MOOSE - TRAIN COLLISIONS: EFFECTS OF ENVIRONMENTAL CONDITIONS

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ABSTRACT: The effects of environmental conditions during winter (1 November-14 April) on moose-train collisions was investigated along a 92.2 km long section of the Nordlandsbanen railway, in Norway between 1980 and 1988. The total number of train kills was 262, and ranged between 71 (1983/84) and 8 (1984/85) kills per year. Mean winter snow depth explained 84% of the annual variation. A high proportion of moose were killed when snow depth exceeded 100 cm. High ambient temperatures reduced the risk of collisions, while low temperatures had the opposite effect. Fifty four % of all moose were killed shortly after a snowfall, however, the mechanisms involved are still unknown. It is recommended that train speed be reduced through high risk sections of the railway, especially in periods with high snow frequency, high snow depth and low ambient temperatures.

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The annual loss of moose to train collisions in Norway has been approximately 500 animals in the last decade. Most of these train kills (83%) occur during winter (Lorentsen *et al.* 1990), when moose are migrating from summer ranges to lower elevations in winter and aggregate in the valley bottoms. The train kills are causing a variety of problems; damage to trains, passengers having longer travel times due to delays, psychical strain on train personnel, reduced income for landowners with hunting rights, and negative consequences for the management of local and regional moose populations in terms of reduced hunting licenses. As a consequence of the steady increase in the number of train kills there has been an increased interest in these problem, from both wildlife managers and the Norwegian State Railways (NSB).

Different remedial actions have been taken in Norway to reduce the risk of moose-train collisions. At present, clearing the forests around the railway seems to be the most promising conflict reducing measure (Jaren *et al.* 1991). In addition to studying the effects of remedial actions taken along certain sections of the railway, it is of great importance for both wildlife managers and the NSB to obtain more precise data concerning the exact nature of the problem. That is, how do environmental factors affect the probability of moose-train collisions ? In this paper we describe the effects of different climatic variables on train kills.

STUDY AREA

The study area is situated in North-Trøndelag county in central Norway at 64° 40'N, 12° 40'E (Fig.1). Along the Nordlandsbanen railway which crosses the

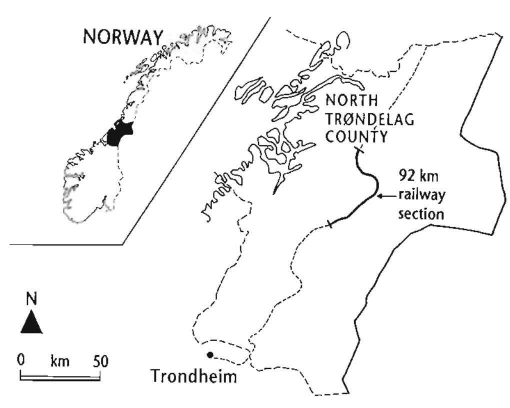

Fig. 1. The study area in North-Trøndelag County, Norway, showing the 92.2 km long railway section included in this study.

county, a large number of train kills are reported each year. Although there is great annual variation in the number of moose killed along this railway, some sections always have a higher number of train kills. The railway mainly runs through boreal forests, and some agricultural areas. The forests are generally dominated by Norway spruce (*Picea abies*) mixed with Scots pine (*Pinus silvestris*). In the riparian areas, where long sections of the railway are located, deciduous trees like birch (*Betula pubescens*), rowan (*Sorbus aucuparia*) and willow (*Salix spp.*) are common. These species are highly preferred by moose during winter (e.g. Hjeljord *et al.* 1982). Consequently, a large number of moose migrate from their summer areas at higher elevations down to lower winter areas along the railway.

The region mainly has a continental climate, with temperatures ranging from -30 to 30°C. Precipitation comes usually as snow from November to March, and average snow depth in January-February in the period 1981-1988 was 70 cm.

METHODS

In the study area we recorded a total of 262 rail kills along a 92.2 km section of the railway, during the period 1 November-14 April each year, between 1980 and 1988. Data concerning daily ambient temperature, snow depth and frequency of precipitation were collected from a permanent meteorological station 25 km north of the study area. Each of the 262 rail kills were characterized with an ambient temperature, snow depth and number of days since last snowfall at the time of the kill. These variables were used in comparisons of frequency distributions. In addition, for 57 rail kills we have registered the exact time of the kill, and compared this with the frequency of train passings.

Although moose normally show a high site fidelity to winter home-ranges (e.g. Sweanor and Sandegren 1989), tracking data from radio-collared moose in Norway (e.g. Sæther and Andersen 1990) shows that the number of moose in valley bottoms in winter is linked to snow conditions during the early part of the winter. That is, high snow depths in early winter e.g. December, are likely to concentrate moose in the valley bottoms. Consequently, based on mean snow depth in December, we calculated for each year a factor;

EARLY SNOW = Mean snow depth in December,

which is likely to affect the number of moose actually using the habitats along the railway. Each winter was characterized by the following variables;

MEAN SNOW = (sum) Mean monthly snow depth (1.November- 14.April)/6

MEAN TEMP = (sum) Mean monthly temperature (1.November- 14.April)/6

SNOW FREQUENCY = Total number of days with snowfall in the period 1.November-14.April.

In order to document the effect of the different environmental variables on annual number of moose killed, a stepwise multiple regression analysis was used. X^2 analysis were used in comparisons of frequency distributions.

RESULTS

During the study period conflict reducing measures, which decreased the number of train kills in these years, were carried out along sections of the railway (Jaren *et al.* 1991). However, during the study annual train kills varied between 71 (1983/84) and 8 (1984/85). More than 56 % of the 262 train kills occured in January and February, while less than 1 % occured in April. Although only 1/5 of the moose were killed in December, EARLY SNOW accounted for 72 % of the annual variation in train kills ($F= 15.7$, $P < 0.01$,). However, due to a close correlation between EARLY SNOW and MEAN SNOW, only MEAN SNOW was able to explain any significant part of the annual variation in train kills when entered together with MEAN TEMP, SNOW FREQUENCY and EARLY SNOW in a stepwise multiple regression analysis (MEAN SNOW; $r^2=0.84$, $F= 32.5$, $P < 0.005$).

The frequency distributions of train killed moose and proportion of days with different snow depths was significantly different ($X^2= 90.4$, $P < 0.001$). A high proportion (44%) of the moose were killed when the snow depth exceeded 100 cm, while only 11 % of the moose were killed when snow depths were between 0-35 cm (Fig.2). For snow depths between 35-100 cm there were no differences in frequency distributions (Fig.2).

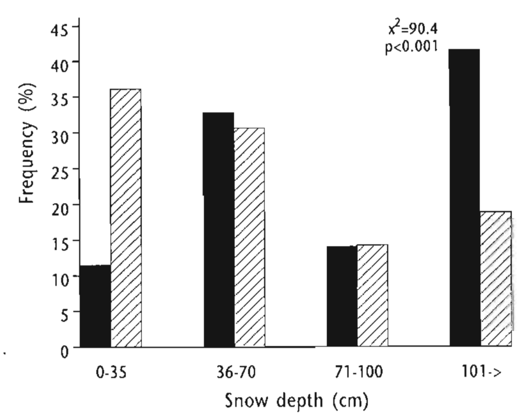

Fig.2. Frequency distribution of killed moose (black columns) and proportion of days (white columns) with different snowdepth 1 November - 14 April, 1980-1988.

Although MEAN TEMP was not able to explain significantly the annual variation in train kills, frequency distributions of killed moose at different temperature intervals was significantly different from frequency distributions of proportion of days in the same intervals ($X^2= 29.1$, $P < 0.001$, Fig.3). Only 5% of the days between 1.November-14.April 1980- 1988 had ambient temperatures below

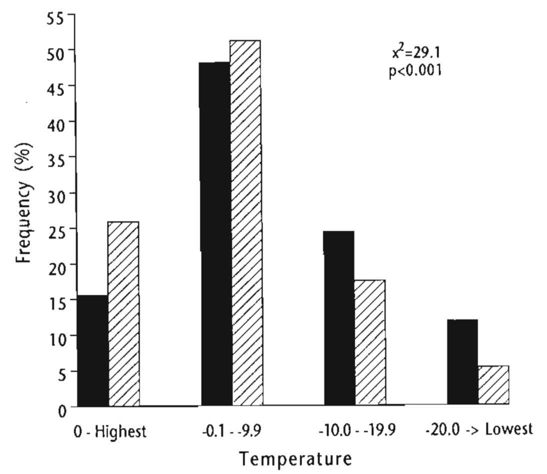

Fig.3. Frequency distribution of killed moose (black columns) and proportion of days (white columns) with different ambient temperatures 1 November - 14 April, 1980-1988.

-20 °C, while nearly 12% of the train kills occured on these days. Temperatures higher than 0 °C had the opposite effect; more than 25% of the days had temperatures in this interval, while only 15% of the train kills occured in the same interval.

There was small annual variation in SNOWFREQUENCY. 1980/81 had 40 days with snowfall, between 1 November-14 April, while in the rest of the study period SNOW FREQUENCY varied between 30 - 32. However, comparing the frequency distributions of train kills with proportion of days in different intervals after snowfall, we found significant differences ($X^2= 31.9$, $P < 0.001$, Fig.4). More than 54% of the train kills occured 0-2 days after a snowfall, while proportion of days in this interval was 37% (Fig.4). On the contrary, periods without snowfall had a low frequency of collisions between train and moose. Approximately 23% of the moose were killed in periods more than 5 days after the last snowfall, while the proportion of days in this interval was more than 40% (Fig.4).

Although there was a higher risk of moose-train collisions during the darkest periods of the day, the difference in frequency

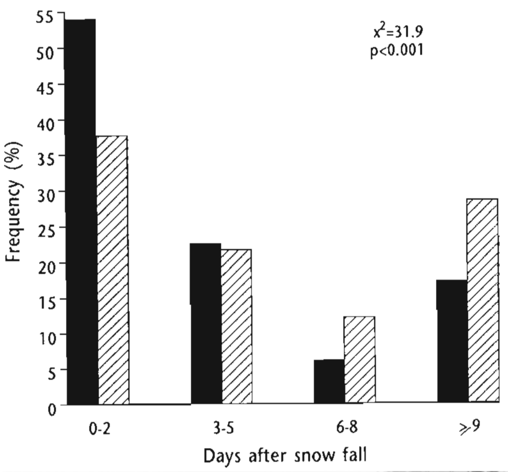

Fig.4. Frequency distribution of killed moose (black columns) and proportion of days (white columns) after a snow fall in the period 1 November - 14 April, 1980-1988.

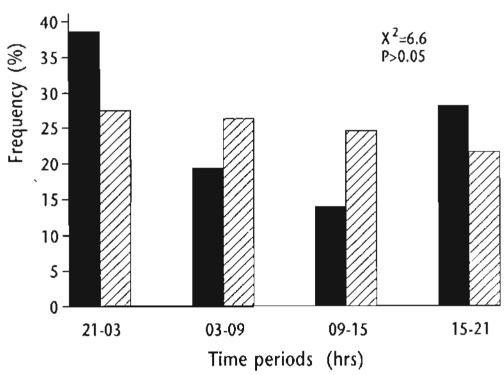

Fig.5. Frequency distribution of killed moose (black columns) and train pasings (white columns) in different time periods, 1 November - 14 April, 1980-1988.

distribution was not significant ($X^2 = 6.6$, $P > 0.05$, Fig.5).

DISCUSSION

The annual variation in train killed moose in this study was greatly influenced by the snow depth. Mean winter snow depth was able to explain 84% of the annual variation in train kills. Three factors may be responsible for this close correlation. First, early winter snowfall will force moose to migrate to lower elevational winter ranges to utilize valley bottoms. Studies of radio-collared moose in southern Norway (Sæther and Andersen, unpubl. data.) have shown that the speed and magnitude of the migration were reduced when snow depths was low, and the moose were utilizing different habitats than in years with higher snow accumulation.

Second, although both moose and caribou have high levels of morphological adaptation for survival in snow (Telfer and Kelsall 1984), deep snow has been reported to restrict moose movements and use of habitats (e.g. Kelsall 1968, Thompson and Vukelich 1980, Pierce 1984). Although snow has a relatively small effect on the energy costs of locomotion (Hanley *et al.* 1989, Fancy 1986), the high frequency of train kills in periods with snow depths above 100 cm reported in this study, seems to reflect an increased use of the plowed railbed for movements between feeding sites.

Third, with high snow accumulation the moose may fail to escape from the tracks. As observed by Hartmann (1962), Hatler (1983) and Child (1983) moose attemt to leave the tracks, but because of snow conditions, return to the solid ground and try to out-distance the approaching train.

Frequency distribution of train killed moose in periods with different ambient temperatures showed that temperatures below -20 °C increased the risk of collisions, while temperatures above 0 °C had the opposite effect. For wild ruminants, the lower critical limit is usually defined as the temperature at which metabolic rate increases to maintain homeothermy, and similarly the upper critical temperature is defined as the temperature at which respiration rate increases for evaporative cooling to occur (Renecker and Hudson 1986). Adult moose are extremely tolerant to cold, and temperatures as low as -30°C do not increase metabolic rate (Renecker and Hudson 1986), on the contrary, moose are intolerant of heat. The winter upper critical temperature for adult cows and calves was found to be -5 to 0 °C (Renecker *et al.* 1979, Renecker and Hudson 1986). These data may explain the observed frequency distribution of train kills at different ambient temperatures. Thus, high ambient temperatures cause the moose to reduce their foraging activity, in order to decrease heat production, while low ambient temperatures allow the moose to maintain high levels of foraging activity, subsequently increasing the risk of train collisions.

High frequency of moose-train collisions during dark hours was found in this study. Some reports (e.g. Rausch 1956) indicate that moose display diurnal response differences to trains. That is, during nights moose remained "hypnotized" by the headlights of the train and do not move away. In addition, like most other cervids the moose are reported to have a peak in activity during dusk and dawn (Risenhoover 1986). We also hypothesize that during dark hours train personnel will have greater difficulties in observing moose on the railway in time to stop the train.

We have not presented sex and age distribution of train killed moose. However, from the same area Lorentsen *et al.* (1990) have documented a biased sex ratio in moose-vehicle and moose-train kills. Fourty-six percent of all moose killed were cows of 2.5 yrs. or older, whereas only 8% of killed animals were adult bulls. Although hunting policy in Norway creates a biased sex ratio in favour of cows, this could hardly explain the differences.

MANAGEMENT IMPLICATIONS

Child (1983) reported that reducing train speed, increased snow clearing and horn and light manipulations had little effect on number of train kills in British Columbia. Although clearing of the forest to 60 m width in high-risk sections of the railway seems to be the most promising method (Jaren *et al.* 1991), we will recommend that train speed be reduced through critical areas, especially so in periods during and immediately after snowfall, high snow accumulation and low ambient temperatures. Special care should be taken during nights under such conditions.

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