RELATIONSHIP OF REDUCED TRAIN SPEED ON MOOSE-TRAIN COLLISIONS IN ALASKA

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ABSTRACT: An experiment to test the effect of track site, train speed, direction of train travel, and train run (first versus second round trip of the day), on moose-train collision mortality along the Alaska Railroad in the lower Susitna River Valley of Alaska, was conducted in February 1988. Reduction of train speed from 79 kmph to 40 kmph did not result in a significant reduction in the number of moose hit by trains ($P = 0.439$), even though the probability of detecting a major reduction was substantial. Significantly more moose were hit in the northern test section than along the southern test section of track ($P = 0.096$) of the Alaska Railroad.

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Collision with vehicles can be a major cause of moose (*Alces alces*) mortality especially where high speed highways transect heavily used moose winter range (Bangs *et al.* 1989). Collisions with trains are less widespread, but can become a major source of mortality in some areas. Muzzi and Bisset (1990) report that 40-50 moose per year are struck and killed by trains along a 225 km section of track in Ontario. Child (1983) estimated that annual moose mortality due to trains in the central interior of British Columbia range from hundreds to in excess of 1000 moose in winters of record snowfall. Similarly, the Alaska Railroad (ARR) has documented a mortality of 3054 moose in train collisions between May 1963 and April 1990, with an annual mortality ranging from 9 to 725 (Modafferi 1991a). During the winter of 1987-88, 173 moose were struck and killed by trains in Game Management Unit (GMU) 14B, a 5594 km^2 area in southcentral Alaska, in comparison to 43 by automobiles and 347 by hunters (Grauvogel 1990). The number of moose killed by trains in GMU 14B dropped to 87 during the winter of 1988-89 compared to 40 by automobiles and 140 by hunters (Grauvogel 1990). During the winter of 1989-90, record snowfalls resulted in a record 351 moose killed by trains and 47 by automobiles in GMU 14B, (Masteller pers. comm.) while hunters harvested 173 moose (Morgan 1991). This mortality coupled with poor overwinter survival caused an estimated 35% reduction in the GMU 14B moose population (Abbott 1991) and a closure of the moose hunting season (Morgan, 1991).

The ARR originates at the coastal port of Seward and extends approximately 756 km north through southcentral and interior Alaska to Fairbanks. Most moose-train collisions occurs in GMU 14B between Wasilla, ARR milepost (MP) 160, and Chulitna (MP 273) where the right-of-way passes through an important moose winter range on the lower Susitna River floodplain and nearby nonriparian lowland habitat (Modafferi 1991a). The number of moose inhabiting this area and the duration of use depends primarily upon timing and quantity of snowfall and the persistence of snowcover (Modafferi 1988, 1991b). The greatest concentration of moose occurs when deep snow persists into late winter covering browse species at higher elevations (Rausch 1958, Modafferi 1988). The ARR and the Alaska Department of Fish and Game (ADF&G) discussed various options for reducing this moose-train collision mortality, including reducing train traffic, reducing train speeds, and increasing the frequency of snow plowing. Reduced train speed was identified as one of the most feasible options.

METHODS

The experiment was conducted on a 85.3 km section of ARR track between Talkeetna (MP 225) and Houston (MP 173) (Fig. 1) from February 16-23, 1988, when snow depths exceeded 76 cm. This area was selected because it had the highest incidence of reported moose mortality, due to collisions with trains, along the entire track (Modafferi 1991a). This section of track also parallels the lower Susitna River Valley, which is an area used as winter range by a population of moose from the east and a population of moose from the west of the Susitna River (Modafferi 1988, 1991b).

A stepwise regression analysis (Neter and Wasserman 1974) of the 1984-85 winter moose kill on the ARR in GMU 14B was conducted to determine if factors such as snow depth, snow fall, temperature, train frequency, train type (freight, passenger), train timing (day, night), and previous moose-train collision mortality were associated with high moose collision mortality. A square root transformation was used on the kill data (Snedecor and Cochran 1980). The experiment was initiated when factors identified by the above analysis were present.

A 2^4 incomplete factorial repeated measures experimental design (Winer 1971:604-684, Milliken and Johnson 1984:80-84), was used to test the hypothesis that slower train speeds reduce the number of moose killed by trains. The train was run at 79 kmph (49 mph) along one-half of the test section of track between Talkeetna and Houston, and at 40 kmph (25 mph) along the other half. A speed of 79 kmph is the regular operating speed of trains and was used as the experimental control, whereas 40 kmph was the slowest speed which the ARR believed to be economically feasible for testing. To break the test section of track into 2 sites the Kashwitna River bridge, MP 199, was used as the halfway point (Fig. 1). On the return trip train speeds were reversed. A total of 2 round trips were run each day, with the speed in the second run being the reverse of the first run. The experiment was conducted for 8 consecutive days with the speeds reversed for each site-direction-run combination of the previous day (Fig. 2). In addition to testing for a train speed

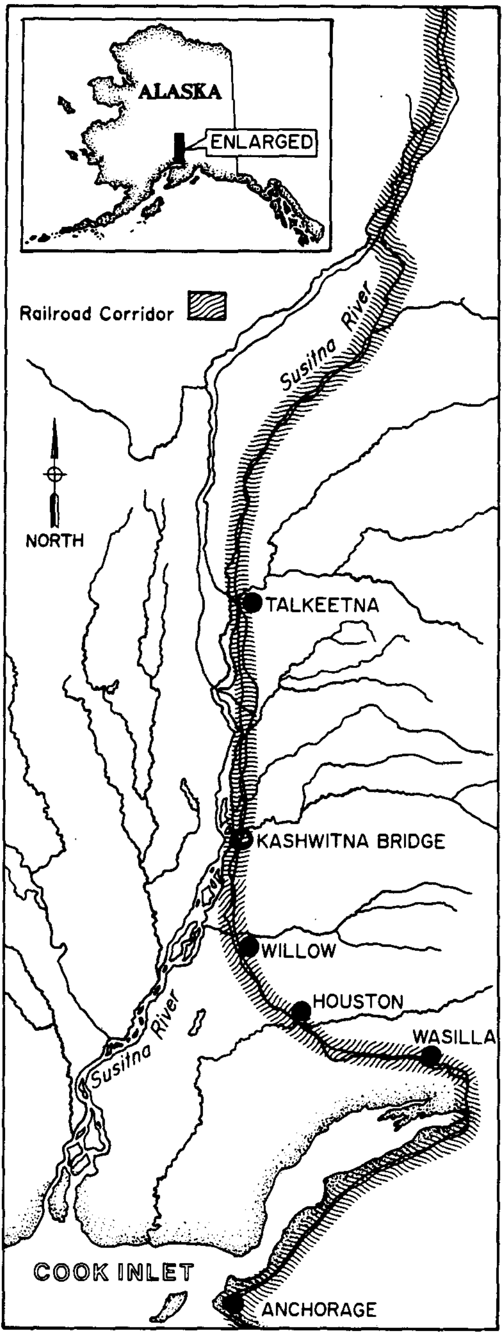

Fig. 1. The location of the Alaska Railroad rail line in the lower Susitna River valley, Alaska.

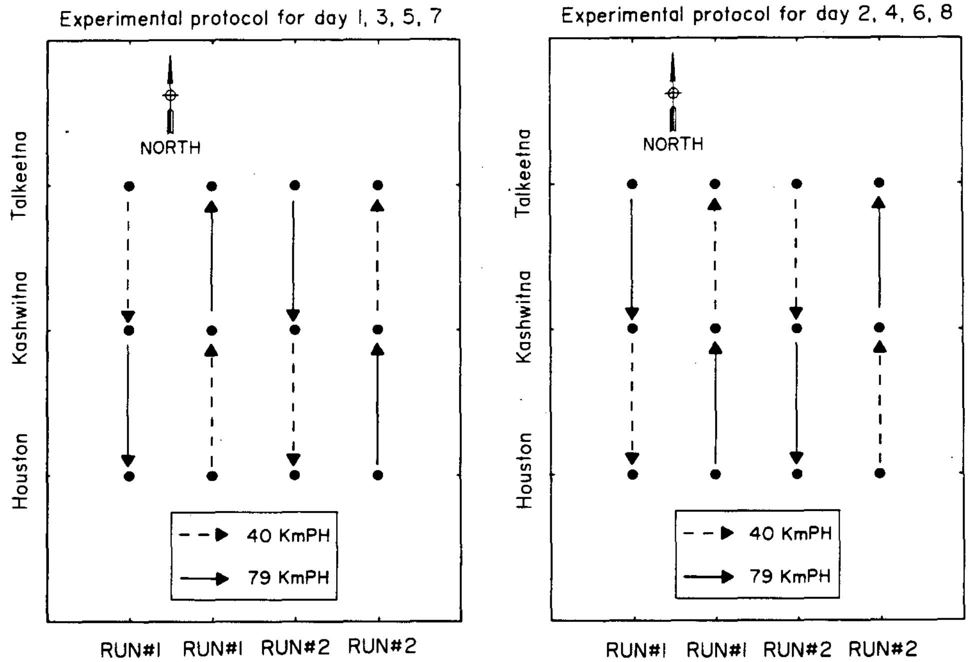

Fig. 2. Schematic of the 2^4 repeated measures factorial design employed from 16-23 February, 1988, in the lower Susitna River valley, Alaska, to determine the effects of track site, train speed, direction, and run on moose-train collisions.

effect; site, train direction, train run, and 3 of 11 possible interactions: train speed by train direction, train speed by site, and train direction by site; were tested for. It was felt that the other interactions were not biologically meaningful.

Snow depth on the tracks was removed as a variable by wing-plowing the tracks 5.5 m off the center line. The ARR provided two 2,500 HP locomotives (model GP35 manufactured by General Motors), connected back to back, so that after each run the crew could move to the other locomotive for the return trip.

The study was terminated when the sample size (number of moose struck) was large enough to ensure that the power to detect a 2:1 difference in the number of moose hit by the 79 kmph vs 40 kmph train was near 80%, at α=0.20. If reduced speeds resulted in fewer moose being struck, it was hoped that additional support could be obtained from the ARR to determine if the reduction was significant at an alpha of 0.05 with a power of 80%. The site, train direction, and train run main effects and the 3 interactions listed above were tested at a=0.10.

After the first day of the experiment, we modified the operational procedures to avoid killing moose. Instead of maintaining a steady 40 or 79 kmph, we instructed the train engineer to abruptly apply full braking when we were sure that continuing on at the designated speed would overtake the moose and kill it. Cows with calves were treated as one observation because the fate of the calf was dependent upon the behavior of the cow. Other than changing train speed, the engineer followed normal ARR operating procedures during the course of the study, these included using train whistles and lights to try to scare the moose off the tracks.

RESULTS

Regression Results

The regression model (Table 1) explained

Table 1. Linear regression coefficients for the square root of train moose kill in Alaska Game Management Unit 14 B for the winter of 1984-85.

Variable	Coefficient	
	Estimate	SE
Y-intercept	1.5074	0.1924
IMAV3SNF[a]	0.6942	0.1398
MAVPNOK[b]	-1.4447	0.2656
INTERACT[c]	-0.5391	0.2653
PREVKILL[d]	-0.2779	0.0919

[a]- Denotes a moving average of the previous 3 days snow fall when ground snow is 91.44 cm or greater, otherwise 0 is used.

[b]- Denotes the proportion of the previous 7 days in which 0 moose were killed.

[c]- Denotes an interaction term between IMAV3SNF and MAVPNOK.

[d]- Denotes the square root of the number of moose killed in the previous day.

a significant (F4,132 = 29.389, P = 0.000) amount of the variation in moose kill along the tracks. The following explanatory variables were included in the final model: a moving average of snow fall on the previous 3 days when snow depth ≥91.4 cm. (IMAV3SNF), a moving average of the proportion of the previous 7 days in which 0 moose were killed (MAVPNOK), an interaction term between these 2 moving averages (INTERACT), and the square root of the number of moose killed on the previous day (PREVKILL). There was no positive serial correlation (Neter and Wasserman 1974) in the residuals (Durbin-Watson statistic = 2.021, p-1 = 4, n = 137). This model predicted that moose mortality due to collisions with trains would be high immediately following a snowstorm, when snow depths exceed 91 cm and the daily incidence of trains missing moose is low. The experiment was implemented when the above conditions were present.

Treatment Effects

During the study a total of 29 moose were 'struck' by the train, of which 20 were 'paper strikes' and 9 were actual collisions. Of the 20 moose recorded as 'paper strikes', 8 came to within 3-7 m of being struck by the deaccelerating train, 2 were missed by a matter of centimeters, and one was bumped. One collision occurred during braking when the train blew a fuse, and as a result, the brakes failed and the moose was killed. The effect of reducing train speed was not significant (P =

Table 2. Analysis of variance for a 2^4 incomplete factorial, repeated measures experiment on moose struck by trains in the lower Susitna River Valley, Alaska.

Source of Variation	MS	DJ	F	P-value
Train Speed (79,40)	0.0165	1	0.024	0.439[a]
Direction (North, South)	0.141	1	0.214	0.646
Site (MP 215-199, 199-173)	1.891	1	2.882*	0.096
Run (First, Second)	0.016	1	0.024	0.878
Speed x Direction	0.141	1	0.214	0.646
Speed x Site	1.266	1	1.930	0.171
Directon x Site	1.266	1	1.930	0.171
Error	0.656	49		

[a]Significant at = 0.20

α = 1 sided test

0.439) (Table 2). Of the 29 moose struck, 14 (48.3%) were hit by the 40 kmph train and the remaining 15 (51.7%) by the 79 kmph train. The site effect was significant (P = 0.096); 20 moose were struck in the northern site, while 9 were struck in the southern site.

The power curve for this experiment (Figure 3) indicates that a true difference of 20:9 in the number of moose struck by the 79 versus 40 kmph trains would result in a significant test statistic 80% of the time. This experiment had a high probability (large power) to detect differences of 2:1 or greater in the number of moose struck by the 79 versus 40 kmph trains.

Moose Behavior

Most moose 'struck' by the train behaved similarly. When first observed moose were usually standing or walking on the railroad bed, often between the rails. Most animals retreated from the train and increased the speed of their escape. Some moose would trot at a slow to medium gait; others would run (sometimes 24-32 kmph) as the train approached. Nearly all moose ran down the center of the track. Because of faster train speeds, moose running on the track were overtaken by the train. Moose recorded as a 'paper' strike often continued to trot in front of the train, sometimes for distances of over 2 km. Moose exhibited a strong tendency to remain on the track when chased, even if exhausted. However, when the train stopped, moose generally left the track after moving 200m. Most moose that were encountered on the track, but not recorded as a 'strike', were crossing the track and apparently not affected by the approaching train.

Moose generally avoided crossing railroad bridges. In one instance a train had slowed down to 5 mph to avoid hitting a moose. The moose trotted up to an unplanked railroad bridge and then turned, and walked back toward the slowly approaching train. After a few minutes of indecision the moose exited the tracks.

DISCUSSION

The main goal of this experiment was to determine if slower train speed would reduce moose kill adequately to solve this pressing management problem. Moose kill reduction had to be substantial to justify the economic costs of using slower train speeds. A 2:1 reduction seemed to be the minimum size which would meet this criteria. A reduction of this magnitude would have reduced the 1987 train kill of moose in GMU 14B from 173 (Grauvogel 1990) to 87 moose.

In our opinion, every animal recorded as a 'paper strike' would have been killed if the braking order was not given. This opinion is supported by the fact that 1 moose was struck and killed during a temporary brake failure and the proximity of the train to the other moose at the time of braking. Additionally, moose which collided with the train and were killed did not exhibit a last second attempt to jump out off the track.

Our results demonstrate that slowing ARR trains to 40 kmph does not result in a significant (2:1) reduction in the moose hit by trains in the lower Susitna River Valley. Obviously there exists train speeds below 40 kmph which would result in lower moose mortality. These speeds were not considered in this experiment, because the ARR would not have been able to implement slower speeds due to economic considerations. These results are probably applicable to any railroad right-of-way where snow depths exceed 76 cm and snow density off the railroad bed hinders the ability of moose to run.

We found differences in the number of moose struck by trains at the 2 different sites, with the northern site having a significantly higher rate of strikes. Abandoned homesteads with early successional stages of birch, willow, and aspen are more common in the northern site. The site difference may have occurred because more moose were wintering at the northern site in the vicinity of the tracks.

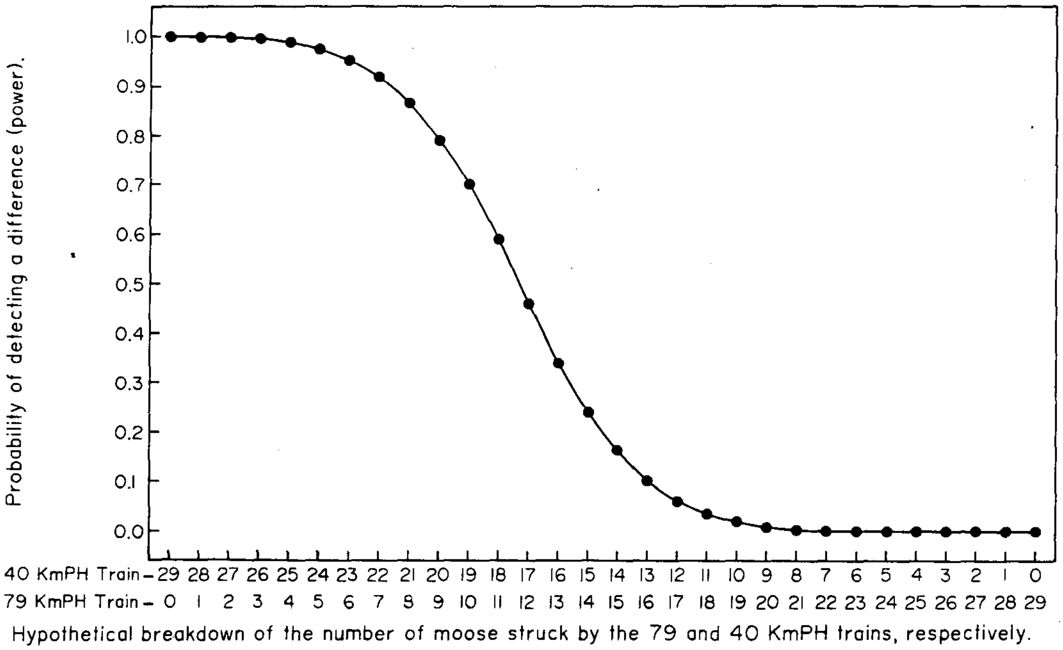

Fig. 3. Power curve for detecting if 40 kmph trains strike fewer moose than 79 kmph trains, at alpha = 0.2.

In order to obtain a more powerful test of the speed effect and separate the effects of potentially confounding factors, such as train direction, site, and run, the 2^4 incomplete factorial design was used instead of a one-way ANOVA or chi-square analysis. This design can be thought of as a specialized ANOVA and has the same assumptions as an ANOVA (normality, independence, and constant variance) plus a sphericity assumption on the residuals of the repeated observations at a site within a given day (Winer, 1971). In this design, the site becomes the experimental unit with regard to testing for a train speed effect, and hence 8 observations about this effect were made every day and a total of 49 df were associated with the variance (MSE) (Table 2) used in testing for a speed effect.

Ideally, the sample size would have been sufficient for the experiment to have large power to detect 2:1 differences with an alpha of 0.05. The duration of the experiment and thus the sample size, was constricted by the high cost of running a special train at an isolated location, and as a result, we had to choose between making a type I or II error (Ostle and Mensing 1982). In the context of this problem, it was much more important to identify a potential solution then to 'fail to detect' a difference due to inadequate sample size. If a significant difference was observed at a=0.20, subsequent data could have been collected to reduce the probability of a type I error while still maintaining large power. Sequential testing of data is often used in clinical experiments (Anscombe 1963, Berry 1989), and could have been used to obtain valid experimental results if subsequent data were collected. The other comparisons were done with an alpha of 0.10 to increase the ability of the experiment to identify potential factors which are important sources of variation in the number of moose struck in this section of track. No follow up study of significant results for these factors (train direction, train run, and track site) was planned because of the expense and the inability to reduce these factors with regard to railroad operations.

Most of the struck moose were using the tracks as a trail or corridor to make north-south movements. The majority of these had sufficient time to exit the tracks, but they usually tried to out run the train. Child (1983) observed similar moose behavior in Canada. He hypothesized that fleeing from oncoming trains was part of a moose's anti-predator behavior.

Our study and Child's (1983), found that moose have a strong tendency to stay on the tracks when fleeing trains. In our study, snow depth was approximately 90 cm, and when a moose left the track it floundered. Child's (1983) moose anti-preditor hypothesis coupled with moose floundering in deep snow off of the tracks would explain the reluctance of moose to leave the tracks.

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