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RESULTS OF SIMULATION STUDIES FOR OPTIMUM MEAT PRODUCTION FROM THE SWEDISH MOOSE POPULATION

Jan-Ake Eriksson and Susanne Sylvén

Department of Animal Breeding and Genetics

Swedish University of Agricultural Sciences

S-750 07 Uppsala 7, Sweden

ABSTRACT

Several alternative forms of hunting policy for moose in Sweden have been evaluated in a simulation study. Three populations native to different geographical and climatic regions were studied. These populations differed mainly with regard to their rate of reproduction and carcass weight. The determining factors which were varied were the proportions and categories (cows with and without singleton or twin calves) of cows harvested and the proportion between yearlings and calves harvested. The winter population was restricted to a constant size. Altogether 60 alternatives were simulated. The results were expressed as: meat yield from a winter population of equal carcass weight, rate of population increase, percentage of calves harvested, and percentage of calves in winter population. These factors are of importance in the formulation of an optimal hunting policy for different parts of Sweden.

Maximum meat production was obtained when the calves represented a 15-25 per cent share of the harvest, the lower figure corresponding to the population with the lowest rate of reproduction. Greatest rate of population increase was observed in the alternatives which had the highest percentage of calves harvested.

In many parts of Sweden the moose population density has reached a level which is now at maximum or even above that which the environment can bear. Air censuses of two counties in central Sweden, Västmanland (520.000 ha) and Värmland (1.744.000 ha), have estimated their respective moose herd densities to be 10.5 moose per 1.000 ha (Stålfelt, 1977) and 23 moose per 1.000 ha (Svensk Jakt, 1978). In view of such figures, it is clear that the size and structure of our moose population will have to be controlled. Wilhelmson & Sylvén (1979) have discussed the causes for this explosive increase in the Swedish moose population.

The moose management plan must take into consideration the effect of the moose herd on the environment, if it is intended to achieve a healthy moose population of good quality. Moose make their presence in the environment known not merely by browsing in forested areas and on cultivated land. Other important considerations in moose management are their increasing involvement in traffic accidents, caused by straying on our highways, the present and future place of moose in meat production, the attitude of hunters to moose harvesting and the attitude of the public to the moose population in general.

To achieve an optimal output from the moose population, taking into account the above-mentioned factors, it is important to know how different hunting regulations would affect the population structure. The structure of the moose population itself exerts a great influence on the environment.

In order to maintain a high density moose population in optimum conditions, the negative factors among the above-mentioned must be minimized and the positive ones maximized. There is otherwise a risk of conflict between different groups of interests, that could itself be to the detriment of the moose population.

Meat production from moose herds of constant winter size and regulated according to varying harvesting models has been simulated by Sylvén et al. (1979). In that simulation study, most interest was devoted to meat yield per winter herd animal, though effect on the average age of adults and the rate of population increase from winter to open season were also treated.

The purpose of the present paper, however, is to consider other effects of varying the harvesting policy in three populations native to different geographical and climatic regions of Sweden. The simulations here are the same as in the aforementioned simulation study and should be considered as complementary to that paper. The results are expressed as:
1. The meat yield, expressed as kg carcass harvested per kg carcass in the winter herd, gives some measure of guidance as to the meat yield to

be expected from a winter herd whose individual members are regarded as of equal weight and whose energy requirements are therefore probably constant too.
2. The rate of increase in the winter herd, from winter to the open season, serves to indicate the number of animals to be harvested.
3. The percentage of calves harvested gives an indication of the difficulties encountered in harvesting.
4. The percentage of calves in the winter herd is an indicator of the structure in the herd.

It is hoped that this investigation will stimulate further research concerning the effects of the Swedish moose population on the environment and also give some guidelines on moose management for the different regions in Sweden.

ASSUMPTIONS AND METHODS

Three populations native to different geographical and climatic regions in Sweden have been chosen for this study. These populations, which differ mainly in their rate of reproduction and carcass weight, have been chosen just because differences have such a profound influence on population dynamics and consequently on meat production.

The basic biological parameters for these populations have been taken from separate estimates made for southern (population I), central (population II) and northern (population III) Sweden.

Reproductive Traits

In the simulations described below, the following reproductive traits have been varied.

(i) proportion of cows with calf

(ii) number of calves per pregnant cow

(iii) proportion of sexually mature yearlings

(iv) sex ratio of calves

The estimated values for the reproductive parameters are given in Table 1. For populations I and II, the estimates are taken from Stålfelt et al. (1974) and for population III from Markgren (1977), except for percentage of sexually mature female yearlings in population III, where information from Haagenrud et al. (1975) is included and percentage of male calves born in populations I and II where information from Persson & Wallin (1970) has been used.

As seen in Table 1, yearling bulls in these simulations are assumed not to be sexually mature, since the question of their ability in this regard has not yet been satisfactorily analysed.

It has been assumed in the simulations that there was no natural mortality among the animals, except for those reaching 20 years of age, all of which were presumed to die off during the winter. This of course does not accord with reality, but no estimates of natural mortality are

Table 1. Population parameters corresponding to the three provinces of Sweden used in the simulation studies (the estimates from Stålfelt et al., 1974; Markgren, 1977)

	Sweden		
	Pop I	Pop II	Pop III
i) Percentage of pregnant females			
♀ = 1.5 years of age	65	47	14
♀ ≥ 2.5 years of age	95	92	90
ii) No. of calves per pregnant female			
♀ = 1.5 years of age	1.18	1.09	1.00
♀ = 2.5 to 3.5 years of age	1.59	1.55	1.03
♀ = 4.5 to 9.5 years of age	1.79	1.56	1.11
♀ = 10.5 to 11.5 years of age	1.59	1.41	1.11
♀ = 12.5 to 19.5 years of age	1.59	1.41	1.00
iii) Percentage of sexually mature animals			
♂ = 1.5 years of age	0	0	0
♂ ≥ 2.5 years of age	100	100	100
♀ = 1.5 years of age	70	55	20
♀ ≥ 2.5 years of age	100	100	100
iv) Percentage male calves born	53	53	60

available for Swedish moose. The natural mortality could be partly off-set by a probable underestimation of fertility. The latter probably arises because the number of calves per female is estimated from a selected sample, namely cows harvested. Hunters in Sweden prefer cows without calf in their hunting bag, and consequently try to protect the most fertile females.

Table 2. The carcass weights in the different age classes used in the simulation studies (the estimates from Stålfelt et al., 1974; Markgren, 1977)

Age in years	Sex	Pop I	Pop II	Pop III[1]) Hunting season 1	Hunting season 2
0.5	♂	82	80	64	74
	♀	77	75	56	65
1.5	♂	158	158	133	138
	♀	157	150	124	124
2.5	♂	195	190	178	163
	♀	175	170	160	160
3.5	♂	208	205	216	216
	♀	180	178	180	180
4.5	♂	225	217	253	223
	♀	181	178	188	188
5.5	♂	234	225	260	225
	♀	184	178	183	183
6.5	♂	245	228	274	256
	♀	189	180	186	186
7.5 and older	♂	241	236	280	253
	♀	192	187	190	190

[1]) Weights from two hunting seasons in Pop III.

Carcass Weight

The different carcass weights according to age are shown in Table 2. In population III the open season is split into two periods, preceding and following the rut; in populations I and II the open season follows the rut. The estimates of carcass weight used for populations I and II are from Stålfelt et al. (1974) and for population III from Markgren (1977).

Harvesting Alternatives

The various harvesting alternatives are comprised of various combinations of preconditions, as shown in Table 3. In population III the open season is split into two periods. In the first period, some 40-60 per cent of the increase in the population that year will be shot and in the second period a fixed number of animals, in fact 20% of the winter herd. The winter herd is held at a constant size. In populations I and II the open season follows the rut.

Calculations

The calculations were done according to a Norwegian simulation program of population dynamics for cervine herds (Digernes & Rusten, 1977). This program has been modified and adapted for the computer at our institution. These modifications and their applications are described by Eriksson et al. (1979). In this program the annual cycle of the

Table 3. Figures used in the simulations both in winter and during the hunting season

	Population	
	I and II	III
Number of mature females per male in the winter population	3	3
Proportion of adult cows (≥ 2.5 years of age) in the harvest	5, 10, 15 and 20%	15, 20, 25 and 30%
Shooting regulations re mature females		
- cows with twin calves are protected, A	*	*
- all categories may be shot, but the proportion of cows with calves is limited, B	*	
Proportions of yearlings to calves in the harvest	70:30, 50:50 30:70	70:30, 50:50 30:70

animals is divided into four main events, winter (mortality), calving season, summer (calf mortality), and autumn (harvesting and rutting). The open season could be divided into two periods, preceding and following the rut.

In the calculations the herds were split into six categories of animals: cows, bulls, yearling bulls, yearling heifers, bull- and heifer calves. The lower age limit for category "cow", which is used in the simulations and is presented in the results, is 2.5 years.

Within the categories yearlings and calves, the animals were assumed

to be shot in proportion to their sex distribution, which is in effect the same as that for calves alone. The shooting of cows and bulls is so regulated that the heavier animals are stalked somewhat more keenly but that the predetermained sex ratio in the winter herd is maintained.

The calculations span a period of 18 years, and the values for meat yield given are the means of results from the last 10 years. The other results (e.g. rate of population increase) are taken from the last available year. Thus the results are drawn from the time when the population structure had stabilized.

The meat production from a winter population of equal carcass weight has been computed in the following way.

$$k = \frac{m}{a}$$

where

k is a 10-year average of meat production expressed in kg per kg carcass weight in the winter population,

m is the meat production in kg per animal in the winter population,

a is the average carcass weight per animal in the winter population.

RESULTS

The relationship between sexually mature animals in the winter herd as used in this simulation study, i.e. 3 cows per bull, may appear rather skew. However, it should be pointed out that during the rutting season the sex distribution among adults (animals older than calf) is about 1.2-1.5 adult cows per adult bull (Sylvén et al., 1979).

Meat Production From A Winter Herd Of Equal Carcass Weight

The protecting of cows with twin calves, alternative A in Figures 1-3, means that some of the most reproductive members of the herd are spared and greater intensity is laid on shooting young and old cows. The shooting of all categories of cows, though with emphasis on cows without calves, alternative B in the figures, means that more 1.5-year-old cows together with cows without calves are harvested than cows with calves. Table 1 shows that the percentage of pregnant cows is assumed to be the same for all categories over the age of 2 years. Varying of the yearling : calf proportion in the harvest within the same proportion of cows harvested makes it possible to compare the effect of shooting the young animals either as calves or as yearlings.

In all three population, protecting cows with twin calves, alternative A, produced most meat, Fig. 1-3, except at 20 per cent of cows in the harvest in population I. A low proportion of calves in the harvest, a yearling : calf proportion of 70:30, gives the highest meat yield in all three populations.

In population I the best meat yield is obtained when cows account for 15 per cent of the harvest in all alternatives, except at a yearling :

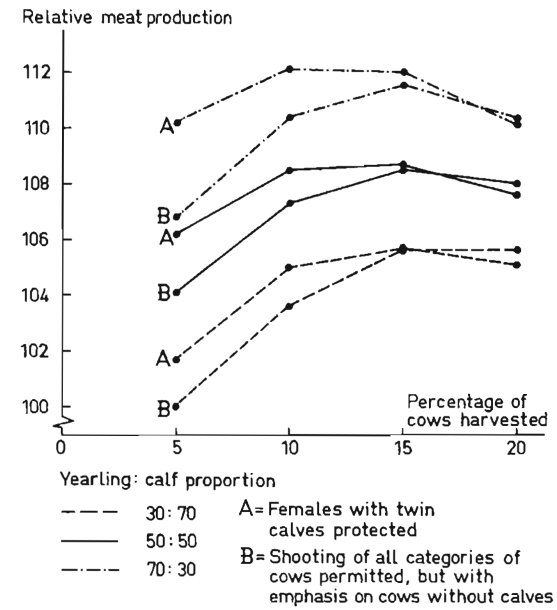

Figure 1. Population I. Relative meat production per kg carcass in winter herd, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. The relative figure of 100 represents a meat yield of 0.524 kg.

calf proportion of 70:30 where 10 per cent of cows in the harvest when mothers of twins are protected, gives the same meat yield, Fig. 1. The pattern is the same for population II and the corresponding figures are 20 per cent and 15 per cent, respectively, Fig. 2.

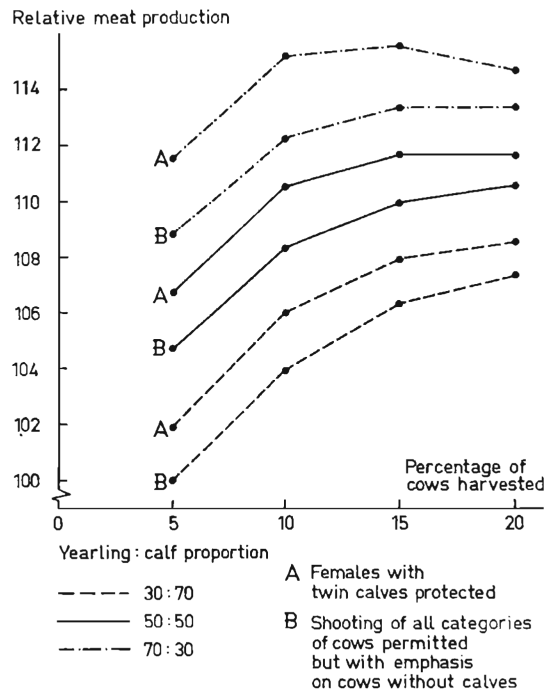

Figure 2. Population II. Relative meat production per kg carcass in winter herd, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. The relative figure of 100 represents a meat yield of 0.465 kg.

In population III, Fig. 3, a high proportion of cows in the harvest leaves a high proportion of orphaned calves in the winter herd, which therefore makes this alternative clearly unrealistic. Hence a 25 per cent

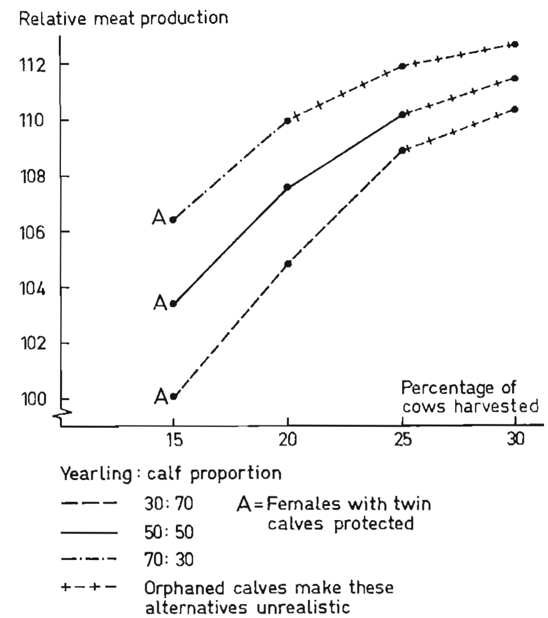

Figure 3. Population III. Relative meat production per kg carcass in winter herd, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. The relative figure of 100 represents a meat yield of 0.375 kg.

share of cows in harvest and a yearling : calf proportion of 50:50 gives the best meat yield.

The percentages of cows in harvest at maximum meat yield are 15, 20, and 25 for population I, II and III, respectively. These figures correspond to cow recruitment percentages, (i.e. percentage recruited heifers in the winter herd) of 15, 19, and 20 respectively, which are at roughly the same level in all three populations. Sylvén et al. (1979) show the connections between fertility level and recruitment of cows for populations having varying fertility levels.

Percentage Of Calves Harvested, Percentage Of Calves In Winter Herd And Rate Of Increase Of Population Between Winter And Open Season

Figures 4-6 show for the three populations the percentages of calves in the harvest and the rates of increase in winter herd size between winter and the open season (rate of population increase) as a function of the percentage of cows in harvest. Only the shooting regulation re mature cows, viz. cows with twin calves protected, alternative A, is shown. The difference between the two alternatives, cows with twin calves protected and shooting of all cows with emphasis on cows without calves, is small. The largest difference is for percentage of calves in the winter herd and in the harvest 1 percentage unit lower and for rate of increase 2 percentage units lower in alternative B than in alternative A.

The pattern is the same for all three populations and Figs. 4-6 shows that: (1) the percentage of calves in the harvest decreases in inverse proportion to the increasing percentage of cows in the harvest, (2) the rate of increase in the population levels off in proportion to

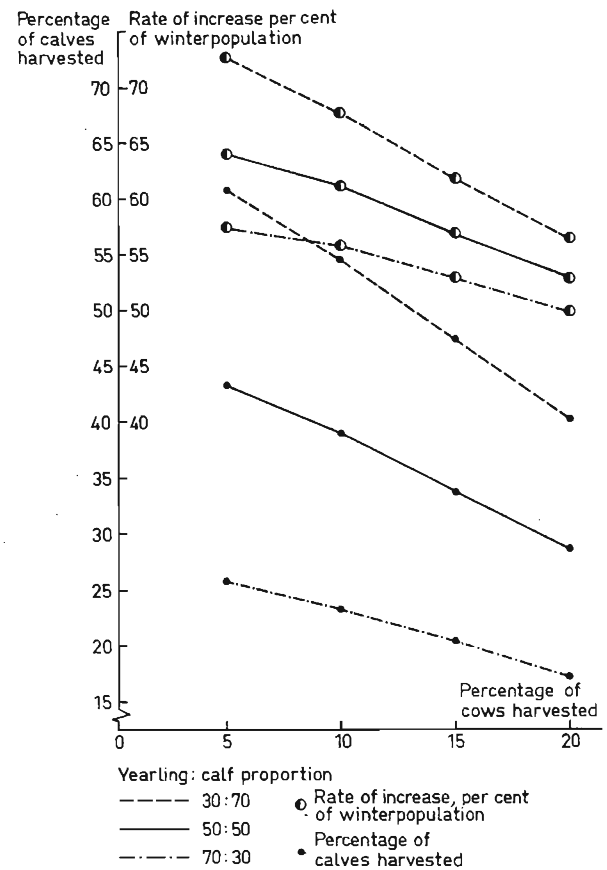

Figure 4. Population I. Percentage of calves in the harvest and rate of increase, percentage of winter population from winter to open season, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. Cows, with twin calves protected.

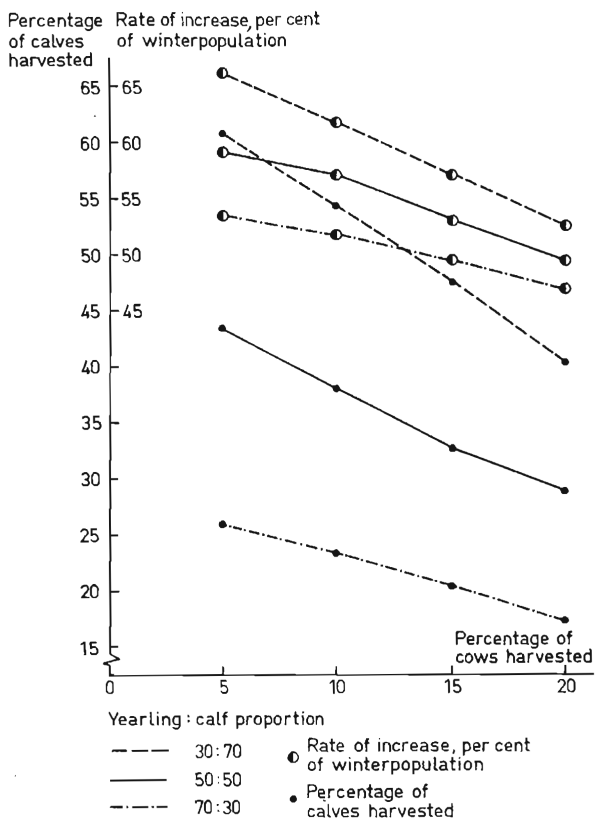

Figure 5. Population II. Percentage of calves in the harvest and rate of increase, percentage of winter population from winter to open season, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. Cows, with twin calves protected.

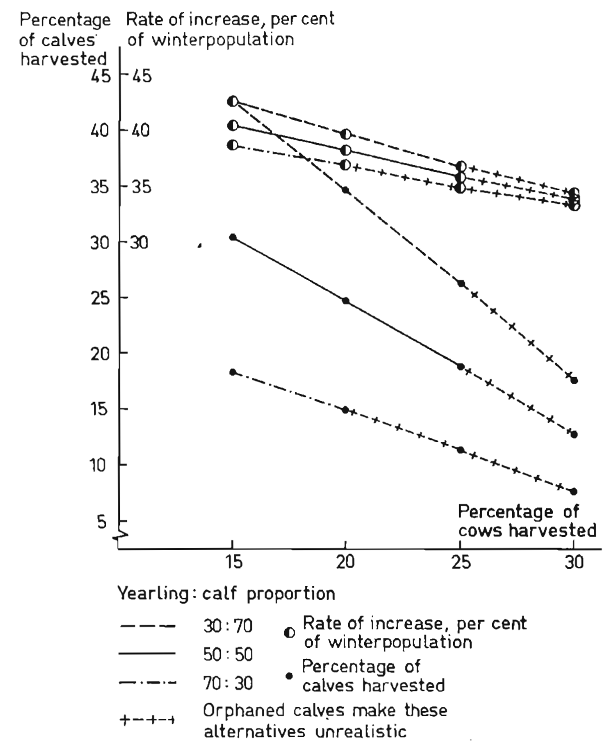

Figure 6. Population III. Percentage of calves in the harvest and rate of increase, percentage of winter population from winter to open season, as a function of percentage of cows in the harvest, with varying yearling : calf proportions in the harvest. Cows, with twin calves protected.

the increasing percentage of cows in the harvest, (3) a high proportion of calves, e.g. a yearling : calf proportion of 30:70, gives the highest rate of increase in the population, (4) differences in the rate of increase in the population, between the various alternatives, increase with increasing fertility in the population.

The percentage of calves in the winter herd is shown in Table 4, the smallest figure in each column referring to the alternative of lowest percentage of cows in harvest and the highest figure to the highest percentage of cows in harvest. Table 4 shows that: (1) the variation in the percentage of calves in the winter herd within each yearling : calf proportion alternative and population is small, (2) the percentage of calves in the winter herd increases in all alternatives with increasing fertility in the population.

Table 4. Population I, II and III. Percentages of calves in winterherd, cows with twin calves protected

Population	Percentage of cows harvested	Yearling : calf proportion in harvest 30:70	50:50	70:30
I	5, 10, 15, 20	29.2-33.7	36.4-37.7	41.2-42.6
II	5, 10, 15, 20	26.6-31.3	33.6-35.3	38.7-39.6
III	15, 20, 25, 30	24.5-28.3	28.2-29.5	30.6-31.5

DISCUSSION

The meat yield expressed as kg meat per kg carcass in the winter herd or as kg meat per animal in the winter herd (Sylvén et al., 1979) had a profound effect on the output from the corresponding alternatives.

It was shown earlier (Sylvén et al., 1979) that in population I an increase in the proportion of calves in the harvest gave a slight increase in meat yield, whereas in population III the effect was the reverse. In population II the output was not dependent on the proportion of calves in the harvest. Maximum meat yield was also achieved with a lower proportion of cows in the harvest.

The difference in output in the two studies can be explained by the fact that a high proportion of calves and young animals in the winter herd gives a winter herd of low total weight. Such a winter herd is achieved by a low proportion of calves and a relatively high proportion of cows in the harvest.

Equal carcass weight in the winter herd makes possible a gross comparison of the alternatives at a constant level of energy requirement in winter, since winter food is one of the restricting factors affecting the moose herd size. The method is open to discussion, as the energy requirement per kg carcass weight is not the same for all categories of animals. Calves and cows which have had calves the preceding summer probably have a higher energy requirement than older animals. Hopefully some of the differences in energy requirements between the alternatives within populations may cancel each other out. Another thing that must be taken into consideration when comparing the food requirements is the varying structures of the winter herds. Different categories of animals could have differing browsing techniques and prefer different species of plants - a fact which could be important to forestry and consequently to their tolerance level of the moose population size.

The percentage of calves to be harvested and the rate of increase in the population are topics of considerable importance. For example, they have a practical bearing on the situation of the hunters and accordingly on the success of the moose harvest. Many hunters are not keen on shooting calves and it certainly seems harder to achieve this sort of harvest than one with a greater proportion of adults. The connection between a high proportion of calves in the harvest and a high rate of population increase will give a herd which is very hard to regulate. It is a good combination when the aim is to increase the herd size, but maybe not so good when the aim is to keep the herd size constant.

The proportion of calves in the winter herd does not vary much between the alternatives. In Sweden, calves are believed to be more prone to highway accidents than are adults, but no firm figures on the subject are available. It is probably of greater importance to be able to regulate the herd size than to have a winter herd with a low proportion of calves.

The protecting of cows with twin calves has (as also was shown by Sylvén et al., 1979) a positive effect on the meat yield, since cows in the most fertile age-classes were spared.

This complementary report to that by Sylvén et al. (1979) gives a

theoretical basis for further theoretical and practical comparisons between various hunting policies. A further theoretical study should comprise the overall value, including all positive and negative effects, of the varying harvesting alternatives. Such a study is impossible today as our knowledge of the Swedish moose population and the attitudes of the hunters are still lacking to a considerable degree. Successful moose management planning must take into account both the moose population itself and those who in many different ways are affected directly or indirectly by the presence and activities of moose.

Sylvén et al. (1979) have pointed to some of the limitations of simulations studies such as these, which must be borne in mind when analysing the results. On the practical level, these two reports have shown that it is not necessary to have a high proportion of calves in the harvest in order to produce a highly productive moose population - especially not in populations which have a low fertility. Productivity includes both meat and fecundity. As the shooting of moose in Sweden is regulated, it would appear that harvesting policy could be adapted to local conditions without detriment to the quality of the moose herd.

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