MIGRATION DISTANCES OF MOOSE POPULATIONS IN RELATION TO RIVER DRAINAGE LENGTH

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ABSTRACT: To aid moose management in Sweden we want to be able to predict the yearly distribution of migratory moose populations based on winter inventory data since summer inventory data are lacking. As a first step in developing this method, we compared migration distances of moose in 11 populations to the upstream-lengths of river drainages that winter concentration areas were located along. The winter concentration areas were in both coastal and mountainous-inland regions in central and northern Sweden. Mean and maximum migration distances of moose in the different winter concentration areas were found to be correlated with the length of the respective river drainage, and moose generally migrated upstream from winter to summer areas. River drainage length and direction of flow appear to be major factors related to the maximum distances and direction that moose migrate from winter concentration areas. By noting the location of a winter concentration area along a river drainage, it may be possible to estimate the migration distances of the population and thus the length of the population's yearly distribution. This method will be further developed to more accurately estimate the area, in addition to the length, of the yearly distributions of migratory moose populations.

ALCES VOL. 24 (1988) pp.112-117

In Sweden, the summer and hunting season distributions of migratory moose populations are often unknown. Migratory populations are aerially inventoried during winter, when snow cover increases the sightability of moose (Gasaway *et al.* 1986). However, migratory populations are often concentrated during winter and thus winter inventory data does not directly give information about the populations' yearly distribution. It can be important to know where winter concentration areas are, for example to predict browsing pressure on forest stands. However, it is also important to know how moose are distributed during the fall hunt, when migratory moose are usually on their summer ranges, in order to determine appropriate hunting quotas on a regional basis. Thus the inclusive seasonal-use regions, i.e., the yearly distribution of migratory populations would be the most effective areas for inventory and harvest management. Therefore, we wanted to develop a method enabling us to easily estimate the yearly distribution of a moose population based on winter inventory data.

As a first step in developing a method to predict the yearly distribution of a migratory moose population, based on winter inventory data, we hypothesized that mean and maximum migration distances of moose in a winter concentration area are related to the length of the river drainage it is located along. In other words, we hypothesized that river drainage length affects a migratory population's migration distances and that the longest axis or length of the yearly distribution of migratory moose population is related to river drainage-length.

A multitude of factors may affect or cause moose migrations, such as food availability, snow depth, elevation, latitude, learned behaviour etc. However, we were not concerned with why moose migrate, we wanted to develop a simple methodology to determine how far migratory moose populations seasonally migrate away from their winter concentration areas, i.e., to estimate the length of their yearly distribution.

To test the hypothesis that the maximum migration distances of a population, i.e., the length of a population's yearly distribution, is related to river drainage length we measured

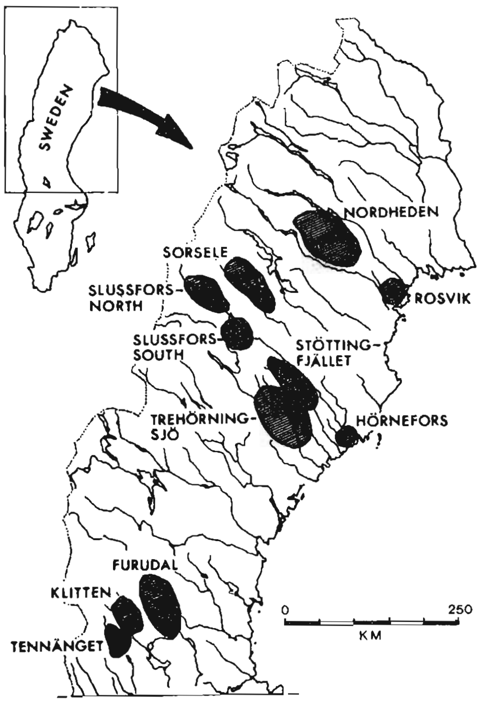

Figure 1. Locations of the 11 migratory moose populations used in the study.

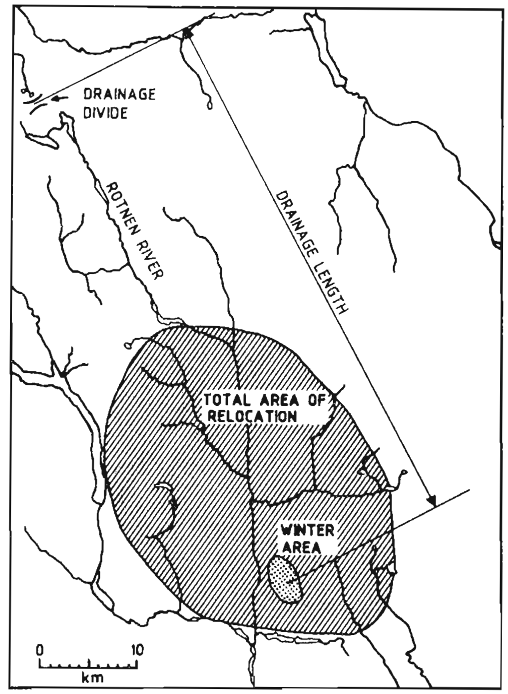

Figure 2. River drainage length along the Rotnen river and total area of the yearly relocations of moose marked in the winter concentration area of Klitten.

the upstream lengths of river drainages that eleven winter concentration areas were located along and compared them to the distances that moose migrated from them.

STUDY AREAS

Eleven migratory moose populations, located along different river drainages, in central and northern Sweden in both coastal and mountainous-inland regions, were included in the study (Sandegren & Ledstrom 1984, Sandegren *et al.* 1984a, Sandegren *et al.* 1984b, Sandegren & Back 1985, Sandegren & Back 1986) (Fig.1). The Furudal, Klitten and Tennanget areas are in the rolling hills of the southern taiga zone, with lowlands dominated by Scotch pine (*Pinus silvestris*) and highlands, by Norway spruce (*Picea abies*) (Sandegren *et al.* 1985). The Trehorningsjo, Stottingfjallet, Sorsele, Nordheden and both Slussfors-North and -South are highland areas of the central taiga zone, characterized by pine forests in lower elevations, spruce forests at higher elevations and subalpine birch on the ridge tops. The Hornefors and Rosvik areas are lowland coastal regions of the central taiga zone.

METHODS

Moose were marked in winter concentration areas and monitored during variable periods from 1980 through 1986. To simplify comparisons of migration distances between populations with differing intensities of relocations, we used the following criteria:

1) Moose were considered to be migratory

Table 1. Migration distances of moose and river drainage lengths in 11 areas in central through northern Sweden.

Area	Mean 4 longest migration distances km (SD)	Mean migration distance km (SD)	N moose	River length (nearest 5 km)
Slussfors South	23.2 (10.2)	23.2 (10.2)	4	20
Hornefors	20.8 (1.5)	15.2 (5.0)	17	45
Klitten	21.0 (2.4)	16.2 (4.9)	9	55
Rosvik	33.3 (8.5)	22.9 (11.3)	9	60
Tennanget	34.2 (10.5)	18.4 (10.0)	18	45
Furudal	77.8 (13.6)	42.8 (17.0)	53	95
Stottingfjallet	58.8 (16.5)	32.0 (21.5)	13	85
Trehorningsjo	74.5 (12.2)	37.3 (19.4)	33	95
Slussfors North	72.0 (19.8)	49.9 (21.2)	11	115
Sorsele	110.5 (31.4)	56.1 (34.1)	18	160
Nordheden	98.0 (11.2)	53.1 (29.1)	20	200

if their average summer and winter locations were greater than 10 km apart, 2) Migration distances were defined as the distance between the average summer and winter locations, and 3) If a moose was monitored for more than one summer and winter, its migration distances were averaged. Moose moving exceptionally long distances (eg. >100 km) and/or moving during periods when other migratory moose were not migrating, and/or moving away from winter areas and not returning when other migratory moose did, were considered dispersals and were not included in this study.

River drainage was measured on a 1:250 000 map to the nearest 5 km, from the center of the winter concentration area to the head waters of the river (Fig. 2). The longest straight line distance was the value used to estimate river length. Migration distances for each population were compared to river drainage length by linear regression.

RESULTS AND DISCUSSION

Migration distances of 205 moose in the 11 areas ranged from the defined lower limit of 10 km up to 155 km. With rare exception, moose migrated upstream from winter to summer areas. Moose from winter concentration areas along short drainages consistently had mean migration distances that were shorter than those of moose from winter concentration areas along longer drainages.

Mean migration distances of the 11 populations were correlated to the lengths of the river drainages that the winter concentration areas were located on ($r^2 = 0.80$, $P < 0.0003$, Fig. 3) by the equation:

$$M = 0.26R + 10.80$$

where M = the mean migration distance of moose in a winter concentration area, and R = the river drainage length. Moose in winter areas located on longer drainages had, on the average, longer but more variable migration distances than moose using winter areas located along shorter drainages (Table 1).

Since migration distances of moose wintering in areas on long drainages were variable, mean migration distances did not give an accurate estimate of the maximum expected length of the area occupied by a migra-

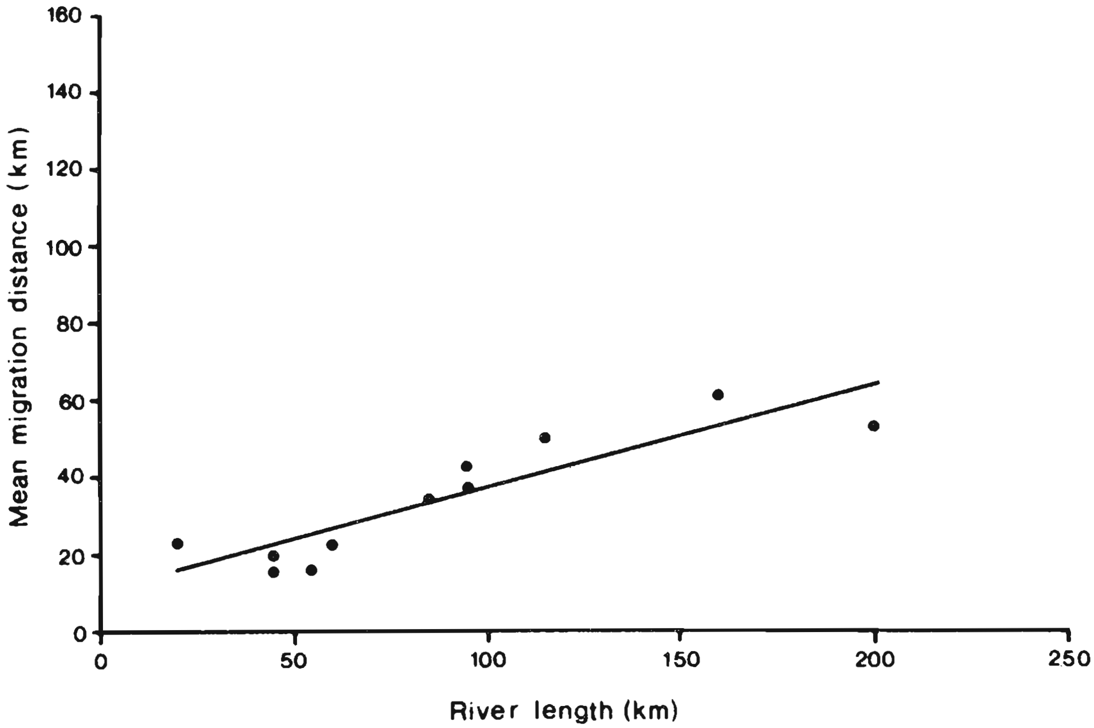

Figure 3. Mean migration distances of moose from 11 winter concentration areas in relation to the length of the respective river drainage, winter concentration areas. ($M = 0.26R + 10.80$; $r^2 = 0.80$; $P<0.0003$)

tory population. To estimate the length of the area occupied by migratory populations, the four longest migration distances from each population were measured against river drainage length. These mean maximum migration distances were well correlated to drainage length ($r^2 = 0.84$, $P<0.0002$, Fig. 4). The relationship between the mean maximum migration distances M^x), i.e., the expected length of the population's distribution and river drainage length (R), was given by the following equation:

$$M^x = 0.55R + 8.03.$$

Thus, via this equation, an easily determined measurement of river drainage length gives a good estimate of the length of the yearly distribution of a moose population using a known winter concentration area.

CONCLUSION

Due to the enhanced sightability of moose in areas covered by snow, moose populations in Sweden are aerially inventoried during winter. No satisfactory nation-wide census method has yet been developed for use during summer. Inventory data from winter alone does not give information about the summer distribution and densities of migratory populations. Moose hunts in Sweden usually occur while migratory moose are on their summer ranges. Since the total or yearly distributions of migratory moose populations are unknown it is difficult to set appropriate harvest quotas and to evaluate the effects of the previous years hunt. Thus we wanted to develop a method to estimate the yearly distribution of a moose population based on winter inventory data.

As a first step towards this goal, we found

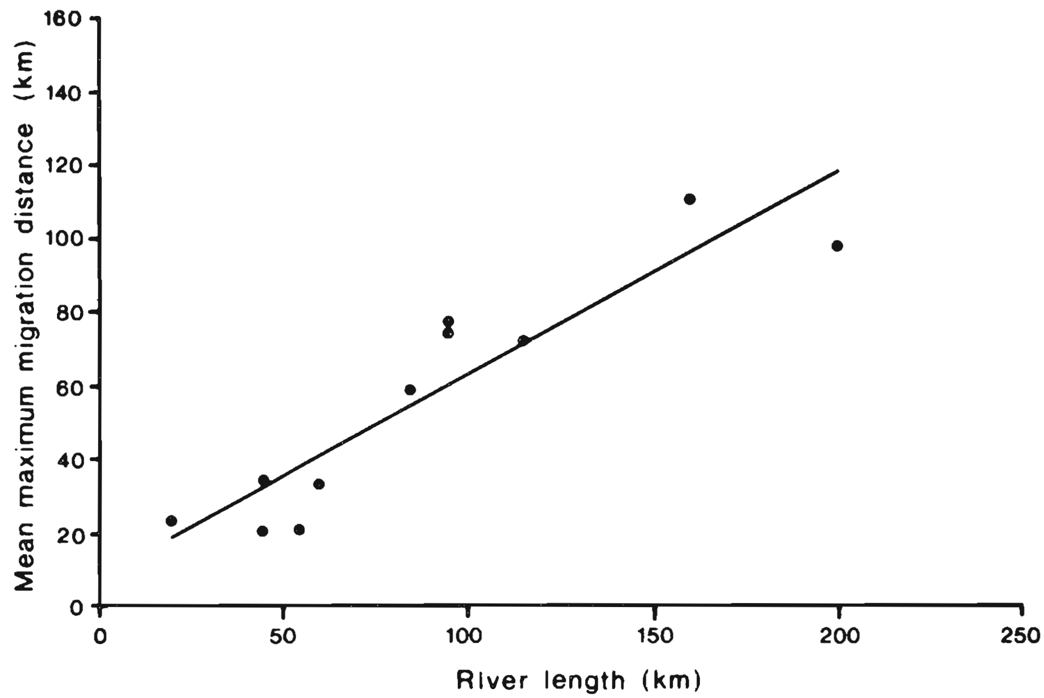

Figure 4. The means of the four longest migration distances of moose from 11 winter concentration areas in relation to the length of the respective river drainage. ($M^x = 0.55 + 8.03$; $r^2 = 0.84$; $P<0.0002$)

that river drainage length and direction of flow were related to the distance and direction that moose in winter concentration areas migrated to summer areas. Thus by noting the location of a winter concentration area along a river drainage, it was possible to estimate the approximate length of the geographical area that the population utilized throughout the year. This method will be further developed to more accurately estimate the area in addition to the length of the yearly distributions of migratory moose populations.

ACKNOWLEDGEMENTS

We thank Per Ahlqvist, Goran Bergman, Nils-Olof Back, Hans Geibrink, Gunnar Ledstrom, Olle Persson, Lennart Pettersson and Sture Sjogren for their devoted work in the field and/or in the office. This project was financed by the Swedish Sportsmen's Association.

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