CONSTRUCTING SIMPLE POPULATION MODELS FOR MOOSE MANAGEMENT

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ABSTRACT: Modeling offers a way to predict population changes and review harvest strategies for moose (*Alces alces*). Here, I review the usefulness of population modeling to moose management and provide an example of how a simple population model can be constructed using spreadsheet software on a microcomputer. I give an example of the potential application of such a model using population data from the Kenai Peninsula, Alaska. Modeling was used to predict the changes in bull harvest, bull:cow ratios, and other population parameters resulting from a change in hunting regulations. The model successfully predicted the effects of a spike-fork harvest strategy. This information was useful in alerting the hunting public to expected changes in hunting success and allowed managers to predict how selective harvest would impact bull:cow ratios. It was also useful in predicting the impact of a severe winter on subsequent harvest.

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The challenge of wise moose management is the same today as it has always been: the long-term maintenance of a valuable renewable resource. In today's complex world, the diverse and ever increasing demands for the moose resource make our task as managers more difficult. Population modeling offers an appropriate way to organize complex information and evaluate management strategies.

According to Webster's 1989 dictionary, "model" is defined as "a mathematical representation of facts, factors, and inferences of an entity or situation". We use models to help us organize data, identify weak or missing information, and formulate hypotheses about biological processes. We do this by developing a framework of quantitative information which allows us to better understand complex processes, make biological predictions, detect flaws in our data base and assumptions, and finally qualify our decisions.

Models can range from simple words to complex mathematical functions, and there is often little relationship between their complexity and reality. The objective of modeling is to develop a useful approximation which includes only the most important facts that correctly interact with one another. Even with this goal, however, no one can deny that the procedure often piles one assumption upon another, inevitably leading to mistakes, even large ones. Models are merely the means to an end. They represent formalized ways of guiding adaptive management of natural resources (Thomas 1986). Models are not meant to replicate the complexity of nature, but to capture the essence of a phenomenon (Krebs 1980). Starfield and Blelock (1986) provides an excellent treatment of the subject of building models for wildlife management.

There are many different types of models available to the moose manager (Page 1987). In a broad sense, we can classify models into (1) single species, (2) multiple-species or community, and (3) habitat-analysis. Single species models often evaluate the response of one dependent and one independent variable. Such models are useful in understanding the effect of one variable upon another (i.e., age at first breeding and twinning in adults). These models are usually deterministic (one outcome) and do not consider normal population stochasticity (variable outcome). Examples of single species models include POPII (Fossil Creek Software, Fort Collins, Co.), habitat suitability index (HSI) (Allen *et al.* 1987, 1988, 1991), and the moose model presented here (Schwartz *et al.* 1992). Examples of multiple species models include community guild models and predator-prey models (Ballard *et al.* 1986, Ballard 1992). Several habitat-analysis models have been used in moose management and include a habitat carrying capacity model (Regelin *et al.* 1987) and habitat evaluation programs (HEP) (Shea 1981).

A number of studies have used various population models for moose. Perhaps the first to attempt to model moose populations was Bubenik et al. (1975) using an old analog simulator in a novel yet informative approach. Both Vanballenberghe (1980), Vanballenberghe and Dart (1982), Ballard *et al.* (1986), and Ballard (1992) used population modeling to evaluate the potential impacts of wolf and/ or bear predation on moose population dynamics. Boer (1988), Heydon (1992), Balciauskas (1992), and Schwartz *et al.* (1992) used population modeling as of means of assessing harvest yields from various populations. Regelin *et al.* (1987), Parsons (1987), Allen *et al.* (1988, 1991), and Jandt (1992) have used modeling to evaluate the habitats of moose, and Bubenik *et al.* (1992) developed a model to evaluate the sociobiological variables of moose management. I do not intend to review in detail all of these studies, but do feel it is important to mention them in general review.

Here I would like to concentrate on a single species model. Although there are existing models available, often managers find that the form of their data does not match the required inputs. In such cases, it may be necessary to develop a working model that suits the existing data base. Unless one knows programming language, model development may be difficult or impossible. However, using standardized computer software can make the task much easier.

The population model used for evaluating the impact of spike-fork harvest on the Kenai Peninsula was developed using Lotus 123 (Lotus Development Corp., Cambridge, MA.), one of the popular spreadsheet software packages. The model projected population size and change, bull:cow ratios, calf:cow ratios, and harvest for a 30 year period. It was structured to consider 20 age classes (calves, yearlings, and adults 3-18), both sexes, and 3 time periods within a year (birth to autumn, hunting season, and post-hunting through the next birth period, or winter). Inputs into the model were survival coefficients for each age class by sex by time period, and reproductive output for adult females. I chose to use survival coefficients because I had good information on neonatal predation, estimates of hunting mortality, and natural survival of adults.

Spreadsheet software provides a working environment with a grid made up of horizontal rows and vertical columns. Cells are units of the worksheet where data are stored. Each cell has a unique address that consists of a specific column (usually identified with a letter) and row (identified with a number). For example, in the most basic model we can put the number of animals alive at the start of a time period in cell A1. In cell A2, we can put the survival value for that time period, and cell A3 would contain the product of A1 and A2 (Fig. 1). For example, we may have 1000 calves born during the calving season with a 55% survival rate during the summer (45% lost to predation). Consequently, the number of calves alive at the start of the hunting season would be 550, or the product of 1000 X 0.55.

In the model here, I considered 3 time periods, so it is necessary to continue the process further (Fig. 2) and calculate the number of animals alive after the remaining 2 time periods. In the example above, I calculated the number of calves surviving the sum-

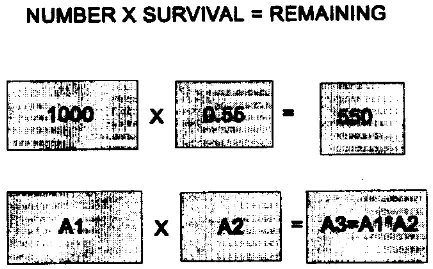

Fig. 1. The basic layout for developing a spreadsheet population model. Information on animal numbers is stored in one cell and a survival coefficient in another. By multiplying the contents of the two cells, the number of animals surviving is calculated.

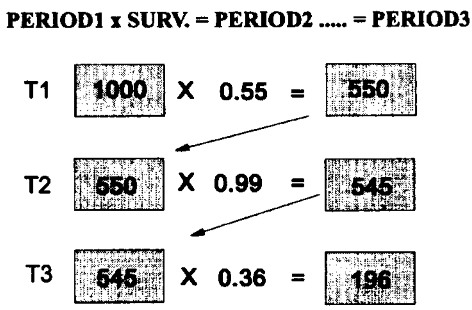

Fig. 2. The basic layout is expanded to include several time periods within a single year. Here three time periods are considered. Time T1 represents birth through the summer, T2 the hunting season, and T3, post-hunting through winter. For each time period there is a separate survival coefficient. The number of animals surviving each period is the product of the number starting each time period and the specific survival coefficient.

mer period. Including the other time periods, I must determine how many calves survive the hunting season (Time period 2) and winter (Time period 3). Consequently, the model predicts that if I start the season with 1000 calves, 196 yearlings will recruit the following year (Fig. 2), assuming 99% survive the hunting season, and 36% survive the winter. Consequently, 196 yearlings recruited into the yearling age class in year 2; this value is copied into that cell (Fig. 3). I treat each age class in a similar fashion, applying survival estimates for the three time periods. The number of adults starting the year is calculated as the number of yearlings recruited plus the number of adults surviving the previous winter (948 + 116 = 1064) (Fig. 3). Once the first year is established, the process is repeated for the number of simulation years (i.e., 30 in our example). Copy commands are used to repeat the process (Fig. 4). The number of time periods, age classes, or other variables can be tailored to fit your existing data base.

The number of calves entering the

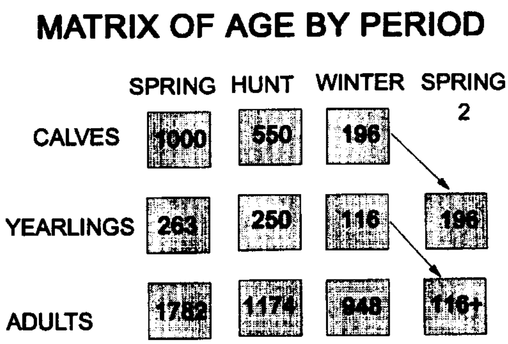

Fig. 3. The basic layout is expanded to include multiple age classes of animals and 3 time periods within a year. Survival coefficients are stored in a separate address within the spread sheet. At the end of each year, those individuals surviving are moved down into the next older age class to start the next year.

populations is calculated by multiplying the number of adult females surviving the winter by the average calf production per female and the sex ratio at birth. For example, if average calf production is 1.1 calves per female, with a 50:50 sex ratio at birth, there would be 585 female calves produced from the 1064 adult cows (1064 X 1.1 X 0.5)(Fig. 5). This reproduction is then copied to the calf cell at the start of the year and the process of calculating survival repeats. If reproductive parameters are known for yearlings, prime age cows, and

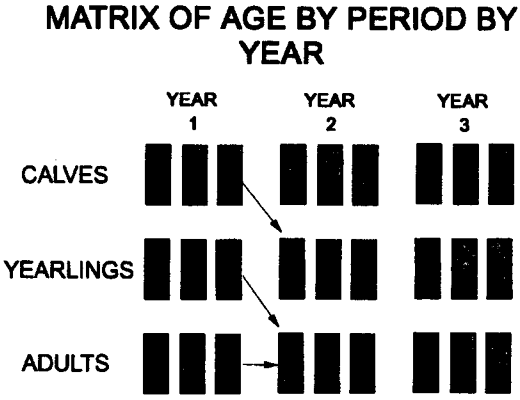

Fig. 4. The basic layout of the model is expanded to include multiple age classes, 3 time periods per year, and multiple years. Survival coefficients are stored in a separate address within the spread sheet. This basic layout can be expanded to include any number of age classes, time periods, or years.

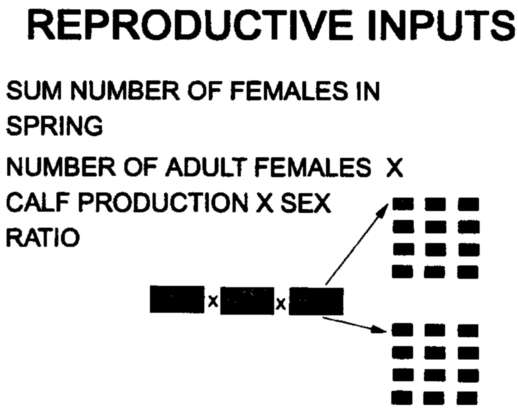

Fig.5. The number of new calves entering the population is calculated at the start of each spring period. This is accomplished by combining the numbers of adult females within each age class, and multiplying this value by a reproductive coefficient (calves/female/year) and the sex ratio of the offspring.

old cows, it is appropriate to track these age classes independently if different production rates apply to each.

Since this model was used to monitor survival of a population where only bulls were hunted, I kept track of bull and cow numbers in 2 separate matrices within the spreadsheet. Likewise, since I treated survival separately for the two sexes, different matrices were used for males and females. Consequently, there were four areas within the spreadsheet where input data (male and female survival estimates) and the calculated population (male and female numbers) (Fig. 6) resided.

For the experienced spreadsheet user, these population models can be made very user friendly with the aid of macros. Macros are similar to batch processing used by programmers. A series of commands is submitted as a unit and the computer acts on the commands in sequence. Macros help automate the spreadsheet and can be used to develop menus, graphics, and data printouts.

Initial population structure to run the model was obtained from autumn composition surveys conducted in November and December (Schwartz *et al.* 1992). These included post-hunt population size, bull:cow ratio, and the percent calves in the population. I distributed the number of individuals within

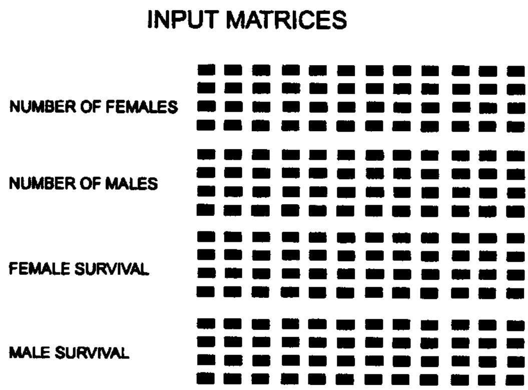

Fig. 6. As more and more information is added to the model, it becomes more complex and difficult to manage. Separate matrices should be maintained for tracking both animal numbers and survival coefficients. It is also important to track sexes separately, since mortality will vary with type of harvest strategy, and because reproductive input is based on the number of adult females. One obvious limit of such a model is that females will continue to reproduce in the absence of males.

the various age classes with fewer animals in the older cohorts. To develop a stable age structure based upon the estimates of survival (input data) I ran the model for one generation (ie., in this example 20 years). By doing this, animal numbers stabilized within each age class. This age distribution was then copied to year one of the model and used as the starting population. Unless you have very good estimates of population structure, this is an easy way to develop one. This process also allowed me to fine tune the model, evaluate the estimates of survival, and determine if the population trajectories were stable, increasing, or declining.

The initial age structure is important during the first 10 or so years of a simulation. Within any population it is often difficult if not impossible to determine the exact age structure, much less if this age structure is stable. The dilemma is that if you do not start with a stable age structure, what do you do instead. I have no general answer to this thorny problem, other than to suggest that if you have some reason to doubt that the age structure is stable, then the particular reason should give you a clue as to what to do. In the situation illustrated here, I had no good reason to start with anything but a stable age structure, so that is what I did.

For illustration of how the model was used for making assessments for population management, I would like to use the Kenai Peninsula, Alaska moose population. During the late 1970's and early 1980's, heavy hunting pressure and an any bull season resulted in post-hunt bull:cow ratios as low as 5 to 12 bulls:100 cows (Schwartz *et al.* 1992). Concern for the population sex ratios and continued hunting opportunity, coupled with the desire to view more bull moose prompted the Alaska Board of Game to institute a selective harvest system (SHS) in 1987. Under SHS, the only legal bull was a spike-fork moose (yearling) or a bull with antlers greater or equal to 50 inches (127 cm). The Board's objectives of SHS were to: (1) increase the bull:cow ratio, (2) increase the number of prime bulls in the population, (3) increase the opportunity to view bull moose, (4) maintain hunting opportunity, and (5) promote hunter ethics.

The initial population structure used for the Kenai Peninsula, had 3,450 moose, a bull:cow ratio of 12:100, 26% calves, low male survival, high adult cow survival, 1.2 calves produced per cow > age 2, and a population declining at about 1% per year (Schwartz *et al.* 1992). Survival estimates were adjusted until these population parameters were met. Because we had reasonable estimates for most inputs, only slight changes were necessary to develop a population structure which seemed reasonable.

Once a stable population was developed, the next objective was to implement the SHS season for the modeled population. I did this in year 10, by adjusting the survival coefficient for males during the hunting season (Schwartz *et al.* 1992) to approximate the change we anticipated in bull mortality. Based upon check station data collected during the general hunting season, we estimated that about 50% of the yearling males were spike-fork and legal for harvest under SHS, whereas the other 50% were not legal because their antler architecture was greater than spike-fork. We also assumed that virtually all of the 2, 3, and 4 year-old bulls would not be legal under SHS, and increased their survival accordingly (Schwartz *et al.* 1992). Survival was reduced for bulls ages ≥ 5 since many would be ≥ 50 inches and legal for harvest under SHS. For details, see Schwartz *et al.* (1992).

By changing survival of males during and after year 10 in the simulation model (Table 1), I projected that the bull harvest would decline the first year by 43% under SHS; the actual decline was 48%. Projected changes in the bull:cow ratio 5 years following implementation of SHS were projected to increase

Table 1. Projected vs. actual results under a selective harvest system (SHS). Harvest was the projected decline the first year after SHS, whereas severe winter was the decline in harvest the year following a severe winter with low recruitment. The projected increase represents the change in harvest 2 years after the severe winter, whereas the projected bull:cow ratio prediction was 5 years after initiation of SHS

	MODEL PROJECTIONS	ACTUAL RESULTS
HARVEST	-43%	-48%
SEVERE WINTER	-63%	-68%
PROJECTED INCREASE	+96%	+87%
BULL:COW RATIO	30:100	27:100

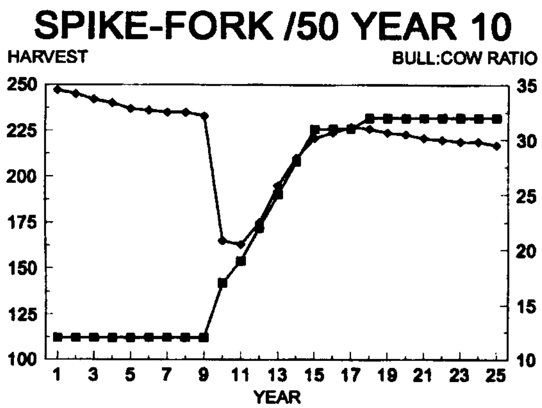

Fig. 7. Projected harvest in number of bulls (diamonds) and bull:cow ratio (squares) following implementation of a selective harvest system in year 10.

from 12 to 30 bulls:100 cows. The actual ratio was 27:100 (Fig. 7).

The long-term projected changes deviated from actual changes in later years because there was a very severe winter in 1989-90 which was not considered in the model. I had no way of knowing if or when such an event may occur. To determine if my projected changes would improve by modeling the severe winter, I re-ran the model and reduced the survival rates of both calves and adults during winter 89-90 (year 13, Fig. 8). For example, during severe winters on the Kenai Peninsula, it is not unusual for >90% of all calves to die of starvation, resulting in virtually no recruitment of yearlings the next fall, which dramatically reduces the harvest of spike-fork bulls. Details can be found in Schwartz *et al.* (1992).

Using the model, I projected the effects of this severe winter would result in a reduced bull harvest of 63%. The actual decline was 68% (Table 1). I also projected that harvest would increase the second year following the severe winter by 96%. The actual increase was only 87% (Table 1). I overestimated projected returns because I did not consider the latent effects of the severe winter on subsequent calf production or survival for winter-stressed pregnant cows.

This population modeling process allowed staff of the Alaska Department of Fish and Game (ADF&G) to make use of an existing data base, develop a population model that accurately simulated the real population, adjust bull survival, and make projections about

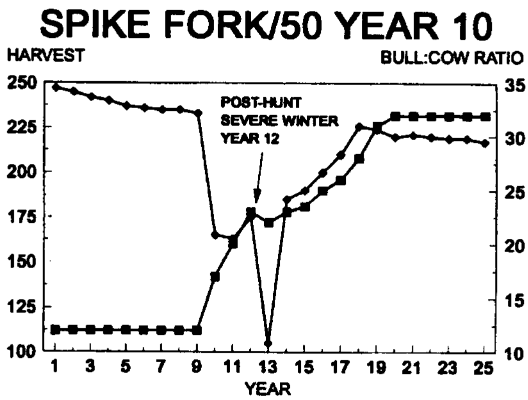

Fig. 8. Projected harvest in number of bulls (diamonds) and bull:cow ratio (squares) following implementation of a selective harvest system in year 10, and a severe winter following the hunt in year 12.

changes in bull:cow ratios and harvest. I was able to accomplish this using simple spreadsheet software and a microcomputer. My projections were very useful when the ADF&G met with public groups to discuss the proposed changes in the hunting season under SHS. They were also useful in presentations to the Board of Game. I was able to predict with some degree of certainty that the proposed restrictions to bull harvest under SHS would help meet management objectives. I have since used this model to predict changes in population structure and harvest under SHS for other Game Management Units in Alaska. These projections were partially responsible for the Board's decision to implement SHS throughout the entire road system in Alaska beginning in 1992-93 hunting season.

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