Model to Evaluate Potential Production and Income Responses of Reindeer Herds under Different Management Strategies

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Abstract

Free–range reindeer in western Alaska are managed for both velvet antler and meat production. Optimal management should maximize the income generated from both meat and antler production while managing the herd at levels below the carrying capacity of the range. Meat production precludes future antler production from harvested animals, therefore harvest decisions should reflect antler and body growth rates, current antler and meat prices, natural survival rates, and population demographics. We present a user–friendly computer model to generate estimates of net income under different harvest levels and market conditions. Input variables include sex– and age– specific survival rates, harvest levels, castration rates, antler weights, body weights, and recapture rates, as well as reproductive rates, fixed and variable costs, antler price, and meat price. Mark–Recapture analysis was used to estimate survival rates. The model was calibrated using reindeer herd records from 1984–1997. Output includes changes in herd size and composition over a thirty–year period, meat production, antler production, female: male ratio, and predicted net income. The model illustrates the sensitivity of herd size to female adult survival rates.

Reindeer calves in July. Photo by Chris Janak

Reindeer in the Davis corral during summer handling. Photo by J. Stephen Lay

Introduction

Reindeer in western Alaska were imported from Russia in 1891 to provide a source of income to Alaska Natives in local communities (Postell 1990). By 1924 the reindeer population in western Alaska had risen to 242,000 animals (Stern et. al. 1980). Alaska Natives on the Seward Peninsula currently herd reindeer in 14 individual herds ranging from 300 to 8000 reindeer.

Reindeer are free ranging throughout the year and are rounded up during summer and in some herds, in January. During handlings, reindeer are herded into a corral and processed individually. During summer handlings reindeer are given uniquely numbered eartags, vaccinated for brucellosis, and velvet antlers are cut.

Reindeer Research Program personnel attend handlings and record eartag numbers, vaccinate animals, and collect data such as body weight, antler weight, lactation status, and abnormalities. Slaughtering of reindeer is primarily done in winter.

Reindeer are an important source of income for communities throughout the Seward Peninsula. Reindeer production generated approximately $1.1 million for the local economy in 1996 (Alaska Agricultural Statistics 1997). This income was derived from both production of meat ($511,000) and sales of velvet antler and other by–products ($564,000). Because male and female reindeer grow antlers every year, the income derived from butchering an animal for meat must be compared to the lost income associated with potential future antler sales. Calculation of optimal harvest strategies requires consideration of carcass weights, antler weights, survival rates, carrying capacity, and current and predicted market conditions.

Methods

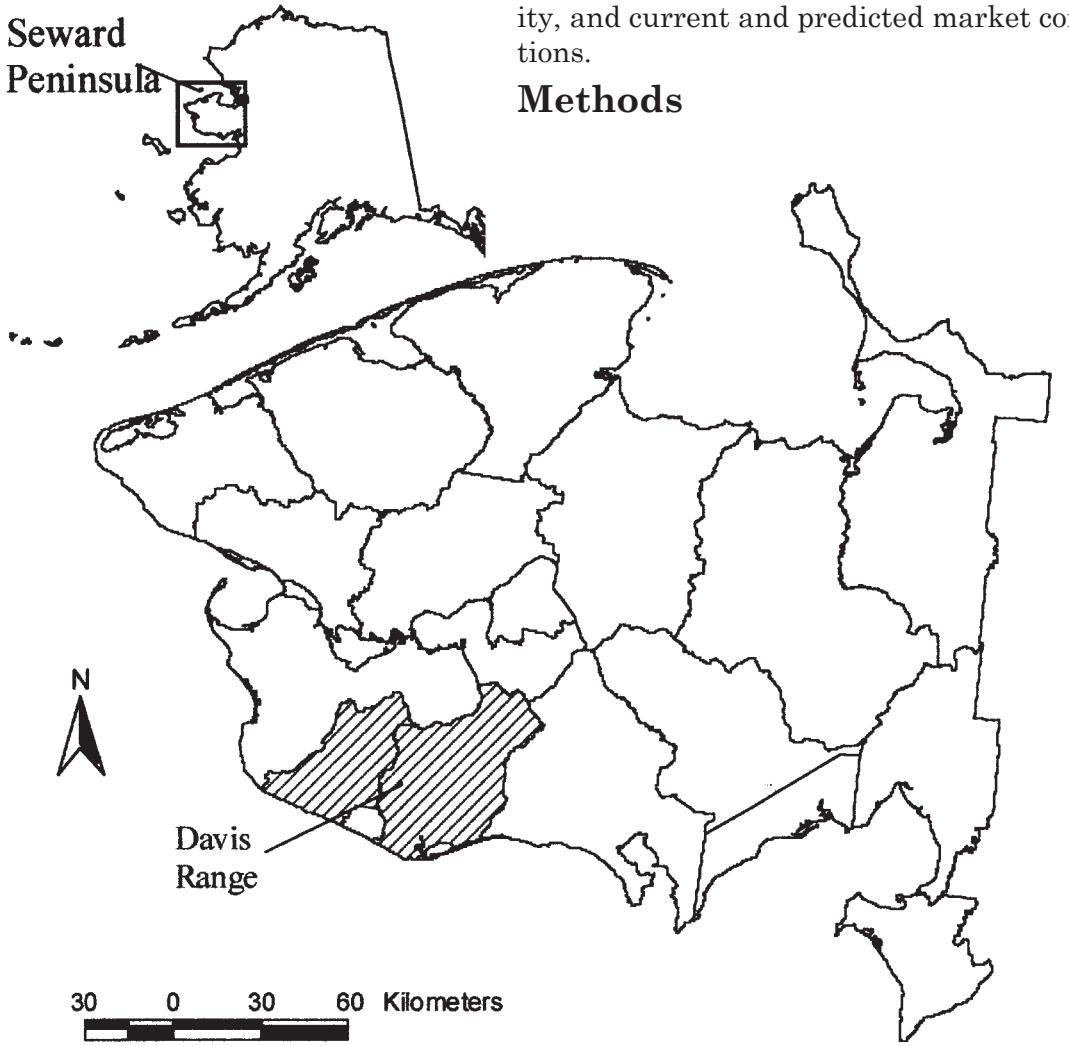

Figure 1. Location of Davis Reindeer Range, Seward Peninsula, Alaska.

A Microsoft Excel spreadsheet was used to create an annual time–step model of herd growth and meat and antler production based on biological parameter inputs and harvest strategy. The model is based on four age classes of females (calves, yearlings, two–year–olds, and three and older), five age classes of males (Calves, yearlings, two–year–olds, three–year–olds, and four and older), and four age classes of steers (yearlings, two–year–olds, three–year–olds, and four and older). These are coded as f0, f1, f2, f3, m0, m1, m2, m3, m4, s1, s2, s3, and s4 respectively.

Model parameters include: 1) initial population levels; 2) age– and sex–specific annual survival rates (June to June); 3) age– and sex–specific recapture rate (corresponding to percent of herd captured for summer handlings); 4) age– and sex–specific harvest rates for males, females, and steers (as proportions); 5) age–specific castration rates; 6) age– and sex–specific antler weights; 7) age– and sex–specific body weights; 8) age–specific female lactation rates; 9) antler price in dollars per Kg; and 10) meat price in dollars per Kg.

The model also allows the user to specify five kinds of costs associated with reindeer herding. These costs include: 1) a general annual fixed cost that does not vary; 2) a fixed cost associated with summer handlings; 3) a fixed cost associated with winter slaughter; 4) a per head cost for summer handlings in addition to the fixed cost; and 5) a per head–slaughtered winter cost in addition to fixed winter cost.

Model outputs include: 1) age– and sex–specific annual herd size; 2) annual gross income from antler sales; 3) annual gross income from meat sales; 4) annual net income over next 30 years; 5) female: male ratio (females two year–old and older / non–castrated males two years–old and older); and 6) annual herd growth rate:

$[r = \exp(\ln(\text{herd size year}_i)-\ln(\text{herd size year}_{i-1}))-1]$.

Biological parameters were estimated using the reindeer herd of Lawrence Davis near Nome, Alaska (latitude 64.50ºN longitude 165.44ºW; see Table 1). The Davis herd occupies a 3875 km^2 range stretching from the Bering Sea coast in the south to the Kigluiak Mountains in the north. The herd has increased in size from about 4000 in 1987 to 8,000 in 1998 (unpublished data). High growth rates of calves and high lactation rates in yearlings suggest that this is a high–quality range (Finstad and Prichard 1998). Predators include wolves (*Canis lupus*), wolverines (*Gulo gulo*), red fox (*Vulpes vulpes*), and brown bears (*Ursus arctos*; Chetkiewicz, 1993).

Survival rates and recapture rates were estimated using mark–recapture in Program MARK (White and Burnham 1999). Average body weights were estimated from weight measurements taken at winter handlings. Antler weights were collected at summer han-

Table 1. Population parameters for females, males, and steers of different age classes, in the model determined from the Lawrence Davis Herd, Nome, AK. Survival, harvest, lactation, and recapture rates are entered as proportions of total for each class.

	Survival	Harvest	Lactation	Recapture	Body Wt (kg)	Antler Wt (kg)
F0	0.78	0	—	0.88	55.93	0
F1	0.89	0	0.10	0.92	79.79	0.41
F2	0.89	0	0.45	0.92	90.68	0.49
F3	0.89	0	0.61	0.9	97.11	0.65
M0	0.8	0	—	0.9	60.22	0
M1	0.89	0	—	0.85	87.9	0.66
M2	0.75	0	—	0.85	100.94	1.38
M3	0.75	0	—	0.85	105.79	2.28
M4	0.7	0	—	0.8	108.86	2.8
S1	0.89	0	—	0.85	91.94	0.66
S2	0.75	0	—	0.85	109.67	1.28
S3	0.75	0	—	0.85	115.03	1.55
S4	0.7	0	—	0.8	123.72	2

Table 2. Results of sensitivity analysis. Change in model parameters, and percent change, required to change herd growth rate 1%.

	Change in Survival Rate	Percent Change	Change in Fecundity Rate	Percent Change
F0	0.0485	6.2		
F1	0.057	6.3	0.167	238.6
F2	0.0655	7.3	0.22	51.2
F3	0.0142	1.6	0.04445	7.3

dlings (Prichard et al. 1999). Carcass weight was estimated using the equation developed by Reimers (1997): Total Body Weight=5.9 + 1.66 * Carcass Weight.

This model assumes: 1) 50:50 sex ratio of calves; 2) all slaughtering occurs in winter; 3) input parameters are correct and stable; 4) no density–dependent effects; 5) no effect of skewed sex ratio on fecundity; and 6) no mortality from time of summer handlings to winter harvest.

Results

The model was calibrated using observed lactation rates and estimated survival rates for the Davis herd from 1984 to 1997 to compare predicted herd size to observed values. The models predicted herd size appears to be close to numbers observed during summer handlings (Fig. 2). Observed herd size is estimated from number of reindeer handled, therefore these are minimum estimates and actual herd growth rate may be larger than reported here. Linear regression was used to compare rates of increase between predicted herd size (328.6 animals per year) and observed herd size (300.5 animals per year). The two linear rates of increase were not significantly different (P = 0.10).

The sensitivity of the model to changes in in-

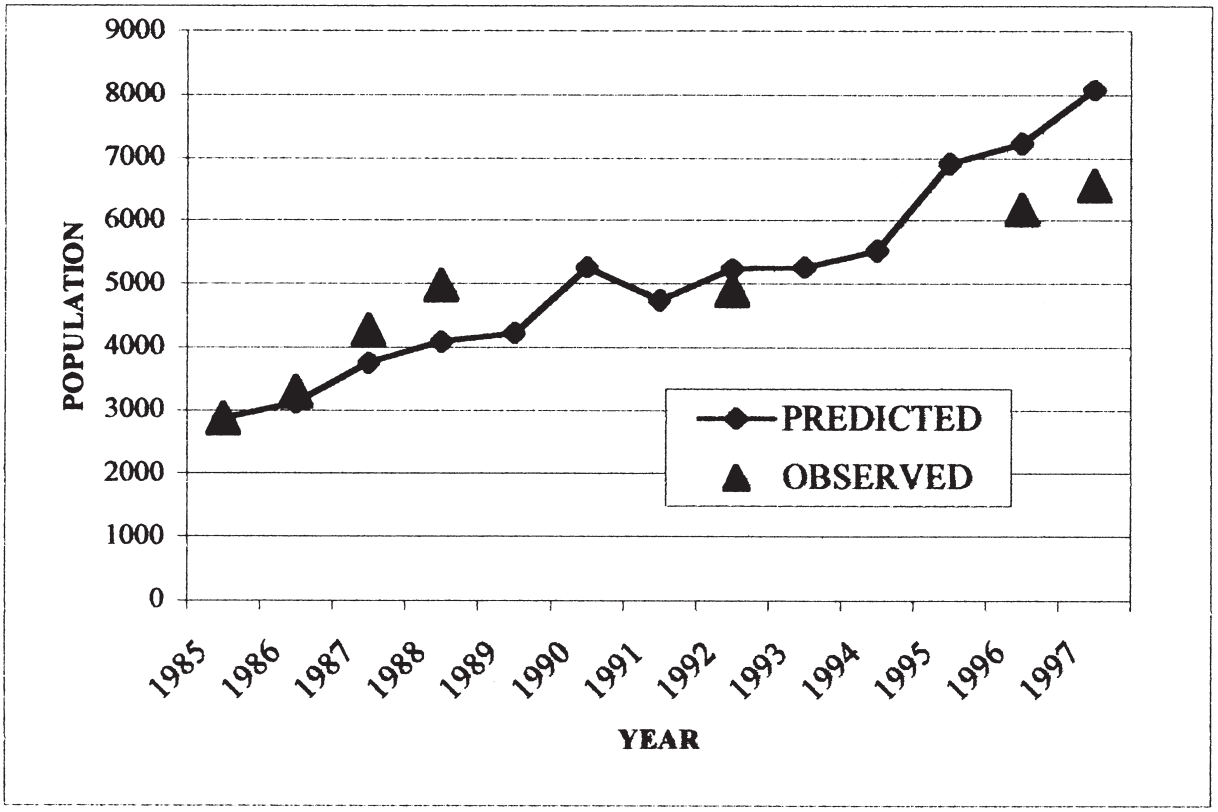

Figure 2. Observed and predicted herd growth of the Davis Reindeer Herd, Nome, Alaska.

Table 3. Herd growth rates under different harvest levels. Below are percent harvests of different age classes and sexes. Model started with a herd size of 1000 reindeer, antler price set to \$44 Kg^{-1} and meat price set to \$5 Kg^{-1}.

Harvest							Castration		Female: Male	Average Gross Income First Ratio	Herd size 10 years	r 10 yrs
F0	F1-F3	M0	M1	M2-M4	S1	S2-S4	M1	M2-M4				
0	0	0	0	0	0	0	0	0	1.79	56,555	2,448	0.083
0	0	0	0	0	0	90	50	50	14.35	67,523	2,154	0.083
0	0	0	0	50	0	90	50	50	18.08	67,309	2,126	0.083
0	0	0	0	0	0	50	50	50	14.35	134,008	2,222	0.083
0	0	0	0	0	0	50	50	75	36.17	147,110	2,202	0.083
0	5	0	0	0	0	50	50	50	12.86	113,779	1,467	0.037
0	10	0	0	0	0	50	50	50	11.44	97,588	952	-0.009
25	0	50	0	0	0	50	0	50	12.96	70,112	1,357	0.041

put parameters was tested by determining the amount of change in the parameters required to change the herd growth rate 1% (Table 2). This analysis showed that changes in adult female survival had the greatest effect on herd growth rate. A change of only 1.6% in adult female survival decreased overall herd growth by 1%. This underscores the importance of getting an accurate estimate of adult female survival as well as maximizing female survival if herd growth is desired.

We compared various harvest strategies to determine effect of alternative strategies on herd growth (r), sex ratio, income in year ten, and herd size after ten years (Table 3). The baseline herd growth rate with no harvest is 8.33% per year. Harvest of males does not affect the herd growth rate in this model, but it will affect the overall herd size as well as the male:female ratio. As expected, even low harvest levels of females greatly affect the herd growth rate. Selection of harvest strategy should maximize income while maintaining the population at or below carrying capacity and maintaining an appropriate sex ratio. In this case, strategy five provides the highest gross income but has an unacceptably large sex ratio. Strategy seven may be most appropriate if the herd is close to the carrying capacity and no further herd growth is desired. Changes in antler or meat price may require selection of an alternative harvest strategy.

Discussion

This model uses estimated parameters from the Davis herd on the Seward Peninsula, Alaska. The model parameters may require adjustment for application to other herds. This model was developed for herders handling in June and slaughtering during the winter. The model would have to be modified for a different management schedule. Although the model requires little knowledge of the use of Excel for basic use, knowledge of general spreadsheet operation is recommended for any alterations to the basic model. This model should be applicable to captive situations, although input parameters, especially survival, would vary considerably.

Because this model does not consider all possible management strategies, it does not determine the optimal harvest strategy, but it does allow the herd manager to compare different management strategies. If the management strategy is to be changed after some predetermined herd size is achieved, the model can be run twice, with the final herd size from strategy one input as the initial herd size in strategy two.

Although the model does not include decreases in herd size associated with overgrazing or highly skewed sex ratios, the user should only use management strategies that maintain acceptable sex ratios and levels of herd growth. As is true for any model, the predictions of this model are only as good as its assumptions and parameter estimates. This model is not intended to make guaranteed predictions of herd income and growth, but rather to be used to choose among potential management strategies and provide another tool for herders to use in making informed

management decisions.

Obtaining the Model

Copies of the model can be obtained free of charge from the Reindeer Research Program by email at fyrrp@uaf.edu, or downloaded from our website at:

http://reindeer.salrm.alaska.edu.

Microsoft Excel97 or later is required to run the model. While the model appears to work well for the Davis herd, we make no guarantees of applicability for other herds.

Acknowledgements

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The Reindeer Research Program was started in 1981 to improve and promote the reindeer industry in Alaska. For more information visit our website at: http://reindeer.salrm.alaska.edu.