HABITAT CHANGES IN MOOSE RANGES: EFFECTS ON MIGRATORY BEHAVIOR, SITE FIDELITY AND SIZE OF SUMMER HOME-RANGE

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ABSTRACT: Due to hydro electric development in a forested area in Oppland County, Norway, a 9.5 km^2 artificial lake was created. The area was previously used as both a migratory and a summer area for moose (*Alces alces*). By following radio- collared moose cows and their calves prior to, and after the habitat alteration, we were able to investigate how this affected their migratory behavior, the size of their summer home-ranges and their site fidelity. The habitat alteration has so far caused only minor changes in migratory behavior. Most moose migrate along the same routes, crossing the artificial lake at the same place as they previously crossed the river. It is hypothesized that in years with unfavourable ice conditions on the lake, irregular mortality will increase.

Although summer home-range size for 7 adult (>1.5 yr.) moose cows increased from 1.403 ha (N=14) prior to the habitat alteration to 1.594 ha (N=17) in the years after, this difference was not significant. While distances between activity centers did not change during the study, there was a significant change in summer home-range overlap. Prior to the habitat alteration, home-ranges for individual cows overlapped by 61.4 %, while the same figure for the years after was 36.9 % ([t=2.4], P< 0.05). Two of the adult cows totally or partly abandoned the area and moved to other summer ranges. The effects of man made habitat alterations are discussed.

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Most moose populations in Norway are reported to show migrations between geographically seperated summer and winter ranges (Andersen 1991). Like most species with long distance seasonal return migration, moose calves accompany their dams for at least one migration circuit. During their first year of life calves learn the migratory routes from their dams (Cederlund *et al.* 1987), subsequently determining their migratory behavior as adults and the future locations of summer and winter ranges (Sweanor & Sandegren 1988). Andersen (1991) has shown that the evolution of such migratory traditions can lag behind natural environmental change. The litterature describing the effects of man made habitat changes to migratory behavior are scarse, and in most cases the extent to which the habitat change has affected migration behavior cannot be determined in the absence of predisturbance data.

Moose generally show strong fidelity to their home-ranges (Goddard 1970, Cederlund & Okarma 1988). Although some controversy exists as to what determines the actual size of home-range in mammals (McNab 1963, Lindstedt *et al.* 1986, Swihart *et al.* 1988), there seems to be general agreement that the size of a specific home-range is a measure of energy availability. During the growing season the moose feed extensively on a variety of deciduous leaves, aquatic macrophytes and herbaceous vegetation (Timmermann and McNicol 1988). Consequently habitat changes or increased levels of disturbance within the summer ranges are likely to affect the size of summer home-ranges.

The objective of this study was to test whether logging activity and dam construction affected (1) the migratory behavior of moose, (2) the size of individual home-ranges and (3) whether moose change their site fidelity to established home-ranges.

STUDY AREA

The study was carried out in an forested area in Oppland county in Central Norway at 61^0 N, 700 m a.s.l. The area is traditionally used both as a summer area and a migration area for two moose populations with geographically seperated winter ranges (Fig.1). Due to hydro electric development a 9.5 km^2 artificial lake was created in 1988. Prior to the inundation, all trees were logged. Before the habitat alteration this area was dominated by Norway spruce (*Picea abies*) forests (72 % of total area), with billberry (*Vaccinium myrtillus*) as the main field layer (60 % of total area), with bogs (15 % of total area) and large stands of *Salix* spp. (8 % of total area) around the natural small lake Dokkfløyvann in the valley bottom. This lake offered the moose in the area a variety of aquatic species known to be highly preferred by moose during summer, e.g. *Carex rostrata*, *Equisetum fluviatile*, *Nitella* spp. and *Chara* spp. (Belovsky and Jordan 1981). Earlier studies (Andersen 1991) revealed that nearly 200 moose used this area on their seasonal migrations between their summer and winter ranges. Archaeological findings in the study area (Coulson *et al.* 1989) provide evidence of extensive utilization of the migration route by moose from the Stone Age to recent times. A total of sixty-seven hunting sites and three rock carvings of moose from 500 B.P. to the bronze age and the location of 124 moose pit-fall traps in 4 different systems used in the period 400 B.P. to A.D.1600, have been found to intercept the main migration route through the study area (Coulson *et al.* 1989)(Fig.2).

METHODS

Migration Behavior

In order to document any changes in the migration behavior of moose in the study area before (1984-1987) and after (1988-1990) the habitat alteration, census lines intercepting the migration route (Fig.3) were visited in April and May when tracks were easily detected in the snow and counted twice a day.

Summer Home-Range

In order to document any effects of the habitat alteration on home-range size and site fidelity, the size of 31 summer home-ranges (June-August) of 4 (1985) to 7 (1989) radio-

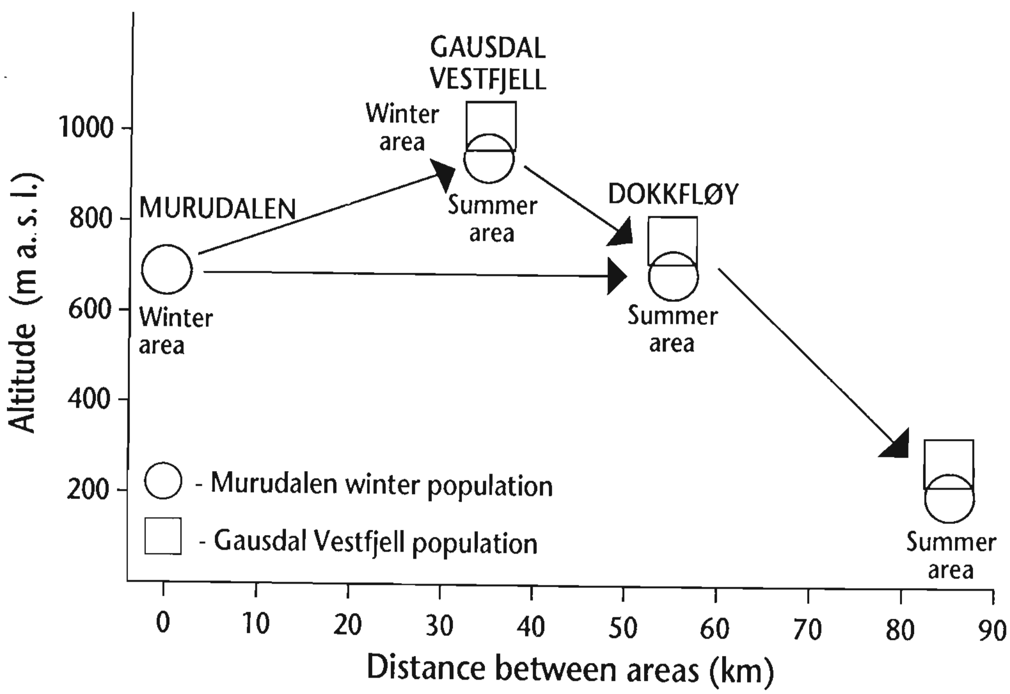

Fig.1. Moose migration routes (arrows) and location of summer and winter ranges for the Gausdal Vestfjell and Murudalen moose populations.

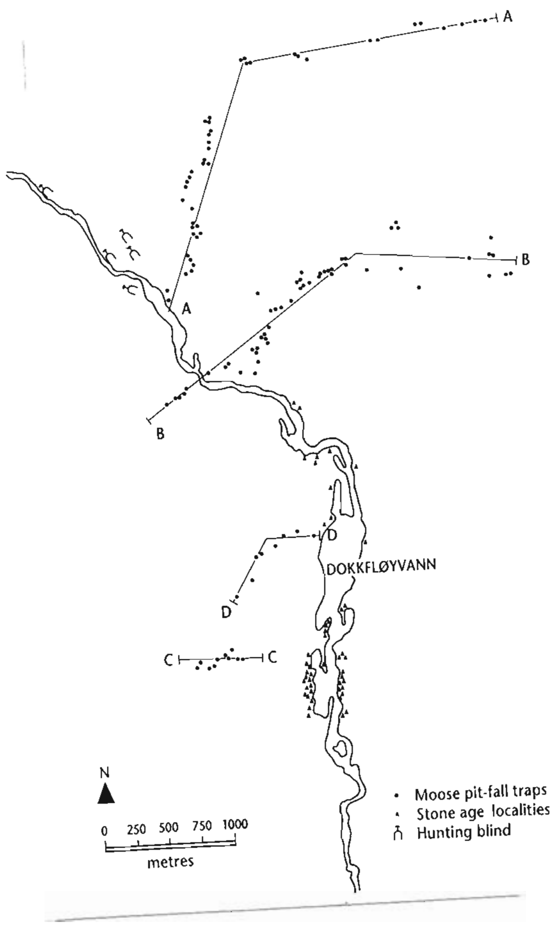

Fig.2. Location of moose pit-fall traps and hunting blinds around the Dokkfløyvann lake.

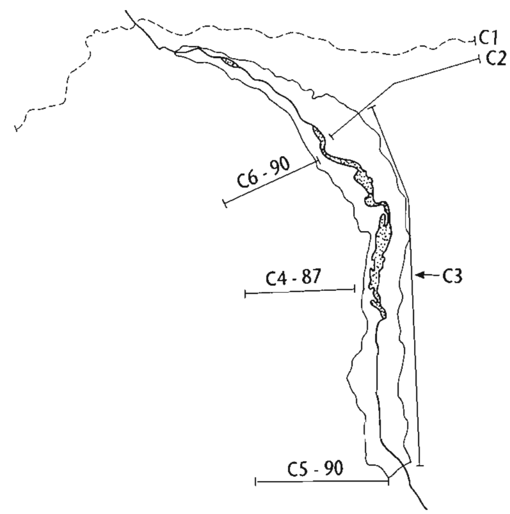

Fig.3. Location of the different census lines used in track counts of moose in the study area. Solid line around the natural lake shows the size of the new reservoir.

collared adult cows (>1.5 yrs.) were estimated in the period 1985-1990 using the RANGES IV program (R.Kenward, Inst. Terrestrial Ecology, Dorset, U.K.).

The following home-range characteristics were calculated:

1. Summer home-range size including 95% of the locations was calculated using a Kernel analysis (Worton 1989).

Variation in site fidelity was estimated using:

2. Kernel activity centers: i.e. the location having the minimum value of the first inverse aerial moment independent of the grid system.
3. Home-range overlap was expressed as the percentage area a home-range overlapped with the previous years home-range.

RESULTS

Migration Behavior

Depending on the snow conditions in the winter ranges (Sæther *et al.* 1986), the start of the migration varied between years. In 1984 the first animals were crossing census line C1 on 16 April, while the first animals two years later were observed on 1 May (Table 1). The number of migrating moose crossing C1 varied between 113 and 234 during the study period, the proportion of moose on the west side of the reservoir varied between 37 % and 20 % in the same period (Table 1).

Track counts prior to the habitat alteration showed that migrating moose west of the river had two different crossing points. One between pit-fall trap systems A and B (Fig.2), and a second south of lake Dokkfløyvann. In 1982 35 animals crossed from west to east between the pit-fall trap systems, while 29 moose crossed south of the lake (Fig.4). The same figure from 1990 showed that 47 moose crossed between A and B, while 16 animals

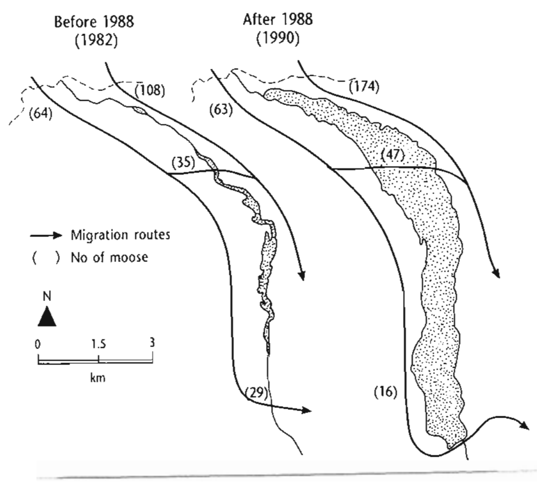

Fig.4. Number of migrating moose ( ) along the different migration routes prior to (1982) and after (1990) the reservoir construction.

changed migration behavior and crossed to the east by the new dam (Fig.4).

Summer Home-Ranges

Although great variation in the size of summer home- ranges was recorded, there was no significant difference in size either between individual cows, or between years (Table 2 and Table 3). Mean summer home-range for adult cows was 1.475 ha and ranged from 505 ha to 4.542 ha. Both these values were found for one of the youngest animals included in the study. Animal No.181 was born close to the dam area in 1986. The cow left the area in her third summer in 1988, but returned the year after and established a small (505 ha) summer area close to the dam.

Table 1. Total number of migrating moose crossing census line C 1 (see Fig. 2), distribution of migrating moose east and west of the reservoir and time for first crossing for six years between 1982-1990.

Year	Date of First Crossing	Total Number of Moose	% East of Reservoir	% West of Reservoir
1982	MAY 2	172	63	37
1984	APRIL 16	113*	72	28
1986	MAY 1	178	69	31
1988	APRIL 28	126	77	23
1989	APRIL 26	229	80	20
1990	APRIL 17	237	73	27

*Early snow melt made track counts uncertain.

Table 2. Individual variation in home-range size, distance between activity centers and home-range overlap for 7 adult moose cows in central Norway in the period 1985-1990.

Anim. No	Home-Range Size (HA.)			Distance Between Activity Centers (M)			Home-Range Overlap (%)		
	X	SD	N	X	SD	N	X	SD	N
100	1242	+ 411	5	1317	+ 752	4	41.0	+ 26.3	4
127	1797	+ 1167	6	1517	+ 730	5	61.0	+ 26.2	5
132	1843	+ 1026	3	5088	+ 4469	4	46.5	+ 44.3	4
147	1313	+ 694	6	2312	+ 1154	5	42.7	+ 26.6	5
172	1268	+ 486	6	1839	+ 827	5	42.6	+ 21.3	5
180	892	+ 257	3	3780	+ 1211	3	37.2	+ 19.7	3
181	2524	+ 2855	2	4141	+ 595	2	3.7	+ 4.5	2
MEAN	1475	+ 938	31	2628	+ 2148	28	42.9	+ 27.7	28
ANOVA	F = 0.9 n.s.			F = 2.3 n.s.			F = 1.1 n.s.		

Table 3. Yearly variation in size of summer home-range (June- August), distance between activity centers and home-range overlap for 7 adult cows in Central Norway in the period 1985- 1990.

Anim. No	Home-Range Size (HA.)			Distance Between Activity Centers (M)			Home-Range Overlap (%)		
	X	SD	N	X	SD	N	X	SD	N
85	1977	+ 348	4						
86	1337	+ 748	5	2246	+ 703	4	76.3	+ 16.4	4
87	809	+ 523	5	1706	+ 1548	5	49.6	+ 33.4	5
88	1478	+ 488	5	3963	+ 3974	6	37.3	+ 27.4	6
89	1287	+ 1243	6	2662	+ 1282	7	29.6	+ 21.8	7
90	1997	+ 1329	6	2277	+ 1294	6	36.0	+ 23.4	6
MEAN	1475	+ 938	31	2628	+ 2148	28	42.9	+ 27.9	28
ANOVA	F = 1.2 n.s.			F = 2.5 n.s.			F = 0.8 n.s.		

However, in September the same year the cow left the area once again and migrated 20 km south. In 1990 the cow returned to the study area and made a nine fold increase in the size of her summer home-range to 4.542 ha.

Although the size of summer home-ranges for adult cows increased from 1.403 ha prior to the habitat alteration to 1.594 ha the years after, this difference was not significant (Table 4).

There was no difference in distance between the activity centers for consecutive years, either between individuals or between years (Table 2, Table 3.). The average distance between activity centers was 2.63 km, but varied considerably. Between 1987 and 1988 home-ranges the mean distance was nearly 4 km, but with a standard deviation of nearly 100% of the mean. Although the mean distance between activity centers increased from 1.95 km prior to habitat deterioration to 2.95 km the years after, this difference was not significant (Table 4).

Although great variation in home-range overlap existed, there were no significant differences either between individuals or between years (Table 2, Table 3). The overlap between home-ranges varied from 76.3% in 1986/85 to 31.2% in 1989/88, with a mean of 42.9% for the whole period. In addition to animal No 181, animal No. 132 left the area in 1988 and established a summer home-range 11 km east of the study area. Comparisons between periods prior to and after habitat alteration revealed significant difference in home- range overlap ([t=2.4], $P < 0.05$, Table 4). In 1985-1987 61.4% of one years home-range was within the previous years home-

Table 4. Comparisons between summer home-range size, distance between activity centers and home-range overlap for 7 adult moose cows prior to (1985-1987) and after (1988-1990) habitat deterioration.

Period	Home-Range Size (HA.)			Distance Between Activity Centers (M)			Home-Range Overlap (%)		
	X	SD	N	X	SD	N	X	SD	N
1985-87	1403	+ 634	14	1946	+ 1210	9	61.4	+ 29.3	9
1988-90	1594	+ 1093	17	2496	+ 1282	17	36.9	+ 22.5	17
T-TEST	t=-0.6 n.s.			t=-1.1 n.s.			t=2.4 p<0.05		

range, while the same figure for the years after the habitat alteration was 34.1%.

DISCUSSION

The variation in the number of migratory moose is likely to reflect both variation in the size of the migrating population as well as variable track counting conditions. Aerial censuses with a fixed wing aeroplane in moose winter ranges in Gausdal Vestfjell between 1980 and 1983 gave an estimated number of 263 moose (Andersen 1991), while only 135 and 146 moose were recorded in the same area in 1989 and 1990, respectively (unpubl. matr.). It is hypothesized that compared with moose from the Murudal winter population (30 km north of Gausdal Vestfjell, Fig.1) that also migrate through the area, a larger proportion of migrating moose from Gausdal Vestfjell are likely to cross C1 west of the reservoir. Consequently, a decreasing winter population in Gausdal is more likely to reflect the general decrease in the proportion of moose migrating west of the reservoir, instead of being an effect of the inundation of the area.

Track count data prior to the habitat alteration showed that moose had two distinct crossing points. A large number of moose crossing between the pit-fall trap systems A and B, explains the need for two pit-fall systems so close together. The location of the hunting blinds in this area (Fig.2) also indicates that this crossing point has been used by moose for many generations. Registration along pit-fall system C (Fig.2) also demonstrated that the moose are using the same migratory tracks as several hundred years ago. A large proportion of the moose crossing from west to east south of the lake cross the 100 m long pit-fall system C. In 1987 11 moose were found to cross this area in two days (Fig.5).

Comparisons between track count data from 1982 and 1990, shows clearly that the moose crossing the valley south of the former natural lake have changed their migratory behavior. In 1990 16 moose were found to cross the valley over the new dam, instead of crossing the new reservoir. Migration route displacement after reservoir construction has also been reported for black-tailed deer (*Odocoileus hemionus columbianus*) (Loft *et al.* 1984). They also reported that some deer walked into the partially frozen reservoir, broke through the ice and drowned. So far we have not registrated any increased mortality caused by the dam and reservoir construction, but we hypothesize that in years with unfavourable ice conditions and large breaking zones around the reservoir irregular mortality will increase.

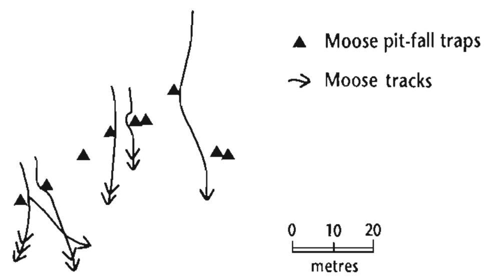

Fig.5. Moose tracks recorded through pit-fall system C in two consecutive days in 1987.

Earlier studies have reported that the size of annual home-range for moose may vary considerably depending on whether the animals are stationary or migratory (Best *et al.* 1978, Hauge and Keith 1981, Lynch and Morgantini 1984). Summer home-range size for nine adult female moose in Sweden (Cederlund and Okarma 1988) averaged 9.1 km², and ranged from 5.2 - 13.0 km². Although these figures are smaller than ours this is mainly due to different home-range estimation methods. Using 95% harmonic mean, as Cederlund and Okarma (1988) gives us a mean home-range size of 10.3 km² (unpubl. matr.), which is close to the size reported in their study.

Despite great logging activity and dam construction in the last part of the study there was no significant change in summer home-range size. Earlier conclusions about the effect of logging activities are not conclusive. Edge *et al.* (1985) found a decrease in home-range size for elk (*Cervus canadensis*), while Pedersen et al. (1980) found an increase for the same species. These differences could be related to variations in access to cover. In our study area all cows had access to cover, and although disturbances may alter habitat selection by increasing use of areas that provide cover, this will occur within the traditional home-ranges. However, in areas with limited cover, we agree with Edge *et al.* (1985) in stating that disturbances may increase home-range size and reduce home-range fidelity.

For white-tailed deer (*Odocoileus virginianus*) Hood and Inglis (1974) presented data indicating that does and bucks had different behavioral mechanisms for handling disturbance problems. Does seemed to exhibit greater range fidelity than bucks. In this study we have only included cows, and consequently the effects of the disturbances may be underestimated. However, two of the 7 radio-collared cows totally or partly left the area and moved to other summer ranges. Other studies in a variety of habitats (Goddard 1970, Van Ballenberge and Peek 1971, Berg and Phillips 1974, Cederlund and Okarma 1988) have shown that moose normally show strong fidelity to their established home-ranges. Consequently, the change in site fidelity (i.e. decreased home-range overlap) reported in this study is likely to be related to increased levels of disturbance and habitat deterioration. This is consistent with earlier studies by Peek *et al.* (1982) and Edge *et al.* (1985).

CONCLUSIONS

Logging activity and dam construction have so far not affected the number of migrating moose. Although some moose show a displacement of the migration route after reservoir construction, the largest proportion of the migratory population still use their traditional migratory routes. The size of summer home-ranges did not change after habitat deterioration, but home-range overlap and site fidelity decreased significantly.

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