

MOOSE-VEHICLE RELATIONS IN SWEDEN: A REVIEW

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ABSTRACT: With increasing moose numbers in Sweden during the last 20-year period, moose vehicle collisions (MVC) along Swedish highways have become a serious problem. Moose as well as accident numbers peaked around 1980 when about 6000 MVC occurred. About 5 - 20 people are killed and 500 hurt in MVC each year. MVC are considered to be a serious road safety problem and are one of the factors determining acceptable moose densities. The number of moose killed on the roads is less than 5% of the number killed by hunters. Numerous research projects have been initiated in Sweden during the last 15 years to answer questions related to MVC. The MVC risk from the viewpoint of the individual driver is highest at dawn and dusk, and higher at night than during daylight hours. In southern Sweden, MVC numbers peak in early summer (calving), and autumn (rutting). In northern Sweden, MVC numbers normally peak in December - January after snow accumulation has initiated moose migrations to lowland ranges where major roads are common. Fencing the roads has decreased the number of accidents by 80%. Road-side clearing decreased the accidents by about 20%. Investigations have been undertaken of what happens when a car collides with a moose, and how and why people in the cars get injured. Other studies have analysed what happens to the car in a collision and which qualities of the car give good or poor protection to the passengers. Some studies have examined the behavior of drivers in relation to moose accidents.

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When the Swedish moose population started accelerated growth in the 1970's (Cederlund & Markgren 1987, Lavsund & Sandegren 1989) the number of MVC (moose vehicle collisions) increased on Swedish roads. The general development of the moose population, the number of moose shot, and the number of MVC on the roads for the period 1970 - 1990 are presented in Fig. 1. When we discuss MVC-numbers we should bear in mind that we are dealing with official statistics. Analysis of these statistics has shown that the number of registered accidents is only about 40% of the real number (Almkvist *et al.* 1980). A small number of the accidents are severe and people are killed. The number varied between 1 and 25 during the period 1970 - 1990, but in the 1980's the number per year has been around 15, representing about 2% of the people killed on Swedish roads, or about 3% of those killed who are drivers or passengers in cars. The statistics concerning the number of killed people are very close to real numbers. These general figures on MVC

explain why the discussion on moose and traffic has been intensive in Sweden since the middle of the 1970's. Moose accidents are well-known to all drivers in Sweden.

The general trend in the number of accidents in the 1970's was an increase probably due to an increase in the number of moose (Fig. 1). Besides the number of moose, the intensity of the traffic is an important factor determining the number of accidents. The traffic in Sweden increased by about 100 % between 1970 and 1990.

ACCIDENTS IN RELATION TO DIFFERENT FACTORS

A more detailed analysis of the situation during the 1980's has been undertaken using official Swedish road statistics. The number of MVC in Sweden varied widely between 1980 and 1990, with peaks in 1980 and 1987 when accident numbers approached 6000 (Fig. 1). The trend for the 1980-90 period is however downwards ($r_s -0.59$; $p < 0.06$) which is probably at least partly a result of declining

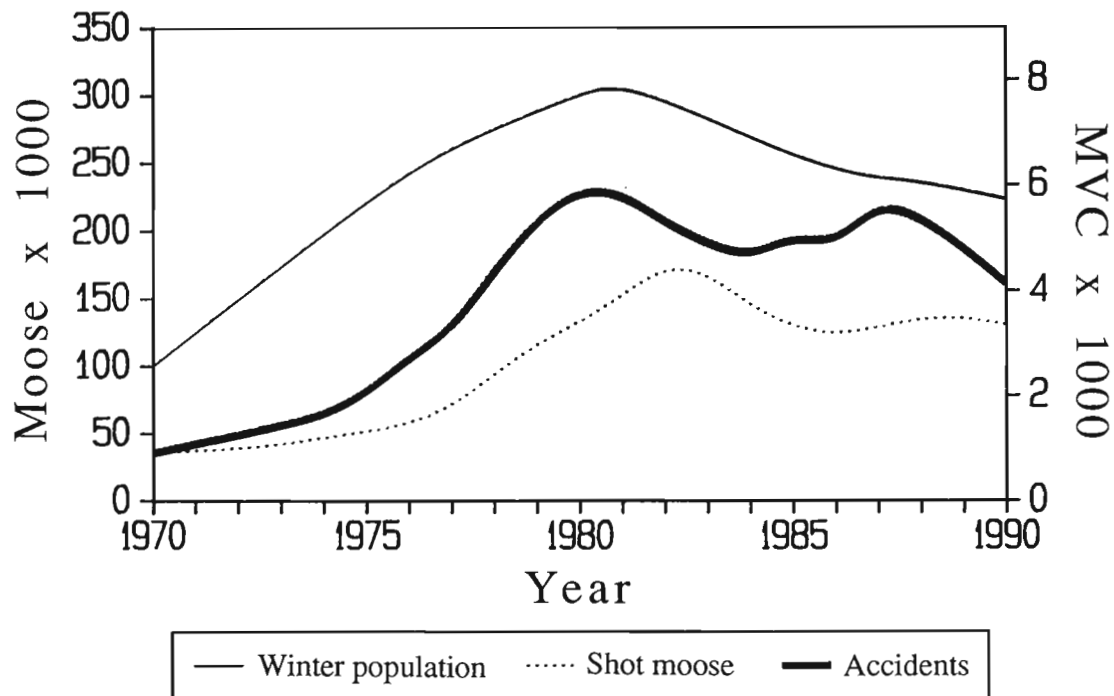


Fig. 1. Moose winter population, shot moose, and number of moose vehicle collisions in Sweden 1970 - 1990.

moose numbers in the country.

If we compare MVC trends in northern and southern Sweden from 1980 to 1990, the figures are, however, quite different. In the north, MVC numbers declined from 3355 in 1980 to 1740 in 1990 (Fig. 2). The general development in the north is that MVC numbers are decreasing ($r_s - 0.76$; $p < 0.015$) while the trend in the south is that MVC numbers remain on the same level throughout the period ($r_s - 0.27$; $p < 0.39$). Variations between years are, however, great. For example, the number of MVC in the south dropped from 3176 in 1988 to 2368 in 1990 and in the north from 2638 in 1987 to 1723 in 1989 (Fig. 2). Decreasing moose populations in the 1980-90 period indicated by a harvest decrease from 116000 to 80000 moose between 1982 and 1990 and milder winters with much less snow towards the end of this period might explain the downward trend in MVC numbers in the north. Moose numbers in the south have probably not declined to the same extent as in the

north (harvest numbers have remained fairly constant between 50000 to 60000 moose per year) during the 1980-90 period which might explain the different MVC trend in this part of the country.

The monthly variation in MVC differs between northern and southern Sweden (Fig. 3). In the north, MVC numbers increase rapidly and normally peak in December - January when extensive snow accumulation has caused the moose to start their migrations (Sandegren *et al* 1985). In the south, where snow accumulation normally is insignificant and moose generally are stationary, MVC reach a peak in late September - early October during the rut when all animals, but especially the bulls, increase their mobility. In the north, the annual collision peak comes early when large amounts of snow come early and late when the snow comes late. Thus, snow accumulation and its effects on moose food availability and movements seems to be a major factor explaining much of the monthly variation.



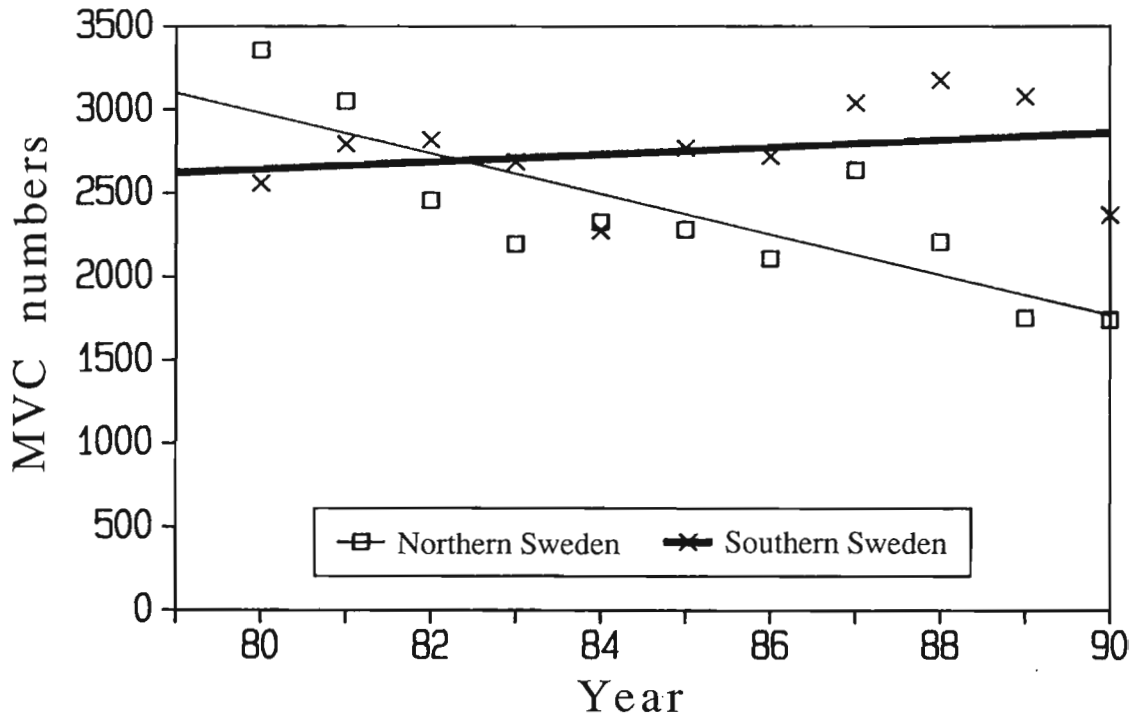


Fig. 2. MVC (Moose vehicle collisions) trends in northern and southern Sweden 1980 - 1990.

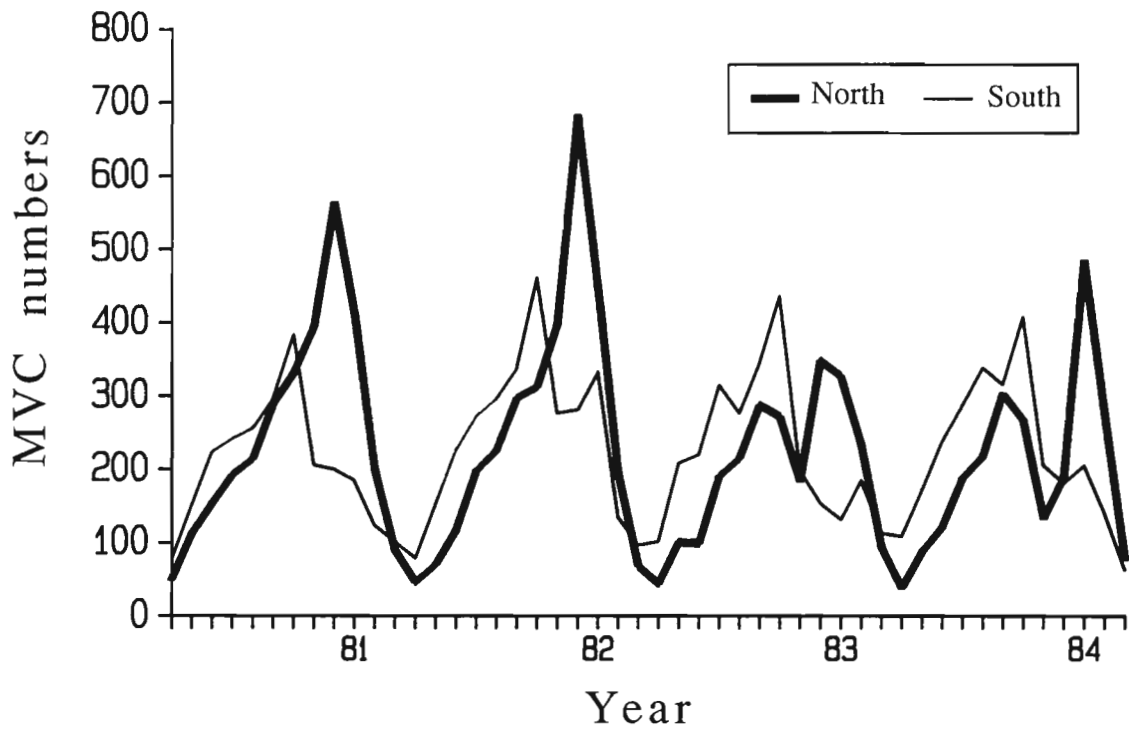


Fig. 3. Monthly variation in MVC numbers for southern and northern Sweden.

The kinds of animals that are killed in southern Sweden during different periods of the year are presented in Fig. 4 (Almkvist *et al.* 1980). The numbers of adults and yearlings killed are relatively high from June to October with a peak in the October rut. Calves are vulnerable during the rut when they are occasionally separated from the cow. Hunting activities do not seem to increase the number of accidents. The rutting period in southern Sweden is in late September and early October. Hunting in this area does not start until the middle of October. Detailed studies have shown that the number of accidents peak during the rut before the hunting season starts.

How MVC affect moose involved is presented in Table 1 (Almkvist *et al.* 1980). Around 60% of the moose involved remain on the

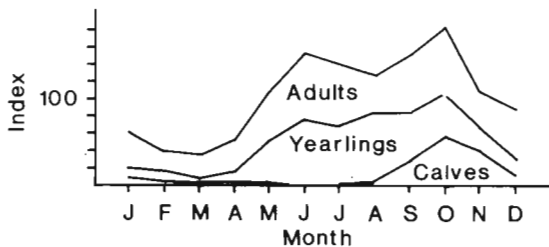


Fig. 4. Relative number of moose, belonging to different categories, killed in moose vehicle collisions in southern Sweden. Index 100 equals mean level for total number for the whole year.

scene of the accident. Of these, 50 % are dead and 50 % have to be killed (shot). Around 20% of the moose involved in MVC are seriously hurt but have moved away from the scene of the accident. They are tracked using dogs, and shot. On main highways with higher speed limits (90 or 110 kmph), 44 % of the moose were killed directly. On country roads (speed limit 70 kmph) only 26 % were killed directly. The system to deal with killed or injured moose along the roads is very well organized. In all parts of Sweden there are experienced hunters with dogs who can track and deal with injured moose at all hours. Even if it is in the middle of the night, hunters with dogs can be on the scene of the accident with

Table 1. How MVC (moose vehicle collisions) affect the moose involved.

Killed immediately	28 %
Unable to walk, shot at the scene of the accident	31 %
Hurt, searched for and shot	22 %
Hurt but not found	11 %
Not hurt	8 %

little delay. The hunters with hunting rights in the area of the accident own the meat from the moose. The killed moose are not included in the ordinary license for the area.

The severity of the accident from the viewpoint of the drivers and car passengers is presented in Table 2 (Almkvist *et al.* 1980). There is a strong correlation between the severity of the accident and the speed limit of the road. But at least in some of the severe accidents where people have been killed the speed of the car has been much higher than the legal speed limit for the road.

Another measurement of the severity of a

Table 2. Severity of the moose vehicle collisions (MVC) on roads with different speed limits (%).

	Speed limit kmph			Total
	70	90	110	
Persons killed	0.1	0.5	1.3	0.5
Persons hurt	6.6	12.5	20.3	11.2
Only damage to the car	93.3	87.0	78.4	88.3
Total	100.0	100.0	100.0	100.0

accident is the cost. The Swedish road authorities have calculated the mean costs per accident on roads with different speed limits (Johansson 1988), as presented in Table 3.

The distribution of MVC throughout the day is presented in Figure 5 (Almkvist *et al.* 1980). The periods of the day are defined as follows:

Dawn	Two hours before sunrise - sunrise
Daylight	Sunrise - sunset

Dusk Sunset - two hours after sunset

Night From dusk to dawn

The number of accidents during the daylight, dusk, and night periods are about the

Table 3. Average cost of MVC (moose vehicle collisions) in relation to the speed limit of the road.

Speed limit kmph	Cost	
	SEK	US \$
70	40000	6000
90	60000	10000
110	105000	17000

same even if the daylight period is far longer than the dusk period. The night period is of about the same length as the daylight period but the number of vehicles is only a fraction of that on the road during daylight. Dawn is a short period with medium numbers of vehicles and relatively few accidents. If we consider the MVC risk for the individual driver (risk is defined as number MVC per km driven) the picture is different (Almkvist *et al* 1980). Fig. 6 shows that despite the great number of accidents in daylight (Fig. 5), the risk is low, and at dusk eight times higher. The risk at night and dawn is six times higher than the risk in daylight.

When new roads are built to by-pass villages and towns they often pass through

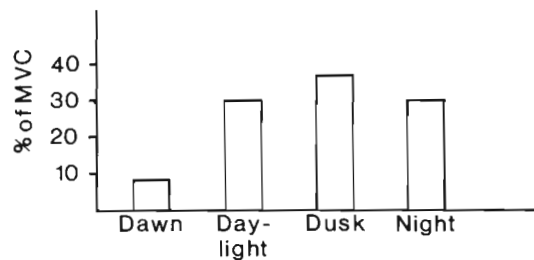


Fig. 5. Twenty-four hour distribution of moose vehicle collisions. For explanation of periods cf. the text.

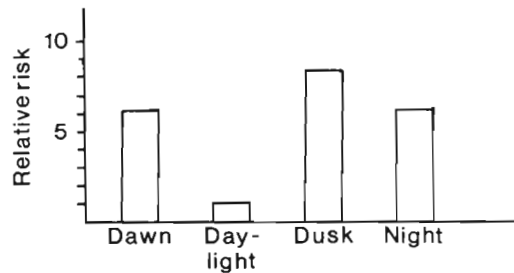


Fig. 6. The risk for a moose vehicle collision from the viewpoint of the individual driver. The risk at daylight equals one.

forested areas earlier without main roads. The number of accidents when the road is opened is five times higher than normal and five years later still higher than what is normally observed along roads in the same area and with the same amount of traffic. The explanation could be that moose in the area are not used to roads and cross the road to a higher extent than they do if the road has been there for many years. After 5-6 years almost all moose in the area have been born after the road was built and cross the road to a less extent or are more watchful of traffic.

Moose carcasses have been used to study what happens when a moose is hit by a car (Nilsson & Svensson 1986). Fig. 7 shows the interaction of moose and car during the first 160 ms (micro seconds) after the collision. Notice especially how the body of the moose moves into the car through the windshield. A very typical situation is that the long legs of the moose will mean that the main force of the collision will hit the car on the roof just above the head of the driver and front passenger. The extent of injuries of the passengers will depend on how deep the roof was depressed (Thorson 1988). Experimental tests of different car makes (Turbell 1984) have shown that they have very different abilities to withstand these forces on the roof. In many cars the front part of the roof is too weak to withstand a collision with a moose. Larger cars are better than small ones. For some reason, Volvo and Saab (two Swedish makes) proved to be among the best to withstand a moose collision. In

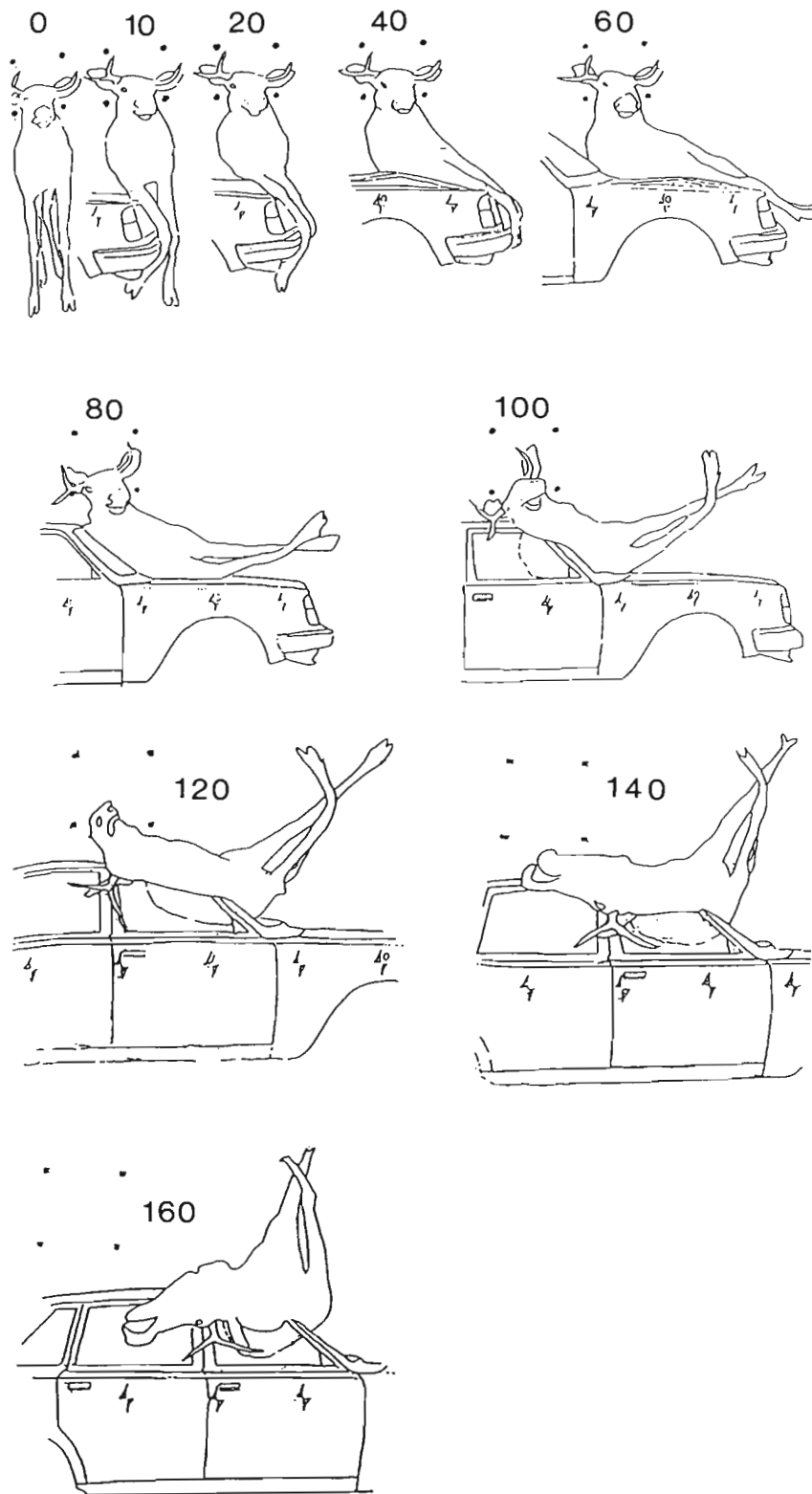


Fig. 7. Experimental collision between a moose carcass and a car. Numbers indicate microseconds (1/1000 of a second).

these makes, special care has been taken to make the roof strong (perhaps not just with regard to moose!). The ability of these makes to withstand a moose collision is used in advertising to sell these cars in Sweden. A typical injury after moose-car collisions is cuts to the head caused by the smashed windshield. Some people also suffer serious eye injuries, and some even get blinded by a crash.

METHODS TO REDUCE THE NUMBER OF MOOSE VEHICLE ACCIDENTS (MVC)

Wildlife mirrors

In the 1960's a method was introduced using a series of small mirrors placed on both sides of the road reflecting the beam light from the cars into the area around the road. This was intended to frighten animals close to the road. The method appeared to be a success. Even in daylight the number of accidents decreased. To test the method a large experiment was undertaken (Almkvist *et al.* 1980) using a great number of test and control road distances (with and without mirrors) over a three-year period. This test proved that the mirrors had no effect whatsoever on the number of accidents. The good results in the beginning resulted from the way the roads equipped with mirrors were chosen. Mirrors were almost always put up along a stretch of road where the number of accidents had been very high. There is a lot of chance involved in the number of accidents on a certain part of a road. If you choose roads past their peak of accidents just due to chance, the most likely result will be a reduction in the number of accidents in the future. This is far more likely than that they will remain on a high level or increase, which is very unlikely. These mirrors are not used in Sweden today, but 10 years ago they could be found along most main roads. Careful testing of such methods is essential.

Fences

Fences along the roads have proved to be effective measures to reduce the number of moose collisions (Almkvist *et al.* 1980, Niklasson 1988). Fences with only single wires (3 - 5 strands) are not effective. The same applies to electrical fences. Moose do not see them and just go straight through them. The fence must be made of strong net and must be more than two meters high. Snow depth can be an essential factor when determining the height. The fences should have an appearance which makes it difficult for the moose to determine the height of the net. When a moose comes to a fence it will try to assess its height. If the highest point of the fence is very well defined, moose will try to jump higher fences than if it is difficult to see how high the fence really is. Special attention must be taken when the fence is put up along connecting roads to the fenced road. Small roads must have some kind of a gate. Today in Sweden about 1300 km of the highways are fenced. This protects a low percentage of all roads (1-2%) but a high percentage of the main roads, especially those with four lanes, with intensive traffic and a high speed limit (110 kmph). The number of moose accidents along a fenced road decreased 80 - 100%. Fences are built according to an economic model which takes into account the expected number of accidents, the cost of an individual accident (cf Table 3) and the cost to build and maintain the fence. If there is a positive relation in this model, a fence will be built. The longest individual stretch of fenced road in Sweden is about 100 km. The effect on the moose populations along fenced roads has not been studied. The main negative effect that has been reported is moose concentrations along the fence in areas where moose migrate and where fences have been built across the migration routes.

Repellents

Some studies (Almkvist *et al.* 1980) have been undertaken concerning the effect of different kinds of repellents to keep moose off

the roads. Three principal types of repellents were tried. Light, sounds and scents. Different kinds of flash-lights and searchlights were used but they were not effective - moose took no notice! Neither did different kinds of sounds disturb the moose after they had become used to them for a short time. Sounds of 70 dB and with frequencies up to 50 Khz were used. Moose did not react to sounds over 21 Khz. Some scents (distasteful smelling substances) were tested and had some effect but their long-term effect was questioned. Nowadays, many ideas are put forward to equip the cars with special sound sources which should keep the moose away from the road. For anyone who has been standing on a road listening to the noise of the traffic it is hard to believe that something can be found to keep moose away from the road if the noise doesn't! To be able to test such equipment in Sweden - with its fairly high number of moose accidents - a vast number of cars have to be observed for several years. Since only one car out of 1000 will collide with a moose each year, to be able to get reliable statistical we may need 25000 cars with the equipment and another 25000 as a control material. After three years of testing we might get a reliable result. This suggests that testing of such equipment on a few cars can never give any useful results.

Roadside clearing

When bushes and branches on trees occur very close to the road it is believed that this decreases the ability of the drivers and the moose to avoid accidents. To test this experimentally, stretches of road with and without clearing of the vegetation close to the road were studied for three years. Clearing means that bushes and branches below three meters height on the trees within 20 meters from the road are removed manually. The experiment showed an accident reduction of nearly 20%, but this was very close to a result which might have been expected just due to chance (Johansson 1987). This method is rather expensive and must be maintained often due to

regrowth.

Behavior of the drivers

Could the number of accidents be reduced by information to and education of the drivers? Experiments have been undertaken concerning the ability of the drivers to see moose along the roads and the effect of warning signs (Åberg 1981). These investigations showed that the normal driver searched the terrain in an inoptimal way to be able to discover moose along the road. The best way is to search both sides of the road all the time. Most drivers just look straight forward along the road and thus they fail to see moose even close to the road. Nor did they see signs along the road with warnings for moose. Studies have been undertaken concerning the effect of special signs for short periods when the risk in an area was extra high. Car drivers paid no attention to these signs either. In many parts of Sweden special booklets are distributed to the drivers to inform them of the risk of moose accidents in their area. This means that most drivers are aware of the risk for a moose accident but the risk for an individual driver is so low that most of them don't take moose accidents into account when they drive. The main problem concerning information to drivers in Sweden is thus that most of them already know about the risk for a moose accident but most do not worry about it. If you drive a car in Sweden for ten years the risk is still not more than one in a hundred that you collide with a moose! An ordinary driver may see a moose on the road once every five years so they don't get a feeling of something especially dangerous.

An effective method of reducing at least the severity of the accidents is to lower the speed limits (cf. Table 2). However, neither the road authorities nor the drivers appear to be interested in such a measure. Violation of speed limits in Sweden is much more common than in North America. Thus, the number of cars driving faster than the speed limits is rather high and these drivers are part of a high



risk group for serious moose accidents which they themselves do not believe will happen.

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