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POPULATION SIMULATION VARIATIONS DUE TO DISTRIBUTION OF VARIABLES

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ABSTRACT: Evaluations of the effects of three different distributions of randomly-selected winter calf mortality rates demonstrated that standard deviations of calculated numbers in moose population simulations were reduced as the distributions of randomly-selected mortality rates varied from flat to clustered. Population modelers should use appropriate distributions of randomly selected variables in stochastic models because the distributions affect the statistical distribution and precision of the results.

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Population models and simulations are becoming more popular as biologists become familiar with electronic information processing. Simulations are based on either deterministic or stochastic models. Deterministic models use constant values for the variables in a given simulation. Stochastic models use some form of random value selection for one or more of the variables. Many computer random number generators produce uniform or flat distributions. We have calculated the effects of differences in calf mortality rates on moose numbers in three deterministic runs, and demonstrate the effects of different distributions of calf mortality rates on standard deviations and calculated numbers of moose in three stochastic runs.

LITERATURE REVIEW

The literature does not provide moose population modelers with as much information as modelers of other species, such as white-tailed deer. Field research has focused on predation. Hauge and Keith (1981) used field data to model Alberta moose populations, and concluded that the best way to increase allowable harvest would be by reducing the high (>75%) calf mortality due to predation. Albright and Keith (1987) attributed high calf survival in Newfoundland to low predation. Larsen *et al.* (1989) suggested that predation limited the growth of a moose population in southwest Yukon. Ballard *et al.* (1991) evaluated the effects of predation on population dynamics of moose in Alaska. Moose populations subject to no predation show a high rate of annual increase (Cederlund and Sand 1991). Predation by wolves and bears was the major factor limiting moose at low densities in experiments in Alaska. These and other smaller studies (Boer 1988 and Franzman *et al.* 1980) enable modelers to input real or at least representative distributions of some of the population parameters.

Predicting the impacts of certain events on population dynamics is one of the goals of population modeling. Using deterministic models, Moen and Ausenda (1987) showed that age at first breeding has a multiplicative effect on population growth. Ballard *et al.* (1986) assessed the impacts of hydroelectric development on moose populations of the Susitna River Basin of Southcentral Alaska, and Boer and Keppie (1988) concluded that natural mortality and poaching were more important than harvest mortality in the dynamics of a New Brunswick moose population.

METHODS

A computer program was written specifically for evaluating the effect that random selection of calf mortality rates from three different distributions has on calculated numbers of moose. The two sexes were represented by four age groups. Representative rates of calf production were held constant for prime-age and older cows, and for five sources of mortality in all runs.

Distributions of winter calf mortality rates included a flat distribution in which each mortality rate in increments of 0.03 from 0.05 to 0.35 had an equal chance of being randomly selected, and two clustered distributions in which the height was one-half the range in one case and equal to the range in the other case. Each distribution had a mean of about 0.20. In the clustered distributions, values closer to the mean had greater chances of being selected, depending on the height-to-width ratio of the distribution, than the more extreme values did. Each run began with 100 moose and continued for 20 years of sequential calculations.

RESULTS

The results illustrate the effects of different distributions in one variable, and are not intended to predict numbers in real moose populations. Two groups of results are presented: the singular results for deterministic runs and the means and standard deviations for the stochastic runs.

Deterministic Runs

Deterministic runs allow for no variability; minimum, midpoint, and maximum calf mortality rates were used in each of the three 20-year calculations. A population of 100 moose grew to 37550 in 20 years when a winter calf mortality rate of 0.05 was used, to 12130 when a rate of 0.20 was used, and to 3456 when a rate of 0.35 was used. The three curves showing population growth are illustrated in Figure 1. Note that the midpoint mortality rate does not result in midpoint moose numbers. The larger span from the midpoint to the low mortality line compared to the high mortality line is due to the "compound interest" effect.

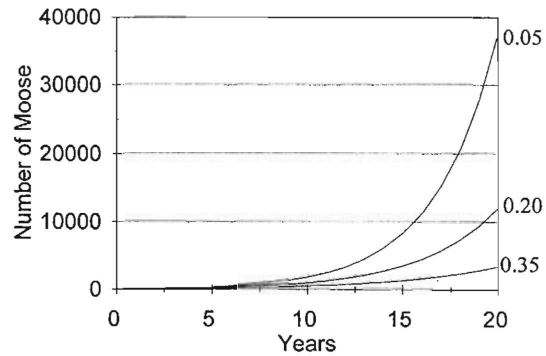

Fig. 1. Number of moose calculated over 20 years with a deterministic model, beginning with 100 moose and winter calf mortality rates of 0.05, 0.20, and 0.35.

Stochastic Runs

The results of the stochastic runs with mean calf mortalities of about 0.20 must fall between the two extremes in Figure 1. Moose numbers and standard deviations in the stochastic runs depended on the distribution from which calf mortality rates were selected. The number of runs made varied from 11 to 72, depending on the accumulated frequencies under each of the three distributions. As calf mortality rates clustered closer to the means, standard deviations of projected moose numbers were less (Figure 2).

For the flat distribution, the standard de-

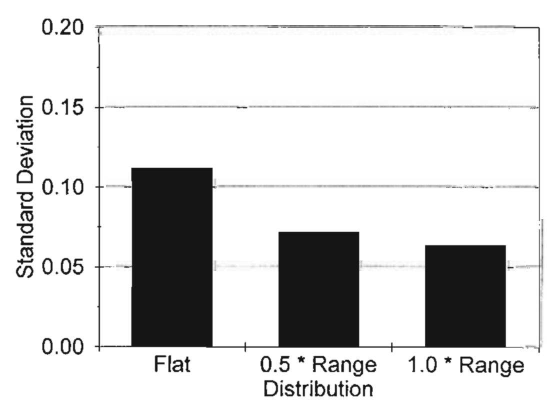

Fig. 2. Standard deviations around mean winter calf mortality rates decreased when rates were randomly selected from flat, height equal to one-half the range, and height equal to the range distributions.

viation in winter calf mortality rates was 0.112, with a mean mortality rate of 0.190. The mean number of moose calculated from 11 runs was 17572, with a standard deviation of 13121.

For the height as half-of-the-range distribution, the standard deviation in winter calf mortality rates was 0.072, with a mean mortality rate of 0.194. The mean number of moose calculated from 36 runs was 14483, with a standard deviation of 7451.

For the height equal-to-the-range distribution, the standard deviation in winter calf mortality rate for an N = 72 dataset was 0.064, with a mean mortality rate of 0.203. The mean number of moose calculated from 72 runs was 13259, with a standard deviation of 6753.

DISCUSSION

Variations in calculated numbers after 20 years depended on the actual winter calf mortality rates used, and the standard deviation of calculated moose numbers was reduced with tighter distributions of randomly-selected calf mortality rates.

The standard deviations decreased as the distributions were more clustered about the mean, especially when going from a flat distribution to a clustered one (Figure 3), as expected. This demonstrates that the frequency distributions of mortality rates, or of any other variable, should be known and the distributions described when using a stochastic model. Smaller standard deviations in variable distributions result in smaller standard deviations in results which use randomly-selected values from these distributions.

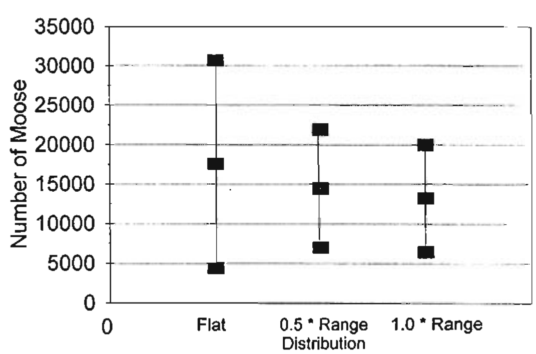

Fig. 3. Standard deviations around calculated moose numbers decreased as mortality rates were randomly selected from flat, height equal to one-half the range, and height equal to the range distributions.

Since many computer-based random number generators produce uniform distributions, modelers should include subroutines which create appropriate distributions from which values are randomly selected. Knowing the distributions of randomly-selected variables provides more insight into reasons for variability in the results generated by population models. If field data are available so distributions with known means and variances can be used, then results of simulations should be more realistic and helpful when making management decisions.

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