MOOSE - TRAIN COLLISIONS: THE EFFECTS OF VEGETATION REMOVAL WITH A COST-BENEFIT ANALYSIS

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ABSTRACT: The number of moose (*Alces alces*) killed annually in collisions along Norwegian railroads averaged about 500 in the late 1980's, representing 2% of the total annual hunting bag (25 000 moose) in the same period. However, consequences for management of local and regional moose populations can be considerable in certain areas where collisions are concentrated. In the period 1980 - 1988 a field experiment was carried out in order to test a conflict reducing method. Vegetation removal in a 20-30 m wide sector on each side of the railway line caused a 56% (+/-16%) reduction in number of train kills. The results from the field experiment have been used in a cost-benefit analysis for the total Norwegian railroad network. If we assume that the number of collisions can be reduced by 50% as a result of vegetation removal, and calculate the cost of this treatment compared to the cost per casualty, it appears to be of positive economical benefit to treat all sections of railroad where the annual number of collisions is higher than 0.3/km. This leads to the conclusion that it is profitable to take these remedial actions along about 500 km of Norwegian railroads, which will require an investment of NOK 11 mill. and give a net economical surplus to society of NOK 31 mill. (1 USD = appr. 6.50 NOK). However, it is necessary to complete the analysis with local evaluations, which must include whether the main problem on each specific railway section really is the vegetation cover.

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Deer-automobile collisions have for a long time been recognized as a serious problem, and as summarized by Feldhamer *et al.* (1986) a variety of methods have been used in attempts to reduce deer accidents on roadways; repellents (Dietz and Tigner 1968), reflectors and mirrors (Gordon 1969), gates (Reed *et al.* 1974), warning signs (Pojar *et al.* 1975), fencing (Falk *et al.* 1978), underpasses and overpasses (Reed 1981) and highway lighting (Reed and Woodard 1981). On the contrary, references discussing moose-train conflicts have been few, and only from the 1980's are we able to find literature discussing the nature of the problem, magnitude of the losses and which remedial actions to take (e.g. Child 1982, 1983).

The number of moose (*Alces alces*) killed annually in collisions along Norwegian railroads averaged about 500 in the late 1980's. The numbers have increased about 10 times during the last 30-40 years, but still represent no more than 2% of the present total annual hunting bag in Norway (25 000 moose). However, the collisions are concentrated along certain parts of the railway network, and more than 50% of them occur on two specific railway lines (Ulleberg and Jaren 1991). In some municipalities the number of animals killed in some years can represent as much as 15% of the hunting bag. In addition, adult females seem to be over represented among the killed animals (Lorentsen *et al.* 1990), and it is evident that consequences for management of local and regional moose populations can be considerable.

Moose-train collisions are mainly a winter phenomenon in Norway. More than 80% of the collisions occur in the months November - April with a peak in December - February. On the two most "risky" lines approximately 95% of the collisions happen during the winter. The problems are in general caused by seasonally migrating moose populations with winter ranges in valley bottoms, where railroads (and roads) are located (Ulleberg and Jaren 1991). However, there are exceptions; along some railways in the southernmost part of Norway collisions are more spread out through the year with less than 50% occuring in the winter months.

Several Norwegian reports in the early 1980's (e.g. Huseby 1982, Sklett and Aasheim 1983) pointed to vegetation removal along the railway as a promising method which could prevent collisions. Removal of available moose browse and cover was expected to reduce the time spent by moose close to the railway line and increase the locomotive driver's chance of seeing moose on or close to the line in time to stop the train. In order to test the conflict reducing effect of this method, a field experiment was carried out.

STUDY AREA

The study area was located in Nord-Trøndelag county in central Norway, restricted to that part of the Nordlandsbanen railroad which is passing through the municipalities of Snåsa and Grong (64°10-40'N, 12°00-40'E, Fig. 1) and where the highest number of moose-train collisions occur.

The railroad passes mainly through areas with boreal forests, but also through some agricultural areas. There are numerous small creeks and rivers, some larger rivers and one big lake in the area. Consequently, long sections of the railroad are located in or close to riparian areas. The forests are in general dominated by Norway spruce (*Picea abies*) mixed with some Scots pine (*Pinus silvestris*), and deciduous trees and woody shrubs like birch (*Betula pubescens*), aspen (*Populus tremula*), rowan (*Sorbus aucuparia*), grey alder (*Alnus incana*), willow (*Salix spp.*) and juniper (*Juniperus communis*). The deciduous trees and woody shrubs, which are preferred moose browse, form the densest stands in riparian and other moist areas, in the edge zones of agricultural areas and on some years old clear-cuts and other open patches in the forest. Consequently, there is a tendency for preferred moose browse to grow in areas close to the railway line.

The region mainly has a continental climate, but can periodically be influenced by oceanic westerly winds. Annual temperatures range from -30 to 30 °C and snow depth from 0 to 140 cm. The biggest snow accumulation is normally in January - February with an average of 70 cm for the period 1981-88. Both temperature and snow depth can vary greatly between years.

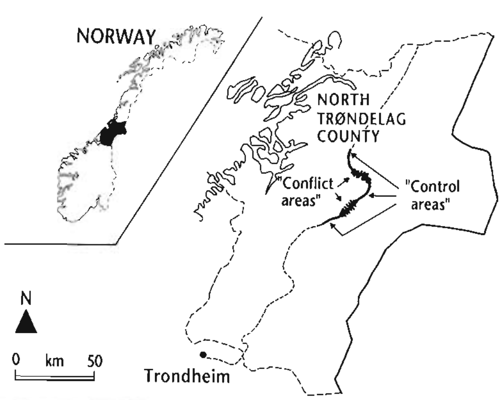

Fig. 1. The study area in Nord-Trøndelag county, Norway, showing the 60.8 km long railway section included in this study.

METHODS

The number of moose killed by trains was recorded along a 60.8 km long railroad section between 1 November and 14 April in the period 1980 to 1988. A total of 183 moose were killed during the study. Based on registrations in the first 4-year period, 2 sections with a high accident risk were given a special treatment while the rest of the section was used as a control over the next 4-year period.

In the 2 sections given a special treatment, totalling 22 km, all bush and tree vegetation in a 20 m wide sector on each side of the railway was removed. In an additional 10 m sector farther out from the railway, all trees and bushes lower than 4 m and all branches growing lower than 3-4 m on higher trees were removed. All distances are measured from the centre of the railway line. Areas treated this way totalled 130 ha. In some smaller areas with an especially limited view for the locomotive driver, e.g. sharp bends, all bush and tree vegetation was removed for up to 60 m on one side of the railway. Additionally, especially attractive moose browse on clearcuts close to the sector were also removed. The areas treated with these additional measures totalled 19 ha. The method of treatment is described in detail by Wiseth and Pedersen (1989).

The vegetation removal was carried out during the summer and autumn of 1984. In the summer of 1986 all treated areas within the closest 20 m sector were sprayed with the herbicide glyphosate (Roundup) in order to prevent new vegetation from growing up. Some smaller areas were also cleaned manually.

The effect of the conflict reducing measure was estimated using the following procedure:

$$\text{Let } \mathbf{k} = X_1/X_0 , \quad (1)$$

where X_1 and X_0 are the total number of moose killed in the first 4-year period in the treated sections and control sections, respectively. In the same manner $\mathbf{k}^*$ is the ratio between moose killed in the treated sections and control sections in the next 4-year period. The effect of the method can now be estimated using;

$$(1 - \mathbf{k}^*/\mathbf{k}) \times 100\% \quad (2)$$

The uncertainty in $\mathbf{k}^*/\mathbf{k}$ was estimated using a bootstrap method (Efron 1982).

In order to estimate the profitability of vegetation removal along the Norwegian railways, we have used the method of cost-benefit analysis (Pierce and Nash 1981). We defined a *model project* where all relevant costs and benefits were estimated in order to find the annual number of prevented moose-kills required to make the project profitable.

As a model project we chose a hypothetical one kilometer long section of railway where vegetation removal was implemented in the way described for the study area. The project would be profitable if the present value of the benefit flow (**A**) is higher than the present value of the cost flow (**B**) at the moment of decision. As the time horizon for estimation we chose 25 years (**n**) with a 7% rate of discount (**p**) according to the Norwegian government's recommendation for evaluation of investments. If **a** is the annual benefit (saved cost) for one prevented collision, the present value of the benefit flow for one prevented collision each year for **n** years can be expressed by the equation;

$$A = a((1+p)^n - 1 / p(1+p)^n) \quad (3)$$

The present value of the cost flow can be expressed by the equation;

$$B = b + c(1+p)^{-2} + c(1+p)^{-10} + c(1+p)^{-18} \quad (4)$$

where **b** is the investment cost of removing the vegetation along 1 km of railroad, and **c** is the cost of necessary maintenance of the situation in the years 2, 10 and 18 after the vegetation removal. If **x** is the annual number of moose prevented from being killed, the model project is profitable if

$$xA > B, \text{ i.e. } x > B / A \quad (5)$$

The number of prevented collisions is the product of the number of collisions expected to happen if nothing is done, **y**, and the conflict reducing effect of vegetation removal, **q**. This leads to the expression;

$$x = yq > B / A, \quad \text{i.e.}$$
$$y > B / A / q \quad (6)$$

The model project is profitable only if we expect more than B / A / q collisions to happen annually on that specific km- section if vegetation removal is not carried out. The higher the value of **y**, the more profitable the project.

In order to transfer results from analysis to total railway network, we now assume that all km-sections of railway are identical with the model project, except for annual number of collisions for the next 25 years (y). For predictions of number of collisions in the future we used exact collision statistics for all railway lines for the period 1.1.1985 - 31.12.1988.

RESULTS

Conflict reduction

Great annual variation in number of train-killed moose was recorded (Table 1). In the control sections the number of train-killed moose ranged from 4 - 23 in the first 4-year period to 4 - 10 in the last period. This variation was even more pronounced in the treated sections, ranging from 4 - 37 and 0 - 16 in the same periods. Although the total number of moose killed decreased from 134 to 49 from the first to the second 4-year period, this trend was most pronounced in the treated sections, with a 75% decrease in the number of killed moose. Estimation based on eq.(2) showed that the conflict reducing method reduced the number of train-killed moose by 56%. The uncertainty in this estimate was found to be 16%, consequently the maximum and minimum values for the effect of vegetation removal were 72% and 40% respectively.

Cost-benefit analysis

Based on recordings of repair costs for trains, loss of production etc. from the Norwegian State Railways (NSB) and a study on the economical value of moose hunting in Norway (Sødal 1989), the benefit from preventing one moose from being killed was estimated to be NOK 20600 in 1990 prices (1 USD = appr. 6.50 NOK). Using eq. (3), this leads to a present value for the benefit flow from preventing one moose-kill annually (A) of NOK 240000.

The costs experienced from the study area, adjusted to 1990 prices, were used for estimating the cost flow. The vegetation removal had an average cost of NOK 22200 per km, spraying with herbicides NOK 2900 per km and additional manual vegetation removal NOK 2700 per km. In the study area herbicide treatment and manual vegetation removal was planned to be implemented after 2, 10 and 18 years and after 2, 7, 12, 17 and 22 years respectively. Using an equation similar to (4), this leads to a present value of the cost flow (B) of NOK 33800.

By the use of (5), we found that the model project is profitable if it prevents more than 0.14 moose (x) from being killed annually through the lifetime of the model project (25 years). Based on results from the study area as estimated above, we chose a collision reduction effect of 50% (q) as a result of vegetation removal. By the use of (6), we found that the model project is profitable if more than 0.28 moose (y) are expected to be killed annually on that specific km-section if nothing is done.

The results transferred to the total length of the Nordlandsbanen railway line are shown in tab.2. Based on the results above, it is

Table 1. Number of moose killed by trains in treated sections and control sections prior to and after vegetation removal.

Sections	Prior to measure (1980/81 - 1983/84) Total	Range	After the measure (1984/85 - 1987/88) Total	Range
Control sections (38.8 km)	47	4 - 23	27	4 - 10
Treated sections (22 km)	87	4 - 37	22	0 - 16

profitable to implement vegetation removal on 167 km from a total of 288 km with recorded moose- train collisions in the period 1985 - 1988. The net social economical surplus from this is estimated to be NOK 9.2 mill.

Similar estimations for the total Norwegian railway network suggest that it would be profitable to carry out vegetation removal on 503 km of a total of 985 km with recorded collisions in the period 1985 - 1988. This will require an investment of NOK 11 mill. and a maintenance cost of NOK 6 mill. in present value. The net economical surplus for society will be NOK 31 mill.

DISCUSSION

Conflict reduction

Two different factors may result in an overestimation of the effect of the measure. First, removal of vegetation from high risk sections may result in an increased utilization of the control areas. This would eventually result in an overestimation of the effect of the method. In this study we have not been able to verify this assumption. Second, selecting only high risk sections for vegetation removal may have introduced an additional error in the estimate as the probability of having a reduction of train kills is obviously highest in the high risk sections.

Cost-benefit analysis

Vegetation removal projects will have a long-time character which makes it reasonable to choose a long time horizon where costs and benefits are counted. The choice of 25 years is hardly too high. This choice of a long time horizon (> 15-20 years) and the high rate of discount (7%) will mean that the time horizon has little influence on the results, because costs and benefits in the near future will be given a high weight compared to similar costs and benefits farther on in the project period. Consequently, these factors can hardly be an important source of error. We would also expect the recreational value from moose hunting to increase more than the general price index in the future, which will cause an underestimation of the benefits. Finally, there are several beneficial effects from preventing collisions which we have not been able to quantify in monetary terms, e.g. reduced suffering for the animals, reduced mental stress for train crew and reduced delays for passengers.

When we transfer results from the model project to the real Norwegian railway network, the most uncertain factor is the choice we have made of 50% as an estimate of the conflict reducing effect from vegetation removal. The field experiment which lead to a 56% reduction effect was carried out within an important winter range for moose, i.e. a typical conflict area with a high annual number of collisions concentrated in the winter months. Small scale projects in other similar areas in Norway have indicated even higher effects. It would be reasonable to expect the effect to be lower in areas with a lower total frequency of collisions and/or a higher proportion of collisions during the summer. However, this will primarily affect the results for the km-sections with the lowest frequency of collisions (Table 2). For sections with an average of 0.5 annual collisions (2 collisions during the 4-year reference period), a conflict reducing effect of 28% will be sufficient to make the method profitable. Percentage reductions of 19% and 14% are needed for sections with 0.75 and 1.00 annual collisions per km respectively.

The method we have used by defining a model project of vegetation removal and transferring the results into the total railway network is based on an important prerequisite; that bush- and tree vegetation along the railway line is a major reason for moose-train collisions. This will not always be true. In a few cases the analysis pointed out for treatment km-sections in the study area where the vegetation already had been removed. This result was not unexpected, since we used frequency of collisions on each km-section in the period 1985- 1988 as the only criterion.

Table 2. Estimation of net social economical surplus from vegetation removal for different 1 km-sections of the Nordlandsbanen railway line. (q = 50% conflict reducing effect, A = present value of the benefit flow, B = present value of the cost flow, 1 USD = appr. 6.50 NOK).

Recorded no. of kills 1985-88	Ann. average of kills (y)	No. of km-sections	Surplus per km (y*q*A)-B NOK	Sum in 1000 NOK
1	0.25	121	-3800	No profit
2	0.50	86	26200	2253
3	0.75	37	56200	2079
4	1.00	25	86200	2155
5	1.25	9	116200	1046
6	1.50	4	146200	585
7	1.75	5	176200	881
8	2.00	-	206200	-
9	2.25	1	236200	236
Sum		288		9235

However, the analysis has clearly documented the large profit which can be obtained by removing vegetation in areas where this factor really is the major problem. It is therefore suggested that local projects begin, including a more detailed evaluation of the nature of the problem in that specific area, and an adjusted cost-benefit analysis based on a realistic budget for investment and maintenance cost for the actual project. Priority for treatment should be given to the most profitable projects. The method has already been recommended and implemented along some road sections with a high accident risk in Nord-Trøndelag county (Lorentsen *et al.* 1990).

This study has also given us an idea as to the proportion of total railway network where some kind of conflict reducing methods should be implemented. There will always be a risk of collisions in areas where moose and trains occur together. However, it should be possible to reduce the number of collisions to a more acceptable level by a combination of different remedial actions like vegetation removal, lowered speed of trains on certain railway sections with high accident risk when certain snow- and weather conditions which increase the risk of collisions occur (Andersen et al. 1991), fences (e.g. Falk *et al.* 1978), etc. The method of cost-benefit analysis will be useful to determine whether any of these methods will be profitable to implement.

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