MODELING MOOSE POPULATIONS FOR MANAGEMENT DECISION MAKING IN ALASKA

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ABSTRACT: We took a previously described moose (*Alces alces*) model for the Kenai Peninsula, Alaska and enhanced its capabilities. The model produced year by year calculations of all pertinent population statistics and harvest by age class. The refined model was used to evaluate proposals for changes to hunting regulations. Predicted population trends over time (e.g., 3, 5, or 9 year durations) in response to various simulated management actions allowed decision makers to judge the relative merits of various harvest regimes. The model allowed planning for moderate to long-term, rather than reacting annually to short-term changes in weather, harvest, or public perceptions. Simulations allowed managers to evaluate various regulatory regimes, looking for those that produced desired outcomes on a long-term basis while considering impacts of severe winters. Easy to understand graphics allowed for quick interpretation of model runs by administrators and the public, which facilitated the manager's ability to demonstrate the consequences of a particular management action. The model and its results were accepted by the public and decision makers. Model output guided decision makers when evaluating proposed changes to harvest regulations.

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Sylven *et al.* (1987) stated that computer simulations of different harvest regimes were a useful and necessary tool for moose managers. However, Page (1987) lamented how population models available at that time had little impact on management decisions, yet stated earlier (Page 1983) that population modeling was the solution for examining management options. Schwartz (1993) developed a population model that utilized existing moose population data whose simulations were used to inform the public and decision makers of potential effects on the population from a proposed harvest regulation change.

Title VIII of the Alaska National Interest Lands Conservation Act (Public Law 96-487) recognized the importance of fish, wildlife, and other renewable natural resources for subsistence uses by rural residents of Alaska. When Alaska's subsistence law was struck down by the Alaska Supreme Court, the Federal land managing agencies (Bureau of Land Management, National Park Service, US Fish and Wildlife Service, and US Forest Service) in Alaska were directed by the Secretaries of Interior and Agriculture to establish hunting seasons and harvest limits for subsistence hunters on Federal public lands (see Huntington [1992] and Bosworth [1995] for extensive background and discussion on the subsistence issue in Alaska). In an effort to expand their hunting opportunities, a small,

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vocal group of rural residents on the Kenai Peninsula, Alaska proposed a liberal bull moose hunt. The basic theme of the proposals from this group was to revert from the existing restricted bull harvest strategy to an "Any Bull" harvest strategy, while other members of the public petitioned to maintain the restricted bull hunt. Variations in the form of season dates, eligibility to hunt, and limited cow harvests to ensure continuation of desired bull:cow ratios were also proposed. While requests for regulations changes were directed to all of Game Management Unit 15, Subunit 15A, the northwest portion of the Kenai Peninsula (Fig. 1), quickly became a major focal point for subsistence decision makers.

Our objective was to employ an existing single species deterministic simulation model, update the population values, and determine the effects to the Kenai Peninsula moose population of changing harvest regulations for subsistence hunters. We modified the Schwartz (1993) model by making it more user friendly, increasing its complexity, and enhancing its ability to answer harvest management options. Model output provided moose managers and subsistence decision makers with a tool to evaluate subsistence moose harvest regulations. We also demonstrate how this model, with simple modifications, was altered for an adjacent area with a completely different population structure and management goal.

METHODS

Study Area and Modeled Population

The moose population for which this model was developed inhabits the Kenai Peninsula in south-central Alaska (Fig. 1), an area of mixed spruce (*Picea* spp.) and birch (*Betula* spp.) forest, lowland black spruce (*P. mariana*) bog, alder (*Alnus* spp.) thickets, and tundra uplands. Much of the moose habitat in this area is accessible by road, all terrain vehicle trails, or boat.

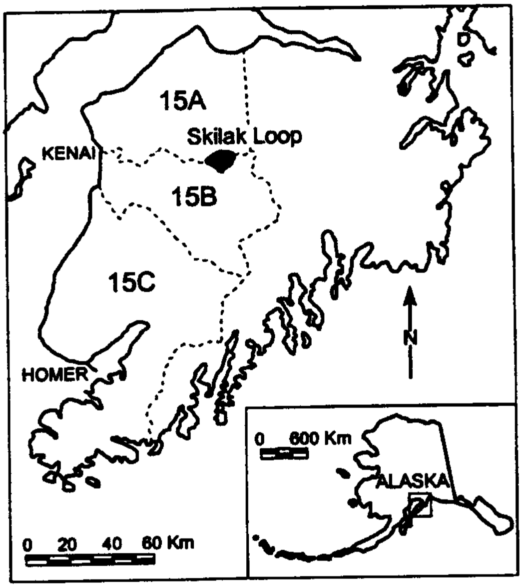

Fig 1. Game Management Unit 15, Kenai Peninsula, Alaska. Dashed lines indicate subunit boundaries, letters indicate subunits; shaded area is Skilak Loop Wildlife Management Area.

Prior to 1987, moose harvest on the Kenai Peninsula was open for any antlered bull; bull calves were protected. In 1987, the definition below of a legal bull was changed to any bull with a spike/fork antler, an antler spread ≥50 inches (127 cm), or with ≥3 brow tines (ADFG 1987; Schwartz *et al.* 1992; see Harvest Definitions for more information).

Schwartz *et al.* (1992) demonstrated that a severe winter in the northern part of the Kenai Peninsula reduced overwinter survival rates and the subsequent fall harvest, but during the same winter moose in the southern part of the Kenai Peninsula were not impacted and had high harvests the next fall. This reinforced the need to limit the geographic scope of the moose population addressed by the model and include the impacts of severe winters.

Due to interest by both hunters and decision makers, we limited our modeling efforts to Subunit 15A, an area approximately 3,400 km². The Skilak Loop Wildlife

Management Area, an area approximately 180 km^2, warranted a separate model because it is managed differently from the balance of Subunit 15A, and the population structure is different enough to skew the overall population structure when added to the balance of the Subunit 15A population.

Basic Model

We began with the discrete deterministic simulation model developed and described by Schwartz *et al.* (1992) and Schwartz (1993). This decision was prompted by: (1) its existence and proven past use; (2) findings by Taylor (1992) that showed deterministic simulation models could produce results similar to more complex stochastic versions of the same model; and (3) the limited time available and needed to produce a new model. We followed the approach of Caswell (1989) in that we used the model to simulate or project what would happen to the moose population given stated conditions.

Schwartz's original model was developed using spreadsheet software (Lotus 123®, Lotus Development Corporation). To enhance the model, we originally utilized Quattro Pro® spreadsheet software (Quattro Pro, Borland International, Inc.) because of its programming and graphics capabilities. Due to the number of people involved in reviewing and evaluating enhancements of earlier versions, we selected version 2.01 of Lotus 123 and version 4 of Quattro Pro (Quattro Pro could directly read and write the Lotus file) during model development. The current model, with minor variations, functions on both DOS based spreadsheets (Lotus 123 version 2.01, Quattro Pro versions 4 and 5) and Windows® based spreadsheets (Lotus 123 version 5; Quattro Pro version 7, Corel Corp. Ltd.; Excel® version 5, Microsoft Corp.).

The basic model structure and computation of sex specific cohort values were described by Schwartz (1993). Like the original version, the only anthropogenic mortality addressed in the model was hunting related; all other mortalities (i.e., natural, predation, and collisions with vehicles) were combined. We began the model with post-hunt population values for fall 1994 (i.e., approximate size and composition) based upon the November 1994 composition survey and February 1995 census survey. Due to recent severe winters, it was known that the standing population had at least 2 cohorts with less than a "normal" number of members (CS, *pers. obs.*; TS, *pers. obs.*). Lacking cohort specific data, however, the initial population was set with a stable age structure.

The moose population on the northern Kenai Peninsula was declining at approximately 9%/year due to habitat changes (Loranger *et al.* 1991). The original model included a slight decline, $X = 0.997$ (Schwartz *et al.* 1992). While it was a straight forward process to set the model to decline at approximately 9%/year, it was determined by managers that non-biologist decision makers and the general public could more easily interpret deviations from a flat line than from one with a negative slope. In order to get a stable population, overwinter survival rates reported by Schwartz *et al.* (1992) and Schwartz (1993) were increased, yet were still lower than what local managers projected.

Like the original model, and all deterministic simulation models, our model utilized mean values for the various survival and productivity rates to produce a mean expected outcome. For the model's harvest to approximate the reported harvest, and stay within harvest rate parameters local moose managers believed to be occurring, we increased the total population size and adjusted Schwartz *et al*'s (1992) hunt survival rates. Modifications to hunt survival rates were based primarily on experience gained by local managers since Schwartz *et al.* (1992). To achieve documented post-hunt cow:calf ratios, neonate mortality was increased over that reported by Schwartz *et al.* (1992). Adjustments to survival rates were necessary to stabilize the population, rather than have it decline as in the original model. In all cases where survival parameters were adjusted (usually to make a better fit to known data), we always started with what we knew to be the best estimate and made minor adjustments from there.

No bull hunts had been allowed in the Skilak Loop Wildlife Management Area prior to 1994; therefore, no previous harvest data existed. Due to similarities between the Skilak Loop Wildlife Management Area and the balance of Subunit 15A in hunter access and habitats, we utilized the same bull harvest survival rates for both models.

The original model utilized a single calf production value for all reproductively active cows. The version described here utilizes the calf production values presented by Schwartz and Hundertmark (1993). Schwartz *et al.* (1992) found no difference in calf production when bull:cow ratios varied between 10:100 and 30:100, so production values were held constant. Despite previous studies that provided an indication that the sex ratio of calves at birth may be 40% female and 60% male (Franzmann and Schwartz 1986), our model used an equal sex ratio based on more recent data presented by Schwartz and Hundertmark (1993).

The selective harvest strategy was designed to remove smaller yearling bulls and protect larger yearling bulls that naturally had a higher winter survival rate (Schwartz *et al.* 1992). Therefore, we assumed that yearling bulls had a higher winter survival rate than yearling cows under the selective harvest. We also assumed a similar situation for adult bulls (≥7 years-of-age) compared to adult cows (≥14 years-of-age) because of a major difference in median age of this group in the population. We assumed that the harvest of males was additive mortality (Modafferi and Becker 1997).

Severe winters have a significant effect on moose survival on the Kenai Peninsula (Schwartz *et al.* 1992; TS, *unpubl. data*). During our modeling effort, we were faced with a severe winter in the middle of ongoing requests to liberalize harvest regulations. Severe winters were known to result in ≥90% loss of calves (Schwartz *et al.* 1992) and were believed to have a significant impact on old aged adults. Schwartz (1993) discussed how earlier efforts to address the population's recovery from a severe winter failed to take into account latent effects. While good composition and population estimate data immediately following severe winters were not always available, local managers strongly believed that the moose population recovered quickly due to increased overwinter survival and increased calf production. We simulated severe winters by lowering overwinter rates (drastically for some sex and age classes) during the severe winter, but then increased the rates above normal in the subsequent winter. Secondly, calf production was increased for the 2 years following the severe winter (i.e., spring of years $t + 1$ and $t + 2$).

Fractions of moose were rounded off using the rounding function of the spreadsheet. The random number approach used by Starfield and Bleloch (1986:48), although elegant, was not practical to implement in this spreadsheet based model.

Model Options

The original model tracked changes in harvest, population abundance, and bull:cow ratios that occurred following modifications in bull harvest strategy. To meet the objectives put forth by subsistence managers, our model needed to incorporate additional options including: (1) specifying a minimum post-hunt bull:cow ratio; (2) an "Any Bull" harvest by all hunters or by local hunters (i.e., subsistence) only; and (3) a cow harvest. The duration of any new harvest option could be specified. The user could select when a severe winter would occur in future years via a checklist function. All variation was introduced and controlled by the user.

To facilitate interpretation of results from our model, a larger suite of population and harvest statistics were presented both tabularly and graphically. These included: (1) total population size; (2) numbers of bulls, cows, and calves; (3) percent calves in population; (4) bull:cow and cow:calf ratios; (5) total bull harvest; (6) harvest of yearling and adult bulls; (7) maximum allowable harvest to maintain a specified bull:cow ratio; (8) total cow harvest; and (9) mean and median age of the bull and cow population (excluding calves). Population values displayed used post-hunt parameters.

The original model was constructed to aid in decision making for a specific management problem. It was not designed to be user friendly and required either manual adjustments to survival rates to determine the effects of different management options or the use of macros to effect changes. We attempted to improve on the basic concept and make this version more user friendly. To implement the variety of user friendly options, simple programming functions (e.g., nested IF statements) were utilized. These improvements did not burden the user with cumbersome actions. Rather, the user could focus attention on variable or scenario inputs and evaluate results.

Harvest Definitions

We modeled 4 different harvest regimes legally allowed at the time (ADFG 1994, FSB 1994). "Spike/Fork" (S/F) bulls were defined as legal if one antler on either side had a spike (1 point) or a fork (2 points); the antler on the other side could have any configuration. Spike/Fork-50 inch (S/F-50) bulls were bulls with either a S/F antler configuration, or with a maximum antler spread ≥50 inches (127 cm), or with ≥3 brow tines present on at least one antler. An Any Bull regulation allowed any antlered moose, excluding a calf of the year, to be harvested. A cow regulation allowed any cow, ≥1 year in age, that was not accompanied by a calf to be harvested.

RESULTS

Model Performance

Composition data (November 1994) indicated that the post-hunt Kenai Peninsula moose population was approximately 60% cows, 18% bulls, and 22% calves and the model used these values. Non-hunting and harvest survival rates (Table 1) and calf production (Table 2) were adjusted so model output matched mean composition and harvest data.

When regulations were changed in 1987 for Subunit 15A from an Any Bull harvest strategy to one targeting S/F-50 bulls, population composition went from 16 bulls:100 cows to 29 bulls:100 cows in 5 years (Schwartz *et al.* 1992). When the same change was incorporated into our model, the population composition changed from 16 bulls:100 cows to 27 bulls:100 cows in 5 years. This response suggests that the model population mimicked the actual population.

We compared the simulated harvest by age class for both the S/F-50 and Any Bull harvest strategies against mean reported harvests (Fig. 2). The differences between the reported harvest and the simulated harvest were insignificant for S/F-50 (χ^2 = 0.068, 3 df, P = 0.995) and Any Bull (χ^2 = 1.380, 3 df, P = 0.710), which suggested that the harvest rates used in our model were

Table 1. Survival rates used in the model for moose on the northern Kenai Peninsula, Alaska.

Age (yrs)	Cows					Bulls					
	Summer	Hunt	Normal Winter	Severe Winter		Summer	Hunt Type		Normal Winter	Severe Winter	
				Initial	Latent		SF/50[1]	Any Bull		Initial	Latent
Calf	0.38	0.97	0.81	0.10	0.98	0.38	0.97	0.97	0.85	0.10	0.98
1	0.96	1.00	0.86	0.76	0.96	1.00	0.48	0.59	0.91	0.89	0.96
2	0.98	1.00	0.90	0.80	0.99	1.00	0.87	0.59	0.90	0.88	0.95
3	0.98	1.00	0.92	0.82	0.99	1.00	0.86	0.58	0.90	0.88	0.95
4	0.98	1.00	0.92	0.82	0.99	1.00	0.82	0.55	0.90	0.88	0.95
5	0.98	1.00	0.92	0.82	0.99	1.00	0.82	0.55	0.90	0.88	0.95
6	0.98	1.00	0.92	0.82	0.99	1.00	0.89	0.42	0.90	0.88	0.95
7	0.98	1.00	0.92	0.82	0.99	1.00	0.89	0.42	0.80	0.78	0.85
8	0.98	1.00	0.92	0.82	0.99	1.00	0.89	0.42	0.75	0.73	0.80
9	0.98	1.00	0.92	0.82	0.99	1.00	0.89	0.42	0.70	0.68	0.75
10	0.98	1.00	0.85	0.60	0.92	1.00	0.89	0.42	0.60	0.58	0.65
11	0.98	1.00	0.80	0.55	0.87	1.00	0.89	0.42	0.50	0.48	0.55
12	0.98	1.00	0.75	0.50	0.82	1.00	0.89	0.42	0.40	0.38	0.45
13	0.98	1.00	0.70	0.45	0.77						
14	0.98	1.00	0.65	0.13	0.72						
15	0.98	1.00	0.62	0.10	0.69						
16	0.98	1.00	0.60	0.07	0.67						
17	0.98	1.00	0.55	0.04	0.62						
18	0.98	1.00	0.50	0.02	0.57						
19	0.98	1.00	0.45	0.01	0.52						
20	0.98	1.00	0.40	0.00	0.47						

[1] SF/50 refers to Spike-Fork or ≥50 inch (127 cm) antlered bulls.

Table 2. Moose calf production rates on the northern Kenai Peninsula, Alaska used in the model. Normal winter values from Schwartz and Hundertmark (1993).

Calves per	Normal Winter	Following Severe Winter	
		1st Year	2nd Year
Young Adult (2 yrs old)	0.22	0.36	0.30
Prime Adult (3-16 yrs old)	1.27	1.50	1.41
Old Adult (17-20 yrs old)	0.14	0.20	0.18

realistic.

Because we used a deterministic approach to model development, output did not include year-to-year variations due to subtle changes in hunter effort or behavior, access, or other environmental events. Severe winters have a marked impact on moose populations on the Kenai Peninsula and posed significant modeling problems. Population composition and density estimates following severe winters were inconsistent, but mortality rates for calves were approximately known. This lack of real data to aid in estimation of model param-

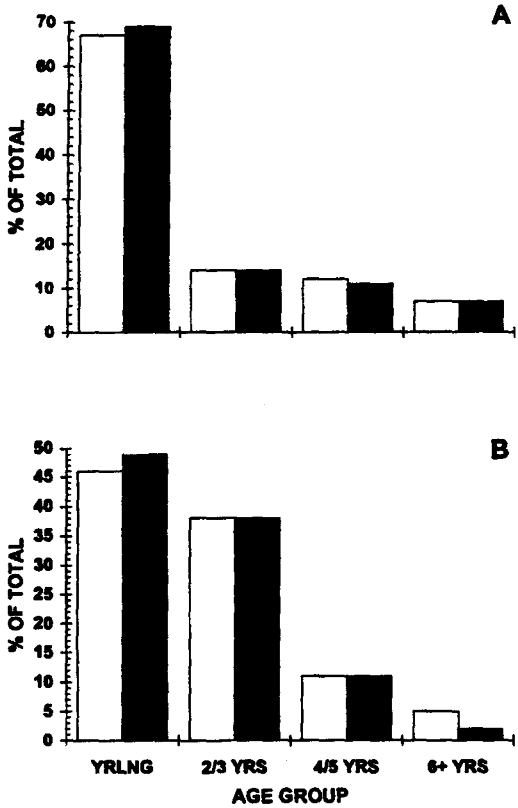

Fig 2. Comparison of mean reported harvest (open bars) and simulated harvest (filled bars) under (A) a Spike/Fork or ≥50" antler strategy (harvest data from 1989-1994) and (B) an Any Bull harvest strategy (harvest data from 1982-1986).

eters was reflected in simulated output. The percentage of yearlings in the simulated harvest was below actual harvest statistics (21.7% vs. 64.2%). Likewise, simulated total bull harvest declined 61.7% whereas the actual harvest declined only 47.9%.

Model Limitations

All models have limitations. In this model, female reproduction was not linked to the male component of the population and cows kept breeding in the absence of bulls. We were aware of this, but accepted the limitation because modeled bull:cow ratios did not drop below 10:100, which was probably a safe minimum breeding sex ratio for *A. a. gigas* at the densities we modeled. Like many models, our model was extremely sensitive to production and adult female survival rates (Medin and Anderson 1979, Sylven *et al.* 1987, Boer and Keppie 1988, Caswell 1989).

Cow harvests did not differentiate between cows with calves versus cows without calves as specified in the regulations. Cows were harvested from each age class in proportion to their abundance under the assumption that there would be a sufficient number of cows not accompanied by calves.

Skilak Loop Wildlife Management Area

Moose are managed in the Skilak Loop area primarily for viewing and photography. Management objectives included maintaining a minimum post-hunt bull:cow ratio of 40:100. The only human harvest was a limited take of cows in order to stabilize the population at an objective of 300 moose. This management resulted in a vastly different population structure from the rest of Subunit 15A. For this reason, managers were concerned with outcomes from other possible harvest regimes. The task presented to us was to adjust our modified model to fit the population structure of this area and have it mimic the observed population parameters. Changes made to the model included: (1) reducing the population size and altering its composition; (2) skewing the age structure to older age classes; (3) modifying survival rates; and (4) developing an algorithm to account for the current cow harvest. Approximately one day's effort was all that was needed to produce a working model for this area.

Management Use of the Model

Primary concerns of decision makers were the numeric harvest levels for bulls and cows, allowable harvest of bulls to meet minimum acceptable bull:cow ratio objectives, and differences in the potential number of legal bulls available under different harvest strategies. Management questions included: (1) what were the likely effects of different harvest strategies on the bull population; (2) potential changes to bull:cow ratios; (3) mean and median age of the post-hunt bull population; and (4) how might the harvest vary with different minimum post-hunt bull:cow ratios? Requests for various harvest scenarios trickled in over a period of 18 months; thus, the capabilities of the model evolved over this period. While the model was being improved to include new capabilities, it was in continual use by managers to analyze proposed changes and provide the public and decision makers with information.

Simulation results of changing from the current S/F-50 harvest strategy to an Any Bull harvest strategy, with no limitation on the number of hunters participating, showed that the Any Bull harvest strategy had a slightly higher harvest than the S/F-50 harvest strategy (Fig. 3A). Initially the harvest under the Any Bull season was larger due to the reservoir of middle aged bulls protected by the S/F-50 regulation. The same pattern was evident if the Any Bull harvest strategy was implemented following a severe winter (Fig. 3B). As expected, maximum allowable harvest was lower under a minimum 25:100 post-hunt bull:cow ratio (Fig. 3C) than under a minimum 20:100 post-hunt bull:cow ratio (Fig. 3D). The decline in the mean age of the post-hunt bull population (Fig. 3E) and the rapid decline in the post-hunt bull:cow ratio (Fig. 3F) showed how the population may have declined with the proposed change in harvest strategy.

We examined 3 harvest rates for cows: 1%, 2%, and 3% of the population $\geq$1 year of age. Simulation results from all three harvest rates showed a declining population (Fig. 4). The modeled rates of decline are likely greater than what would occur in the actual population due to the lack of density dependent feedbacks in our model.

Harvest options examined for the Skilak Loop Wildlife Management Area were: S/F bulls only; S/F-50 bulls only; and Any Bull. Simulation results indicated that only a small number of bulls could be harvested (Fig. 5A), lower than anticipated by many members of the general public. Results also suggested a rapidly changing bull:cow ratio in response to harvest (Fig. 5B). The low number of bulls within the population reduced differences between projected harvests with the S/F-50 bulls only and Any Bull harvest options (Fig. 5C). The net result of the simulations indicated that the number of viewable bull moose declined immediately and bull:cow ratios would likely fall below management objectives after 1 year with a S/F-50 bull or an Any Bull harvest strategy, and after 2 years with a S/F bull harvest strategy.

DISCUSSION

Many models in the literature that deal with moose are predator-prey or habitat models (e.g., Zarnoch and Turner 1974, Crête *et al.* 1981*a*, Stocker 1981, Bergerud *et al.* 1983, Blackwell 1983, Van Ballenberghe and Dart 1983, Theberge and Gauthier 1985, Ballard *et al.* 1986, Regelin *et al.* 1987, Allen *et al.* 1988, Sæther *et al.* 1989, Messier 1994). Fewer models deal with the effects of hunting (Crête *et al.* 1981*b*, Boer and Keppie 1988, Heydon *et al.* 1992, Courtois and Crête 1993, Ferguson 1993). Other than Schwartz (1993), we could not find examples in the literature of moose population models being used to aid the decision making process although models have been used to facilitate decisions for other species groups (e.g., Cowardin *et al.* 1988). Several papers presented models whose intention were to show how they could be used to aid managers and decision makers, or were created with the intention

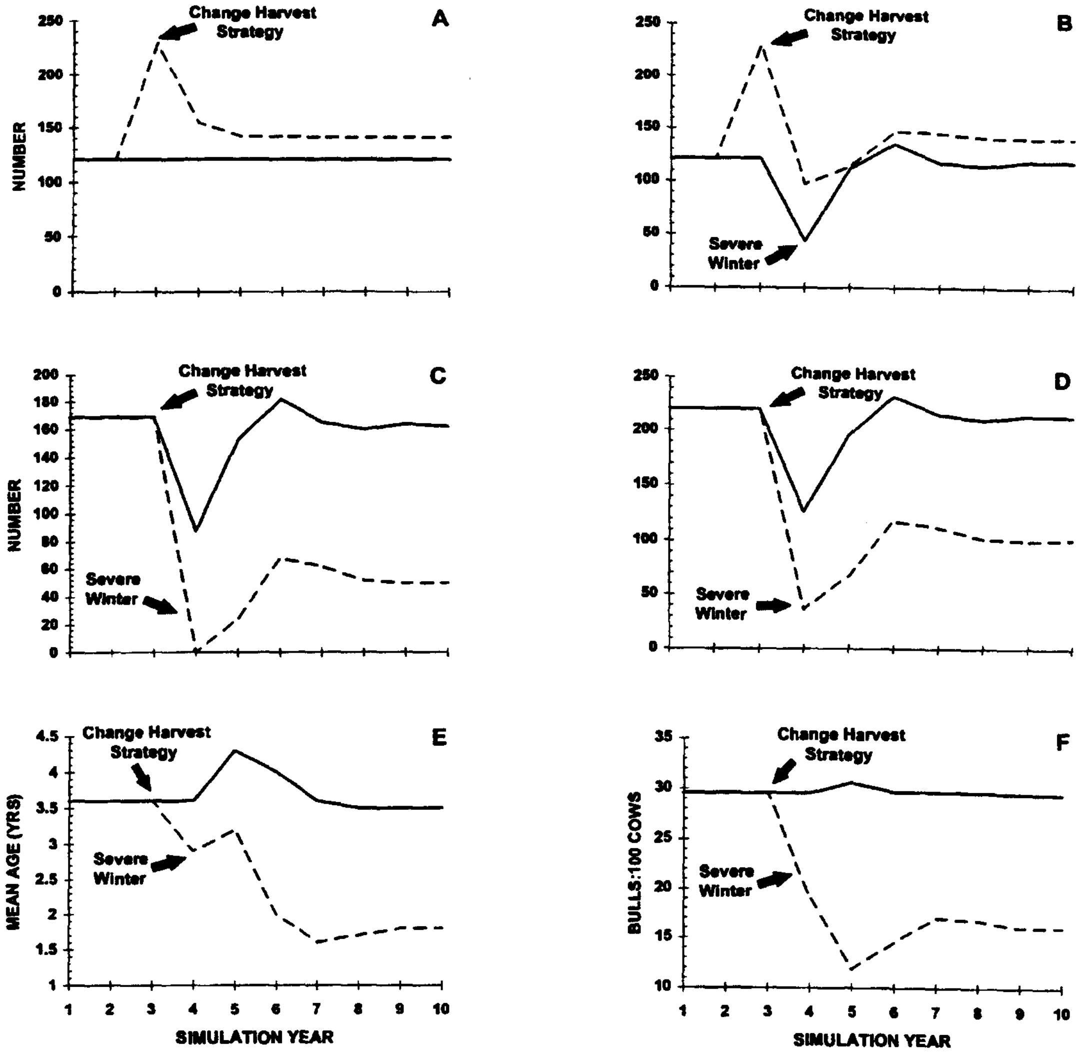

Fig 3. Simulations comparing Spike/Fork or ≥50" antler harvest (solid line) and an Any Bull harvest (dashed line): (A) without a severe winter; (B) with a severe winter; (C) maximum allowable harvest to maintain 25 bulls:100 cows post-hunt; (D) maximum allowable harvest to maintain 20 bulls:100 cows post-hunt; (E) post-hunt mean bull age; and (F) post-hunt bull:cow ratio.

to aid decision makers. Crête *et al.* (1981*b*) created a stochastic model to evaluate various harvest regimes and provided a number of recommendations to alter harvest regulations; however, no follow-up publications on this model were found. Sylven *et al.* (1987) constructed a model that considered population dynamics and effects of different harvest strategies on moose population structures; again, no follow-up publications on this model were found. Boer and Keppie (1988) constructed a model to evaluate how different types of harvest and timing of the harvest may affect a moose population, and discussed how decision makers could compare harvest parameters when considering future harvest regulations. Heydon *et al.* (1992) commented on a population model that was intended to assist in management decisions. The model was expected to simulate the moose population in 16 management units, but performed poorly over-

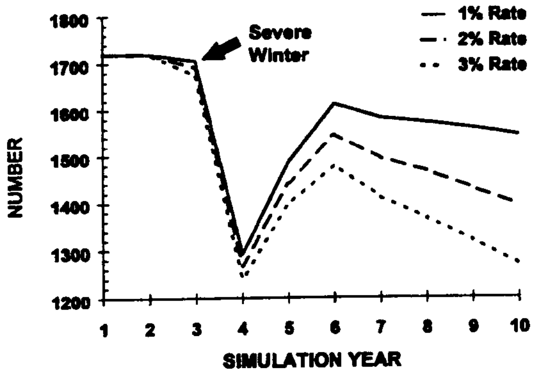

Fig 4. Simulated population trend from three different cow harvest rates.

all. Poor model performance was partly believed to be due to the large geographic area it was expected to address; heterogeneity in the moose population parameters associated with a large geographic area may also have played a role in poor model performance. Ferguson (1993) used a cohort based model originally developed for fisheries and showed how it provided useful information for research and management purposes, despite acknowledged limitations.

Our Model

We believe that limiting the geographic scope of input into our model contributed to its success in simulating responses of the moose population to different harvests. The Skilak Loop Wildlife Management Area, a very small geographic area, had no previous bull harvests with which to use as a guide. However, using inputs from the Subunit 15A model as the basis, the Skilak Loop Wildlife Management Area modeling effort provided us with simulations that appeared to be reasonable.

Lack of survey and research data certainly impacted our ability to accurately simulate the harvest following a severe winter. We believe that: (1) the model severe winter survival rate of 10% for calves may be too high for the winter we modeled; (2) there may be a change in the

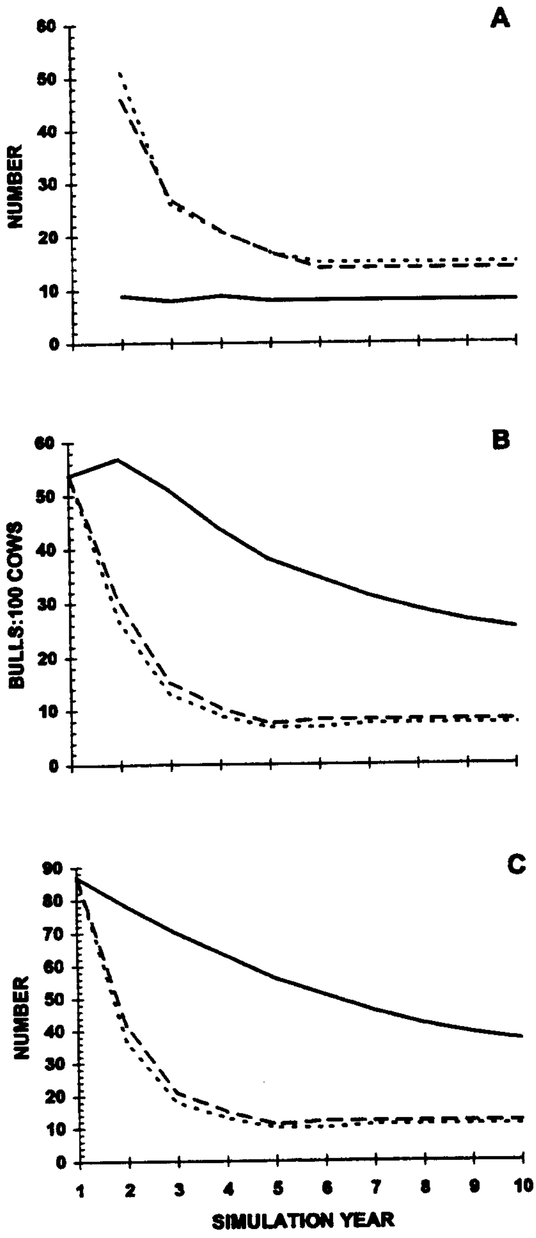

Fig 5. Simulations for three bull moose harvest strategies (Spike/Fork antlers only [solid line], Spike/Fork or ≥50" antlers only [dashed line], and Any Bull [dotted line]) in the Skilak Loop Wildlife Management Area showing: (A)anticipated harvest; (B) bull:cow ratio; and (C) bull population size.

vulnerability of bulls following a severe winter, which may be at least partly due to increased effort by hunters; and (3) the sizes of bulls hunters reported harvesting may be inaccurate. Further refinements to the model will enhance its ability to simulate severe winter effects to the population.

Van Ballenberghe (1983), Meon and Ausenda (1987), and Boer (1992) describe moose population responses from changes in the proportion of yearling females that breed. Each of these models use different survival and fecundity rates which resulted in differences in the magnitude of model responses, however, the basic responses are similar. When we manipulated our model in a similar manner, results were consistent with those previously reported.

Page (1987) believed that a good model was a balance between fitting real data, including all biologically necessary details, and common sense. Page (1987) also stated that a good model had three basic components: all moose must die; only females give birth, and births must occur; and there is a finite population density. Our model fits these criteria with the exception of the last one. Our model did not consider population density for three reasons. First, the population in Subunit 15A is at carrying capacity and is declining with the declining quality of the habitat. Secondly, survival rates incorporated into the model prevented the model population from growing. Lastly, the model was designed only to look at moderate term (i.e., <10 years) population responses to different harvest strategies. Based upon this, we felt that adding the algorithms for density dependent feedback loops were unnecessary.

Management Use

Like the original version (Schwartz *et al.* 1992), this model, with the user friendly improvements, was developed to facilitate the managers' ability to answer questions about different harvest proposals and how they might impact the moose population and affect the current harvest. Our model allowed managers to run simulations on a variety of regulatory strategies and look at changes (e.g., 2, 5, or 9 years in the future). It allowed us to analyze each proposal in a consistent manner (i.e., the same population subjected to different harvest survival coefficients) and examine likely responses by the population. The matrix structure of the model allowed us to examine probable impacts to specific population components when regulatory strategies targeted specific subgroups (e.g., yearling bulls). Additionally, model output became stronger through time as input values were refined with each year's additional harvest or survey data. We found that the model could be easily tuned to local conditions based on local research and knowledge, as exemplified with our efforts to create a model for the Skilak Loop Wildlife Management Area.

The model displayed the results of each simulation in easy to understand graphics. The matrix layout of spreadsheets facilitated rapid construction of specific graphics for presentations to the general public and decision makers. The model and its graphics also facilitated our attempts to get the general public and the decision makers to "see the big picture" of population level impacts likely to result from a given decision, rather than focus on just one or two aspects such as anticipated harvest.

When presenting model results to the public and decision makers, we did not portray the results of any one model run to predict the exact number of moose to be harvested or the exact population size. Rather, we focused on the relative differences of various values between different management regimes, which we believed to be representative of how the population would respond. The model produced simulation results for a 30 year period which allow for analysis of changing from one strategy to another and then back again. However, due to possible errors (and their compounding effects over time), particulary severe winter impacts, we believe that this model is best used as a short to mid-term (i.e., <10 years) response/evaluation model.

MANAGEMENT IMPLICATIONS

Models are tools with limited capabilities. For models to be successful and accepted, they need to be based upon solid data and documented functional relationships. Yet, not everything must be known about the population for the model to function in a biologically believable manner. All models are limited and their scope, purpose, intent, and major assumptions must be clearly explained. When survival rates are sex and age-class specific, the effects of various regulatory changes which target subgroups of the population (e.g., cow hunts, antler restrictions) can be simulated and evaluated. If a model is to be used to plan for the long-term, or used to evaluate management strategies over the long-term, then the model would ideally include frequency and severity of winters and density dependent feedbacks. Our modeling effort highlighted areas where managers needed to refine their thinking and perceptions about different components of the population (e.g., survival rates, total size).

This model allowed for moderate to long-term planning, rather than reacting annually to short-term changes in weather, harvest, and public perceptions. The public expects biologists to manage so that natural "highs and lows" in moose population abundance are smoothed, creating stable hunting or viewing opportunities. Models can allow managers to evaluate various regulatory options, looking for those that will produce the desired conditions on a continuing basis, while accounting for the inevitable and uncontrollable impacts of severe winters.

Additionally, models such as this can assist managers in a number of ways, including: (1) interpolating population size and composition between periodic surveys; (2) identifying weak or missing information most critical to model predictions, and thus establish priorities for research; or (3) formulating hypotheses on how other environmental perturbations such as prescribed burns or wildfires may impact harvested moose populations. Our model has potential for refinement through research, such as improving accuracy of survival and productivity rates through radio tracking of known-age animals.

The original model met its intended goals. This version was designed to meet radically changing needs and goals, was accepted by the public and decision makers, and was influential in assisting decision makers in evaluating regulatory change requests.

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