SEASONAL MOOSE MIGRATION RELATED TO SNOW IN SWEDEN

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Abstract: Radio-collared moose (*Alces alces*) in central Sweden were tracked during fall and spring migrations from 1980 through 1984. Moose were located within an average of ± 6 days (SD=5.6) of 163 migration onsets.

Adult moose (>2 yr) began fall migration at an average snow depth of 42 cm (SD=9.2) and approximately one month after the first snow accumulated on the summer range. Snow depth and days of snow accumulation at onset of fall migration were similar between years ($p>0.05$), however, adult moose migrated at significantly different seasonal dates in different years ($p<0.05$).

Adult moose began spring migration at an average snow depth of 6 cm (SD=12.4). However, timing in relation to snow melt was different in different years ($p<0.05$) as were seasonal dates of spring migration ($p<0.01$).

Subadults (1-2 yr) had earlier fall, but similar spring migration onsets ($p>0.05$), than older moose. Unlike adult moose, yearlings and two year olds had fall and spring migration onsets that appeared to be related to the seasonal date.

The environmental factors which may initiate seasonal migrations of moose have been widely discussed. Factors such as snow depth (Formozov 1946; Phillips *et al*. 1973; Coady 1974; Van Ballenberghe 1977; Addison *et al*. 1980; Hauge and Keith 1981), snow density and hardness (Edwards and Ritcey 1956; Peek 1971), food availability (Formozov 1946; Edwards 1956; Coady 1974; Le Resche 1974), shelter availability (Edwards 1956), plant phenology (Knowlton 1960; Le Resche 1974; Hauge and Keith 1981) and predation (Peterson and Allen 1974) and their significance in relation to moose migration and movements have been considered. Yet none of these environmental factors have been intensively measured on winter and summer ranges and then related to monitored migration movements of moose.

The objective of this study was to find a measureable environmental factor which was related to migration onset. Based on the results of previous studies we decided to test the hypothesis that migration onset is related to snow depth. This relationship was quantitatively tested by monitoring snow depth on the summer and winter ranges of a seasonally migrating population of moose, and comparing those measurements to the migration onsets of radio-tracked individuals.

STUDY AREA

The study area (1359 km^2), described by Sandegren *et al*. (1982), is located in central Sweden (61°10'-61°50'N, 14°35'-15°20'E) (Fig. 1). The terrain is gently rolling with a mean elevation of about 200 m in the lowland (winter range area) and 500 m in the upland (summer range). The main winter range (area A) is characterized by a high percentage of pure pine (*Pinus silvestris*) forests with lichens (*Cladonia spp*)

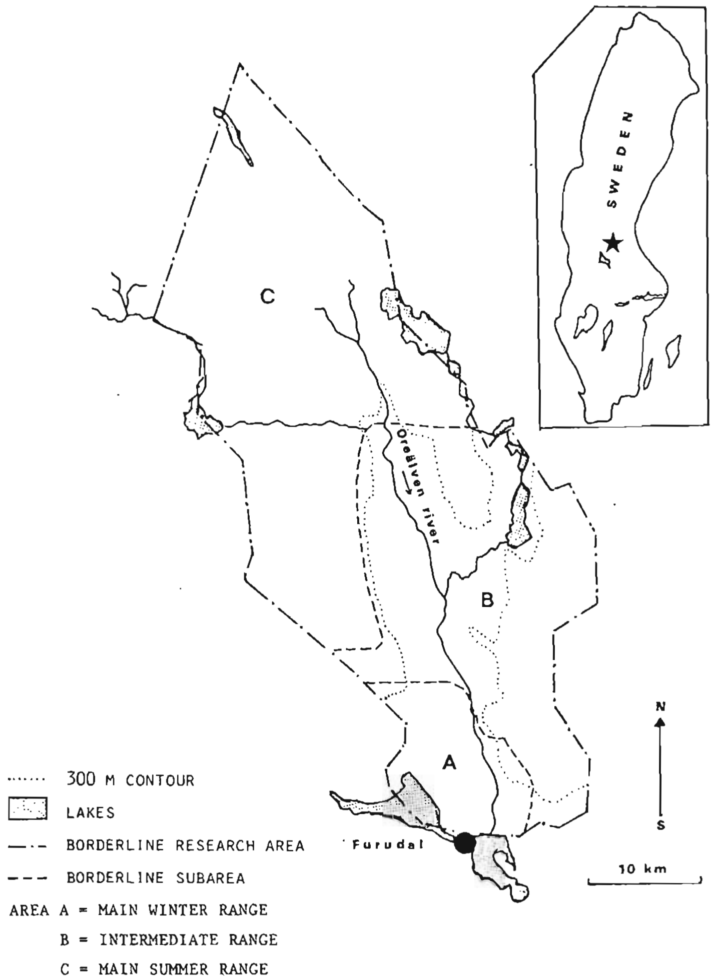

FIGURE 1. The Furudal study area and its location in Sweden.

dominating the field layer. Spruce (Picea abies) forests and mixed coniferous forests with dwarf-shrubs (mainly Vaccinium spp) are more common in areas B and C than in area A. Decidous trees are generally found scattered throughout the study area. The percentage of wetlands increases at higher elevations. The forests are intensively managed and young stands (0-20 years) cover about 20% of the total area.

The mean temperature of the hottest month (July) is +15°C and of the coldest (January) -7°C. Snow cover lasts for approximately five and a half months in the southern part of the research area and usually remains more than two weeks longer in the north.

The moose population has been aerially surveyed several times during the last four winters. Overall densities approximate 1 moose/km^2 with variations from 0.2/km^2 (area C), to 1/km^2 (area B) and to about 7/km^2 (area A, Fig. 1). The population is harvested at an average rate of about 30% per year.

MATERIAL AND METHODS

Within the study area a total of 127 moose were equipped with neck-collars mounted with radiotransmitters for the purpose of migration studies (1980-1985). Most moose were immobilized from helicopters using 1.0-1.2 ml of a concentrated etorphin-xylazin mixture (Sandegren et al. in press). Immobilized moose were aged from tooth wear and eruption and classified as calves, subadults (1-2 yr) and adults (>2 yr).

Moose were tracked mainly from the air but were also, occasionally tracked from the ground. Ground tracking was done either from a van with an extendable and rotatable antenna through the roof (Cederlund et al. 1979) or with an hand held antenna. Tracking from the air was carried out from a Cessna - 172 aircraft, with a 2.4 - element Yagi antenna mounted on each wing strut. Continuity was maintained by replacing old and faulty transmitters each winter.

Moose were located within an average of 6 ± 5.6 ($\bar{X}$±SD) days of their migration onset. An animal was considered to have started migration when it had moved 5 km from the summer or winter home range geometrical center and kept moving away. Onset date was defined as the mid date between the last location in the home range and the next location. Due to poor weather during migration periods regular and consecutive aerial radio-tracking was not always possible. Moose which were not located frequently enough (within ± 20 days of migration onset) were not included in the results.

Spring and fall migration patterns are based on data from 52 moose with well defined home ranges.

Home ranges were mapped by combining the outermost positions forming a convex polygon (Mohr 1947) of a minimum of 5 positions per individual.

Snow depth was measured in open plots (10 x 50 m) usually in clearcuts (0-6 yr) at three locations in both areas A and B and four in area C during three consecutive winters (1981/82-1983/84). At each location ten metric measuring sticks were permanentely placed in a fixed pattern within the plot. Every 14 days the snow depth at each stick was recorded to the nearest cm. The ten values within each plot were averaged and used in the further analyses. Snow depth data from a standard meteorological station in the center of area C (The Swedish Meteorological and Hydrological Institute unpubl. data) provided supplementary data. Snow depths on the summer and winter ranges from 1979 to 1984 are shown in Fig. 2.

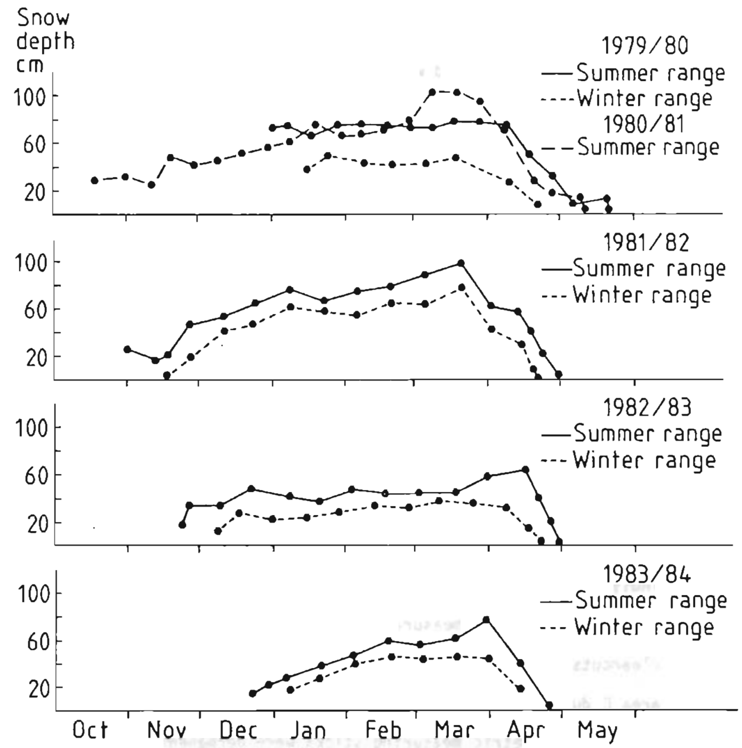

FIGURE 2. Snow depths on summer and winter ranges from 1979 to 1984.

Kruskal-Wallis test (Steel and Torrie 1980) was used to detect possible differences in snow variables and calender date at the migration onsets in the nine seasons of study. Possible sex and age related differences in onset dates were tested using Kruskal-Wallis test and Wilcoxon-Mann-Whitney test (Steel and Torrie 1980). respectively.

RESULTS

Fall migration

There were no detectable differences in snow depths between 1980, -81, -82 and -83 at the time of fall migration onset for adult moose ($p>0.05$, N=42) (Fig. 3). The mean snow depth at migration onset, for all four years, was 42 cm (SD=9.2). Adult moose began fall migration approximately one month ($\bar{X}$=31 days, SD=14.2) after the first snow accumulated on the summer range. This response was not significantly different between years ($p>0.05$). Adult moose migrated at different seasonal dates in different years ($p<0.05$). The average migration onset dates were 23 Nov (SD=17.9, N=16) in 1980, 29 Nov (SD=6.4, N=8) in 1981, 15 Dec (SD=9.3, N=9) in 1982 and 25 Jan (SD=11.4, N=9) in 1983. Migration onsets were later during years of later snow accumulation.

Subadults (n=10) began fall migration earlier than older moose (Fig. 3). The data indicates that, unlike the migration onsets of adult moose, their migration onsets were better related to seasonal date than to first snow accumulation or snow depth. The mean seasonal dates of fall migration for subadults were similar in: 1980 (14 Nov, N=1); 1981 (12 Nov, SD=15.0, N=3); 1982 (12 Nov, SD=17.0, N=5) and 1983 (12 Nov, N=1). The snow depth at the onset of fall migration of subadults was

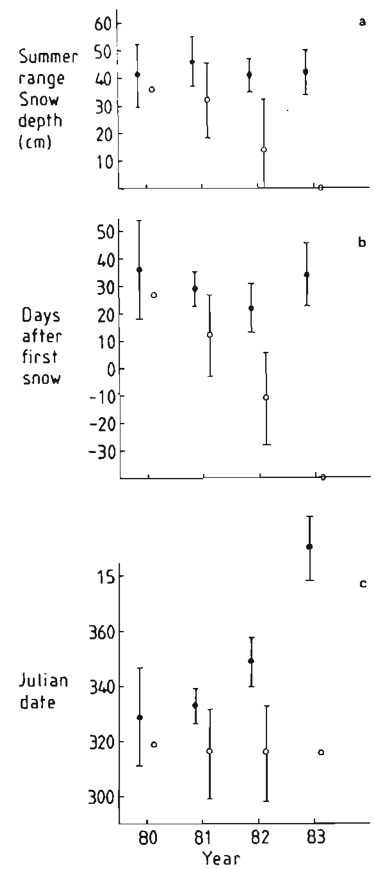

FIGURE 3. Fall migration onset dates ($\bar{X} \pm$ SD) for adult moose (>2 yr - ●) and subadults (≤2 yr - ○) in relation to a) snow depth on summer range, b) first day of measurable snow and c) Julian date from 1980 to 1983 (see text for N).

extremely variable: from 0 cm to 48 cm ($\bar{X}$=17.5 cm, SD=18.0). In addition, fall migration onset of subadults did not appear to be related to the first day of snow accumulation on the summer range. The range of responses varied from 40 days before to 29 days after the first snow accumulated. On an average, subadults migrated three days (SD=23.1) before snow accumulated on their summer ranges.

Spring migration

Adult moose (N=74 onsets) began spring migration, in 1980, -82, -83, and -84 when the mean snow depth on the winter range was 6 cm (SD=12.4) (Fig. 4). According to Sandegren et al. (1982), an average snow depth of 6 cm during spring 1982 occurred when approximately 50% of the ground was snow free. Adult moose migrated at similar snow depths in different years. However, adult moose did not respond to the last measureable snow on the winter range in the same way in different years. Their spring migration began a different number of days after the last measureable snow in different years ($p<0.05$). In addition, they did not migrate on the same seasonal date each year ($p<0.01$). The mean spring migration onset (N=90 onsets) was 25 April (SD=8.6, N=22) in 1980; 27 April (SD=17.2, N=16) in 1981; 29 April (SD=10.4, N=25) in 1982; 21 April (SD=7.5, N=15) in 1983 and 18 April (SD=5.9, N=12) in 1984.

The seasonal dates of spring migration for subadults (N=21) were similar to those of adult moose ($p>0.05$) (Fig. 4). Subadults began spring migration when snow depth averaged 3 cm (SD=4.2, N=18 onsets). These moose migrated at similar snow depths in different years. In addition, unlike adult moose, they responded to the last measureable snow on the winter range in the same way in different years ($p>0.05$)

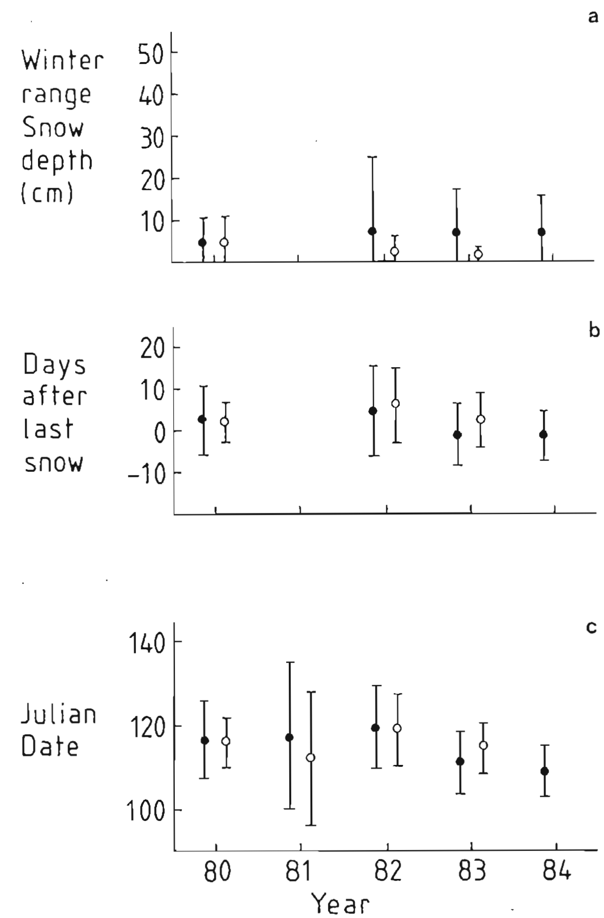

FIGURE 4. Spring migration onset dates ($\bar{X} \pm$ SD) for adult moose (>2 yr - ●) and subadults (≤2 yr - ○) in relation to a) snow depth on winter range, b) last day of measurable snow and c) Julian date from 1980 to 1984.

by migrating an average of three days (SD=6.8) before the last measureable snow melted. Furthermore, as in fall migration, they began spring movement at a similar time of year in different years (p>0.05). The mean migration onsets were 25 April (SD=6.3, N=5) in 1980; 22 April (SD=16.1, N=3) in 1981; 29 April (SD=8.4, N=5) in 1982 and 25 April (SD=6.4, N=8) in 1983.

Both fall and spring average migration onset dates could be predicted by using the snow depth records from the summer range only (Fig. 5). The average length of time adult moose stayed on the winter range, including time spent in fall migration, was well correlated to the length of time snow depth was greater than 42 cm on the summer range.

Adult bulls (N=24 onsets) and cows (N=108 onsets) exhibited similar spring and fall migration onsets (p>0.05).

Three moose had migratory behaviour so aberrant to the norm, that their migration data were separated from the rest before analyses. Two moose that had summer home ranges in an area where many moose had winter home ranges had variable and unpredictable fall migration onset dates. One adult cow commenced migration within 11 days of the average fall migration onset of other moose in 1982 and 1983 but snow depths on her summer range were only 16 and 29 cm at that time. An adult bull migrated long after other moose left their summer range in 1982 and 1983, i.e. 117 and 43 days respectively after snow accumulations reached 40 cm on the summer range. In addition, one three year old cow without calf began fall migration 72 days before snow began to accumulate.

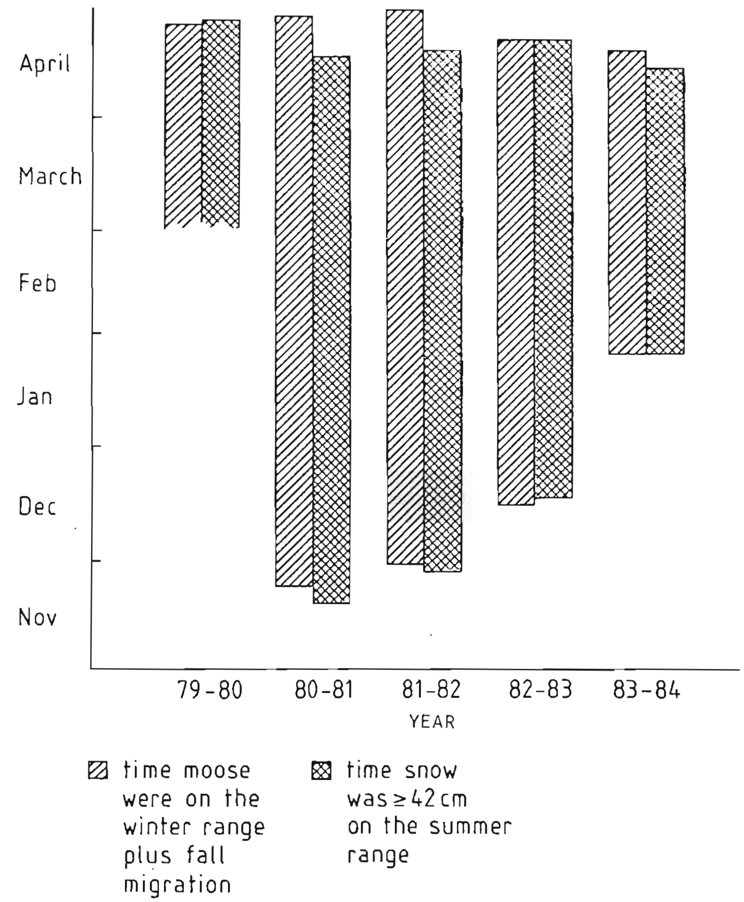

FIGURE 5. Time adult moose spent on the winter range and in fall migration compared to time snow depth was $\geq$42 cm on the summer range.

SUMMARY AND DISCUSSION

Results from this study showed that snow depth was an accurate predictor of mean spring and fall migration onset among adult moose in the Furudal study area. These results are in general agreement with observations from North America, the USSR and Finland which show that snow depth affects seasonal movements of moose (Van Ballenberghe 1977; Nasimovitch 1955; Pulliainen 1974).

In our study the mean adult moose migration onset in fall consistently occurred when 42 cm of snow accumulated on summer range. Thus, during the four fall migration periods 1980-83, mean migration onset could have been predicted by measuring snow depth on summer range. Mean spring migration onset occurred when there was 6 cm of snow on the winter range, with slight variation between years, so that each of the four spring adult migration periods could have been predicted by measuring snow depth on winter range.

Spring migration onset could also have been predicted by measuring snow depth on summer range. Spring migration for all five years began on average five days (SD=5.5) before snow depth was reduced to 42 cm on the summer range in the spring for all five years. Thus both spring and fall migration onset were predicted by snow depth on the summer range.

Even though the mean migration onsets during spring and fall were at similar snow depths each year, moose in this study did not commence instantaneous migration movements at snow depths of 42 cm. In fact some moose in the study area were not migratory. We hypothesize that habitat conditions in terms of food availability on individual summer ranges may cause different migration responses to snow accumulation (see also Edwards 1956). If habitat structure or other variables such as predation

(Peterson and Allen 1974) or plant phenology (Knowlton 1960) affect moose response to snow accumulation, snow depth at mean migration onset may vary from region to region. But snow depths around 40 cm might also predict moose movements in other populations. This is indicated by Van Ballenberghe's (1977) observation that individually recognized moose left the summer range when snow depth was above average, but stayed for most of the winter when snow depths were generally less than 40 cm. Furthermore Nasimovitch (1955) concluded that extensive seasonal moose movements are uncommon in areas where maximum depth averages less than 50 cm. Sweney and Sweney (1984) found that in three consecutive winters elk (*Cervus elaphus*) migrated to areas with less than 40 cm of snow.

Snow depths greater than 70 cm may seriously restrict moose movement and negatively affect their energy budget (Ritcey 1967; Kelsall 1969; Coady 1974; Thomson and Vukelich 1981). Lower depths without crusts do not appear to seriously impede moose activity. Why should moose then migrate at depths around 40 cm and 6 cm in fall and spring respectively? The fact that migratory moose in our study area left their summer and winter ranges at predictable snow depths each year does not mean that snow depth is the ultimate factor triggering migration onset. Accumulated snow may have been a proximate factor and indicative of changes in food availability and phenology which might initiate migration. For example in 1980, a dramatic phenological change occurred in blueberry (*Vaccinium myrtillus*) during the week of spring migration onset in the study area (Scharin 1980). Cederlund *et al.* (1980) reports that moose in south central Sweden increase the percent of dwarf-shrubs in their diet during spring and fall. By migrating, moose may extend the period when dwarf-shrubs are available to them a month or more. Moose depend on different food in different seasons and snow conditions and this could affect their movements. Moose movements in relation to habitat structure and food availability are little understood. If moose movements are affected by these factors migratory behaviour may be modified by habitat management practices.

Young moose are considered more erratic and unpredictable in their movements then adults (Le Resche 1974). Subadults in this study did not have predictable migration responses to snow depth, however, the sample size was relatively small. Their movements occurred at similar dates each season, and always earlier than adult moose. We have no good explanation for this behaviour. Perhaps their movements could be related to photo-period or post-rutting activities in combination with a week site fidelity compared to adults.

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