                 C
C    FKILL      = EXPECTED NUMBER OF FEMALES TO BE KILLED                      C
C    FMAXS      = THE MAXIMUM AMOUNT OF FORAGE AVAILABLE DURING THE SUMMER     C
C    FMAXW      = THE MAXIMUM AMOUNT OF FORAGE AVAILABLE DURING THE WINTER     C
C    FMINS      = THE MINUMUM AMOUNT OF FORAGE AVAILABLE DURING THE SUMMER     C
C    FMINW      = THE MINUMUM AMOUNT OF FORAGE AVAILABLE DURING THE WINTER     C
C    GIRL       = NUMBER OF DOE FAWNS                                          C
--------------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

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------------------------------------------------------------------------
------------------------------------------------------------------------
C    HAR      = DUMMY VARIABLE FOR XHAR                                 C
C    HUNT     = PROPORTION OF THE POPULATION REMOVED BY HUNTING         C
C    IBK      = INTEGER FORM FOR XBK                                    C
C    IDK      = INTEGER FORM FOR XDK                                    C
C    IX       = RANDOM INTEGER NEEDED TO GET A RANDOM NUMBER BETWEEN    C
C               0 AND 1 FROM RANDU, A RANDOM NUMBER GENERATOR           C
C    IYR      = THE YEAR OF THE SIMULATION                              C
C    JAREA    = THE NUMBER OF AREAS CONSIDERED BY THE USER              C
C    KILL     = CONTROL VARIABLE                                        C
C               IF 0, THERE IS A CONSTANT ANTLERED KILL AND AS MANY     C
C               ANTERLESS DEER NEEDED TO MAINTAIN THE VEGETATION.       C
C               IF 1, THERE IS A CONSTANT ANTLERED KILL AND ANTERLESS   C
C               KILL AS SPECIFIED.                                      C
C               IF 2, THERE IS A CONSTANT ANTLERLESS KILL AND AS MANY   C
C               ANTLERED DEER NEEDED TO MAINTAIN THE VEGETATION.        C
C               IF 3, THE KILL IS DESIGNED TO ACHIEVE A DESIRED SEX RATIOC
C               IF 4, THE DESIRED KILL AND A CONTROL VARIBLE IS READ IN C
C               ANNUALLY FROM CARDS.                                    C
C    KILLP    = A CONTROL VARIBLE TO ALLOW THE KILL AND A CONTROL       C
C               VARIBLE TO BE READ IN ANNUALLY FROM CARDS               C
C               IF 0, THE KILL IS NOT READ IN ANNUALLY.                 C
C               IF 1, THE KILL IS READ IN ANNUALLY.                     C
C    LEVEL    = THE LEVEL OF ENERGY AVAILABLE TO THE DEER POPULATION    C
C               IF 1, 90% OF THE ENERGY REQUIREMENTS ARE SUPPLIED BY THE C
C               HABITAT.                                                C
C               IF 2, LESS THAN 90% AND GREATER THAN 70% OF THE ENERGY  C
C               REQUIREMENTS ARE SUPPLIED BY THE HABITAT.               C
C               IF 3, LESS THAN 70% OF THE ENERGY REQUIREMENTS ARE      C
C               SUPPLIED BY THE HABITAT.                                C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
C    LOWER      = THE LOWER LIMIT FOR THE MAXIMUM PROPORTION OF THE       C
C                 ANTLERED OR ANTERLESS DEER TO BE REMOVED IN A GIVEN YEAR C
C    LTB        = SUBROUTINE USED TO CALCULATE A LIFE TABLE               C
C    MORT       = A SUBROUTINE TO DETERMINE AND REMOVE THE NATURAL        C
C                 MORTALITY FROM EACH AGE CLASS                           C
C    NSPC       = THE ALLOWABLE DIFFERENCE BETWEEN THE ACTUAL POPULATION  C
C                 AND THE SUPPORTABLE POPULATION                          C
C    NYR        = NUMBER OF YEARS THE SIMULATION IS TO RUN                C
C    PBD1       = THE LOWER LIMIT FOR THE PROPORTION OF THE POPULATION    C
C                 TAKEN IN ANTLERED DEER IN AN ANY DEER SEASON            C
C    PCTF       = PROPORTION OF THE POPULATION THAT IS FEMALE             C
C    PCTM       = PROPORTION OF THE POPULATION THAT IS MALE               C
C    PDB1       = THE LOWER LIMIT FOR THE PROPORTION OF THE POPULATION    C
C                 TAKEN IN ANTERLESS DEER IN AN ANY DEER SEASON           C
C    PLOS       = NUMBER OF DEER LOST TO POACHERS                         C
C    PLSEX      = LOWER LIMIT FOR THE PROPORTION OF THE POPULATION CRASH  C
C                 THAT IS BUCK                                            C
C    PP         = MEAN PROPORTION OF THE POPULATION TAKEN BY POACHERS     C
C    POACH      = PROPORTION OF THE POPULATION LOST DUE TO POACHING       C
C    POACH1     = LOWER LIMIT FOR THE PROPORTION OF THE POPULATION LOST TO C
C                 POACHING                                                C
C    POP        = TOTAL POPULATION BEFORE THE HUNT AND NATURAL MORTALITY  C
C    POPC(I)    = LOWER AND UPPER LIMITS FOR THE PROPORTION OF THE        C
C                 POPULATION LOST TO CRIPPLING                            C
C    POPP(I)    = LOWER AND UPPER LIMITS FOR THE PROPORTION OF THE        C
C                 HARVEST LOST TO POACHING                                C
C    PROD(I,J)= FORAGE PRODUCTION PER ACRE ON UNIT J                      C
C                 I=1 FOR SUMMER                                          C
C                 I=2 FOR WINTER                                          C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
C    PUSEX     = UPPER LIMIT FOR THE PROPORTION OF THE POPULATION CRASH    C
C                THAT IS BUCK                                              C
C    PYD&PYR   = DATA TO DRAW AGE AND SEX PYRAMIDS                         C
C    QX(I)     = LOWER LIMIT FOR THE MINIMUM PROPORTION OF THE POPULATION C
C                LOST TO NATURAL MORTALITY                                 C
C                I=1 FOR SUMMER                                            C
C                I=2 FOR WINTER                                            C
C    RAD       = FAWNS PER ADULT DEER                                      C
C    RANDU     = A SUBROUTINE THAT WILL GENERATE RANDOM NUMBERS            C
C                BETWEEN 0 AND 1 WHEN FED A RANDOM INTEGER                 C
C    RBC(I)    = PROPORTION OF STARVATION LOSS IN AGE CLASS I              C
C    RDB(I)    = NUMBER OF BUCKS DYING NATURALLY IN AGE CLASS I            C
C    RDD(I)    = NUMBER OF DOES DYING NATURALLY IN AGE CLASS I             C
C    RFE       = FAWNS PER ADULT DOE                                       C
C    RJTO      = PROPORTION OF IMMATURE IN THE POPULATION (J RATIO)        C
C    RMORT     = TOTAL NUMBER OF DEER LOST WHEN THE POPULATION CRASHES     C
C    SAP       = POPULATION LEVEL WHERE A CRASH OCCURS                     C
C    SAT       = UPPER LIMIT FOR THE PROPORTION OF THE POPULATION LOST     C
C                WHEN THE POPULATION CRASHES DUE TO STARVATION             C
C    SBXK2     = THE WEIGHTED SUM OF ALL ANTLERED DEER                     C
C    SBXK5     = DUMMY VARIABLE FOR SBXK2                                  C
C    SDXK      = THE WEIGHTED SUM OF ALL ANTLERLESS DEER                   C
C    SDXK1     = DUMMY VARIABLE FOR SDXK                                   C
C    SEX       = DIFFERENCE BETWEEN THE DESIRED PROPORTION OF FEMALES AND C
C                THE ACTUAL PROPORTION OF FEMALES AFTER ALL MORTALITY      C
C    SEXB      = PROPORTION OF FAWNS THAT ARE MALE                         C
C    SEXO      = LOWER LIMIT FOR THE PROPORTION OF FAWNS THAT ARE BUCKS    C
C    SP(I)     = SUPPORTABLE POPULATION                                    C
C                I=1 FOR SUMMER                                            C
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
C                  I=2 FOR WINTER                                      C
C    SP1         = UPPER LIMIT OF THE POPULATION AFTER HARVEST         C
C    SP2         = LOWER LIMIT OF THE POPULATION AFTER HARVEST         C
C    SR          = THE NUMBER OF YEARS AN ANY DEER SEASON WAS HELD     C
C    STARV       = LOWER LIMIT FOR THE PROPORTION OF THE POPULATION LOST C
C                  WHEN THE POPULTION CRASHES DUE TO STARVATION        C
C    SUM         = WEIGHTED SUM OF THE ANTERLESS POPULATION            C
C    SUMB        = SUM OF THE PROPORTION OF THE POPULATION REMOVED AS  C
C                  ANTLERED DEER FOR THE YEARS OF AN ANY DEER SEASON   C
C    SUMD        = SUM OF THE PROPORTION OF THE POPULATION REMOVED AS  C
C                  ANTLERLESS DEER FOR THE YEARS OF AN ANY DEER SEASON C
C    SXO         = THE PROPORTION OF THE POPULATICN CRASH THAT IS MALE C
C    SXX         = DESIRED PROPORTION OF DOES IN THE POPULATION        C
C    SXXL        = THE LOWER LIMIT FOR THE DESIRED PROPORTION OF DOES IN THEC
C                  POPULATION                                          C
C    SXXU        = THE UPPER LIMIT FOR THE DESIRED PROPORTION OF DOES IN THEC
C                  POPULATION                                          C
C    SY          = THE ABSOLUTE VALUE OF THE DIFFERENCE BETWEEN THE ACTUAL C
C                  AND THE DESIRED PROPORTICN OF FEMALES IN THE POPULATION C
C                  AFTER ALL MORTALITY                                 C
C    TBUC        = TOTAL NUMBER OF ADULT BUCKS                         C
C    TCONS       = TOTAL AMOUNT OF FORAGE CONSUMED BY A STANDARD DEER  C
C    TDOE        = TOTAL NUMBER OF ADULT DOES                          C
C    TKILL       = TOTAL KILL IN ACHIEVING THE DESIRED PROPORTION OF THE C
C                  POPULATION TO BE REMOVED                            C
C    TOT(I)      = THE TOTAL POUNDS OF FORAGE ON THE TOTAL AREA CONSIDERED C
C                  I=1 FOR SUMMER FORAGE PRODUCTION                    C
C                  I=2 FOR WINTER FORAGE PRODUCTION                    C
C    TOTLOS      = NUMBER OF DEER LOST DUE TO POACHING AND CRIPPLING   C
------------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
C    TOTPOP   = TCTAL POPULATION                                       C
C    TOTS     = THE MEAN FORAGE PRODUCTION PER ACRE DURING THE SUMMER  C
C    TOTW     = THE MEAN FORAGE PRODUCTION PER ACRE DURING THE WINTER  C
C    TP       = STORED VALUES TO BE PLOTTED                            C
C    TPS      = THE NUMBER CF DEER REMOVED IN A POPULATICN CRASH       C
C    TQMAX(I) = UPPER LIMIT FOR THE MAXIMUM PROPORTION OF THE POPULATION C
C               TC BE LOST DUE TC NATURAL MCRTALITY                    C
C               I=1 FCR SUMMER MORTALITY                               C
C               I=2 FCR WINTER MORTALITY                               C
C    TQMIN(I) = LOWER LIMIT FOR THE MAXIMUM PRCPORTION OF THE POPULATION C
C               TO BE LOST DUE TO NATURAL MORTALITY                    C
C               I=1 FOR SUMMER MORTALITY                               C
C               I=2 FOR WINTER MORTALITY                               C
C    TRP      = DUMMY VARIABLE FOR TOTPOP                              C
C    TRPX     = PCPULATICN AFTER HUNTING, POACHING AND CRIPPLING LOSSES C
C    UPPER    = THE UPPER LIMIT FOR THE MAXIMUM PROPORTION OF THE      C
C               ANTLERED OR ANTERLESS DEER TO BE REMOVED IN A GIVEN YEAR C
C    VARB     = VARIANCE OF THE PROPORTICN OF THE POPULATION REMOVED AS C
C               ANTLERED DEER                                          C
C    VARD     = VARIANCE OF THE PROPORTICN OF THE POPULATION REMOVED AS C
C               ANTLERLESS DEER                                        C
C    VCRIP    = UPPER LIMIT FOR THE PROPORTION OF THE HARVEST LOST TO  C
C               CRIPPLING                                              C
C    VPBD     = THE UPPER LIMIT FOR THE PRCPCRTION OF THE POPULATION   C
C               TAKEN IN ANTLERED DEER IN AN ANY DEER SEASON           C
C    VPDB     = THE UPPER LIMIT FCR THE PROPCRTION OF THE POPULATION   C
C               TAKEN IN ANTERLESS DEER IN AN ANY DEER SEASON          C
C    VPOAC    = UPPER LIMIT FOR THE PROPORTICN OF THE POPULATION LOST TO C
C               POACHING                                               C
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
C    VQX(I)    = UPPER LIMIT FOR THE MINIMUM PROPORTION OF THE POPULATION C
C                LOST TO NATURAL MORTALITY                                C
C                I=1 FOR SUMMER MORTALITY                                 C
C                I=2 FOR WINTER MORTALITY                                 C
C    VSAP      = LOWER LIMIT FOR THE RATIO OF THE ACTUAL POPULATION TO    C
C                THE SUPPORTABLE POPULATION AT WHICH HEAVY MORTALITY      C
C                OCCURS                                                   C
C    VSEXO     = UPPER LIMIT FOR THE PROPORTION OF FAWNS THAT ARE BUCKS   C
C    VUL(I,J)  = VULNERABILITY TO BEING HARVESTED FOR DEER IN AGE CLASS J C
C                I EQUALS 1 FOR BUCKS.                                    C
C                I EQUALS 2 FOR DOES.                                     C
C    VULC(I,J)= VULNERABILITY TO CRIPPLING FOR THE DEER IN AGE CLASS J    C
C                I EQUALS 1 FOR BUCKS.                                    C
C                I EQUALS 2 FOR DOES.                                     C
C    VULN(I,J)= VULNERABILITY TO NATURAL MORTALITY FOR THE DEER IN AGE    C
C                CLASS J                                                  C
C                I EQUALS 1 FOR BUCKS.                                    C
C                I EQUALS 2 FOR DOES.                                     C
C    VULP(I,J)= VULNERABILITY TO POACHING FOR THE DEER IN AGE CLASS J     C
C                I EQUALS 1 FOR BUCKS.                                    C
C                I EQUALS 2 FOR DOES.                                     C
C    X         = AGE OF THE DEER FOR THE SEX AND AGE PYRAMID              C
C    XBF       = PROPORTION OF THE POPULATION REMOVED AS BUCK FAWNS       C
C    XBK       = PERCENT OF BUCKS IN A GIVEN AGE CLASS                    C
C    XBU       = DUMMY VARIABLE FOR XBUC                                  C
C    XBUC      = TOTAL NUMBER OF BUCKS HARVESTED (XBU)                    C
C    XDE       = DUMMY VARIABLE FOR XDOE                                  C
C    XDK       = PERCENT OF DOES IN A GIVEN AGE CLASS                     C
C    XDOE      = TOTAL NUMBER OF DOES HARVESTED (XDE)                     C
------------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
C    XERO      = THE PROPORTICN OF THE FORAGE THAT IS AVAILABLE ONE SEASONC
C                THAT CAN BE PRODUCED BY THE HABITAT THE FOLLOWING SEASON C
C                FCR A GIVEN SEASON                                       C
C    XHAR      = TCTAL NUMBER OF DEER HARVESTED                           C
C    XNEG(J,I)= THE LOWER AND UPPER LIMITS FOR THE PROPORTION OF OVER-    C
C                BROUSING THAT THE HABITAT IS UNABLE TO REPLACE           C
C                I=1 FOR LOWER LIMIT                                      C
C                I=2 FOR UPPER LIMIT                                      C
C                J=1 FOR SUMMER                                           C
C                J=2 FOR WINTER                                           C
C    XPOS(J,I)= THE LOWER AND UPPER LIMITS FOR THE PROPORTION OF THE      C
C                FORAGE THAT IS NOT USED THAT IS AVAILABLE THE FOLLOWING  C
C                SEASON.                                                  C
C                I=1 FOR LCWER LIMIT                                      C
C                I=2 FOR UPPER LIMIT                                      C
C                J=1 FOR SUMMER                                           C
C                J=2 FOR WINTER                                           C
C    XQ        = NUMBER OF AGE CLASSES                                    C
C    XSP       = UPPER LIMIT FOR THE RATIO OF THE ACTUAL POPULATION TO    C
C                THE SUPPORTABLE POPULATICN AT WHICH HEAVY MORTALITY      C
C                OCCURS                                                   C
C    Y         = YEARS THAT ARE STORED TO BE PLOTTED                      C
C    YFAD      = DOE FAWNS PER ADULT DOE                                  C
C    YIELD     = THE DIFFERENCE BETWEEN THE FORAGE AVAILABLE AND THE      C
C                FORAGE REQUIRED                                          C
C    YNEG      = THE PROPORTICN OF OVER-BROUSING THAT THE HABITAT IS      C
C                UNABLE TO REPLACE FOR A GIVEN SEASON                     C
C    YPOS      = THE PROPORTION OF THE FORAGE THAT IS NOT USED THAT IS    C
C                AVAILABLE THE FOLLOWING SEASCN FOR A GIVEN SEASON        C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
C    YQ        = 1 LESS THAN THE NUMBER OF AGE CLASSES                 C
C    Z         = RANDOM NUMBER BETWEEN 0 AND 1                         C
C    ZB        = THE MAXIMUM PROPORTION OF ANY SEX THAT CAN BE REMOVED C
C                IN ANY SEASON                                         C
C    ZERO(J,I)= THE LOWER AND UPPER LIMITS FOR THE PROPORTION OF THE   C
C                FORAGE THAT IS AVAILABLE ONE SEASON THAT CAN BE PRODUCED C
C                BY THE HABITAT THE FOLLOWING SEASON.                  C
C                I=1 FOR LOWER LIMIT                                   C
C                I=2 FOR UPPER LIMIT                                   C
C                J=1 FOR SUMMER                                        C
C                J=2 FOR WINTER                                        C
C    ZQX       = PROPORTION OF THE POPULATION LOST REGARDLESS OF THE KILL C
C                FOR A GIVEN YEAR                                      C
C    ZX        = PROPORTION OF THE POPULATION LOST IN A POPULATION CRASH C
C---------------------------------------------------------------------C
C                                                                     C
C---------------------------------------------------------------------C
C--------------------------              ----------------------------C
C-------------------------- MAIN PROGRAM ----------------------------C
C--------------------------              ----------------------------C
C---------------------------------------------------------------------C
C                                                                     C
      INTEGER XQ,YQ
      REAL LOWER
      INTEGER DXK(11),BXK(11),DD(11),DB(11),RDD(11),RDB(11),CPD(11),
     1 CPB(11)
      DIMENSION DWD(11),DWB(11),RBC(11),AREA(20),AGA(11),AR(11),Y(50)
     1 ,TP(50,5),PROD(2,20),VULS(2,11),DAREA(2,20),TOT(2),SP(2),
     1 TQMAX(2),TQMIN(2),QX(2),VQX(2)
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
      DIMENSION XNEG(2,2),XPOS(2,2),ZERO(2,2)
      DIMENSION PYD(30),PYR(30)
      DIMENSION DNX(3,11), VUL(2,11), VULC(2,11), VULN(2,11), VULP(2,11)
      DIMENSION FAWN(2,3), ADULT(2,3),POPP(2),POPC(2),TDEER(11)
      DIMENSION SX2(6),XY(6),SXS(6),RANG(6)
      COMMON/ONE/ BXK, DXK
      COMMON/TWO/RDB, RDD, POP, XQ
      COMMON/THREE/ DD, DB
      COMMON/FOUR/ CPB, CPD
      COMMON/FIVE/ IX
      COMMON/SIX/ DWB,DWD
      COMMON/SEVEN/ YIELD
      DATA PYR/30*' '/
      DATA PYD/30*'-'/
      DATA PYD(1)/' '/
      XQ=11
      YQ=10
      WRITE(6,2500)
 2500 FORMAT('1')
 1000 IX=50236931
      IYR=0
      SIRY=0.0
C----------------------------------------------------------------------------C
C   READ INPUT DATA                                                          C
C----------------------------------------------------------------------------C
      READ(5,211) (AGA(I),I=1,XQ)
      READ(5,211) DWD
      READ(5,211) DWB
      READ(5,211) (AR(I),I=1,XQ)
------------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      READ(5,211)((DNX(I,J),J=1,XQ),I=1,3)
      READ(5,211) (RBC(J),J=1,XQ)
      READ(5,211) ((VUL (I,J),J=1,XQ),I=1,2)
      READ(5,211) ((VULC(I,J),J=1,XQ),I=1,2)
      READ(5,211) ((VULN(I,J),J=1,XQ),I=1,2)
      READ(5,211) ((VULS(I,J),J=1,XQ),I=1,2)
      READ(5,211) ((VULP(I,J),J=1,XQ),I=1,2)
      READ(5,214) POACH1,VPOAC
      READ(5,214) POPP
      READ(5,214) CRIPL1,VCRIP
      READ(5,214) POPC
      READ(5,214) VSAP,XSP
      READ(5,214) LOWER, UPPER
      READ(5,214) STARV,SAT
      READ(5,214) SEXO,VSEXO
      READ(5,214) (QX(I),VQX(I),I=1,2)
      READ(5,214)(TQMIN(I),TQMAX(I),I=1,2)
      READ(5,214) PLSEX, PUSEX
      READ(5,214) ((FAWN(I,J),I=1,2),J=1,3)
      READ(5,214)((ADULT(I,J),I=1,2),J=1,3)
      READ(5,214) SXXL, SXXU
      READ(5,214) ((XNEG(I,J),J=1,2),I=1,2)
      READ(5,214) ((XPOS(I,J),J=1,2),I=1,2)
      READ(5,214) ((ZERO(I,J),J=1,2),I=1,2)
      READ(5,214) PBD1,VPBD
      READ(5,214) PDB1,VPDB
      READ(5,212) KILL
      READ(5,215) BUCK
      READ(5,215) TOTPOP
```

TABLE 3. (CCNTINUED)

```
      READ(5,212) NSPC
      READ(5,212) NYR
      READ(5,230) FMINS,FMAXS,DMINS,DMAXS
      READ(5,230) FMINW,FMAXW,DMINW,DMAXW
      READ(5,212) JAREA
      DO 206 I=1,JAREA
  206 READ(5,213) AREA(I),(PROD(J,I),J=1,2),(DAREA(J,I),J=1,2)
      C2=VPBD-PBD1
      C3=VPDB-PDB1
  211 FORMAT(11F7.0)
  212 FORMAT(I2)
  213 FORMAT(5F7.C)
  214 FORMAT(2F7.0)
  215 FORMAT(F7.0)
  230 FORMAT(4F7.0)
      DO 54 J=1,50
      DO 55 I=1,5
   55 TP(J,I)=0.0
   54 Y(J)=1.0
C-----------------------------------------------------------------------C
C   CONVERT POUNDS TO KILOGRAMS                                         C
C-----------------------------------------------------------------------C
      FMINS=FMINS/2.2046
      FMAXS=FMAXS/2.2046
      FMINW=FMINW/2.2046
      FMAXW=FMAXW/2.2046
      DO 56 I=1,JAREA
      DO 56 J=1,2
   56 PROD(J,I)=PROD(J,I)/2.2046
```

TABLE 3. (CCNTINUED)

```
      DO 51 J=1,XQ
      DWD(J)=DWC(J)/2.2046
      DWB(J)=DWB(J)/2.2046
   51 CONTINUE
C-----------------------------------------------------------------------C
C    PROPORTICN OF THE POPULATICN THAT IS MALE AND FEMALE               C
C-----------------------------------------------------------------------C
      PCTM=BUCK/(100.+BUCK)
      PCTF=1.-PCTM
C-----------------------------------------------------------------------C
C    CHECKING TO SEE IF THE DESIRED KILL IS READ IN ANNUALLY            C
C-----------------------------------------------------------------------C
      KILLP=0
      IF(KILL.EQ.4) KILLP=1
      DO 231 I=1,6
      XY(I)=C.C
      SXS(I)=0.0
      SX2(I)=0.0
      RANG(I)=0.0
  231 CONTINUE
      SYS=0.0
      SYS2=0.0
      ACRES=0.0
C-----------------------------------------------------------------------C
C    DETERMINING THE TOTAL NUMBER OF ACRES IN THE HABITAT               C
C-----------------------------------------------------------------------C
      DO 221 I=1,JAREA
  221 ACRES=ACRES+AREA(I)
      IF(FMAXS.GT.0.0.AND.FMAXW.GT.0.0) GO TC 222
```

TABLE 3. (CONTINUED)

```
C-----------------------------------------------------------------------C
C    DETERMINING THE MAXIMUM AND MINIMUM FORAGE PRODUCTION IF THE       C
C    NUMBER OF DEER PER ACRE IS KNOWN                                   C
C-----------------------------------------------------------------------C
      IP=1
  224 FOOD=0.0
      IF(IP.EQ.1) P=ACRES*DMINS
      IF(IP.EQ.2) P=ACRES*DMAXS
      IF(IP.EQ.3) P=ACRES*DMINW
      IF(IP.EQ.4) P=ACRES*DMAXW
      DO 223 J=1,XQ
      ID=P*AR(J)*PCTF+0.5
      IB=P*AR(J)*PCTM+0.5
  223 FOOD=FOOD+(0.141*DWD(J)**0.75*ID*183.)
     1         +(0.152*DWB(J)**0.75*IB*183.)
      IF(IP.EQ.1) FMINS=FOOD
      IF(IP.EQ.2) FMAXS=FOOD
      IF(IP.EQ.3) FMINW=FOOD
      IF(IP.EQ.4) FMAXW=FOOD
      IP=IP+1
      IF(IP.EQ.5) GO TO 225
      GO TO 224
C-----------------------------------------------------------------------C
C    DETERMINE THE MAXIMUN FORAGE PRODUCTION FOR SUMMER AND WINTER      C
C-----------------------------------------------------------------------C
  222 FMAXS=FMAXS*ACRES
      FMAXW=FMAXW*ACRES
C-----------------------------------------------------------------------C
C    DETERMINE THE MINIMUM FORAGE PRODUCTION FOR SUMMER AND WINTER      C
```

TABLE 3. (CONTINUED)

```
C-------------------------------------------------------------------------C
      FMINS=FMINS*ACRES
      FMINW=FMINW*ACRES
  225 CONTINUE
C-------------------------------------------------------------------------C
C   CHECKING TO SEE IF OPERATOR KNOWS THE POUNDS OF FORAGE PER ACRE OR    C
C   THE NUMBER OF DEER PER ACRE                                           C
C-------------------------------------------------------------------------C
      DO 5 J=1,2
      DO 5 I=1,JAREA
      IF(PROD(J,I).GT.0.0) GO TO 5
      IF(DAREA(J,I).GT.0.0) GO TO 8
    5 CONTINUE
      DO 100 J=1,2
      TOT(J)=0.0
      DO 100 I=1,JAREA
C-------------------------------------------------------------------------C
C   TOTAL BROUSE PRODUCTION                                               C
C-------------------------------------------------------------------------C
  100 TOT(J)=TCT(J)+AREA(I)*PRCD(J,I)
      GO TO 7
C-------------------------------------------------------------------------C
C   DETERMINING THE SUPPORTABLE POPULATION GIVEN THAT THE NUMBER OF       C
C   DEER PER ACRE IS KNOWN                                                C
C-------------------------------------------------------------------------C
    8 DO 9 J=1,2
      SP(J)=0.0
      DO 9 I=1,JAREA
    9 SP(J)=SP(J)+AREA(I)*DAREA(J,I)
```

TABLE 3. (CONTINUED)

```
C--------------------------------------------------------------------C
C   DETERMINING THE TOTAL FORAGE AVAILABLE IF AN ESTIMATE OF THE NUMBER C
C   OF DEER PER ACRE IS AVAILABLE                                    C
C--------------------------------------------------------------------C
      DO 11 J=1,2
      TOT(J)=0.0
      DO 11 I=1,XQ
      ID=SP(J)*AR(I)*PCTF+0.5
      IB=SP(J)*AR(I)*PCTM+0.5
   11 TOT(J)=TOT(J)+(0.141*DWD(I)**0.75)*ID*183.
     1            +(0.152*DWB(I)**0.75)*IB*183.
    7 CONTINUE
C--------------------------------------------------------------------C
C   INITALIZE THE POPULATION IF AN ESTIMATE OF THE TOTAL POPULATION IS  C
C   KNOWN                                                            C
C--------------------------------------------------------------------C
      IF(TOTPOP.LE.1.0) GO TO 852
      DO 851 J=1,XQ
      DXK(J)=TOTPOP*AR(J)*PCTF+0.5
      BXK(J)=TOTPOP*AR(J)*PCTM+0.5
  851 CONTINUE
  852 CONTINUE
      SR=0.0
      SUMB=0.0
      BSQ=0.0
      SUMD=0.0
      DSQ=0.0
      DPOP=0.0
      IF(TOTPOP.GT.1.0) CALL LEVELS(TOT(2),LEVEL,XQ)
```

TABLE 3. (CONTINUED)

```
      IF(TOTPOP.LE.1.0) LEVEL=1
C---------------------------------------------------------------------C
C   FORAGE REQUIREMENTS OF A STANDARD DEER                            C
C---------------------------------------------------------------------C
      TCONS=0.0
      IF(TOTPOP.GT.1.0) GO TO 226
C---------------------------------------------------------------------C
C   DETERMINING FORAGE REQUIREMENTS FOR A 'STANDARD' DEER             C
C---------------------------------------------------------------------C
      DO 20 I=1,XQ
      CON=(0.141*(DWD(I))**0.75)*183.*PCTF+
     1  (0.152*(DWB(I))**0.75)*183.*PCTM
      CON=CON*AR(I)
   20 TCONS=TCONS+CON
C---------------------------------------------------------------------C
C   DETERMINING THE SUPPORTABLE POPULATION WITH A STRUCTURE AS SPECIFIEDC
C---------------------------------------------------------------------C
      ISP=TOT(2)/TCONS+0.5
      SP(2)=ISP
C---------------------------------------------------------------------C
C   IF NO ESTIMATE OF THE POPULATION IS AVAILABLE, THE POPULATION     C
C   IS SET TO WHAT THE HABITAT WILL SUPPORT. INITALIZE THE POPULATION. C
C---------------------------------------------------------------------C
      TOTPOP=SP(2)
      DO 4001 J=1,XQ
      DXK(J)=TOTPOP*AR(J)*PCTF+0.5
      BXK(J)=TOTPOP*AR(J)*PCTM+0.5
 4001 CONTINUE
  226 CONTINUE
```

TABLE 3. (CONTINUED)

```
      TOTS=0.0
      TOTW=0.0
      DACRES=0.0
      DACREW=0.0
      JACK=0
      CALL LTB (AGA,DXK,XQ,E,JACK)
      SXX=0.0
   10 CONTINUE
C-----------------------------------------------------------------------C
C   INCREMENT THE NUMBER OF YEARS                                      C
C-----------------------------------------------------------------------C
      IYR=IYR+1
C-----------------------------------------------------------------------C
C   READ IN ANNUAL KILL IF IT IS DESIRED                               C
C-----------------------------------------------------------------------C
      IF(KILLP.EQ.1) READ(5,245) PBD1,VPBD,PDB1,VPDB,KILL
  245 FORMAT(4F7.0,I2)
      IF(KILLP.EQ.1) C2=VPBD-PBD1
      IF(KILLP.EQ.1) C3=VPDB-PDB1
C-----------------------------------------------------------------------C
C   SAVE THE INITIAL VALUES OF THE POPULATION                          C
C-----------------------------------------------------------------------C
      DO 3001 J=1,XQ
      DD(J)=0
      DB(J)=0
      CPB(J)=0
      CPD(J)=0
      RDB(J)=0
      RDD(J)=0
```

TABLE 3. (CONTINUED)

```
 3001 CONTINUE
C-----------------------------------------------------------------------C
C    RANDOMLY DETERMINE THE PROPORTION OF DOE FAWNS THAT FAWN           C
C    SUCCESSFULLY                                                       C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      BXB=(FAWN(2,LEVEL)-FAWN(1,LEVEL))*Z+FAWN(1,LEVEL)
C-----------------------------------------------------------------------C
C    PROPORTION OF ADULT DOES THAT FAWN SUCCESSFULLY                    C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      BR=(ADULT(2,LEVEL)-ADULT(1,LEVEL))*Z+ADULT(1,LEVEL)
C-----------------------------------------------------------------------C
C    RANDOMLY DETERMINE THE SEX RATIO OF THE FAWNS                      C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      SEXB=(VSEXO-SEXO)*Z+SEXO
C-----------------------------------------------------------------------C
C    CALL NATAL IN ORDER TO REPRODUCE FAWNS                             C
C-----------------------------------------------------------------------C
      CALL NATAL ( XQ, DXK, DNX, SEXB, BXB, BR, BOY, GIRL, LEVEL)
      TBUC=0.0
      TDOE=0.0
C-----------------------------------------------------------------------C
C    DETERMINING THE TOTAL NUMBER OF ADULT BUCKS AND DOES               C
C-----------------------------------------------------------------------C
      DO 4343 J=2,XQ
      TDOE=TDOE+DXK(J)
      TBUC=TBUC+BXK(J)
```

TABLE 3. (CONTINUED)

```
 4343 CONTINUE
C------------------------------------------------------------------------C
C   INCREMENT DEER AGE CLASSES TO MAKE ROOM FOR THE FAWNS                C
C------------------------------------------------------------------------C
      BXK(XQ)=BXK(XQ)+BXK(YQ)
      DXK(XQ)=DXK(XQ)+DXK(YQ)
      DO 901 J=2,YQ
      N=XQ+1-J
      DXK(N)=DXK(N-1)
      BXK(N)=BXK(N-1)
  901 CONTINUE
C------------------------------------------------------------------------C
C   PLACING THE FAWNS INTO THE POPULATION                                C
C------------------------------------------------------------------------C
      BXK(1)=BOY+.5
      DXK(1)=GIRL+.5
      TOTPOP=0.0
      BIOMAS=0.0
C------------------------------------------------------------------------C
C   DETERMINING THE TOTAL POPULATION AFTER FAWNS ARE ADDED               C
C------------------------------------------------------------------------C
      DO 6020 J=1,XQ
      BIOMAS=BIOMAS+BXK(J)*DWB(J)+DXK(J)*DWD(J)
 6020 TOTPOP=TOTPOP+BXK(J)+DXK(J)
      POP=TOTPOP
C------------------------------------------------------------------------C
C   CALCULATION OF THE AGE RATIOS AFTER THE FAWNS ARE ADDED              C
C------------------------------------------------------------------------C
      DO 1006 J=1,XQ
```

TABLE 3. (CCNTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      AR(J)=(DXK(J)+BXK(J))/TCTPOP
 1006 CONTINUE
C----------------------------------------------------------------------C
C    CALCULATION OF POPULATION CHARACTERISTICS                        C
C----------------------------------------------------------------------C
      IF(TDOE.LE.C.0) TDOE=1.0
      YFAD=DXK(1)/TDOE
      RAD=(BXK(1)+DXK(1))/(TDOE+TBUC)
      RFE=(BXK(1)+DXK(1))/TDOE
      RJTO=AR(1)
      BORN=(BXK(1)+DXK(1))/(TDOE+DXK(2))
      TCONS=0.0
C----------------------------------------------------------------------C
C    DETERMINE FORAGE REQUIREMENTS FOR A STANDARD DEER                 C
C----------------------------------------------------------------------C
      DO 24 J=1,XQ
      CON=((0.141*(DWD(J))**0.75)*183.)*(DXK(J)/TOTPOP)+
     1    ((0.152*(DWB(J))**0.75)*183.)*(BXK(J)/TOTPOP)
   24 TCONS=TCONS+CON
C----------------------------------------------------------------------C
C    DETERMINE THE SUPPORTABLE POPULATION DURING THE SUMMER            C
C----------------------------------------------------------------------C
      ISP=TOT(1)/TCONS+0.5
      SP(1)=ISP
      TOTS=TCTS+TCT(1)/ACRES
      DACRES=DACRES+SP(1)/ACRES
      CALL RANDU(IX,Z)
      ZQX=(VQX(1)-QX(1))*Z+QX(1)
      TQ=(TQMAX(1)-TQMIN(1))*Z+TQMIN(1)
------------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
      WRITE(6,80)
   80 FORMAT('1',14(/))
      WRITE(6,204) IYR,POP
  204 FORMAT(16X,'FOR YEAR ',I4,' THE SPRING POPULATION WAS ',F10.0,
     1 ' DEER')
      WRITE(6,216) SP(1)
  216 FORMAT(16X, 'THE SUPPOROABLE PCPULATION WAS ',F10.0)
      WRITE(6,903)
  903 FORMAT(      16X,'AGE CLASS',2X,'FAWN',3X,'1.5',4X,'2.5',4X,'3.5',
     1 4X,'4.5',4X,'5.5',4X,'6.5    7.5    8.5    9.5+')
      I=XQ-2
      IB=BXK(YC)+BXK(XQ)
      ID=DXK(YC)+DXK(XQ)
      WRITE(6,904) (BXK(J),J=1,I),IB,(DXK(J),J=1,I),ID
  904 FORMAT(16X,'BUCKS',2X,10(2X,I5)/16X,'DOES',3X,10( 2X,I5))
      WRITE(6,205) (DNX(LEVEL,I),I=1,YQ)
  205 FORMAT(16X,'NATALITY=',10(F5.2,2X))
C----------------------------------------------------------------------C
C    DETERMINE SUMMER NATURAL MORTALITY                                C
C----------------------------------------------------------------------C
      CALL MCRT(ZQX,TQ,SUMMER,VULS,SP(1))
C----------------------------------------------------------------------C
C    MANIPULATE AGE AND SEX RATIOS TO CONSTRUCT A SEX-AGE PYRAMID      C
C----------------------------------------------------------------------C
      WRITE(6,57)
   57 FORMAT(' ')
      X=XQ+.5
      DO 760 M=1,XQ
      J=XQ+1-M
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      BK=BXK(J)/TOTPOP
      DK=DXK(J)/TOTPOP
      XBK=BK*100.+.5
      XDK=DK*100.+.5
      IBK=XBK
      IDK=XDK
      IF(IBK.GE.30) IBK=29
      IF(IDK.GE.30) IDK=29
      IB=30-IBK
      ID=30-IDK
      IBK=IBK+1
      IDK=IDK+1
      X=X-1.0
      WRITE(6,761) BK,(PYR(I),I=1,IB),(PYD(I),I=1,IBK),X,
     1 (PYD(I),I=1,IDK),(PYR(I),I=1,ID),DK
  761 FORMAT(16X,F5.3,31A1,' |',F4.1,'|',31A1,F5.3)
  760 CONTINUE
      WRITE(6,763)
  763 FORMAT(16X,6X,68('-'))
      WRITE(6,762)
  762 FORMAT(16X,31X,'BUCKS         DOES')
      WRITE(6,217) SUMMER
  217 FORMAT('0',15X,'THE PROPORTION OF THE POPULATION LOST TO SUMMER',
     1' MORTALITY WAS ',F7.4)
      WRITE(6,218)
  218 FORMAT(16X,'SUMMER MORTALITY')
      WRITE(6,903)
      I=XQ-2
      IB=RDB(YQ)+RDB(XQ)
```

TABLE 3. (CONTINUED)

```
--------------------------------------------------------------------------
--------------------------------------------------------------------------
      ID=RDD(YQ)+RDD(XQ)
      WRITE(6,904) (RDB(J),J=1,I),IB,(RDD(J),J=1,I),ID
C-----------------------------------------------------------------------C
C    DETERMINING THE PROPORTION OF FEMALES DESIRED IN THE POPULATION FOR C
C    STABILITY ( QUICK'S METHOD 1963 )                                   C
C-----------------------------------------------------------------------C
      IF(IYR.EQ.1) JIM=0
      IF(JIM.EQ.0.AND.LEVEL.EQ.1) GO TO 52
      IF(KILLP.EC.1) GO TO 52
      GO TO 53
   52 SXX=1.0/(E*BORN)
      IF(SXX.LT.0.75.AND.SXX.GT.0.25) JIM=1
   53 IF(SXX.GE.0.75.OR.SXX.LE.0.25) SXX=0.50
C-----------------------------------------------------------------------C
C    DETERMINING THE WEIGHTED SUM OF THE ANTERLESS POPULATION            C
C-----------------------------------------------------------------------C
      SUM=BXK(1)*VUL(1,1)
      TBUC=0.0
      TDOE=0.0
      DO 50 I=1,XQ
      TDOE=TDOE+DXK(I)
      TBUC=TBUC+BXK(I)
   50 SUM=SUM+VUL(2,I)*DXK(I)
      TOTPOP=TDOE+TBUC
C-----------------------------------------------------------------------C
C    DETERMINING THE PROPORTION OF THE POPULATION THAT IS MALE AND THE   C
C    THE PROPORTICN OF THE POPULATION THAT IS FEMALE                     C
C-----------------------------------------------------------------------C
      PCTF=TDOE/TOTPOP
--------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
----------------------------------------------------------------------
----------------------------------------------------------------------
      PCTM=1.0-PCTF
C--------------------------------------------------------------------C
C   DETERMINING THE FORAGE AVAILABLE NEXT SEASON                     C
C--------------------------------------------------------------------C
      CALL LEVELS(TOT(1),LEVEL,XQ)
      CALL RANDU(IX,Z)
      YNEG=(XNEG(1,2)-XNEG(1,1))*Z+XNEG(1,1)
      YPOS=(XPOS(1,2)-XPOS(1,1))*Z+XPOS(1,1)
      XERO=(ZERO(2,2)-ZERO(2,1))*Z+ZERO(2,1)
      CALL HABTAT(TOT(2),YNEG,YPOS,XERO)
      IF(TOT(2).GT.FMAXW) TOT(2)=FMAXW
      IF(TOT(2).LT.FMINW) TOT(2)=FMINW
      TCONS=0.0
C--------------------------------------------------------------------C
C   DETERMINE FORAGE REQUIREMENTS FOR A STANDARD DEER                C
C--------------------------------------------------------------------C
      DO 22 J=1,XQ
      CON=((0.141*(DWD(J))**0.75)*183.)*(DXK(J)/TOTPOP)+
     1    ((0.152*(DWB(J))**0.75)*183.)*(BXK(J)/TOTPOP)
   22 TCONS=TCONS+CON
C--------------------------------------------------------------------C
C   DETERMINE THE SUPPORTABLE POPULATION DURING THE WINTER           C
C--------------------------------------------------------------------C
      ISP=TOT(2)/TCONS+0.5
      SP(2)=ISP
      TOTW=TOTW+TOT(2)/ACRES
      DACREW=DACREW+SP(2)/ACRES
      SP1=SP(2)+NSPC
      SP2=SP(2)-NSPC
----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
C-----------------------------------------------------------------------C
C    DESIRABLE HARVEST OF DEER                                          C
C-----------------------------------------------------------------------C
      DEZRE=TOTPOP-SP(2)
      IF(DEZRE.LT.0.0) DEZRE=0.0
C-----------------------------------------------------------------------C
C    PREDICTING THE YEARS OUTCOME AND DETERMINING THE DESIRED PROPORTION C
C    OF THE POPULATION TO BE REMOVED                                    C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      ZQX=(VQX(2)-QX(2))*Z+QX(2)
C-----------------------------------------------------------------------C
C    CHECK TO SEE IF A CONSTANT KILL IS DESIRED                         C
C-----------------------------------------------------------------------C
      IF(KILL.EQ.1) GO TO 7009
      PBD=PBD1+C2/2.0
      PP=(VPOAC+POACH1)/2.0
      CP=(VCRIP+CRIPL1)/2.0
      IF(VPOAC.LE.0.0) PP=(POPP(2)+POPP(1))/2.0
      IF(VCRIP.LE.0.0) CP=(POPC(2)+POPC(1))/2.0
      PDB=PBD
 7003 CONTINUE
C-----------------------------------------------------------------------C
C    CHECK TO SEE IF A CONSTANT ANTLERED KILL IS DESIRED                C
C-----------------------------------------------------------------------C
      IF(KILL.EQ.0) PBD=PBD1+C2/2.0
C-----------------------------------------------------------------------C
C    CHECK TO SEE IF A CONSTANT ANTLERLESS KILL IS DESIRED              C
C-----------------------------------------------------------------------C
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      IF(KILL.EQ.2) PDB=PDB1+C3/2.0
      TRP=TOTPOP
      TKILL=PDB *TRP+PBD *TRP
      TRP=TRP-TKILL
      CRPLOS=CP*TKILL
      PCHLOS=PP*POP
      IF(VCRIP.LE.0.0) CRPLOS=CP*POP
      IF(VPOAC.LE.0.0) PCHLOS=PP*TKILL
      TRP=TRP-CRPLOS-PCHLOS
      TRPX=TRP
      TRP=TRP-ZQX*POP
      IF(TRP.LT.SP1.AND.TRP.GT.SP2) GO TO 7005
      PDB=PDB+((TRP-SP(2))/TOTPOP)/2.0
      PBD=PBD+((TRP-SP(2))/TOTPOP)/2.0
      IF(PBD .LE.0.0) PBD =0.0
      IF(PDB .LE.0.0) PDB =0.0
      IF(PDB .LE.0.0.AND.PBD .LE.0.0) GO TO 7008
      IF(PDB .LE.0.0.OR.PBD .LE.0.0) GO TO 7005
      GO TO 7003
 7005 CONTINUE
C-----------------------------------------------------------------------C
C   DETERMINATION OF THE SEX RATIO OF THE KILL TO ACHIEVE A DESIRED SEX C
C   RATIO                                                               C
C-----------------------------------------------------------------------C
      IF(KILL.EQ.0.OR.KILL.EQ.2) GO TO 7008
      IF(SXXL.GT.0.0.OR.SXXU.GT.0.0) SXX=(SXXU-SXXL)*Z+SXXL
      CALL RANDU (IX,Z)
      FEMALE=PCTF*TOTPOP
      XP=TOTPOP
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      XF=(BXK(1)*VUL(1,1))/SUM
      FKILL=(PDB-(XF*PDB))*XP
      FEMALE=FEMALE-FKILL
      CRPLOS=CP*FKILL
      PCHLOS=PP*FCP*PCTF
      IF(VCRIP.LE.0.0) CRPLCS=CP*POP*PCTF
      IF(VPOAC.LE.0.0) PCHLOS=PP*FKILL
      FEMALE=FEMALE-CRPLCS-PCHLOS
      FEMALE=FEMALE-((FEMALE/TRPX)*ZQX*POP)
      SEX=FEMALE/TRP
      SEX=SEX-SXX
      IF(ABS(SEX).LT.0.02) GO TO 7008
      PDB=PDB+((FEMALE-SXX*TRP)/TOTPOP)
      PBD=PBD-((FEMALE-SXX*TRP)/TOTPOP)
      IF(PDB .LE.0.0) PDB =0.0
      IF(PBD .LE.0.0) PBD =0.0
      IF(PDB .LE.0.0.OR.PBD .LE.0.0) GO TO 7008
      GO TO 7005
 7008 CONTINUE
      PBD1=PBD-C2/2.0
      PDB1=PDB-C3/2.0
      IF(PBD1.LE.0.0) PBD1=0.0
      IF(PDB1.LE.0.0) PDB1=0.0
 7009 CONTINUE
C-----------------------------------------------------------------------C
C   RANDOM DETERMINATION OF KILL FOR VARIOUS TYPES OF SEASONS           C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      PDB=C3*Z+PDB1
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      CALL RANDU ( IX, Z)
      PBD=C2*Z+PBD1
      IF(PBD.LE.0.0) PBD=0.0
      IF(PDB.LE.0.0) PDB=0.0
C---------------------------------------------------------------------CC
C   CHECKING TO SEE IF THE MAXIMUM PROPORTION OF THE ANTLERED OR      CC
C   ANTERLESS DEER IS BEING HARVESTED                                 CC
C---------------------------------------------------------------------CC
      TDOE=TDOE+BXK(1)
      TBUC=TBUC-BXK(1)
      CALL RANDU ( IX, Z)
      ZB=(UPPER-LOWER)*Z+LOWER
      IF(PBD*TOTPOP.GT.ZB*TBUC) PBD=(ZB*TBUC)/TOTPOP
      IF(PDB*TOTPOP.GT.ZB*TDOE) PDB=(ZB*TDOE)/TOTPOP
C----------------------------------------------------------------------C
C   PRESENTATION OF POPULATION STSTISTICS                              C
C----------------------------------------------------------------------C
      WRITE(6,81)
   81 FORMAT('1',18(/))
      WRITE(6,219) TOTPOP
  219 FORMAT('0',15X,'THE FALL POPULATION WAS ',F10.0)
      WRITE(6,216) SP(2)
      WRITE(6,220) DEZRE
  220 FORMAT(16X,'THEREFORE THE DESIRED REMOVAL WAS ',F10.0)
      WRITE(6,105) PCTF,SXX
  105 FORMAT(    16X,'BEFORE THE HUNT, THE PROPORTION OF DOES WAS ',F6.3
     1/16X,'THE DESIRED PROPORTION OF DOES WAS ',F6.3)
C----------------------------------------------------------------------C
C   CHECKING TO SEE IF THE NUMBER OF YEARS DESIRED IN THE RUN HAS BEEN C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
C   ACHIEVED                                                          C
C---------------------------------------------------------------------C
      IF(IYR.EQ.NYR) GO TO 500
C---------------------------------------------------------------------C
C   SAVING DATA TO BE PLOTTED                                         C
C---------------------------------------------------------------------C
      TP(IYR,1)=POP
      Y(IYR)=IYR
C---------------------------------------------------------------------C
C   BEGIN THE HARVEST                                                 C
C---------------------------------------------------------------------C
      XHAR=0.0
      XDOE=0.0
      XBUC=0.0
      IF(PBD.LE.C.0.AND.PDB.LE.0.0) GO TC 705
C---------------------------------------------------------------------C
C   THE HUNTING SEASON                                                C
C---------------------------------------------------------------------C
      IF(PBD.LE.C.C) WRITE(6,7031)
 7031 FCRMAT('0',16X,'TOTAL KILL TAKEN IN AN ANTLERLESS SEASCN')
      IF(PBD.GT.0.0.AND.PDB.GT.0.0) WRITE(6,210)
  210 FORMAT('0',16X,'HAVE AN ANY DEER SEASON')
      IF(PDB.LE.0.0) WRITE(6,4004)
 4004 FORMAT('0',16X,'THE TOTAL KILL WAS TAKEN IN A BUCKS ONLY SEASON')
      XBUC=PBD*TOTPOP
      IF(PDB.LE.0.0) GC TO 705
      XDOE=PCB*TOTPOP
  705 CONTINUE
C---------------------------------------------------------------------C
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
C    WEIGHTING THE DEER POPULATION ACCORDING TO THEIR VULNERABILITY        C
C---------------------------------------------------------------------------C
      SDXK=VUL(1,1)*BXK(1)+VUL(2,1)*DXK(1)
      SBXK2=0.0
      DO 8010 J=2,XQ
      SDXK=SDXK+(DXK(J)*VUL(2,J))
      SBXK2=SBXK2+(BXK(J)*VUL(1,J))
 8010 CONTINUE
      XBU=XBUC
      XDE=XDOE
      SBXK5=SBXK2
      SDXK1=SDXK
C---------------------------------------------------------------------------C
C    REMOVING DEER FROM EACH AGE CLASS KILLED DURING THE HUNT              C
C---------------------------------------------------------------------------C
      IF(XBU.LE.0.0) GO TO 3333
C---------------------------------------------------------------------------C
C    REMOVING THE ANTLERED KILL                                            C
C---------------------------------------------------------------------------C
      DO 33 I=1,YQ
      J=XQ+1-I
      B=XBU*((BXK(J)*VUL(1,J))/SBXK5)
      IB=B+.5
      CALL RANDU ( IX, Z)
      IF(J.GE.6.AND.Z.GE.0.75) IB=IB+1
      IF(IB.GT.BXK(J)) GO TO 4010
      BXK(J)=BXK(J)-IB
      DB(J)=IB
      GO TO 33
-----------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
 4010 SBXK5=SBXK5-(BXK(J)*VUL(1,J))
      XBU=XBU-BXK(J)
      DB(J)=BXK(J)
      BXK(J)=0
   33 CONTINUE
 3333 CONTINUE
      IF(XDE.LE.0.0) GO TO 36
C-----------------------------------------------------------------------C
C    REMOVING THE ANTLERLESS KILL                                       C
C-----------------------------------------------------------------------C
      DO 4011 I=1,XQ
      J=XQ+1-I
      D=XDE*((DXK(J)*VUL(2,J))/SDXK1)
      ID=D+.5
      CALL RANDU ( IX, Z)
      IF(J.GE.6.AND.Z.GE.0.75) ID=ID+1
      IF(ID.GT.DXK(J)) GO TO 4012
      DXK(J)=DXK(J)-ID
      DD(J)=ID
      GO TO 4011
 4012 SDXK1=SDXK1-(DXK(J)*VUL(2,J))
      XDE=XDE-DXK(J)
      DD(J)=DXK(J)
      DXK(J)=0
 4011 CONTINUE
C-----------------------------------------------------------------------C
C    DETERMINING THE NUMBER OF BUCK FAWNS KILLED IN THE ANTLERLESS KILL C
C-----------------------------------------------------------------------C
      D=XDE*((BXK(1)*VUL(1,1))/SDXK1)
------------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
      ID=D+.5
      IF(ID.GT.BXK(1)) ID=BXK(1)
      DB(1)=ID
      BXK(1)=BXK(1)-ID
C-----------------------------------------------------------------------C
C    SEX RATIO AFTER HUNTING                                            C
C-----------------------------------------------------------------------C
   36 BUC=0.0
      DOE=0.0
C-----------------------------------------------------------------------C
C    DETERMINING THE SEX RATIO AFTER THE HARVEST                        C
C-----------------------------------------------------------------------C
      DO 2000 M=1,XQ
      BUC=BUC+BXK(M)
      DOE=DOE+DXK(M)
 2000 CONTINUE
      PCTM=BUC/( DOE+BUC)
      PCTF=DCE/( DOE+BUC)
C-----------------------------------------------------------------------C
C    DETERMINING HUNTING KILL                                           C
C-----------------------------------------------------------------------C
      XDOE=0.0
      XBUC=0.0
      DO 38 I=1,XQ
      XDOE=XDOE+DD(I)
      XBUC=XBUC+CB(I)
   38 CONTINUE
      XHAR=XBUC+XDOE
      IF(IYR.LE.3) GO TO 234
```

TABLE 3. (CONTINUED)

```
      SIRY=SIRY+1
      YR=IYR
      SX2(1)=SX2(1)+PCTF**2
      SX2(2)=SX2(2)+BIOMAS**2
      SX2(3)=SX2(3)+POP**2
      SX2(4)=SX2(4)+XBUC**2
      SX2(5)=SX2(5)+XDOE**2
      SX2(6)=SX2(6)+TOT(2)**2
      XY(1)=XY(1)+ YR*PCTF
      XY(2)=XY(2)+ YR*BIOMAS
      XY(3)=XY(3)+ YR*POP
      XY(4)=XY(4)+ YR*XBUC
      XY(5)=XY(5)+ YR*XDOE
      XY(6)=XY(6)+ YR*TOT(2)
      SXS(1)=SXS(1)+PCTF
      SXS(2)=SXS(2)+BIOMAS
      SXS(3)=SXS(3)+POP
      SXS(4)=SXS(4)+XBUC
      SXS(5)=SXS(5)+XDOE
      SXS(6)=SXS(6)+TOT(2)
      SYS= YR+SYS
      SYS2=SYS2+ YR**2
      IF(IYR.EQ.4) GO TO 234
      X=ABS(PCTFL-PCTF)
      RANG(1)=RANG(1)+X
      X=ABS(BIOMAL-BIOMAS)
      RANG(2)=RANG(2)+X
      X=ABS(POPL-POP)
      RANG(3)=RANG(3)+X
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      X=ABS(XBUCL-XBUC)
      RANG(4)=RANG(4)+X
      X=ABS(XDOEL-XDOE)
      RANG(5)=RANG(5)+X
      X=ABS(TOTL-TOT(2))
      RANG(6)=RANG(6)+X
  234 CONTINUE
      PCTFL=PCTF
      BIOMAL=BIOMAS
      POPL=POP
      XBUCL=XBUC
      XDOEL=XDOE
      TOTL=TOT(2)
C----------------------------------------------------------------------C
C   PROPORTION OF THE POPULATION REMOVED BY HUNTING                    C
C----------------------------------------------------------------------C
      HUNT=XHAR/POP
      TOTLOS=0.0
C----------------------------------------------------------------------C
C   PRESENTATION OF HUNTING REPORT                                     C
C----------------------------------------------------------------------C
      WRITE(6,706)
  706 FORMAT(     17X,'YEAR   POPULATION   TOTAL KILL   BUCK KILL   DOE KILL
     1 PROPORTION DOE')
      WRITE(6,707) IYR, TOTPOP, XHAR, XBUC, XDOE, PCTF
  707 FORMAT(16X,I4,1X,4(F9.0,2X),6X,F6.3)
C----------------------------------------------------------------------C
C   CRIPPLING LOSS FOR THIS YEAR                                       C
C----------------------------------------------------------------------C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      CALL RANDU ( IX, Z)
      CRIPL=(VCRIP-CRIPL1)*Z+CRIPL1
      IF(VCRIP.LE.0.0) CRIPL=(POPC(2)-POPC(1))*Z+POPC(1)
C----------------------------------------------------------------------C
C   POACHING LOSS FOR THIS YEAR                                        C
C----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      POACH=(VPOAC-POACH1)* Z+POACH1
      IF(VPOAC.LE.0.0) POACH=(POPP(2)-POPP(1))*Z+POPP(1)
      CLOS=XHAR*CRIPL
      PLOS=POP*POACH
      IF(VCRIP.LE.0.0) CLOS=CRIPL*POP
      IF(VPOAC.LE.0.0) PLOS=POACH*XHAR
C----------------------------------------------------------------------C
C   REMOVING CRIPPLING AND POACHING LOSS FROM EACH AGE CLASS           C
C----------------------------------------------------------------------C
      CALL CRIPLE( CLOS, XQ, VULC)
      CALL POCHER (PLOS, XQ, VULP)
      TOTLOS=CLOS+PLOS
      WRITE(6,2708) TOTLOS
 2708 FORMAT('0',15X,'THERE WAS A LOSS OF ',F5.0, ' DEER DUE TO POACHING
     1 AND CRIPPLING')
      WRITE(6,708) PLOS
  708 FORMAT(     16X,F5.0,' DEER WERE LOST TO POACHING')
      WRITE(6,1708) CLOS
 1708 FORMAT(16X,F5.0,' DEER WERE LOST DUE TO CRIPPLING')
      CALL RANDU ( IX, Z)
C----------------------------------------------------------------------C
C   DETERMINING THE MAXIMUM PROPORTION OF THE POPULATION THAT DIE      C
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
C   NATURALLY WITHOUT A POPULATION CRASH                                        C
C------------------------------------------------------------------------------C
      TQ=(TQMAX(2)-TQMIN(2))*Z+TQMIN(2)
C------------------------------------------------------------------------------C
C   NATURAL MORTALITY IN A NORMAL YEAR                                          C
C------------------------------------------------------------------------------C
      CALL MORT ( ZQX, TQ, DEER, VULN, SP(2))
 9003 CONTINUE
C------------------------------------------------------------------------------C
C   DETERMINING ENERGY LEVEL                                                    C
C       LEVEL 1 = 90% OF ENERGY REQUIREMENTS ARE AVAILABLE                      C
C       LEVEL 2 = 70% TO 90% OF ENERGY REQUIREMENTS ARE AVAILABLE               C
C       LEVEL 3 = LESS THAN 70% OF ENERGY REQUIREMENTS ARE AVAILABLE            C
C------------------------------------------------------------------------------C
      CALL LEVELS(TOT(2),LEVEL,XQ)
C------------------------------------------------------------------------------C
C   DETERMINING THE FORAGE AVAILABLE NEXT SEASON                                C
C------------------------------------------------------------------------------C
      CALL RANDU( IX, Z)
      YNEG=(XNEG(2,2)-XNEG(2,1))*Z+XNEG(2,1)
      YPOS=(XPOS(2,2)-XPOS(2,1))*Z+XPOS(2,1)
      XERO=(ZERO(1,2)-ZERO(1,1))*Z+ZERO(1,1)
      CALL HABTAT(TOT(1),YNEG,YPOS,XERO)
      IF(TOT(1).GT.FMAXS) TOT(1)=FMAXS
      IF(TOT(1).LT.FMINS) TOT(1)=FMINS
C------------------------------------------------------------------------------C
C   INITALIZING DATA TO BE PLOTTED                                              C
C------------------------------------------------------------------------------C
      TP(IYR,2)=XDOE
--------------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      TP(IYR,3)=XBUC
      TP(IYR,4)=SP(2)
C-----------------------------------------------------------------------C
C    DETERMINING THE POINT ABOVE THE SUPPORTABLE POPULATION WHERE A     C
C    POPULATION CRASH OCCURS                                            C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      SAP=SP(2)*((XSP-VSAP)*Z+VSAP)
      TOTPOP=0.0
      DO 6000 J=1,XQ
      TOTPOP=TOTPOP+BXK(J)+DXK(J)
 6000 CONTINUE
      IF(TOTPOP.LT.SAP) GO TO 6001
C-----------------------------------------------------------------------C
C    DETERMINING POPULATION LOSSES WHEN A CRASH OCCURS                  C
C-----------------------------------------------------------------------C
      CALL RANDU ( IX, Z)
      ZX=(SAT-STARV)*Z+STARV
      RMORT=TOTPOP*ZX
      BMORT=PCTM*RMORT
      DMORT=PCTF*RMORT
      TPS=0.0
      CALL RANDU (IX, Z)
      SXO=(PUSEX-PLSEX)*Z+PLSEX
C-----------------------------------------------------------------------C
C    CHECKING TO SEE IF A DIFFERENTIAL SEX MORTALITY OCCURS IN A        C
C    POPULATION CRASH                                                   C
C-----------------------------------------------------------------------C
      IF(SXO.GT.0.0) BMORT=SXO*RMORT
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      IF(SXO.GT.0.0) DMORT=RMORT-BMORT
      DO 5000 J=1,XQ
      ID=RBC(J)*DMORT+0.5
      IB=RBC(J)*BMORT+0.5
      IF(ID.GT.DXK(J)) ID=DXK(J)
      IF(IB.GT.BXK(J)) IB=BXK(J)
      BXK(J)=BXK(J)-IB
      DXK(J)=DXK(J)-ID
      RDB(J)=RDB(J)+IB
      RDD(J)=RDD(J)+ID
      TPS=TPS+ID+IB
 5000 CONTINUE
C-----------------------------------------------------------------------C
C    DETERMINING THE PROPORTION OF THE POPULATION LOST WHEN A CRASH    C
C    OCCURS                                                            C
C-----------------------------------------------------------------------C
      ZX=TPS/POP
      ZX=ZX*100.
      WRITE(6,6003) ZX
 6003 FORMAT('0',15X,'THERE WAS A',F6.1,' PERCENT MORTALITY DUE TO OVER
     1POPULATION')
      GO TO 5001
 6001 CONTINUE
      WRITE(6,8001)DEER
 8001 FORMAT('0',15X,'THE PROPORTION OF THE POPULATION LOST DUE TO NATUR
     1AL MORTALITY WAS',F6.3)
 5001 CONTINUE
      IF(XHAR.EQ.0.0) GO TO 9000
      WRITE(6,8002) HUNT
```

TABLE 3. (CONTINUED)

```
--------------------------------------------------------------------------
--------------------------------------------------------------------------
 8002 FORMAT  ('0',15X,'THE PROPORTION OF THE POPULATION REMOVED BY HUNT
     1ING WAS',F6.3)
C------------------------------------------------------------------------C
C    WRITING THE STRUCTURE OF THE KILL                                   C
C------------------------------------------------------------------------C
      WRITE(6,4030)
 4030 FORMAT(    16X,'STRUCTURE OF KILL')
      WRITE(6,903)
      I=XQ-2
      IB=DB(YQ)+DB(XQ)
      ID=DD(YQ)+DD(XQ)
      WRITE(6,904) (DB(J),J=1,I),IB,(DD(J),J=1,I),ID
 9000 CONTINUE
      BUC=0.0
      DOE=0.0
C------------------------------------------------------------------------C
C    DETERMINATION OF THE SEX RATIO AFTER ALL MORTALITY                  C
C------------------------------------------------------------------------C
      DO 639 M=1,XQ
      BUC=BUC+BXK(M)
      DOE=DOE+DXK(M)
  639 CONTINUE
      PCTM=BUC/(BUC+DOE)
      PCTF=DOE/(BUC+DOE)
      TOTPOP=BUC+DOE
      TP(IYR,5)=TOTPOP
C------------------------------------------------------------------------C
C    WAS THE DESIRED SEX RATIO ACHIEVED?                                 C
C------------------------------------------------------------------------C
--------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      WRITE(6,70)
   70 FORMAT('0')
      SY=PCTF-SXX
      IF(ABS(SY).LE.0.02) WRITE(6,7012) SXX
 7012 FORMAT(     16X,'THE DESIRED PORTION OF FEMALES',F6.3,' HAS BEEN AC
     1HIEVED')
C-----------------------------------------------------------------------C
C    DETERMINATION OF THE TOTAL NUMBER OF DEER LOST DURING THE ENTIRE   C
C    YEAR                                                               C
C-----------------------------------------------------------------------C
      DIF=POP-TOTPOP
      WRITE(6,7007) DIF
 7007 FORMAT(     16X,'THE POPULATION HAS BEEN REDUCED',F6.0,
     1 ' DEER BY HUNTING AND NATURAL CAUSES')
      WRITE(6,4026) TOTPOP
 4026 FORMAT('0',15X,'TOTAL POPULATICN AFTER NATURAL MORTALITY',F8.0)
C-----------------------------------------------------------------------C
C    CALL A SUBROUTINE TO CALAULATE LIFE TABLES                         C
C-----------------------------------------------------------------------C
      WRITE(6,82)
   82 FORMAT('1',11(/))
      WRITE(6,8034)
 8034 FORMAT(44X,'LIFE TABLE FOR BUCKS')
      JACK=1
      CALL LTB (AGA,BXK,XQ,E,JACK)
      WRITE(6,8035)
 8035 FORMAT('0',43X,'LIFE TABLE FOR DOES')
      CALL LTB (AGA,DXK,XQ,E,JACK)
      JACK=2
```

TABLE 3. (CONTINUED)

```
      WRITE(6,83)
   83 FORMAT('1',22(/))
      WRITE(6,58)
   58 FORMAT(    16X,'TOTAL POPULATION')
      DO 59 I=1,XQ
   59 TDEER(I)=DXK(I)+BXK(I)
      CALL LTB(AGA,TDEER,XQ,DE,JACK)
C-----------------------------------------------------------------------C
C   CALCULATING NEW AGE RATIOS AFTER ALL MORTALITY                      C
C-----------------------------------------------------------------------C
      DO 39 J=1,XQ
   39 AR(J)=(DXK(J)+BXK(J))/TOTPOP
      WRITE(6,6004) RJTO
 6004 FORMAT(16X,'THE POPULATION HAS A J RATIO OF ',F6.3)
      WRITE(6,60) RFE
   60 FORMAT(16X,'YOUNG PER ADULT DOE ',F6.3)
      WRITE(6,745) BORN
  745 FORMAT(16X,'YOUNG PER DOE ',F6.3)
      WRITE(6,61) YFAD
   61 FORMAT(16X,'DOE FAWNS PER ADULT DOE ',F6.3)
      WRITE(6,62) RAD
   62 FORMAT(16X,'YOUNG PER ADULT DEER ',F6.3)
C-----------------------------------------------------------------------C
C   DETERMINING THE PROPORTION OF THE POPULATION KILLED DURING THE      C
C   HUNTING SEASON AS ANTLERED AND ANTLERLESS DEER                      C
C-----------------------------------------------------------------------C
      XDOE=XDOE+DB(1)
      XBUC=XBUC-DB(1)
      PBD=XBUC/POP
```

TABLE 3. (CONTINUED)

```
----------------------------------------------------------------------
----------------------------------------------------------------------
      PDB=XDCE/PCP
      WRITE(6,7006) PDB,PBD
 7006 FORMAT('0',15X,'PROPORTION OF THE POPULATION REMOVED AS ANTLERLESS
     1 DEER IS',F6.3/55X,'AS ANTLERED DEER IS',F6.3)
      WRITE(6,7500)
 7500 FORMAT('0',15X,'TOTAL NATURAL MORTALITY')
      WRITE(6,903)
      I=XQ-2
      IB=RDB(YQ)+RDB(XQ)
      ID=RDD(YQ)+RDD(XQ)
      WRITE(6,904) (RDB(J),J=1,I),IB,(RDD(J),J=1,I),ID
      WRITE(6,7501)
 7501 FORMAT('0',15X,'CRIPPLING AND POACHING LOSS' )
      WRITE(6,903)
      I=XQ-2
      IB=CPB(YQ)+CPB(XQ)
      ID=CPD(YQ)+CPD(XQ)
      WRITE(6,904) (CPB(J),J=1,I),IB,(CPD(J),J=1,I),ID
      IF(IYR.LE.3) GO TO 10
      SR=SR+1.0
      DPOP=DPOP+POP
      SUMD=SUMD+PDB
      DSQ=DSQ+PDB**2
      SUMB=SUMB+PBD
      BSQ=BSQ+PBD**2
      GO TO 10
  500 CONTINUE
C---------------------------------------------------------------------C
C   PRESENTATICN OF HABITAT CHARACTERISTICS                           C
----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
--------------------------------------------------------------------------
--------------------------------------------------------------------------
C------------------------------------------------------------------------C
      SRY=IYR
      TOTS=TOTS/SRY
      TOTW=TOTW/SRY
      DACRES=DACRES/SRY
      DACREW=DACREW/SRY
      PDS=TOTS*2.2046
      PDW=TOTW*2.2046
      WRITE(6,40)
   40 FORMAT('0',21X,'HABITAT CHARACTERISTICS')
      WRITE(6,45)
   45 FORMAT(16X,34('-'))
      WRITE(6,41)
   41 FORMAT(24X,'FORAGE PER ACRE   DEER PER'/39X,
     1 'LBS.    KG.',6X,'ACRE')
      WRITE(6,45)
      WRITE(6,42) PDS,TOTS,DACRES
   42 FORMAT(16X,'SUMMER ',F7.0,1X,F7.0,3X,F7.4)
      WRITE(6,43) PDW,TOTW,DACREW
   43 FORMAT(16X,'WINTER ',F7.0,1X,F7.0,3X,F7.4)
      WRITE(6,45)
C------------------------------------------------------------------------C
C   CALCULATING THE MEAN ANTLERED AND ANTERLESS KILL                     C
C------------------------------------------------------------------------C
      DPOP=DPOP/SR
      PDB=SUMD/SR
      PBD=SUMB/SR
      IB=DPOP*PBD+0.5
      BUCKS=IB
--------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
----------------------------------------------------------------------
----------------------------------------------------------------------
      ID=DPOP*PDB+0.5
      DOES=ID
      TOTAL=BUCKS+DOES
      WRITE(6,7000) TOTAL,BUCKS,DOES
 7000 FORMAT(    16X,'IN ORDER TO MAINTAIN A STABLE POPULATION, THE TOTA
     1L HARVEST SHOULD BE',F6.0/'0',15X,'THE KILL SHOULD CONSIST OF',
     2 F6.0,' ANTLERED',F6.0,' ANTLERLESS DEER')
      BUCKS=PBD*100.
      DOES=PDB*100.
      WRITE(6,7443) BUCKS, DOES
 7443 FORMAT('0',15X,'THE HARVEST SHOULD REMOVE',F6.1,
     1 ' % OF THE POPULATION AS ANTLERED AND'/41X,
     2 F6.1,' % OF THE POPULATION AS ANTLERLESS DEER')
C---------------------------------------------------------------------C
C   CALCULATING THE VARIANCE OF THE ANTLERED AND ANTLERLESS KILL       C
C---------------------------------------------------------------------C
      VARD=(DSQ-(SUMD**2/SR))/(SR-1.0)
      VARB=(BSQ-(SUMB**2/SR))/(SR-1.0)
      HALFD=SQRT(VARD/SR)
      HALFB=SQRT(VARB/SR)
      WRITE(6,2)
    2 FORMAT('0',15X,'CONFIDENCE',6X,'ANTLERED',7X,'ANTLERLESS')
      WRITE(6,3)
    3 FORMAT(16X,48('-'))
    4 FORMAT(16X,'|  ',I2,'%',5X,F6.1,' TO ',F6.1,' | ',F6.1,' TO ',
     1F6.1,' |')
      I=95
C---------------------------------------------------------------------C
C   PRESANTATION OF THE CONFIDENCE INTERVALS FOR THE PROPORTION OF THE  C
----------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
C    POPULATICN TC BE REMCVED AS ANTLERED ANE ANTERLESS DEER TO MAINTAIN C
C    A STABLE PCPULATION                                                 C
C------------------------------------------------------------------------C
   15 IF(I.EQ.95) P=1.960
      IF(I.EQ.9C) P=1.645
      IF(I.EQ.80) P=1.282
      BUCKL=PBD-P*HALFB
      BUCKU=PBC+P*HALFB
      DCEL=PDB-P*HALFD
      DOEU=PDB+P*HALFD
      BUCKU=BUCKU*100.
      BUCKL=BUCKL*100.
      DOEL=DCEL*100.
      DOEU=DCEU*100.
      WRITE(6,4) I, BUCKL, BUCKU, DCEL, DOEU
      I=I-5
      IF(I.LT.90) I=I-5
      IF(I.GE.80) GO TO 15
      WRITE(6,3)
      WRITE(6,8000) SR
 8000 FORMAT('0',15X,'THE BUCK AND DOE KILL WAS SAMPLED FOR',F4.0,'YEARS
     1')
      WRITE(6,2500)
      IYR=IYR-1
      DO 232 I=1,6
  232 CALL ANCVA(SYS,SYS2,SXS(I),SX2(I),XY(I),SIRY,I)
      WRITE(6,250C)
      DO 235 I=1,6
      RANG(I)=RANG(I)/(SIRY-1.0)
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-----------------------------------------------------------------------
-----------------------------------------------------------------------
      SXS(I)=SXS(I)/SIRY
  235 CONTINUE
      DO 243 I=1,6
      TOP=SXS(I)+3.0*RANG(I)/1.128
      BOTTOM=SXS(I)-3.0*RANG(I)/1.128
      IF(I.EQ.1) WRITE(6,236)
      IF(I.EQ.2) WRITE(6,237)
      IF(I.EQ.3) WRITE(6,238)
      IF(I.EQ.4) WRITE(6,239)
      IF(I.EQ.5) WRITE(6,240)
      IF(I.EQ.6) WRITE(6,241)
  236 FORMAT('0',15X,'PRCPORTION DOE')
  237 FORMAT('0',15X,'BICMASS')
  238 FORMAT('0',15X,'TOTAL POPULATICN')
  239 FORMAT('0',15X,'BUCK KILL')
  240 FORMAT('0',15X,'DOE KILL')
  241 FORMAT('0',15X,'FORAGE')
      WRITE(6,242) TCP,BCTTCM
  242 FORMAT(16X,'UPPER LIMIT  ',F16.4/16X,'LCWER LIMIT  ',F16.4)
  243 CONTINUE
      WRITE(6,2500)
C---------------------------------------------------------------------C
C   PLOTTING THE SIMULATION RESULTS                                   C
C---------------------------------------------------------------------C
      IZ=250
      IY=50
      X=2.0
      YJK=3.25
      RLX=(IYR-1)*0.25
-----------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      RLY=6.0
      CALL PLOT(X,YJK,-3)
      CALL SCALE(Y,IY ,RLX,YMIN,DY,1)
      CALL AXIS(0.0,0.0,4HYEAR,-4,RLX,0.0,1.0,4.0)
      CALL SCALE(TP,IZ,RLY,TMIN,DT,1)
      CALL AXIS(0.0,0.0,6HNUMBER,6,RLY,90.0,TMIN,DT)
      DO 4032 I=1,5
      N=-1
      IF(I.EQ.1)M=9
      IF(I.EQ.2) M=4
      IF(I.EQ.3) M=3
      IF(I.EQ.4) M=2
      IF(I.EQ.5) M=1
      DO 4033 J=1,IYR
      CALL SYMBOL(Y(J),TP(J,I),.15,M,0.0,N)
 4033 N=-2
 4032 CONTINUE
      CALL SYMBOL(0.0,-0.6,0.10,3,0.0,-1)
      CALL SYMBOL(0.0,-0.9,0.10,4,0.0,-1)
      CALL SYMBOL(0.0,-1.2,0.10,9,0.0,-1)
      CALL SYMBOL(2.5,-0.75,0.10,2,0.0,-1)
      CALL SYMBOL(2.5,-1.05,0.10,1,0.0,-1)
      CALL SYMBOL(0.2,-0.60,0.10,9HBUCK KILL,0.0,9)
      CALL SYMBOL(0.2,-0.90,0.10,8HDOE KILL,0.0,8)
      CALL SYMBOL(0.2,-1.20,0.10,16HTOTAL POPULATION,0.0,16)
      CALL SYMBOL(2.7,-0.75,0.10,22HSUPPORTABLE POPULATION,0.0,22)
      CALL SYMBOL(2.7,-1.05,0.10,8HSURVIVAL,0.0,8)
      CALL PLOT(0.0,0.0,-4)
      STOP
```

TABLE 3. (CONTINUED)

END

TABLE 3. (CONTINUED)

```
----------------------------------------------------------------------
----------------------------------------------------------------------
      SUBROUTINE LEVELS (TOT, LEVEL, XQ)
C---------------------------------------------------------------------C
C   LEVELS IS DESIGNED TO DETERMINE THE LEVEL OF ENERGY AVAILABLE TO  C
C   THE POPULATION.                                                   C
C---------------------------------------------------------------------C
C   BXK(I)    = SAME AS IN MAIN PROGRAM                               C
C   DXK(I)    = SAME AS IN MAIN PROGRAM                               C
C   DWB(I)    = SAME AS IN MAIN PROGRAM                               C
C   DWD(I)    = SAME AS IN MAIN PROGRAM                               C
C   FORAGE    = TOTAL FORAGE REQUIRED                                 C
C   LEVEL     = LEVEL OF ENERGY AVAILABLE TO THE POPULATION           C
C   TOT       = TOTAL FORAGE AVAILABLE                                C
C   X         = RATIO OF THE TOTAL FORAGE AVAILABLE TO THE TOTAL      C
C               FORAGE REQUIRED BY THE POPULATION                     C
C---------------------------------------------------------------------C
      INTEGER XQ
      INTEGER BXK(11), DXK(11)
      DIMENSION DWB(11), DWD(11)
      COMMON/ONE/ BXK, DXK
      COMMON/SIX/ DWB,DWD
      COMMON/SEVEN/ YIELD
      FORAGE=0.0
      DO 1 J=1,XQ
    1 FORAGE=FORAGE+BXK(J)*(0.152*DWB(J)**0.75)*183.+
     1              DXK(J)*(0.141*DWD(J)**0.75)*183.
      X=TOT/FORAGE
      YIELD=TOT-FORAGE
      IF(X.LE.0.7) LEVEL=3
      IF(X.GT.0.7.AND.X.LT.0.9) LEVEL=2
----------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
      IF(X.GE.0.9) LEVEL=1
      RETURN
      END
```

TABLE 3. (CONTINUED)

```
---------------------------------------------------------------------------
---------------------------------------------------------------------------
      SUBROUTINE NATAL (NC,D,XN,S,X,B,BF,GF,LEVEL)
C-------------------------------------------------------------------------C
C   NATAL IS DESIGNED TO SIMULATE THE PRODUCTION OF FAWNS BY THE FEMALE C
C   SECTION OF THE POPULATION.                                            C
C-------------------------------------------------------------------------C
C   B          = PROPORTION OF ADULT DOES THAT REPRODUCE                  C
C   BF         = NUMBER OF BUCK FAWNS PRODUCED                            C
C   D(I)       = NUMBER OF DOES IN AGE CLASS I                            C
C   GF         = NUMBER OF DOE FAWN PRODUCED                              C
C   F          = THE NUMBER OF FAWNS PRODUCED                             C
C   LEVEL      = SAME AS IN MAIN PROGRAM                                  C
C   S          = PROPORTION OF FAWNS THAT ARE BUCKS                       C
C   X          = PROPORTION OF DOE FAWNS THAT REPRODUCE                   C
C   XN(I)      = NATALITY FOR AGE CLASS I                                 C
C-------------------------------------------------------------------------C
      INTEGER D(11)
      DIMENSION XN(3,11)
      F=D(1)*XN(LEVEL,1)*X
      DO 1 J=2,NC
    1 F=F+D(J)*XN(LEVEL,J)*B
      BF=S*F
      GF=F-BF
      RETURN
      END
---------------------------------------------------------------------------
```

TABLE 3. (CCNTINUED)

```
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
      SUBROUTINE RANDU (IX,Y)
C-----------------------------------------------------------------------------C
C   RANDU IS A SUBROUTINE DESIGNED TC PRCDUCE RANDOM NUMBERS BETWEEN           C
C    0 AND 1.                                                                 C
C-----------------------------------------------------------------------------C
C   IX        = RANDOM INTEGER GIVEN TO THE SUBROUTINE                        C
C   IY        = RANDOM INTEGER PRODUCED BY THE SUBROUTINE                     C
C   Y         = RANDOM REAL NUMBER BETWEEN 0 AND 1.                           C
C-----------------------------------------------------------------------------C
      IY=IX*65539
      IF (IY) 5,6,6
    5 IY=IY+ 2147483647 +1
    6 Y=IY
      Y=Y* .4656613 E-9
      IX=IY
      RETURN
      END
-------------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
-------------------------------------------------------------------------
-------------------------------------------------------------------------
      SUBROUTINE MORT ( ZQ, TQ, SUM, VULN, SP)
C-----------------------------------------------------------------------C
C    MORT IS A SUBROUTINE DESIGNED TO DETERMINE THE NATURAL MORTALITY IN C
C    THE POPULATION AND REMOVE THIS MORTALITY FROM EACH AGE CLASS.       C
C-----------------------------------------------------------------------C
C    BXK(I)    = SAME AS IN MAIN PROGRAM                                  C
C    DXK(I)    = SAME AS IN MAIN PROGRAM                                  C
C    ISUM      = ACTUAL NUMBER OF DEER DYING BY NATURAL MORTALITY         C
C    JSUM      = DUMMY FOR ISUM                                           C
C    POP       = SAME AS IN MAIN PROGRAM                                  C
C    R         = THE PREDICTED NUMBER OF DEER DYING DUE TO NATURAL        C
C                MORTALITY                                                C
C    RBD(I)    = SAME AS IN MAIN PROGRAM                                  C
C    RDB(I)    = SAME AS IN MAIN PROGRAM                                  C
C    SUM       = PROPORTION OF THE POPULATION LOST TO NATURAL MORTALITY   C
C    SUMQ      = SUMATION OF D(I)                                         C
C    T         = TOTAL NUMBER IN AGE CLASS I BEFOR ANY MORTALITY AT ALL   C
C    TP        = TOTAL NUMBER IN THE POPULATION BEFORE NATURAL MORTALITY  C
C    VULN(I,J)= VULNERABILITY TO NATURAL MORTALITY                       C
C                IF VULN(I,J) EQUALS 1, THE BUCKS (I=1) OR DOES (I=2) IN  C
C                AGE CLASS J ARE REPRESENTED IN NATURAL MORTALITY IN THE  C
C                SAME PROPORTION AS THEY ARE REPRESENTED IN THE POPULATIONC
C    XPOP      = POPULATION AFTER NATURAL MORTALITY                       C
C    XQ        = NUMBER OF AGE CLASSES                                    C
C    ZQ        = THE PROPORTION OF THE POPULATION TO BE REMOVED REGARDLESSC
C                OF THE KILL OR OTHER LOSSES                              C
C-----------------------------------------------------------------------C
      INTEGER XQ
      INTEGER DXK(11),BXK(11),RDD(11),RDB(11)
-------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      DIMENSICN VULN(2,11)
      COMMON/CNE/ BXK, DXK
      COMMON/TWO/RDB, RDD, POP, XQ
      IPOP=PCP
      JPOP=(IPOP/2)*2
      IF(IPOP.EQ.JPOP) IX=IPOP
      IF(IPOP.NE.JPOP) IX=JPOP
      JSUM=0
      TD=0.0
      TP=0.0
      DO 1 J=1,XQ
      TP=TP+BXK(J)+DXK(J)
      TD=TD+VULN(1,J)*BXK(J)+VULN(2,J)*DXK(J)
    1 CONTINUE
      IF(TD.LE.0.0) TD=1.0
      R=ZQ*POP
    8 ISUM=0
      DO 2 J=1,XQ
      RD=R*((VULN(2,J)*DXK(J))/TD)
      RB=R*((VULN(1,J)*BXK(J))/TD)
      IRD=RD+.5
      IRB=RB+.5
      IF(IRB.GT.BXK(J)) IRB=BXK(J)
      IF(IRD.GT.DXK(J)) IRD=DXK(J)
      ISUM=ISUM+IRD+IRB
    2 CONTINUE
      IF(JSUM.EQ.0) GO TC 4
      IF(JSUM.LT.ISUM) GC TO 4
      R=R+0.25
```

TABLE 3. (CONTINUED)

```
      GO TO 8
    4 CONTINUE
      JSUM=ISUM
      XPOP=TP-ISUM
      SUM=ISUM/POP
      IF(SUM.GE.ZQ.AND.XPOP.LE.SP ) GO TO 3
      IF(SUM.GT.TQ) GO TO 3
      GO TO 8
    3 CONTINUE
      SUM=0.0
      DO 9 J=1,XQ
      RD=R*((VULN(2,J)*DXK(J))/TD)
      RB=R*((VULN(1,J)*BXK(J))/TD)
      IRD=RD+.5
      IRB=RB+.5
      CALL RANDU(IX,Z)
      IF(Z.GT.0.80) IRB=IRB+1
      CALL RANDU(IX,Z)
      IF(Z.GT.0.80) IRD=IRD+1
      IF(IRB.GT.BXK(J)) IRB=BXK(J)
      IF(IRD.GT.DXK(J)) IRD=DXK(J)
      BXK(J)=BXK(J)-IRB
      DXK(J)=DXK(J)-IRD
      RDD(J)=IRD +RDD(J)
      RDB(J)=IRB +RDB(J)
      SUM=SUM+IRD+IRB
    9 CONTINUE
    7 SUM=SUM/POP
      RETURN
```

TABLE 3. (CCNTINUED)

END

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      SUBROUTINE CRIPLE ( CLOS, NC, VULC)
C----------------------------------------------------------------------C
C    THIS SUBROUTINE IS DESIGNED TO REMOVE THE CRIPPLING LOSSES FROM   C
C    EACH AGE CLASS.                                                    C
C----------------------------------------------------------------------C
C    BXK(I)     = SAME AS IN THE MAIN PROGRAM                           C
C    CLOS       = SAME AS IN MAIN PROGRAM                               C
C    CPB(I)     = SAME AS IN THE MAIN PROGRAM                           C
C    CPD(I)     = SAME AS IN THE MAIN PROGRAM                           C
C    DB(I)      = SAME AS IN THE MAIN PROGRAM                           C
C    DD(I)      = SAME AS IN THE MAIN PROGRAM                           C
C    DXK(I)     = SAME AS IN THE MAIN PROGRAM                           C
C    LOS        = TOTAL NUMBER OF DEER LOST TO CRIPPLING                C
C    NC         = NUMBER OF AGE CLASSES CONSIDERED                      C
C    TP         = TOTAL NUMBER OF DEER KILLED IN THE REGULAR SEASON     C
C    VULC(I,J)= SAME AS IN MAIN PROGRAM                                 C
C               IF VULC(I,J) EQUALS 1, THE BUCKS (I=1) OR DOES (I=2) IN C
C               AGE CLASS J ARE REPRESENTED IN CRIPPLING LOSSES IN THE  C
C               SAME PROPORTION AS THEY ARE REPRESENTED IN THE HARVEST  C
C----------------------------------------------------------------------C
      DIMENSION VULC(2,11)
      INTEGER DD(11), DXK(11), DB(11), BXK(11), CPB(11), CPD(11)
      COMMON/ONE/ BXK, DXK
      COMMON/THREE/ DD, DB
      COMMON/FOUR/ CPB, CPD
      COMMON/FIVE/ IX
      TP=0.0
      DO 1 J=1,NC
    1 TP=TP+DB(J)*VULC(1,J)+DD(J)*VULC(2,J)
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      IF(TP.LE.0.0) TP=1.0
      LOS=0
      DO 2 J=1,NC
      I=NC+1-J
      ID=CLOS*(DD(I)*VULC(2,I))/TP+0.5
      IB=CLOS*(DB(I)*VULC(1,I))/TP+0.5
      IF(CLOS.LE.0.0) GO TO 3
      CALL RANDU ( IX, Z )
      IF(I.GE.6.AND.Z.GE.0.75) IB=IB+1
      CALL RANDU ( IX, Z )
      IF(I.GE.6.AND.Z.GE.0.75) ID=ID+1
    3 IF(ID.GT.DXK(I)) ID=DXK(I)
      IF(IB.GT.BXK(I)) IB=BXK(I)
      DXK(I)=DXK(I)-ID
      BXK(I)=BXK(I)-IB
      CPD(I)=ID
      CPB(I)=IB
      LOS=LOS+ID+IB
    2 CONTINUE
      CLOS=LOS
      RETURN
      END
```

TABLE 3. (CCNTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      SUBROUTINE POCHER ( PLOS, NC, VULP)
C-----------------------------------------------------------------------C
C   THIS SUBROUTINE IS DESIGNED TO REMOVE THE POACHING LOSSES FROM      C
C   EACH AGE CLASS                                                      C
C-----------------------------------------------------------------------C
C   BXK(I)    = SAME AS IN MAIN PROGRAM                                 C
C   DXK(I)    = SAME AS IN MAIN PROGRAM                                 C
C   CPB(I)    = SAME AS IN MAIN PROGRAM                                 C
C   CPD(I)    = SAME AS IN MAIN PROGRAM                                 C
C   LOS       = NUMBER OF DEER LCST TC POACHERS                         C
C   NC        = NUMBER OF AGE CLASSES                                   C
C   PLOS      = NUMBER OF DEER LOST TO POACHERS                         C
C   TPOP      = TOTAL POPULATION BEFCRE ANY POACHING LOSSES             C
C   VULP(I,J)= SAME AS IN MAIN PROGRAM                                  C
C              IF VULP(I,J) EQUALS 1, THE BUCKS (I=1) OR DOES (I=2) IN  C
C              AGE CLASS J ARE REPRESENTED IN POACHING LCSSES IN THE    C
C              SAME PROPORTION AS THEY ARE REPRESENTED IN THE POPULATIOMC
C-----------------------------------------------------------------------C
      DIMENSION VULP(2,11)
      INTEGER DXK(11),BXK(11), CPB(11), CPD(11)
      COMMON/CNE/ BXK, DXK
      COMMON/FOUR/ CPB, CPD
      COMMON/FIVE/ IX
      TPOP=0.0
      DO 1 J=1,NC
    1 TPOP=TPOP+BXK(J)*VULP(1,J)+DXK(J)*VULP(2,J)
      LOS=0
      DO 2 J=1,NC
      I=NC+1-J
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      ID=PLOS*(DXK(I)*VULP(2,I))/TPOP+0.5
      IB=PLOS*(BXK(I)*VULP(1,I))/TPOP+0.5
      IF(PLOS.LE.0.0) GO TO 3
      CALL RANDU ( IX, Z )
      IF(I.GE.6.AND.Z.GE.0.75) IB=IB+1
      CALL RANDU ( IX, Z )
      IF(I.GE.6.AND.Z.GE.0.75) ID=ID+1
    3 IF(ID.GT.DXK(I)) ID=DXK(I)
      IF(IB.GT.BXK(I)) IB=BXK(I)
      BXK(I)=BXK(I)-IB
      DXK(I)=DXK(I)-ID
      CPB(I)=CPB(I)+IB
      CPD(I)=CPD(I)+ID
      LOS=LOS+IB+ID
    2 CONTINUE
      PLOS=LOS
      RETURN
      END
```

TABLE 3. (CCNTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      SUBROUTINE LTB(AGA,XK,MC,DEX,JACK)
C-----------------------------------------------------------------------C
C   LTB IS A SUBROUTINE DESIGNED TO PREFORM ALL THE CALCULATIONS        C
C   NECESSARY TC PRODUCE A LIFE TABLE.                                  C
C-----------------------------------------------------------------------C
C   AGA(I)    = SAME AS IN MAIN PROGRAM                                 C
C   DEX       = ADJUSTED LIFE EXPECTANCY FOR AGE CLASS 1                C
C   DX(I)     = THE NUMBER OF ANIMALS IN THE COHORT DYING IN AGE CLASS I C
C   EX(I)     = LIFE EXPECTANCY FOR AGE CLASS I                         C
C   LC        = ONE LESS THAN THE NUMBER OF AGE CLASSES WITH DEER IN THEMC
C   MC        = NUMBER OF AGE CLASSES CONSIDERED                        C
C   NC        = NUMBER OF AGE DLASSES WITH DEER IN THEM                 C
C   PRS(I)    = NUMBER OF ANIMALS SURVIVING PER 1000 FOR AGE CLASS I    C
C   QX(I)     = NUMBER OF ANIMALS DYING PER 1000 ANIMALS IN AGE CLASS I C
C   RMA       = AVERAGE ANNUAL MORTALITY                                C
C   RMQX      = AVERAGE RATE OF MORTALITY                               C
C   SDX       = SUM OF DX(I)                                            C
C   SQX       = SUM OF QX(I)                                            C
C   SSX       = SUM CF SX(I)                                            C
C   SX(I)     = NUMBER OF SURVIVCRS IN THE COHCRT FOR AGE CLASS I       C
C   SZ        = THE TOTAL POPULATION                                    C
C   T9        = TURNCVER PERIOD                                         C
C   XK(I)     = ACTUAL NUMBER OF ANIMALS IN ACE CLASS I                 C
C   XL(I)     = MEAN NUMBER OF ANIMALS SURVIVING BETWEEN AGE CLASS I AND C
C               I+1                                                     C
C-----------------------------------------------------------------------C
      INTEGER XK(11)
      DIMENSICN CX(11),SX(11)
      DIMENSION PRS(11),XL(11)
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      DIMENSION  EX(11),QX(11),AGA(11)
      DO 45 J=1,MC
      I=MC+1-J
      IF(XK(I).LE.0) GO TO 45
      GO TO 46
   45 CONTINUE
   46 NC=I
      IF(NC.LE.1) NC=2
      LC=NC-1
      SZ=0.0
      DO 43 J=1,NC
   43 SZ=SZ+XK(J)
      DO 47 I=1,NC
   47 DX(I)=XK(I)/SZ*1000.0
      SX(1)=1000.0
      DO 48 J=2,NC
      N=J-1
      SX(J)=SX(N)-DX(N)
      IF(SX(J).LT.0.0) SX(J)=0.0
   48 CONTINUE
      DO 7 I=1,NC
      IF(SX(I).LE.0.0) GO TO 6
      QX(I)=DX(I)*1000./SX(I)
      GO TO 7
    6 QX(I)=0.0
    7 PRS(I)=1000.-QX(I)
      DEX=1.0
      DO 8 K=1,LC
    8 XL(K)=(SX(K)+SX(K+1))/2.0
```

TABLE 3. (CCNTINUED)

```
      XL(NC)=SX(NC)/2.0
      REX=0.0
      DO 9 J=1,NC
    9 REX=REX+XL(J)
      DO 10 I=1,NC
      IF(SX(I).EQ.0.0) GO TO 14
      EX(I)=REX/SX(I)
      GO TO 10
   14 EX(I)=1.0
   10 REX=REX-XL(I)
      DEX=EX(1)
      IF(JACK.EQ.0) GO TO 15
      IF(JACK.EQ.2) GO TO 18
      WRITE(6,107)
  107 FORMAT(28X,'X',4X,2HKX,        6X,2HDX,6X,2HSX,6X,2HQX,4X,4HPR.S,5
     2X,2HLX,5X,'EX ')
      DO 30 K=1,NC
   30 WRITE(6,108) AGA(K),XK(K),       DX(K),SX(K),QX(K),PRS(K),XL(K),
     1  EX(K)
  108 FORMAT(26X,F4.1,I5,2X,     F8.1,3F8.1,F7.1,F7.2,2F9.2,F7.2,F9.2)
   18 SDX=0.0
      SQX=0.0
      SSX=0.0
      DO 12 K=1,NC
      SDX=SDX+DX(K)
      SSX=SSX+SX(K)
      SQX=SQX+QX(K)
   12 CONTINUE
      RMA=(SDX/SSX)*100.
```

TABLE 3. (CONTINUED)

```
      R=NC-1
      RMQX=((SQX-1000.)/R)/10.
      DO 16 I=1,NC
      J=NC+1-I
      IF(SX(J).GE.9.0) GO TO 17
   16 CONTINUE
   17 T9=((SX(J)-9.0)/SX(J))+AGA(J)
      WRITE(6,13) RMA,RMQX,T9
   13 FORMAT(' ',25X,'POPULATION RATIOS: AVERAGE ANNUAL MORTALITY',F6.1/
     1 45X,'AVERAGE RATE OF MORTALITY',F6.1/45X,'TURNOVER ',F6.1)
   15 RETURN
      END
```

TABLE 3. (CONTINUED)

```
------------------------------------------------------------------------
------------------------------------------------------------------------
      SUBROUTINE HABTAT( TOT, YNEG, YPOS, XERO)
C----------------------------------------------------------------------C
C    'HABTAT' IS DESIGNED TO FLUCTUATE THE VEGETATION AVAILABLE TO THE   C
C    DEER HERD ACCORDING TO THE AMOUNT OF VEGETATION THAT IS USED BY THE C
C    DEER HERD                                                         C
C----------------------------------------------------------------------C
C    ALL VARIABLES ARE DEFINED IN THE MAIN PROGRAM                     C
C----------------------------------------------------------------------C
      COMMON/SEVEN/ YIELD
      TOT=TOT*XERO
      IF(YIELD.GT.0.0) TOT=TOT+YPOS*YIELD
      IF(YIELD.LT.0.0) TOT=TOT+YNEG*YIELD
      RETURN
      END
------------------------------------------------------------------------
```

TABLE 3. (CONTINUED)

```
      SUBROUTINE ANOVA(X,X2,Y,Y2,XY,N,I)
      REAL N
      IF(I.EQ.1) WRITE(6,7)
      IF(I.EQ.2) WRITE(6,8)
      IF(I.EQ.3) WRITE(6,9)
      IF(I.EQ.4) WRITE(6,10)
      IF(I.EQ.5) WRITE(6,11)
      IF(I.EQ.6) WRITE(6,12)
    7 FORMAT(16X,'PROPORTION DOE')
    8 FORMAT(16X,'TOTAL BIOMASS')
    9 FORMAT(16X,'TOTAL POPULATION')
   10 FORMAT(16X,'BUCK KILL')
   11 FORMAT(16X,'DOE KILL')
   12 FORMAT(16X,'FORAGE')
      XX=X2-(X**2/N)
      YX=XY-((X*Y)/N)
      TSS=Y2-(Y**2/N)
      RSS=YX**2/XX
      ESS=TSS-RSS
      RMS=RSS
      EMS=ESS/(N-2)
      F=RMS/EMS
      J=1
      WRITE(6,1)
    1 FORMAT(38X,'ANOVA')
      WRITE(6,2)
    2 FORMAT(16X,53('-'))
      WRITE(6,3)
    3 FORMAT(16X,'SOURCE  DF',10X,'SS',14X ,'MS',12X,'F')
```

TABLE 3. (CONTINUED)

```
      WRITE(6,2)
      WRITE(6,4) J,RSS,RMS,F
    4 FORMAT(16X,'REG      ',I3,2F16.4,F10.5)
      J=N-2
      WRITE(6,5) J,ESS,EMS
    5 FORMAT(16X,'ERROR    ',I3,2F16.4)
      J=N-1
      WRITE(6,6) J,TSS
    6 FORMAT(16X,'TOTAL    ',I3,F16.4)
      WRITE(6,2)
      RETURN
      END
```

h) the proportion of females before the harvest and the desired proportion of females,

i) the type of season held, the total kill, buck kill, doe kill, and the proportion of does after the harvest,

j) the number of deer lost to poaching and crippling,

k) the proportion of the population lost to winter mortality,

l) the kill by sex and age class,

m) the proportion of the population removed by hunting,

n) the total number of deer lost due to all causes,

o) the population surviving the winter,

p) a life table for the bucks and for the does,

q) reproductive characteristics,

r) total natural mortality by sex and age class,

s) crippling and poaching losses by sex and age class.

These reports provide the user with a detailed report of the deer brought into the population by reproduction and the deer lost due to poaching, crippling, and natural mortality. The deer lost are reported according to age and sex class.

The structure of the population is presented in the form of a sex-age pyramid and life tables. The sex-age pyramid provides the user with a graphical description of the population. The life tables provide the user with a mathematical description of the structure of the buck and doe portions of the population. The symbols used are:

X = the age of the animals in each age class,
XX = the number of surviving in each age class,
KX = the number dying per 1000,
SX = the number surviving per 1000,

PR.S = proportion survival times 1000,
LX = average number living between age classes,
EX = mean expectation of life remaining.

The reproductive capacity of the population is described in the following manner:

a) the natality of the does in each age class,

b) the proportion of the population in age class 1 (J ratio),

c) the number of fawns per adult doe,

d) the number of fawns per adult deer,

e) the doe fawns per adult doe,

f) the number of fawns per female.

These data provide a means of comparing the reproductive capacity of the simulated population and an actual population.

First year: The first annual report provided by DEER describes the population characterized by input data. The first report of a simulation run is presented in Fig. 4.

Year before the last year: The year before the last year of the simulation describes the population that results due to manipulation of the population under the alternative methods of harvest specified by the user. This report is provided in Fig. 5.

Management Plan

The last report provides the user with a habitat condition summary along with a harvest strategy to stabilize the population under consideration. The last year in a simulation run is presented in Fig. 6.

```
FOR YEAR     1 THE SPRING POPULATION WAS        404. DEER
THE SUPPORTABLE POPULATION WAS           380.
AGE CLASS  FAWN    1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5+
BUCKS        73     53      47      21       4       1       0       1       1       1
DOES         73     53      47      21       4       1       0       1       1       1
NATALITY= 1.00    1.75    1.75    2.00    1.50    1.25    1.00    1.00    1.00    1.00

0.002                                           |10.5|                                  0.002
0.0                                             | 9.5|                                  0.0
0.002                                           | 8.5|                                  0.002
0.002                                           | 7.5|                                  0.002
0.0                                             | 6.5|                                  0.0
0.002                                           | 5.5|                                  0.0
0.010                                         - | 4.5| -                                0.010
0.050                                     ----- | 3.5| -----                            0.052
0.114                               ----------- | 2.5| -----------                      0.114
0.126                             ------------- | 1.5| -------------                    0.126
0.158                          ---------------- | 0.5| ----------------                 0.158
      --------------------------------------------------------------------------------
                                          BUCKS         DOES

THE PROPORTION OF THE POPULATION LOST TO SUMMER MORTALITY WAS  0.0644
SUMMER MORTALITY
AGE CLASS  FAWN    1.5     2.5     3.5     4.5     5.5     6.5     7.5     8.5     9.5+
BUCKS         9      2       1       1       0       0       0       0       0       0
DOES          9      2       1       0       0       1       0       0       0       0
```

Fig. 4. The first year of a simulation

THE FALL POPULATION WAS 378.
THE SUPPORTABLE POPULATION WAS 251.
THEREFORE THE DESIRED REMOVAL WAS 127.
BEFORE THE HUNT, THE PROPORTION OF DOES WAS 0.500
THE DESIRED PROPORTION OF DOES WAS 0.595

HAVE AN ANY DEER SEASON

YEAR	POPULATION	TOTAL KILL	BUCK KILL	DOE KILL	PROPORTION DOE
1	378.	58.	48.	10.	0.559

THERE WAS A LOSS OF 47. DEER DUE TO POACHING AND CRIPPLING
29. DEER WERE LOST TO POACHING
18. DEER WERE LOST DUE TO CRIPPLING

THE PROPORTION OF THE POPULATION LOST DUE TO NATURAL MORTALITY WAS 0.064

THE PROPORTION OF THE POPULATION REMOVED BY HUNTING WAS 0.144
STRUCTURE OF KILL

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	2	19	17	8	2	0	0	0	0	0
DOES	2	3	3	1	0	0	0	1	0	0

THE DESIRED PORTION OF FEMALES 0.595 HAS BEEN ACHIEVED
THE POPULATION HAS BEEN REDUCED 157. DEER BY HUNTING AND NATURAL CAUSES

TOTAL POPULATION AFTER NATURAL MORTALITY 247.

Fig. 4. The first year of a simulation (continued)

LIFE TABLE FOR BUCKS

X	KX	DX	SX	QX	PR.S	LX	EX
0.5	49	480.4	1000.0	480.4	519.6	759.8	1.64
1.5	21	205.9	519.6	396.2	603.8	416.7	1.69
2.5	20	196.1	313.7	625.0	375.0	215.7	1.47
3.5	7	68.6	117.6	583.3	416.7	83.3	2.08
4.5	1	9.8	49.0	200.0	800.0	44.1	3.30
5.5	1	9.8	39.2	250.0	750.0	34.3	3.00
6.5	0	0.0	29.4	0.0	1000.0	29.4	2.83
7.5	1	9.8	29.4	333.3	666.7	24.5	1.83
8.5	1	9.8	19.6	500.0	500.0	14.7	1.50
9.5	0	0.0	9.8	0.0	1000.0	9.8	1.50
10.5	1	9.8	9.8	1000.0	0.0	4.9	0.50

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 46.8
AVERAGE RATE OF MORTALITY 33.7
TURNOVER 10.6

LIFE TABLE FOR DOES

X	KX	DX	SX	QX	PR.S	LX	EX
0.5	49	337.9	1000.0	337.9	662.1	831.0	1.82
1.5	39	269.0	662.1	406.2	593.8	527.6	1.50
2.5	34	234.5	393.1	596.5	403.5	275.9	1.18
3.5	17	117.2	158.6	739.1	260.9	100.0	1.20
4.5	4	27.6	41.4	666.7	333.3	27.6	2.17
5.5	0	0.0	13.8	0.0	1000.0	13.8	4.50
6.5	0	0.0	13.8	0.0	1000.0	13.8	3.50
7.5	0	0.0	13.8	0.0	1000.0	13.8	2.50
8.5	1	6.9	13.8	500.0	500.0	10.3	1.50
9.5	0	0.0	6.9	0.0	1000.0	6.9	1.50
10.5	1	6.9	6.9	999.9	0.1	3.4	0.50

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 43.0
AVERAGE RATE OF MORTALITY 32.5
TURNOVER 8.8

Fig. 4. The first year of a simulation (continued)

TOTAL POPULATION

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 18.4
AVERAGE RATE OF MORTALITY 18.4
TURNOVER 11.4

THE POPULATION HAS A J RATIO OF 0.361
YOUNG PER ADULT DOE 1.921
YOUNG PER DOE 1.132
DOE FAWNS PER ADULT DOE 0.961
YOUNG PER ADULT DEER 0.961

PROPORTION OF THE POPULATION REMOVED AS ANTLERLESS DEER IS 0.030
AS ANTLERED DEER IS 0.114

TOTAL NATURAL MORTALITY

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	15	4	3	3	0	0	0	0	0	0
DOES	15	5	5	1	0	1	0	0	0	0

CRIPPLING AND POACHING LOSS

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	7	9	7	3	1	0	0	0	0	0
DOES	7	6	5	2	0	0	0	0	0	0

Fig. 4. The first year of a simulation (continued)

FOR YEAR 21 THE SPRING POPULATION WAS 412. DEER
THE SUPPORTABLE POPULATION WAS 392.

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	82	56	26	12	6	3	2	0	0	0
DOES	82	56	36	23	14	7	3	2	0	2
NATALITY=	1.00	1.75	1.75	2.00	1.50	1.25	1.00	1.00	1.00	1.00

```
0.0                                      |10.5|                          0.002
0.0                                      | 9.5|                          0.002
0.0                                      | 8.5|                          0.0
0.0                                      | 7.5|                          0.005
0.005                                    | 6.5| -                        0.007
0.005                                    | 5.5| -                        0.015
0.015                                  - | 4.5| ---                      0.032
0.029                                --- | 3.5| -----                    0.053
0.063                             ------ | 2.5| ---------                0.087
0.131                      ------------- | 1.5| -------------            0.131
0.180                  ----------------- | 0.5| -----------------        0.180
         -------------------------------------------------------------------
                                 BUCKS          DOES
```

THE PROPORTION OF THE POPULATION LOST TO SUMMER MORTALITY WAS 0.0583
SUMMER MORTALITY

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	8	2	0	0	0	1	0	0	0	0
DOES	8	2	0	1	1	1	0	0	0	0

Fig. 5. The next to the last year of a simulation

THE FALL POPULATION WAS 388.
THE SUPPORTABLE POPULATION WAS 259.
THEREFORE THE DESIRED REMOVAL WAS 129.
BEFORE THE HUNT, THE PROPORTION OF DOES WAS 0.546
THE DESIRED PROPORTION OF DOES WAS 0.595

HAVE AN ANY DEER SEASON

YEAR	POPULATION	TOTAL KILL	BUCK KILL	DOE KILL	PROPORTION DOE
21	388.	59.	34.	25.	0.568

THERE WAS A LOSS OF 47. DEER DUE TO POACHING AND CRIPPLING
31. DEER WERE LOST TO POACHING
16. DEER WERE LOST DUE TO CRIPPLING

THE PROPORTION OF THE POPULATION LOST DUE TO NATURAL MORTALITY WAS 0.070

THE PROPORTION OF THE POPULATION REMOVED BY HUNTING WAS 0.143
STRUCTURE OF KILL

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	5	15	7	3	2	1	1	0	0	0
DOES	5	3	5	3	2	1	0	0	0	1

THE POPULATION HAS BEEN REDUCED 135. DEER BY HUNTING AND NATURAL CAUSES

TOTAL POPULATION AFTER NATURAL MORTALITY 253.

Fig. 5. The next to the last year of a simulation (continued)

LIFE TABLE FOR BUCKS

X	KX	DX	SX	QX	PR.S	LX	EX
0.5	54	500.0	1000.0	500.0	500.0	750.0	1.37
1.5	30	277.8	500.0	555.6	444.4	361.1	1.24
2.5	14	129.6	222.2	583.3	416.7	157.4	1.17
3.5	6	55.6	92.6	600.0	400.0	64.8	1.10
4.5	3	27.8	37.0	750.0	250.0	23.1	1.00
5.5	0	0.0	9.3	0.0	1000.0	9.3	1.50
6.5	1	9.3	9.3	1000.0	0.0	4.6	0.50

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 53.5
AVERAGE RATE OF MORTALITY 49.8
TURNOVER 6.5

LIFE TABLE FOR DOES

X	KX	DX	SX	QX	PR.S	LX	EX
0.5	54	372.4	1000.0	372.4	627.6	813.8	1.92
1.5	37	255.2	627.6	406.6	593.4	500.0	1.76
2.5	25	172.4	372.4	463.0	537.0	286.2	1.63
3.5	14	96.6	200.0	482.8	517.2	151.7	1.60
4.5	7	48.3	103.4	466.7	533.3	79.3	1.63
5.5	4	27.6	55.2	500.0	500.0	41.4	1.63
6.5	2	13.8	27.6	500.0	500.0	20.7	1.75
7.5	1	6.9	13.8	500.0	500.0	10.3	2.00
8.5	0	0.0	6.9	0.0	1000.0	6.9	2.50
9.5	0	0.0	6.9	0.0	1000.0	6.9	1.50
10.5	1	6.9	6.9	1000.0	0.0	3.4	0.50

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 41.3
AVERAGE RATE OF MORTALITY 36.9
TURNOVER 7.8

Fig. 5. The next to the last year of a simulation (continued)

TOTAL POPULATION

POPULATION RATIOS: AVERAGE ANNUAL MORTALITY 19.2
AVERAGE RATE OF MORTALITY 18.4
TURNOVER 11.4

THE POPULATION HAS A J RATIO OF 0.398
YOUNG PER ADULT DOE 1.885
YOUNG PER DOE 1.147
DOE FAWNS PER ADULT DOE 0.943
YOUNG PER ADULT DEER 1.206

PROPORTION OF THE POPULATION REMOVED AS ANTLERLESS DEER IS 0.073
AS ANTLERED DEER IS 0.070

TOTAL NATURAL MORTALITY

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	15	4	1	1	0	2	0	0	0	0
DOES	15	5	2	3	3	2	0	0	0	0

CRIPPLING AND POACHING LOSS

AGE CLASS	FAWN	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5+
BUCKS	8	7	4	2	1	0	0	0	0	0
DOES	8	6	4	3	2	0	1	1	0	0

Fig. 5. The next to the last year of a simulation (continued)

```
FOR YEAR   22 THE SPRING POPULATION WAS        423. DEER
THE SUPPORTABLE POPULATION WAS         392.
AGE CLASS  FAWN    1.5    2.5    3.5    4.5    5.5    6.5    7.5    8.5    9.5+
BUCKS        85     54     30     14      6      3      0      1      0      0
DOES         85     54     37     25     14      7      4      2      1      1
NATALITY= 1.00   1.75   1.75   2.00   1.50   1.25   1.00   1.00   1.00   1.00

0.0                                      |10.5|                          0.0
0.0                                      | 9.5|                          0.0
0.0                                      | 8.5|                          0.002
0.0                                      | 7.5|                          0.005
0.0                                      | 6.5| -                        0.007
0.007                                  - | 5.5| --                       0.017
0.014                                  - | 4.5| ---                      0.031
0.033                                --- | 3.5| ------                   0.059
0.071                            ------- | 2.5| ----------               0.087
0.123                       ------------ | 1.5| -------------            0.123
0.180                  ----------------- | 0.5| -------------------      0.180
     ---------------------------------------------------------------------
                                   BUCKS          DOES

THE PROPORTION OF THE POPULATION LOST TO SUMMER MORTALITY WAS  0.0615
SUMMER MORTALITY
AGE CLASS  FAWN    1.5    2.5    3.5    4.5    5.5    6.5    7.5    8.5    9.5+
BUCKS         9      2      0      0      0      0      0      1      0      0
DOES          9      2      0      0      1      0      1      0      0      1
```

Fig. 6. The habitat summary and management plan

```
THE FALL POPULATION WAS        397.
THE SUPPORTABLE POPULATION WAS        259.
THEREFORE THE DESIRED REMOVAL WAS        138.
BEFORE THE HUNT, THE PROPORTION OF DOES WAS  0.544
THE DESIRED PROPORTION OF DOES WAS  0.595
```

HABITAT CHARACTERISTICS

	FORAGE PER ACRE LBS.	KG.	DEER PER ACRE
SUMMER	120.	54.	0.1312
WINTER	80.	36.	0.0868

IN ORDER TO MAINTAIN A STABLE POPULATION, THE TOTAL HARVEST SHOULD BE   70.

THE KILL SHOULD CONSIST OF   35. ANTLERED   35. ANTLERLESS DEER

THE HARVEST SHOULD REMOVE   8.1 % OF THE POPULATION AS ANTLERED AND
8.1 % OF THE POPULATION AS ANTLERLESS DEER

CONFIDENCE	ANTLERED	ANTLERLESS
95%	7.8 TO 8.3	7.8 TO 8.4
90%	7.9 TO 8.3	7.9 TO 8.4
80%	7.9 TO 8.2	7.9 TO 8.3

THE BUCK AND DOE KILL WAS SAMPLED FOR 18.YEARS

Fig. 6. The habitat summary and management plan (continued)

The average condition of the summer and winter habitat is presented as the pounds and kilograms of forage per acre and as the number of deer per acre the habitat will support. This habitat condition is to be maintained if the management plan is to apply to the population.

The management plan is presented as the number of antlered and antlerless deer that should be harvested in order to stabilize the population. Also, confidence limits have been determined for the percent of the population to be harvested as antlered and antlerless deer. The management plan is determined according to the alternative harvest strategy specified by the user in input data.

Computer Plot

In order to allow the user to have a means of rapidly evaluating the status of a deer herd, a computer plot (Calcomp plotter) of the results is presented. The plot shows the relation of the summer population (total population), the winter supportable population (supportable population), the buck kill, the doe kill, and the winter population (survival). A computer plot is presented in Fig. 7.

Testing the Simulator

All harvest alternatives available in the simulator are fully operable. The simulator was tested with each alternative. If extreme situations are encountered, the simulation would terminate. Error messages are printed when such extremes are reached.

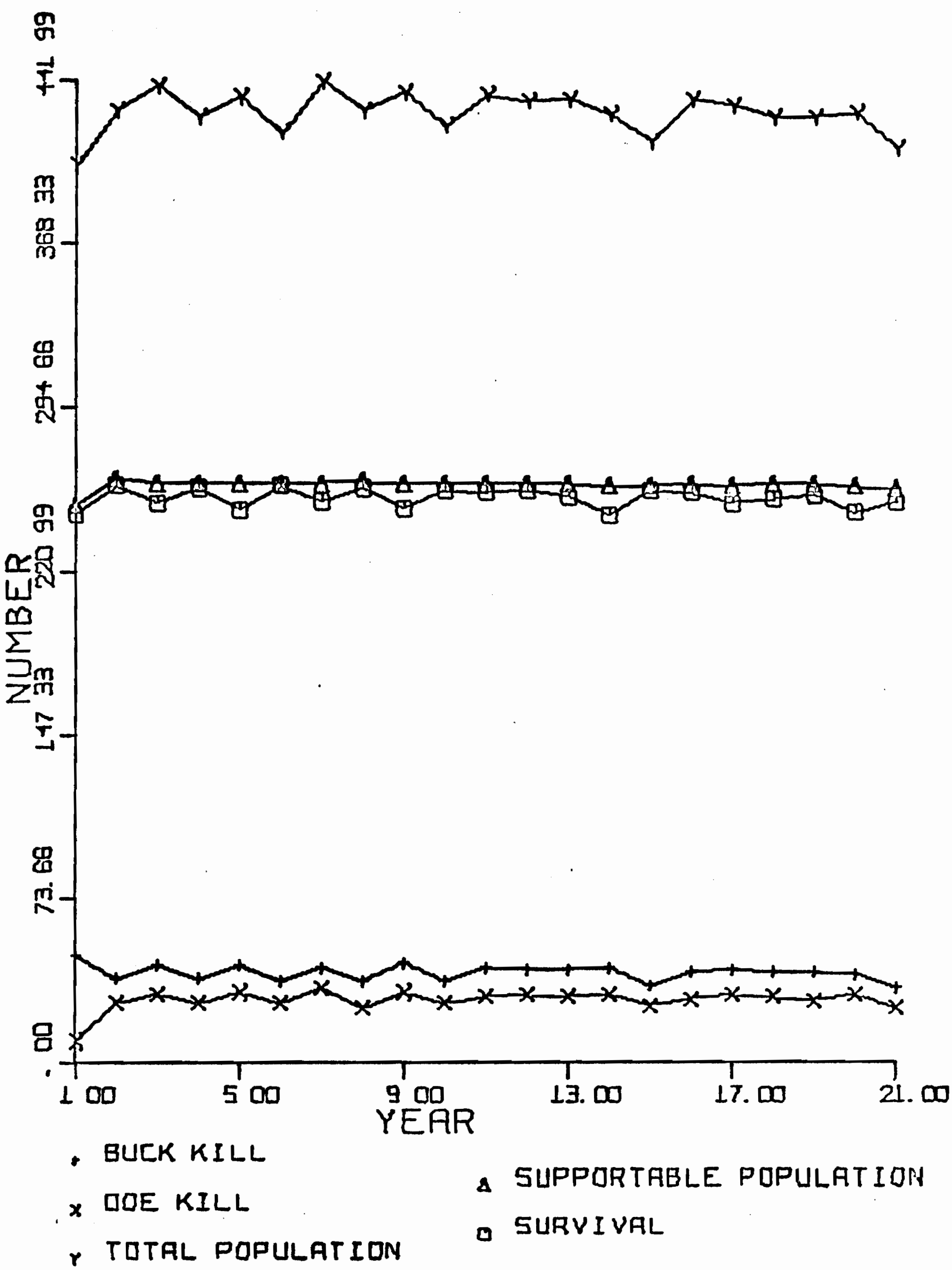

Fig. 7. Computer plot of a 21 year simulation

Long-term Stability

In order to obtain an algorithm for achieving long-term stability, Quick's method (1963) was employed. With this method a sex ratio of 66 bucks per 100 does is usually maintained. This sex ratio results when natality (fawns per doe) is approximately 1.13 and the mean life expectancy of the does in age class 1 is 1.83.

When a different sex ratio was achieved, the population would also stabilize but the number of harvestable deer would change. If the proportion of does was increased (as by a buck season) the harvest would increase. The converse is also true. These simulation results are shown in Table 4. Sex ratio seems to have very little influence over population stability as long as it is managed to be constant. The sex ratio, however, affects the expected harvest and management practices. By changing the proportion of does, there is a trade-off between the number of antlered (trophy) deer harvested and the total harvest (column 5 of Table 4). Long-term stability can be achieved if a desired sex ratio is chosen and all management practices are oriented toward achieving that sex ratio.

As can be seen in Table 4 (column 5) the ratio of antlered to antlerless deer harvested for a given proportion doe changes with the level of reproduction. The results in Table 4 were obtained by assuming that 50% of the fawns were buck. When the fawns are added to the population the result is a change in the sex ratio of the population from the desired proportion doe (except where the desired proportion doe equals 0.50). An increase in reproduction increases the ability

Table 4. Management plans to achieve a desired proportion of doe with varying levels of reproduction

Natality or young per female	Proportion doe	Antlered kill	Antler-less kill	Ratio of antlered to antlerless	Total kill
High $\simeq 1.6$	0.65	55	62	0.89	117
	0.60	46	57	0.81	103
	0.55	37	51	0.73	88
	0.50	29	45	0.64	74
	0.45	21	41	0.51	62
	0.40	16	39	0.41	55
	0.35	10	35	0.29	45
Medium $\simeq 1.1$	0.65	42	43	0.98	85
	0.60	35	34	1.03	69
	0.55	29	35	0.83	64
	0.50	24	35	0.69	59
	0.45	17	32	0.53	49
	0.40	10	26	0.38	36
	0.35	4	24	0.17	28
Low $\simeq 0.6$	0.65	30	24	1.25	54
	0.60	23	23	1.00	46
	0.55	19	20	0.95	39
	0.50	13	17	0.76	30
	0.45	8	14	0.57	22
	0.40	3	12	0.25	15
	0.35	0	8	0.00	8

of the fawns to influence the sex ratio of the population and therefore influences the planned harvest strategies to maintain the desired proportion of doe. When a proportion of doe greater than 0.50 is desired, the ratio of the antlered to the antlerless deer harvested decreases with an increase in reproduction. For a desired proportion of doe that is less than or equal to 0.50, the ratio of the antlered to the antlerless harvest in the management plan increases with an increase in reproduction. Therefore when attempting to set harvest regulations to achieve a desired proportion of doe (i.e. achieve a stable population), the reproductive attainment of the population is critical.

The matter of choosing the desired sex ratio should be determined by the manager based on the objectives of his system. Quick's method is one approach. Another approach would be to determine what sex ratio will best achieve the management objectives by use of a simulation.

Long-range Management Plan

A long-range management plan is developed by DEER under the alternatives specified in the input data. When the management plan is applied through simulation to the population being considered, the population will stabilize over the long run. The population resulting when a management plan is applied is shown in Fig. 8. For example, if a desired sex ratio is specified, the management plan produced by DEER will achieve this desired sex ratio in the population described. The management plan determined by DEER is applicable only if the conditions used in the simulation are maintained in the deer herd.

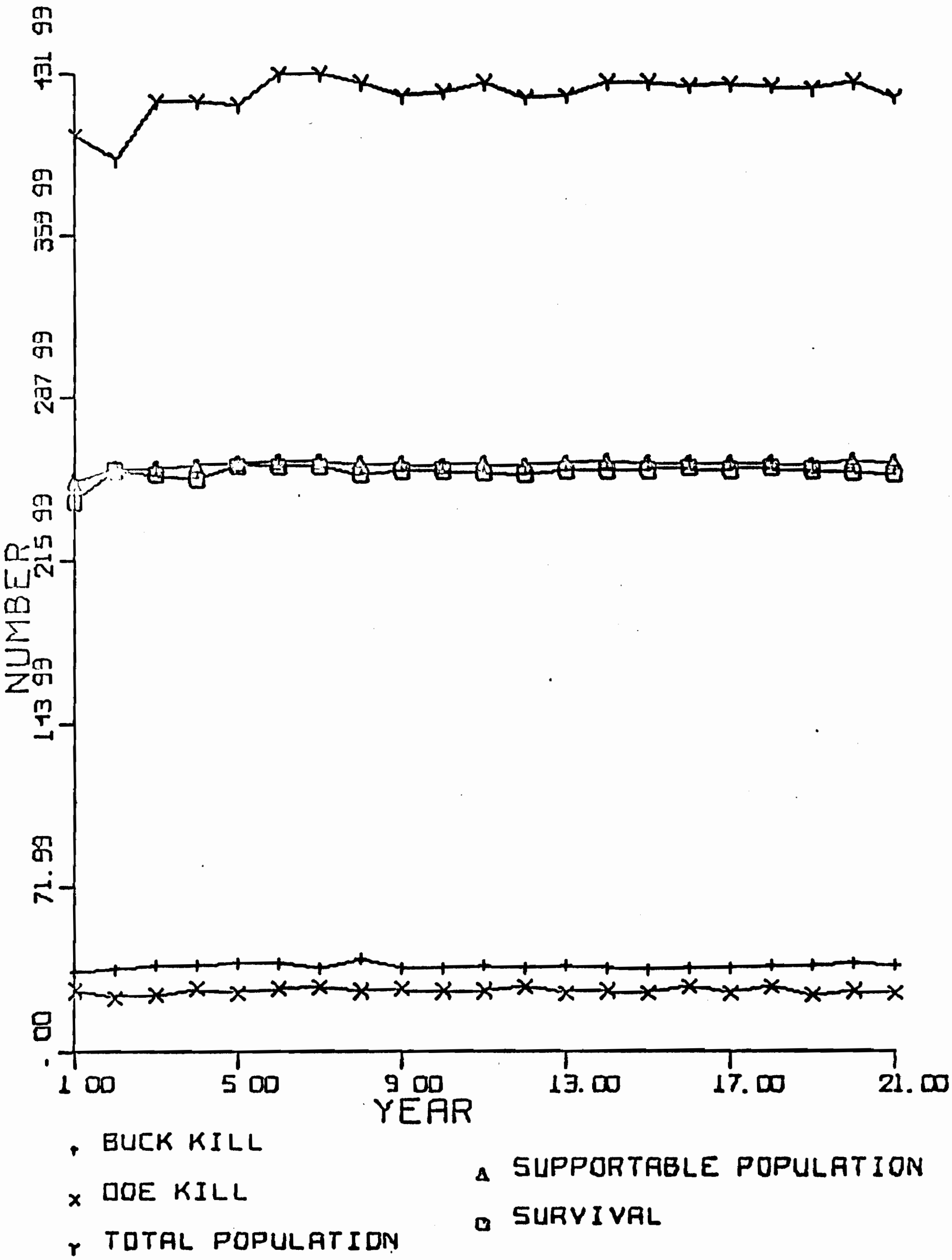

Fig. 8. Results of applying a management plan to a specified population

Sensitivity Analysis

A stable population was developed with a management plan (Fig. 8) and a sensitivity analysis was conducted for the following variables:

a) proportion of doe fawns breeding successfully,
b) proportion of adult does breeding successfully,
c) poaching losses,
d) crippling losses,
e) natality of doe fawns,
f) antlered harvest,
g) antlerless harvest.

Proportion of Doe Fawns Breeding Successfully

A stable situation was developed specifying that 30 per cent of the doe fawns were producing a single fawn each. When the proportion of fawns reproducing was decreased to 20 per cent or increased to 40 per cent there was no significant (0.05 level of significance) change in the population stability. Changes greater than 10 per cent were not studied.

Proportion of Adult Does Breeding Successfully

A stable situation was developed specifying that 95 per cent of the adult does reproduced successfully. When the adult does reproducing successfully was decreased to 85 per cent or increased to 100 per cent, there was an insignificant (0.05 level of significance) change in stability. Decreases greater than 10 per cent were not studied.

Poaching Losses

A stable population was developed when 7 per cent of the population was lost to poaching. When poaching losses were decreased to 4 per cent or increased to 10 per cent of the population there was no significant

(0.05 level of significance) change in population stability. Increases or decreases greater than 3 per cent were not studied.

Crippling Losses

With crippling loss set as 30 per cent of the harvest, a stable population was developed. When the crippling losses were decreased to 27 per cent or increased to 33 per cent of the harvest, the result was a non-significant (0.05 level of significance) change in stability. Decreases or increases greater than 3 per cent were not studied.

Natality of Doe Fawns

The population was stabilized assuming that each fawn doe reproducing was able to produce a single fawn. When the number of young per fawn doe breeding was decreased to 0.50 or increased to 1.50, there was no significant (0.05 level of significance) change in the population stability. Decreases or increases greater than 0.50 in the number of young per fawn doe breeding were not studied.

Antlered Harvest

The population was stabilized with an antlered harvest of 8 per cent of the population. When the antlered harvest was decreased to 5 per cent of the population there was a non-significant (0.05 level of significance) change in population stability. When the antlered harvest was increased to 11 per cent of the population, there was a significant (0.01 level of significance) change in stability. The change in the harvest strategy resulted in a change in the sex ratio (increase in proportion doe) resulting in an increase in the allowable harvest. The population increased for approximately 8 years and leveled off afterwards (Fig. 9).

Antlerless Harvest

A stable population was developed when the antlerless harvest was set at 8 per cent of the population. When the antlerless harvest was decreased to 5 per cent of the population, there was a non-significant (0.05 level of significance) change in population stability. When the antlerless harvest was increased to 11 per cent of the population the result was a drastic decline in the population (Fig. 10). The change in the antlerless harvest resulted in a change in the sex ratio (decrease in the proportion of the population that is doe). As a result of the change in sex ratio, the reproduction decreased. The decreased reproduction and the increase in harvest resulted in the population decline.

The deer population system described herein is more sensitive to the antlerless harvest than to the other variables considered.

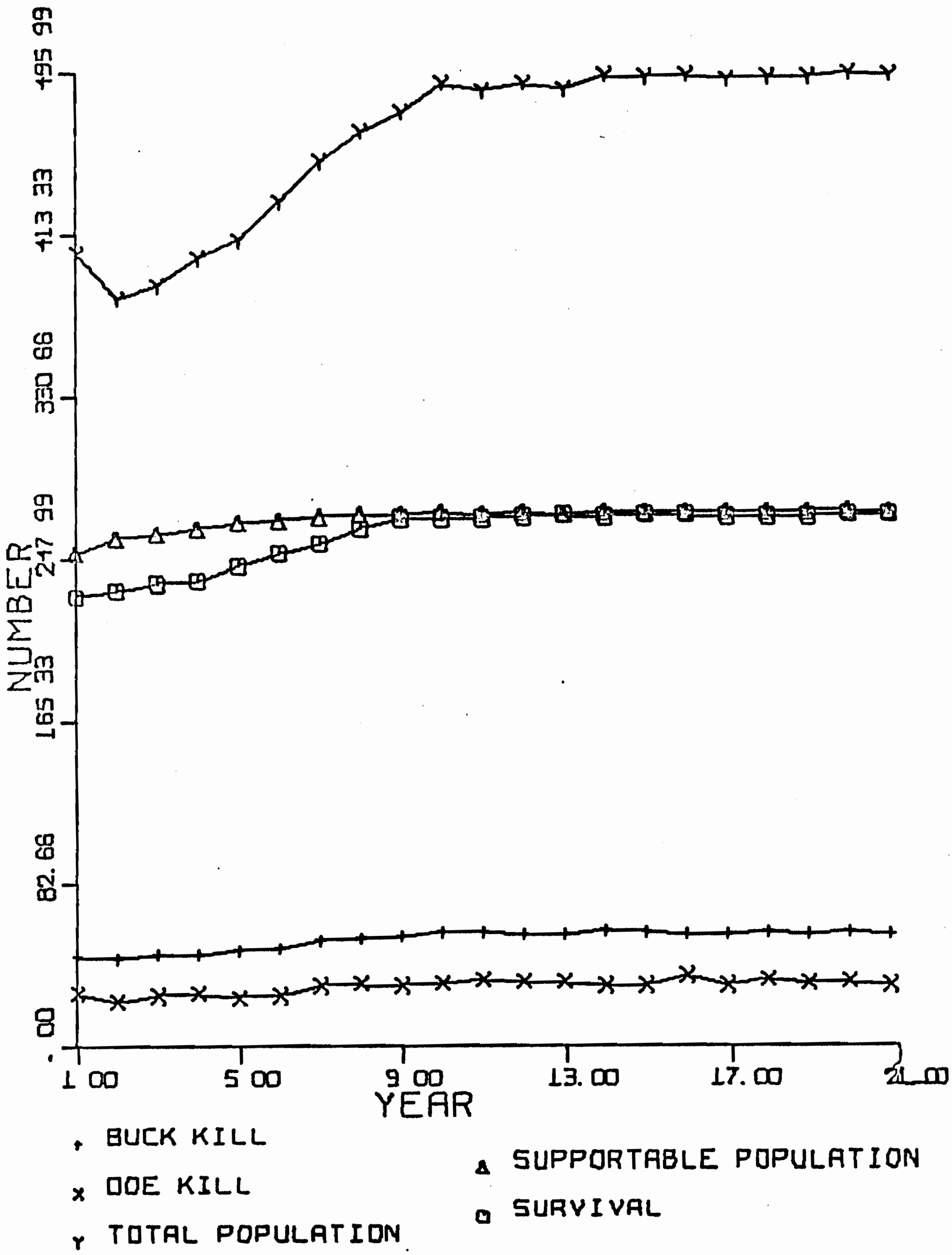

Fig. 9. The population resulting when the antlered harvest is increased in a stable population

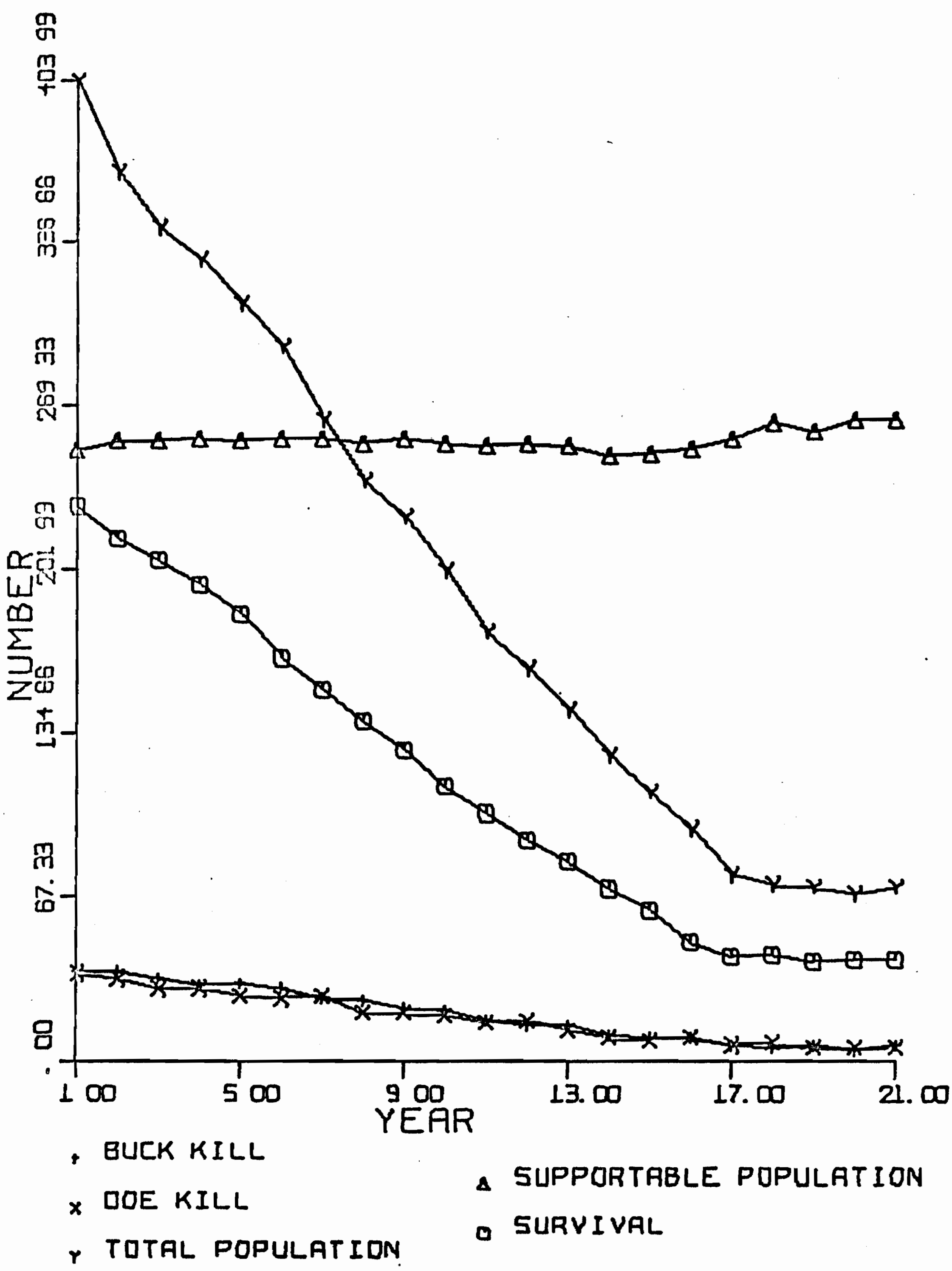

Fig. 10. The population resulting when the antlerless harvest is increased in a stable population

DISCUSSION

Learning from Simulation

One not only obtains knowledge by use of simulation but he also obtains an understanding of a system when he attempts to model the system for a simulation study. In my search of the literature for information to develop a model of a deer population, an understanding of the complexity of a deer population became evident. There has been a great deal of information reported on the white-tailed deer but there are still many missing elements in knowledge of a year of a deer herd's life.

Once the model was developed and simulations made, the relative importance of different processes became apparent. The proportion of the doe fawns that reproduce is very important in determining the allowable harvest. The simulation indicates that when the fawns reproduction is high, the harvestable surplus is high; when fawn reproduction is low the harvest is likely to be poor. Another critical process was poaching or illegal kill. If poaching and illegal kill could be controlled, the result could be: longer hunting seasons, larger harvest, and a more even distribution of the wildlife resource (deer) for the public. Poaching varies in degree from locality to locality and law enforcement techniques are often used to combat this problem. Another approach to combating poaching would be to acquaint the public with the serious consequences of poaching and the benefits to be shared by reducing poaching. This approach may not change the attitude or activity of the poacher but could encourage the non-poachers to aid (e.g. telephone tips) in apprehending poachers. The incentive of the non-poachers would be to obtain a fairer share of the deer resource.

Different Models and Simulation Results

Models developed to be used in deer simulation studies differ in many aspects. They differ in data requirements, natural mortality, reproduction, and various other processes that are displayed by a deer population. Even though models may differ in their methods of describing population processes, the results obtained from different simulators should be the same.

Simulators differ because of the data available in the construction of the model, the emphasis that is placed upon the design of the system, the interest of the person constructing the model and the questions to be answered by use of the simulation. Even though deer population simulators may differ in details, they are all descriptions of the processes acting in a deer population.

Simulators also may differ in the type of output presented. When the results are transformed into the number of fawns produced and the number of deer dying, simulator results can be compared. If simulators effectively describe the processes in a deer herd, the results should be the same if compared using these two criteria.

The author is not suggesting that a single model of a deer population be used in simulation studies. Simulators are systems that process information and produce results that can be used in decision making and problem solving. Some simulators are constructed to aid in the solution of a single problem. Some have a more general design. The more general the design of the simulator, the more questions it attempts to answer.

Removing Deer from Each Age and Sex Class

How are the different age-and sex-classes represented in (a) natural mortality during the summer or winter, in (b) the number of deer lost due to illegal kill or poaching, and in (c) the harvest? Data on these questions were not found in my literature search. A major improvement in the simulation would result if these questions could be answered. It is sometimes assumed, especially in the construction of life tables from harvest data, that the proportion of the harvest in a given age and sex class is equal to these proportions in the population. There are few data to either substantiate or discredit this assumption. DEER has a means of challenging this assumption by employing alternative means of representing each age and sex class in the harvest. No assumptions or suggestions are made as to how each age and sex class is represented in natural mortality, crippling losses, or poaching losses. DEER provides a means of experimenting with these aspects of the population.

Harvest Techniques

There are various harvest strategies which are possible in deer management. In the author's opinion, the management plan for an established deer herd has to include the harvest of both bucks and does in order to stabilize the herd.

There is no general rule of thumb that can be used in setting harvest regulations to stabilize a population. The harvest should contain both antlered and antlerless deer but the ratio of the antlered to the antlerless deer in the harvest is unique for the conditions existing in a population. With a reproduction of 1.1 young per doe and a 50:50 sex ratio in the fawns, the simulator produced favorable results when the ratio of the antlered to the antlerless deer in the harvest equaled 1. With this type of harvest, the population was stabilized with 60 per cent of the population as female.

Ratio of Antlered to Antlerless Harvest

Some game agencies often have the practice of setting harvest regulations so that the ratio of the antlered to the antlerless deer harvested equals some predetermined value. Some agencies think that setting the ratio equal to 1 is a method of conservatively setting the harvest. Basically, game agencies seek to establish harvest regulations which will, hopefully, stabilize the harvest. The regulation produces a particular sex ratio but one which varies as a function of natality, sex ratio of the fawns, and for a few years the sex ratio of the population before the regulations were imposed.

For example, Table 4 shows the desired proportion of does and the ratio of the antlered to antlerless deer to be harvested to stabilize the population. When the sex ratio of the fawns equals 50:50 and the harvest regulations are set so that the ratio of antlered to antlerless deer equals 1 the following situations result:

a) where the young per doe ratio (r_j) is approximately 1.6 (Table 4. High) the proportion of does that would result is greater than 0.65;

b) with a r_j ratio of 0.6 young per doe (Table 4. Low) and 1.1 young per doe (Table 4. Medium), the proportion of does that would result is approximately 0.60.

The resulting populations are distinctly different and would not achieve the same objectives equally. Therefore, setting harvest regulations for a population by using a constant ratio of antlered to antlerless deer can only be done by entering natality, the sex ratio of the fawns, and sex ratio existing before the regulations are imposed into the calculations. Therefore, the same harvest regulation should not be applied to all populations because the regulation will not achieve the same objective in different populations.

Summer Forage Limiting

The general concensus is that the availability of winter forage is the limiting factor in deer population size. This may be true in the majority of deer herds but the summer forage can also be a limiting factor. If the population after reproduction cannot be supported by the summer forage, the number of deer that can survive until winter to reproduce will be reduced. In this manner, the summer forage can limit the size of the deer herd. The simulator can now be used to study this phenomenon.

Application of Simulation Results

Many wildlife managers look upon simulation as simply an educational game. They do not use simulation enough to see its practical application.

Deer managers realize that management practices should vary responsive to varying populations, habitat, and human demands. In the past, deer biologists rarely had the time or manpower to make the many complex computations for individual populations. They are thus usually forced to apply a general rule of thumb in determining management strategies. With this approach to management, the full potential of the deer resource is not likely to be achieved.

With the advent of the computer, the problems of time and manpower required in calculating the consequences of many management alternatives for herds are alleviated. Simulation can be used to determine how modeled populations react under various harvest strategies. Simulations are not optimization systems, but they can provide major inputs for the mental optimization of the manager working with ill-defined objectives, sparce data, and the uncertainties of seasonal climate. By using the simulator, a greater resource potential can be achieved.

SUMMARY AND CONCLUSIONS

Using data reported in the literature, DEER, a deer population simulator, was developed that can be used to conduct population studies in either a discrete or stochastic mode. The simulator is a FORTRAN IV computer program requiring at least 56 units of input to describe the habitat, the deer population and the type of harvest desired. Employing the input, the simulator provides the user with anternatives which will result in a management plan that can be used to stabilize the population under stated conditions.

A sensitivity analysis of DEER was performed testing the following variables: the proportion of the fawn does reproducing, the proportion of the adult does reproducing, the natality of the fawn does, the poaching losses, the crippling losses, the antlered harvest, and the antlerless harvest. The system demonstrated that the populations studied were sensitive to an increase in the antlerless harvest. Therefore, great care should be taken in setting the antlerless season to control the population.

Quick's method was employed to determine a proportion of does that would produce long-term stability in the population. As a result of experimenting with sex ratio, it was determined that any sex ratio could be used to stabilize a population. An increase in the proportion of does resulted in an increase in the number of deer harvested but a decrease in the number of trophy deer harvested. The opposite is also true. The sex ratio chosen to stabilize a population should be based on management objectives.

DEER is a fully operational system that can be used to simulate any deer population and determine a management plan that can be used to conduct experiments with the population dynamics of a deer herd.

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APPENDIX

SAMPLE OF INPUT DATA FOR DEER

COL 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 CARD

											CARD
0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	1
53.35	92.6	92.6	92.6	92.6	92.6	92.6	92.6	92.6	92.6	92.6	2
64.13	121.6	121.6	121.6	121.6	121.6	121.6	121.6	121.6	121.6	121.6	3
0.41	0.36	0.16	0.03	0.01	0.00	0.01	0.01	0.00	0.01	0.00	4
1.00	1.75	1.75	2.00	1.50	1.25	1.00	1.00	1.00	1.00	1.00	5
0.50	1.50	1.50	1.75	1.25	1.00	1.00	1.00	1.00	1.00	1.00	6
0.00	1.00	1.25	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7
0.60	0.30	0.05	0.05								8
0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9
0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0	1.00	12
1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	13
1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	14
3.00	1.00	0.20									15
3.00	1.00	0.20									16
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	17
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1. 0	18
0.075	0.075										19
											20
0.30	0.30										21
											22
1.30	1.30										23
0.70	0.70										24

(INPUT DATA CONTINUED)

COL 1–5	COL 6–10	COL 11–15	COL 20–75	CARD
0.40		0.40		25
0.50		0.50		26
0.02		0.02		27
0.05		0.05		28
0.05		0.05		29
0.15		0.15		30
				31
0.29		0.29		32
0.04		0.04		33
				34
0.99		0.99		35
0.93		0.93		36
0.83		0.83		37
				38
				39
				40
				41
				42
1.00		1.00		43
1.00		1.00		44
0.081		0.081		45
0.081		0.081		46
3				47
100.0				48

(INPUT DATA CONTINUED)

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
                                                                           C
                                                                           A
COL 5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   R
    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    D
------------------------------------------------------------------------------
                                                                          49
 3                                                                        50
22                                                                        51
                  0.11    0.21                                            52
                  0.06    0.15                                            53
 3                                                                        54
  1000.    120.    80.                                                    55
  1000.    120.    80.                                                    56
  1000.    120.    80.                                                    57
------------------------------------------------------------------------------
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VITA

Mack Leslie Walls, son of Mr. and Mrs. Glinford E. Walls, was born in Saltville, Virginia, on September 8, 1950. From 1968 to 1972, he attended Virginia Polytechnic Institute and State University. He was awarded a Bachelor of Science Degree in Forestry (Wildlife option).

In the summer of 1972, he married Nerissa Coleen Hogston also a graduate of Virginia Polytechnic Institute and State University.

Mack L. Walls entered the graduate school on a teaching and research assistantship at Virginia Polytechnic Institute and State University in June, 1972. While on an assistantship, he had the opportunity of teaching laboratories in Forest Photogrammetry and Forest Mensuration.

The author is currently a member of the Wildlife Society, Zi Sigma Phi and Phi Kappa Phi. Upon receiving his B.S. degree, the author was recognized as the member of Phi Kappa Phi with the highest quality credit average in the College of Agriculture.

Mack L. Walls

A DYNAMIC WHITE-TAILED DEER POPULATION SIMULATOR

AND

LESSONS FROM ITS USE

by

Mack L. Walls

(ABSTRACT)

From data and concepts in the literature, DEER, a FORTRAN IV program that operates on an IBM 370/65 computer, was written. The general purpose population simulator was designed for managers of white-tailed deer (Odocoileus virginianus). It is based on a dynamic age and sex specific algorithm, unifying bioenergetic, sociological, hunter, and population characteristics.

The system determines a management plan that will stabilize a population under the conditions specified. The system is also designed to be used for examining deer populations and for educating students of wildlife ecology and management.

The concept that achieving a constant sex ratio can be used to stabilize a population was explored. The results indicate that a population will stabilize with any sex ratio when all management activities are oriented toward achieving such a sex ratio. An increase

in the proportion of doe deer in the herd results in an increase in the allowable harvest but causes a decrease in the ratio of the antlered(trophy)-to-antlerless deer changes with a population natality change. A static management strategy (e.g. to achieve a constant ratio of antlered-to-antlerless deer) results in unstable (and probably suboptimal) harvest when the reproductive rate, adult sex ratio, and fawn sex ratios are dynamic. DEER is a decision aid useful for replacing rule-of-thumb management.