Paper presented at The First Arctic Ungulate Conference,
Nuuk, Greenland, 3-8 September, 1991.

Simulated production losses in reindeer herds caused by accidental death of animals

C. J. Petersson and **Ö. Danell**

Dept. of Animal Breeding and Genetics, The Swedish University of Agriculture Sciences, S-75007 Uppsala, Sweden

Abstract: A dynamic age-structured model was used to simulate the consequences on herd production if an extra animal from a particular age class and season was lost. Herd size was adjusted to 1000 animals and a sex ratio of .75/.25 via slaughter in late autumn. Three harvest strategies were applied, ranging from extreme calf to adult harvest. Equilibrium herd structure was disturbed with the loss of an extra animal and the consequences in terms of the number of animals slaughtered and kilogram of carcasses produced were followed over a simulation period of 15 years. The loss of a male corresponded largely to 0.70 to 0.90 times its own carcass weight. Loss of a female decreased herd production by 1.2 to 1.7 times the carcass weight of the lost animal. The highest losses were observed for 4-6 year old females. Loss of a calf reduced herd production by 0.3 to 1.6 times the calf's carcass weight, depending on season of loss and harvest strategy. In general, a loss during winter decreased herd production 10 to 20 percent more than a loss during autumn.

Keywords: reindeer, herd dynamics, simulation, production loss, accidents, predators

Rangifer, 12 (3): 143-150

Introduction

Animal losses are a major limitation on productivity of reindeer husbandry. Normal mortality is related to the conditions to which the animals are kept. Some of them occur due to nonspecific reasons, but mainly, they occur due to identifiable reasons such as diseases, starvation, predators, traffic accidents, etc.

Disease and starvation influence herd productivity and alternate with high calving success and growth rates. Control of these disturbances can be seen as part of the production technique. Losses caused by predators and train or traffic accidents differ, that they affect individual animals and alter only the demographic structure of the herd. From the reindeer owner's point of view, these are unnecessary detriments to production caused by external circumstances, which they cannot control. However, the marginal effects of accidental losses are important both to the owner and other parties.

Predators alone may account for a considerable portion of total reindeer losses. Bjärvall *et al.* (1990) found in a survey of two herds in northern Sweden, that between 66% and 75% of all calf mortalities were caused by predators. Official Swedish statistics indicates that a total annual loss of about 3% of the animal stock has been caused by predators in recent years (B. Sörensen, pers. comm.).

Accidental losses affect herd productivity directly via their potential slaughter values. Indirect consequences involve the dynamic effects on the herd's age structure and its impact on the productivity during subsequent years. Direct effects are easy to evaluate, while evaluation of indirect effects requires prediction of the herd's dynamic behaviour over time. The purpose of this study was to illustrate the use of herd simulation as a tool to evaluate the consequences of an individual animal loss in specific age and sex classes and during different seasons on production.

Methods

A dynamic simulation model of a reindeer herd with an arbitrary size of 750 females and 250 males was developed. Twenty-five discrete classes of animals were distinguished; 9 classes of calves (age 0) with mothers of different ages, females in age-classes from 1 to 9+ years of age and males in age-classes from 1 to 7 years of age. The sex ratio in the calf classes were assumed to be 0.5/0.5.

The year was divided into six discrete periods as shown in Fig. 1. Periods P1, P3 and P5 were together assumed to cover the whole year. During these periods, all reduction of animals due to mortality were assumed to occur. Periods

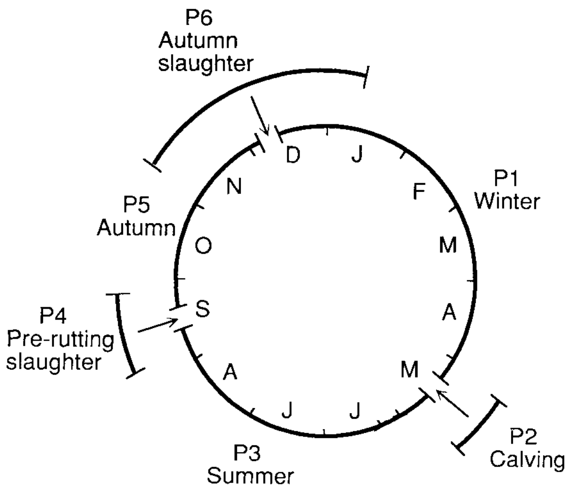

Fig. 1. Division of the year in periods P1 – P6.

Table 1. Assumed calving rates, survival probabilities and carcass weights (kg). The parameters are based mainly on Korak (1985) and B. Saitton (pers. comm. 1985).

Animal age-class		Calving rate	Calf[1,2] survival	Own survival winter	Own survival summer	Own survival autumn	Carcass[3] weight (kg)
Females	1	.05	.00	.965	.970	.975	26
	2	.50	.50	.970	.975	.980	30
	3	.70	.65	.	.	.	33
	4	.80	.70	.	.	.	36
	5	.85	.75	.	.	.	38
	6	.90	.80	.	.	.	39
	7	.95	.85	.	.	.	40
	8	.95	.90	.	.	.	40
	9+	.90	.95	.970	.975	.980	40
Males	1			.970	.975	.980	29
	2			.	.980	.	35
	3			.	.	.	40
	4			.	.	.	44
	5			.	.	.	47
	6			.	.	.	49
	7			.970	.980	.980	50

[1] Assumed total survival rates. Total loss (1 – surv. rate) is divided among winter, summer and autumn periods in the amounts of 31, 33 and 36 percent, respectively.

[2] Survival rates of calves becoming motherless during winter, summer and autumn were set at .70, .00 and .30, respectively.

[3] Carcass weights for male and female calves were set to 19 and 17 kg, respectively.

Table 2. Predetermined involuntary slaughter (figures with 2 decimals) and the ultimate proportions slaughtered (with 4 decimals) under equilibrium at pre-rutting (P4) and autumn slaughter (P6) in the three studied harvest models. Values within parenthesis represent the intended harvest in these age-classes, although no animals occurred in them under equilibrium herd structure.

Animal age-class		Involuntary slaughter	Comb. calf and adult harvest		Extreme calf harvest model		Extreme adult harvest model	
			P4	P6	P4	P6	P4	P6
Females	0	.01		.1102		.4506		.01
	1	.01		.2700		.01		.01
	2	.01		.01		.01		.01
	3	.03		.03		.03		.03
	4	.04		.04		.04		.04
	5	.05		.05		.05		.05
	6	.07		.07		.07		.8377
	7	.09		.1100		.09		1.0000
	8	.11		.3000		.11		(1.00)
	9+	.25		.6000		.25		.(1.00)
Males	0	.01		.2466		.7670		.01
	1	.01	.3132	.0468	.0087	.0014	.3480	.0739
	2	.01	.8400		.01		.8400	1.0000
	3	.03	.3300		.03			(1.00)
	4	.04	.2504		.04			(1.00)
	5	.05	.2495		.05			(1.00)
	6	.07	.3314		.07			(1.00)
	7	1.00	1.0000		1.00			(1.00)

P2, P4 and P6 were treated as momentaneous events. At this time, calving, transmission to an higher age-class and harvest of slaughter animals take place. Actually, these periods cover time frames which partially overlap with P1, P3 and P5.

The transition of animals between age-class compartments of the model is determined by calving percentages, survival probabilities and proportions retained at slaughter. For the evaluation of production output, carcass weights are required. The parameters used in the so-called «normal herd» by The National Board of Agriculture (Korak, 1985) were chosen as a base, assuming that they are valid averages for reindeer husbandry in Sweden. A summary of the parameters used, except harvest removals, is given in Table 1. Differentiation of the survival probabilities of calves according to the different mother ages as well as survival probabilities of motherless calves was applied subjectively with the guidance of empirical knowledge gained from reindeer herders (B. Saitton, pers. comm.).

Harvest of slaughter animals occurred in periods P4 and P6. In P4, the pre-rutting slaughter, only males were slaughtered, while animals of both sexes were harvested in P6. Three different harvest policies were studied: i) a combined calf and adult harvest model which resembled the average harvest practice in Sweden; ii) an extreme calf harvest model; and iii) an extreme adult harvest model. All harvest models assumed the same involuntary harvest as a base. The remainder of the harvest was modelled in two steps. First, the majority of slaughter animals were removed in a predetermined harvest which followed the intentions of each harvest model. The second harvest step at the end of P6, regulated the number of animals to satisfy the predetermined herd size and sex ratio. The harvest strategies for the three models is given in Table 2.

Productivity of the herd was measured by the number of slaughtered animals and the total amount of carcass produced. Conversion to revenues used the average Swedish price for

1990/91 of SEK 22.30 per kg carcass plus the production support of SEK 364.00 per carcass for the same production year.

The model was coded in DYNAMO (Gustafsson, 1983), which is a simulation language predominantly designed for time-continuous models. In this case, the six discrete periods of the year were used as time steps.

The evaluation began by running the model until equilibrium was obtained. The model was then disturbed with the loss of an extra animal in a particular sex and age-class during one of the periods P1, P3 or P5 and then run for another 15 years in order to closely reach equilibrium. The slaughter output was monitored and contrasted with the equilibrium simulation. Actual revenues and revenues discounted to the year of loss were accumulated. The discounting *(D)* factor used was:

$$D=(1+R)^{-y}$$

where, R is the discount rate, determined to be .05, and y is the number of years since the extra loss occurred.

Results and discussion

Equilibrium herd structures and productivities in the three harvest alternatives are given in Table 3.

Results over a 15-year simulation that followed the accidental loss of animals in different age-classes and during different seasons are given in Table 4 – 6. Fig. 2 gives examples of fluctuations in annual revenue for the 15 years in the combined calf and adult harvest alternative.

The simulations indicated surprisingly small differences in total productivity between the three harvest models. However, the price system introduced some differences in total revenue.

Table 3. Number of animals in different age-classes at the start of the winter period (P1) and total harvest under equilibrium in the three slaughter harvest models.

		Comb. calf and adult harvest	Extreme calf harvest model	Extreme adult harvest model
Age-classes				
Females	0	164.2	113.8	164.1
	1	104.8	99.5	139.4
	2	95.7	90.8	127.2
	3	86.0	81.7	114.4
	4	76.5	72.7	101.8
	5	67.4	64.0	89.6
	6	58.1	55.2	13.5
	7	47.9	46.5	0.0
	8	31.1	38.4	0.0
	9+	18.3	87.5	0.0
Males	0	139.0	48.3	164.1
	1	80.4	42.6	85.9
	2	12.0	39.3	0.0
	3	7.5	35.5	0.0
	4	5.2	31.8	0.0
	5	3.7	28.1	0.0
	6	2.3	24.4	0.0
	7	0.0	0.0	0.0
Yearly harvest				
No. of animals		283.5	335.7	239.3
Kg carcass		8 575	8 135	8 309
Revenue, SEK		297 417	303 605	272 396

Table 4. Combined calf and adult harvest model. Production loss in terms of number of animals slaughtered (in parenthesis) and kg of carcass over 15 years as a result of the loss of an extra animal in different seasons and age-classes during year 1.

Age-class of		Season of loss year 1					
lost animal		winter	(P1)	summer	(P3)	autumn	(P5)
Females	0	(1.54)	29.06	(.91)	15.32	(1.00)	16.81
	1	(2.35)	43.56	(1.59)	29.94	(1.62)	30.63
	2	(2.73)	53.38	(2.41)	44.63	(2.36)	43.18
	3	(2.89)	59.69	(2.70)	52.81	(2.59)	51.00
	4	(2.91)	62.88	(2.81)	57.75	(2.66)	55.44
	5	(2.86)	64.56	(2.80)	60.56	(2.64)	57.75
	6	(2.73)	64.94	(2.71)	61.69	(2.52)	58.44
	7	(2.52)	63.81	(2.55)	61.50	(2.34)	58.00
	8	(2.36)	62.44	(2.32)	59.69	(2.08)	55.88
	9+	(2.36)	62.31	(2.14)	58.00	(1.89)	53.13
Males	0	(.99)	26.31	(.91)	17.25	(1.00)	19.00
	1	(.99)	32.63	(1.02)	26.94	(1.05)	26.63
	2	(1.01)	30.44	(1.01)	32.25	(1.06)	24.38
	3	(1.01)	33.63	(1.03)	31.06	(1.06)	27.44
	4	(1.00)	37.88	(1.03)	34.31	(1.06)	31.63
	5	(1.00)	43.25	(1.02)	38.69	(1.05)	36.75
	6	(.98)	49.00	(1.02)	44.13	(1.04)	42.31
	7			(1.00)	50.00	(1.04)	46.69

Table 5. Calf harvest model. Production loss in terms of number of animals slaughtered (in parenthesis) and kg of carcass over 15 years as a result of the loss of an extra animal in different seasons and age-classes during year 1.

Age-class of		Season of loss year 1					
lost animal		winter	(P1)	summer	(P3)	autumn	(P5)
Females	0	(1.57)	28.94	(.92)	15.50	(1.00)	16.87
	1	(2.20)	41.94	(1.62)	29.69	(1.66)	30.44
	2	(2.56)	50.06	(2.26)	43.06	(2.20)	41.87
	3	(2.76)	55.44	(2.59)	50.69	(2.47)	48.62
	4	(2.86)	58.87	(2.75)	55.37	(2.61)	52.87
	5	(2.88)	61.06	(2.83)	58.37	(2.67)	55.69
	6	(2.86)	62.37	(2.85)	60.50	(2.67)	57.44
	7	(2.77)	62.06	(2.82)	61.37	(2.61)	58.00
	8	(2.64)	61.19	(2.71)	61.12	(2.49)	57.44
	9+	(2.64)	61.25	(2.56)	59.94	(2.35)	56.19
Males	0	(.98)	21.18	(.92)	17.38	(1.00)	18.94
	1	(.98)	24.56	(1.00)	22.38	(1.02)	22.75
	2	(.98)	27.69	(1.00)	25.06	(1.01)	25.50
	3	(.97)	31.13	(1.00)	28.31	(1.02)	28.56
	4	(.98)	34.88	(1.00)	31.88	(1.02)	32.06
	5	(.97)	39.00	(1.00)	35.56	(1.01)	35.81
	6	(.98)	49.00	(.99)	39.94	(1.01)	40.00
	7			(1.00)	50.00		

Table 6 Adult harvest model. Production loss in terms of number of animals slaughtered (in parenthesis) and kg of carcass over 15 years as a result of the loss of an extra animal in different seasons and age-classes during year 1.

Age-class of lost animal		Season of loss year 1 winter	(P1)	summer	(P3)	autumn	(P5)
Females	0	(.39)	16.88	(.03)	5.00	(.03)	5.81
	1	(.77)	28.38	(.41)	17.44	(.41)	17.88
	2	(1.06)	37.81	(.79)	29.06	(.75)	28.19
	3	(1.25)	44.13	(1.03)	36.88	(.97)	35.25
	4	(1.37)	48.81	(1.18)	41.88	(1.11)	40.06
	5	(1.47)	52.50	(1.29)	45.88	(1.21)	43.88
	6	(1.52)	55.06	(1.37)	49.19	(1.27)	46.81
	7			(1.41)	51.44	(1.30)	48.69
Males	0	(.96)	27.88	(.82)	18.81	(.92)	21.06
	1	(.97)	34.19	(.98)	28.63	(1.00)	29.00
	2			(.99)	34.88	(1.00)	35.00

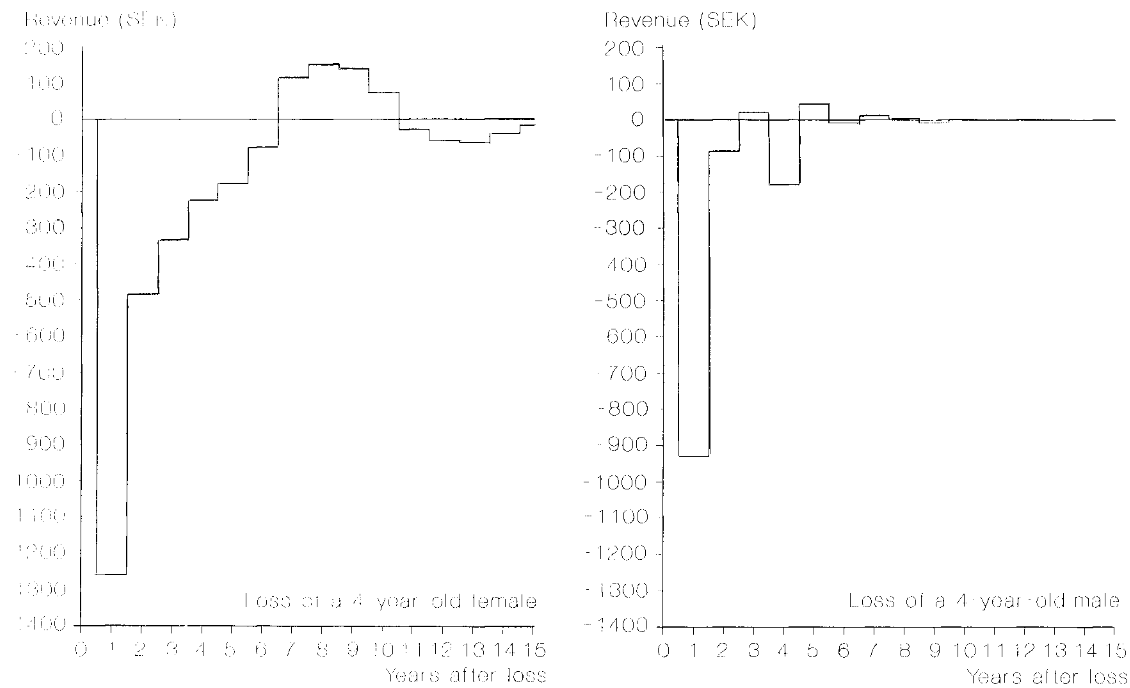

Fig. 2. Two examples of changes in the yearly revenue of the flock caused by the loss of one animal during summer (P3) in the combined calf and adult harvest alternative.

Consequences of an adult female loss differed mainly between the extreme adult harvest model and the other harvest models. Loss in carcass weights were 15 - 40% lower in the extreme adult harvest model. For males, loss in carcass weight was slightly lower in the calf harvest model than in the others. Loss of a female calf caused considerably less damage to production than loss of a male calf in the adult harvest model. Corresponding differences in the other models were small. This reflects the loss of a replacement female calf and results in an adult female retained for another year of production before slaughter. Contrary, a male calf mortality is more directly a lost slaughter animal.

Losses of females generally caused more severe consequences than that of males. This is a natural result of the dual role of females as both calf producers and potential slaughter animals. This is clearly illustrated in the recovery pattern in herd production. Recovery from a female loss was generally much slower. Oscillations in productivity were predicted to occur before equilibrium was reached due to disturbed age distributions. These were least pronounced in the adult slaughter alternative, however, because of the faster turn-over of producing females in that alternative.

Disturbance in herd production was greatest when females losses occurred during winter and lowest for losses during autumn. Winter losses cannot be repaired by retaining extra replacement animals until the next autumn. This delays the recovery of herd productivity. For males a winter loss results in the loss of a heavier potential slaughter animal, but is counterbalanced by the risk that it will not survive until slaughter. Because of this interaction, a loss of a 3-year-old male during winter is the least severe, while loosing it during autumn as a 4-year-old is the most severe. It is probable that these patterns are sensitive to the parameters used and, consequently, results would vary among regions.

The most valuable females in the combined calf and adult and the extreme calf harvest models were those between 4 - 6 years of age. These animals are productive, still have a long productive life, and have reached relatively high values as slaughter animals. In the adult harvest model, the oldest animals were the most valuable, since their slaughter values dominate more due to their shorter productive lives. In males, oldest animals were most valuable because of assumed higher weights.

Fig. 3 interprets production losses into discounted losses in revenue for the three harvest alternatives. There was little differences (2 - 5 percent) between discounted and actual change in revenue since the main consequences of loosing an animal occurred shortly after the loss. The economic consequences are specific for the Swedish price system where payment is partly based on the number of animals slaughtered.

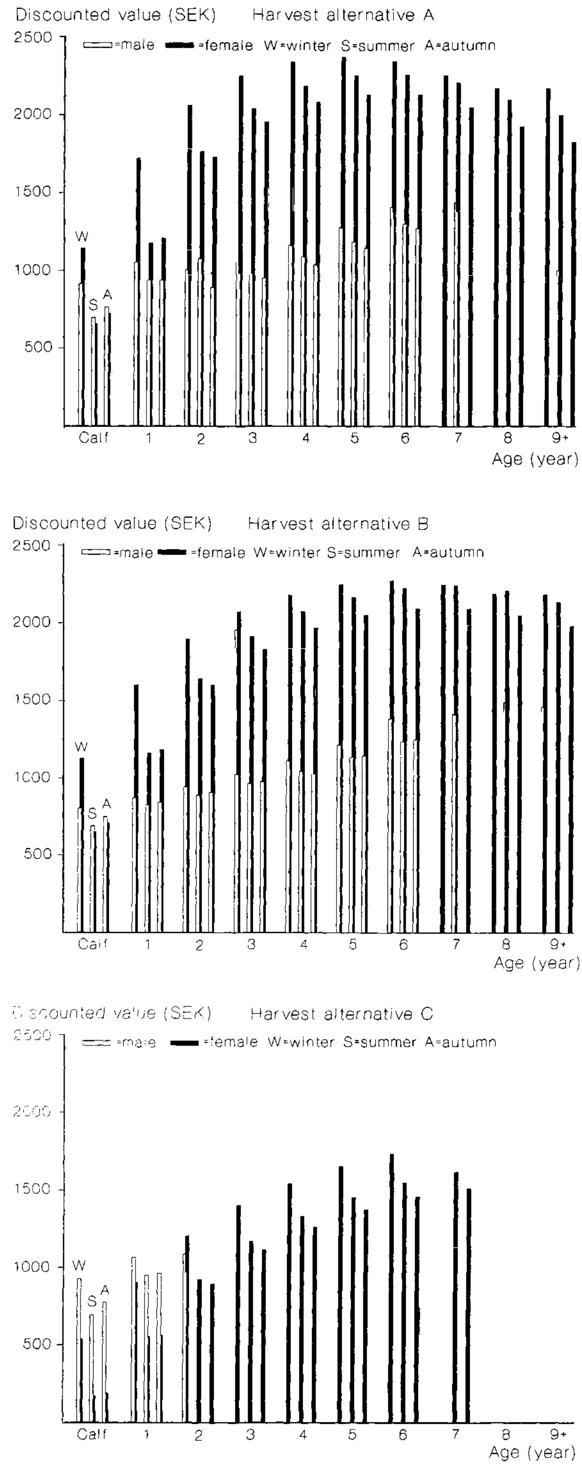

Fig. 3. Expected discounted marginal production values of animals lost at different ages and during different seasons in the three harvest alternatives (A = combined calf and adult harvest, B = extreme calf harvest, C = extreme adult harvest).

No grading of carcasses is done, but the per head payment gives advantage to younger over older animals (on average more than SEK 40.00 per kg carcass for calves vs. around SEK 30.00 per kg carcass for adult animals).

For an average reindeer owner, having about 300–400 animals in the winter herd, an additional annual 3% overall animal loss due to accidents and predators corresponds, according to the result of this study, to a reduction of the slaughter return at around 17% or around SEK 15 000 - 20 000.

Compensation for loss due to predators or traffic accidents is currently SEK 850, 2900 and 1900 per calf, adult female and adult male respectively (B. Sörensen, pers. comm.). The values in Fig. 3 agree with these compensations as they include the compensation for an extra one-third animal that is supposed to have been killed by a predator but not retrieved.

References

Bjärvall, A., Franzén, R., Nordkvist, M. and **Åhman, G.** 1990. *Renar och rovdjur.* Stockholm: Naturvårdsverket. 296 pp.

Korak, H. 1985. *Värdering av livrenar renskötselåret 1985/86.* Lantbruksstyrelsen-Rennäringsenheten, Jönköping. Mimeo. 6 pp.

Gustafsson, L. 1983. *Modellbyggnad och simulering i DYNAMO.* Uppsala: Uppsala universitet. 149 pp.

Personal communications:

Bror Saitton. Svenska Samernas Riksförbund, Umeå.

Bengt Sörensen. Statens jordbruksverk, Jönköping.

Manuscript accepted 7 February, 1992