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Source: Wildlife Biology, 16(1) : 85-92

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/08-085

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Wildl. Biol. 16: 85-92 (2010)
DOI: 10.2981/08-085
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Original article

Can supplementary feeding be used to redistribute moose *Alces alces*?

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Foraging patterns, behaviour and the distribution of animals are affected by the availability and distribution of food in the landscape. Increasing numbers of ungulates may also be in conflict with agriculture, timber, infrastructure and conservation interests. Understanding foraging habits of ungulates and how these are affected by a change in forage availability or composition are, therefore, issues of major importance both from ecological and management perspectives. Supplementary feeding (i.e. artificial supply of food) is being used to improve local habitat, and thereby affecting ungulate movements, habitat choice and migration patterns. We experimentally tested the predictions that supplementary feeding redistributes moose *Alces alces* during two different migration phases (early, i.e. during the onset of migration and late, i.e. in the wintering areas). We used individually marked moose and pellet group counts to investigate the effect of supplementary feeding both at the individual and population level. We monitored 30 moose with GPS-collars before, during and after the supplementary feeding experiment, corresponding to 8-10% of the moose population in two different valleys in Northern Scandinavia. During early migration, moose ignored supplementary feeding sites even though migration routes were close to the sites. At the end of the migration route, supplementary feeding affected moose movement, distribution and behaviour. In conclusion, we suggest that there is a clear difference in response to supplementary feeding by moose due to the phase of migration. We conclude that supplementary feeding can be used under certain conditions to redistribute moose in relation to browsing, or to traffic, preferably at the end-point of migration.

Key words: Alces alces, forage, GPS-collars, habitat improvement, management tool, migration, moose, pellet counts, ungulates

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Received 17 December 2008, accepted 12 October 2009

Associate Editor: Iain J. Gordon

Ungulate distribution and movements are driven by resource availability and foraging decisions (Grover & Thompson 1986, Krebs & Davies 1997). This may lead to a high abundance of browsing ungulates, which in turn may give rise to conflicts among different management regimes, which may further affect forestry, infrastructure, agriculture and conservation interests (Côte et al. 2004, Skonhoft 2005). To alleviate these conflicts, management of large ungulates has included culling, fencing, habitat management and supplementary feeding in order to manipulate ungulate population size and to influence distribution and movement (Weisberg & Bugmann 2003). Therefore, it is important to under-

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stand the effects of altering forage availability on distribution patterns and foraging habits of the species concerned (Gordon et al. 2004). In our study, we investigate the effect of supplementary feeding on moose *Alces alces* at the individual and the population level.

Changes in distribution patterns stemming from forage availability have been found for a number of species, such as the Iberian lynx *Lynx pardinus* (Lopez-Bao et al . 2008), red deer *Cervus elaphus* (Smith 2001) and white-tailed deer *Odocoileus virginianus* (Cooper & Owens 2006). Based on energetic considerations, large herbivores should attempt to use their feeding time to gain the maximum intake of essential nutrients (e.g. Belovsky 1978). Thus, ungulates should be expected to change their foraging pattern if forage composition is changed. This change could be achieved by natural disturbances, altered human land use or by supplementary feeding (Lautenschlager et al. 1997, Smith 2001, Putman & Staines 2004). Moreover, in the context of feeding and movement, it has been shown that moose modify their habitat use when searching for sodium sources (Laurian et al. 2007).

Our study concentrates on supplementary feeding defined as a localised improvement in forage availability. Large herbivores may show different responses to this improvement. In Washington, USA, red deer readily habituated to feeding operations and also left the location when feeding was interrupted e.g. by a winter storm (Smith 2001). Further, roe deer *Capreolus capreolus* changed their movement patterns when provided with supplementary food, and also moose have been shown to use areas close to feeding stations more intensively (Guillet et al. 1996, Gundersen et al. 2004).

Food resources mostly show uneven temporal and spatial distributions (Senft et al. 1987, Fortin et al. 2003), and this is a probable cause of large scale movement. Many animals perform seasonal or periodic movement in a determined direction, known as migration (Bolger et al. 2008). Migrating animals that are looking for food may be a source of damage to crops or forest stands. A common motivation to improve forage availability is to prevent or reduce damage on forests and agriculture and reduce the risk of vehicle collisions caused by wildlife (Ball et al. 2000, Franzmann et al. 2007). However, previous studies have shown that forage availability appears to increase browsing intensity in the vicinity of the supplementary feeding sites (e.g. Gundersen et al. 2004). This will have implications for management strategies for both forests and moose populations.

In our paper, we experimentally test the prediction that supplementary winter feeding will affect the distribution of moose in areas close to feeding sites. Using female moose individually equipped with GPS-collars from two migrating populations, we determined positions before, during and after feeding sites were established. In order to investigate the usage of sites, at the individual and population level, respectively, we also conducted pellet group counts.

Methods

Data collection

Our study was conducted in two areas in Northern Scandinavia during 2005 - 2007 as part of a large scale moose project (Schön et al. 2007). The study areas are referred to as Höbäcken, Sweden (66°2'00 N, 16°13'00E (WGS84); Fig. 1) and Susendalen Valley, Norway (65°35'00N, 13°59'00E; see Fig. 1). Adult female moose (N = 33, 15 in Susendalen and 18 in Höbäcken) were equipped with GPS/GSM (Global positioning system/Global system for mobile communication) collars in November 2005 (GPS/GSM Plus 7D, Vectronic Aeorospace GmbH, Berlin, Germany; Dettki et al. 2004, Dettki & Ericsson 2008).

Locations of the animals were taken once per hour during 2005 - 2007 (i.e. one year before, during and after the supplementary feeding sites were established). The positions acquired by the GPS-receiver on the collars were transmitted every 3.5 hours into a database by a short messaging service (SMS) message, using the global system for mobile communication (GSM) net (Dettki et al. 2004, Dettki & Ericsson 2008).

Höbäcken is in a narrow valley 4 km wide where about 110 moose migrated during 2006-2007 (*sensu* Schön et al. 2007). On average, female moose from the Höbäcken subpopulation migrate 88 km in the autumn (Schön et al. 2007). In the Höbäcken area, we knew the migration pattern of 15 moose from GPS data from 2005. We utilised their migration history to place five feeding stations within 50 m of the migration route along a narrow stretch of the valley. In Susendalen, which is a wintering area at the end of the migration route, we established a feeding experiment for another subpopulation of

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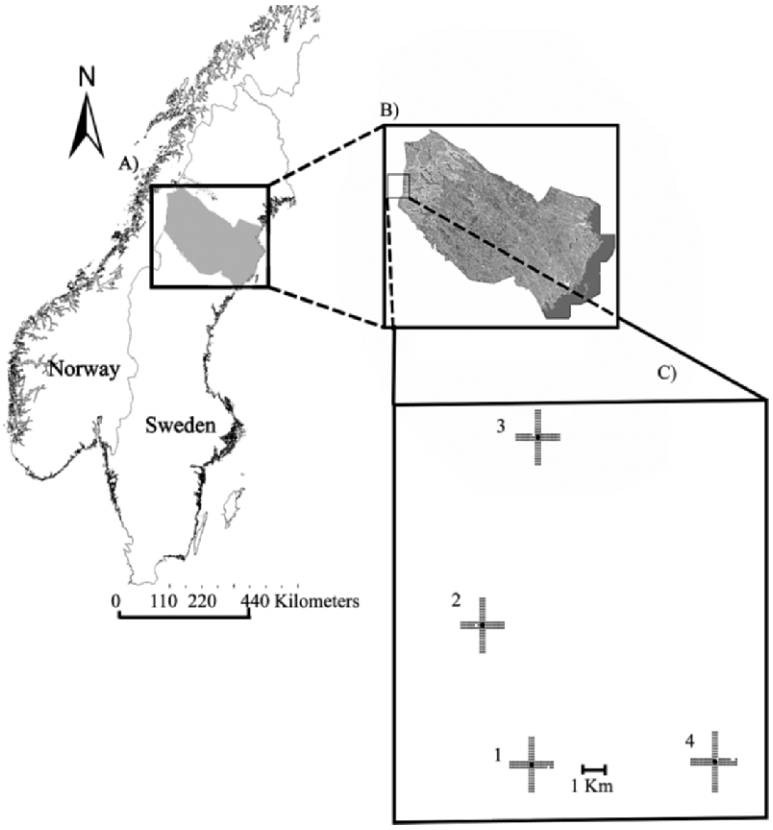

Figure 1. A) The location of supplement feeding sites near the border between Sweden and Norway (approximately 65°35'00 N, 13°59'00 E). B) In the county of Västerbotten, Sweden. C) Distribution of feeding stations in the Susendal area with the sampling plots for pellet group counts systematically distributed along transects in four directions (N, W, S, E).

moose using four stations. Here the average migration distance for females is 20 km (Schön et al. 2007). In Susendalen, we placed the supplementary feeding sites at the end of the migration route (i.e. within the wintering areas) > 7 km apart to avoid moose potentially using more than one station, but within the GPS-collared moose wintering area noted from previous years. From November 2006 to April 2007, the feeding sites were continuously loaded with bales of silage grass. The forage was not protected from the weather since any such construction might have impacted the behaviour of the moose. The quality of the forage was not checked by chemical analysis. However, the general quality of the silage grass was considered high. Feeding sites were checked repeatedly every week to control for quality and asset of forage, and they were therefore never empty of food.

Moose distribution

In the Susendalen area, we created circular buffer zones with a radius of 100, 300 and 1,000 m around each of the feeding stations (ArcMap, ArcGIS 9.1, ESRI 2006) to determine if moose actually used the feeding sites, or if they only spent time in the area without approaching the feeding sites. We assumed that moose found within the 100-m buffer zone have visited the feeding site. A 100-m buffer was used because of the inaccuracy of GPS location of the animal. By using the buffer zones as different spatial scales it was possible to determine which moose had used the feeding stations, and which moose were only present in the area. The 1,000-m buffer was considered to be the maximum distance a moose could be from the feeding sites and still be considered present in the area. The 1,000-m buffer size also coincided with the length of transects along which the pellet counts were conducted. By using positional data within the buffer zones, we determined the number of days spent within the buffer zones. In addition, we used the buffer zones to determine if moose made any behavioural adjustments near the supplementary feeding sites. Because no moose stopped or used any of the feeding sites in Höbäcken, the analogous buffer zone analysis was obsolete in this area.

To determine if and when moose used the supplementary feeding sites, the data were divided into

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three time periods: 1) before, 2) during and 3) after supplement feeding. The period 'before' was set from 16 November 2005 to 1 April 2006 and the period 'during' was set from 16 November 2006 to 1 April 2007. Finally, the period 'after' was set to 16 November 2007 to 1 April 2008.

Pellet group counts

In the Susendalen area, we conducted pellet group counts in the years 2006 and 2007 to reflect the winter moose distribution one year before and during the feeding trial. Unfortunately, financial constraints meant that the planned pellet count for 2008 was cancelled. The sampling plots were distributed along three parallel transects (1,000 m) in four directions (N, W, S, E) with a distance of 100 m between transects (see Fig. 1). The occurrence of roads and lakes led to a few gaps in this pattern. The plots were distributed at distances of 100, 200... 1,000 m from the feeding sites. The plots were monitored just after snow melt and before the start of the vegetation growth period (between 8 June and 22 June 2006, and between 22 May and 10 June 2007). Pellet groups were counted within a 5.64 m radius (100 m^2) from the centre in each plot. Pellet groups from the preceding winter that contained 20 or more pellets and that had their centre within the plot were counted (Lavsund 1975). The pellet groups were aged by colour and position in relation to the litter and old vegetation (Neff 1968). The size of the plot was chosen in order to avoid problems with low frequency of pellet groups and to avoid overlooking any pellet groups (Neff 1968, Lavsund 1975). Because no moose usage of the feeding stations in Höbäcken was recorded according to field verification by helicopter and snow tracking, the analogous pellet group analysis was obsolete in this area.

Results

Moose distribution

In Susendalen in 2006 (prior to the establishment of the supplementary feeding sites), out of the 15 moose with GPS-collars, eight were utilising the migration route inside the 1,000-m buffer from the feeding site. We assumed that these moose were likely to be familiar with the area. In 2007, during the establishment of supplementary feeding, a moose (female #5) used the feeding site within 100 m for a period of approximately three months, whereas female #1 used the feeding site only for one day, and female #4 for < 3 weeks (Fig. 2). Both moose that used the area for more than one day did not spend time at the feeding site together, hence they did not show any temporal overlap in the usage.

During the time of supplementary feeding, one moose (female #2) that had used the area the

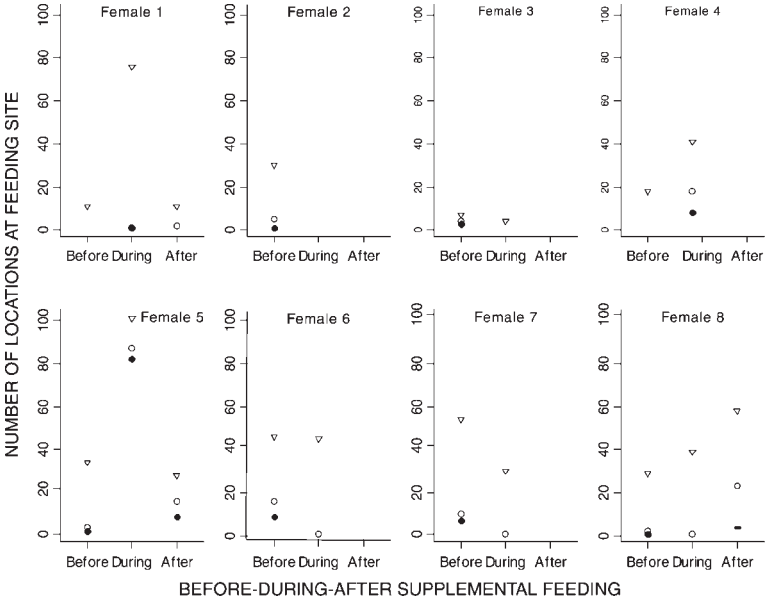

Figure 2. Number of moose locations before, during and after the placement of a feeding station. Filled circles indicate positions within the 100-m buffer around the feeding station, open circles indicate the 300-m buffer, and triangles indicate positions within the 1,000-m buffer.

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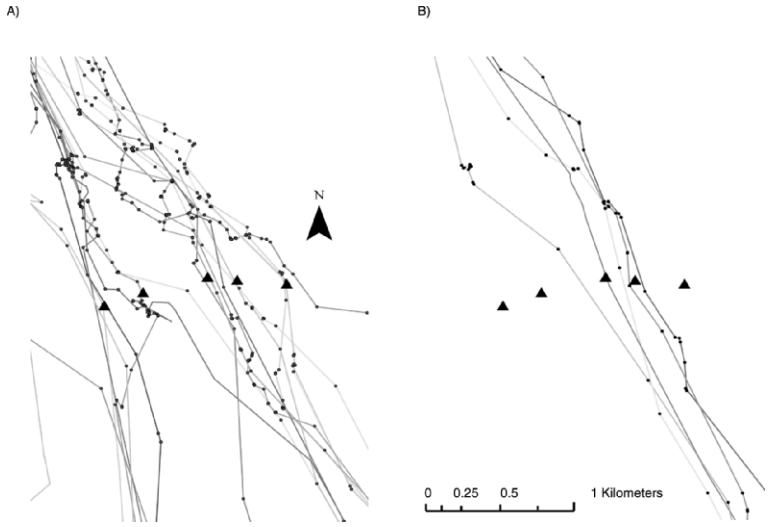

Figure 3. The pattern of movement around the site at Höbäcken where supplementary food was provided between 1 November 2006 and 1 January 2007. A) The movement pattern in 2005, the year before supplementary feeding. B) The movement pattern in 2006 when supplementary feeding sites were present. The ▲ represent supplementary feeding sites. They are represented in A) for reference purposes only.

previous year, left the feeding site. Four moose (females # 3, 6, 7 and 8) which used the feeding site area (within 1,000 m from the feeding site) in 2006 did so also during the winter when supplementary food was offered. However, they did not use the immediate area of the feeding site (100 m) (see Fig. 2). Three moose (females # 1, 5 and 8; see Fig. 2) were present in the area (within 1,000 m) the winter after supplementary feeding ceased.

In Höbäcken, none of the moose with GPS-collars stopped at a feeding site (Fig. 3). Field verification by helicopter and by manual snow tracking after moose had migrated through the areas showed no visitation of moose whatsoever at the feeding sites.

Pellet group counts, Susendalen area

Moose equally used the areas within the buffer zones (within 1,000 m from feeding sites) during 2006, when no supplementary food was available (ANOVA: $F_{9,432} = 1.8$, $P = 0.07$; Fig. 4). In 2007, when supplementary food was provided, a significant difference was found between the distance classes (ANOVA: $F_{9,450} = 5.8$, $P < 0.001$, see Fig. 4). Post hoc analyses of year 2007 showed that areas 100 m from the feeding sites were significantly more used compared to all other distances (Tukey: $P < 0.02$ for all cases). No significant effect of feeding sites was found between the other distance classes for year 2007 (Tukey: 200-1,000 m, $P > 0.12$), but there was a non-significant trend for increased use of areas 200 m from feeding sites (see Fig. 4).

Discussion

Our study showed that moose did use the supplementary feeding sites in their winter home ranges (i.e. Susendalen). Our study also showed that, early in their migration, moose were completely indifferent to any attempts to distract them with food (Höbäcken). At the population level, pellet group counts in Susendalen revealed that the vicinity of supplementary feeding sites (up to 100-200 m) was utilised more than the surrounding area (up to 1,000 m). However, at the individual level only three out of 15 moose were using the supplementary feeding sites (i.e. spent time within the 100-m buffers), and only one for a substantial amount of time (three

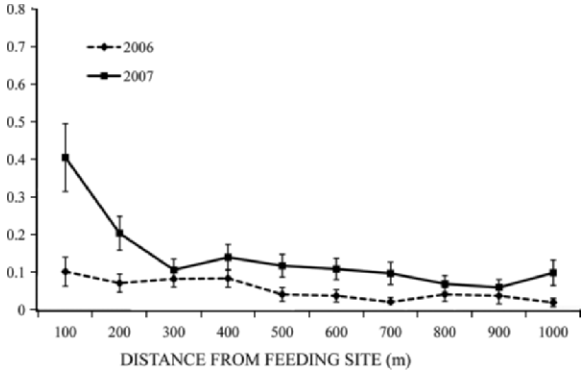

Figure 4. Pellet groups per census plot (log) in relation to distance from feeding site. Distribution is divided between the two years, with (2007) and without (2006) supplementary feeding. Also indicating a threshold in the use of areas closer than 200 m from feeding site ($P = 0.12$). Error bars indicate S.E.

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months). Thus, we infer that within their winter home ranges, it may be possible to redistribute moose, but early in their migration, the animals are inclined to keep moving. This may be locally important in terms of moose-vehicle collision risks, since it has been shown that collisions are not spatially or temporally random (Seiler & Sjölund 2005). Furthermore, accidents may be reduced by clearing roadsides of forage to steer animals away (Seiler 2003). Thus, according to our findings that moose do utilise supplementary feeding sites in their wintering areas, it may be possible to reduce encounters between vehicles and moose in those areas by steering moose away from roadsides using supplementary feeding sites in combination with other actions, such as clearing of forage along road sides.

Additionally, damage to forest adjacent to supplementary feeding sites may increase, due to the increased density of animals within an area leading to increased browsing pressure (Hörnberg 2001, Gundersen et al. 2004). Increased browsing on pine twigs and leader stems in the vicinity of feeding sites has been shown previously (Gundersen et al. 2004). While our study shows that feeding sites can be used to redistribute animals, it also suggests that there may be a higher risk of increased browsing pressure on the vegetation in close vicinity to any established feeding sites. Thus, it is important to carefully consider the location of any potential feeding sites, especially since they probably will be maintained for several years.

In addition to increased browsing, the risk of spreading disease is another aspect of artificial feeding that may have adverse consequences to the populations concerned. As observed in red deer and white-tailed deer (Hines et al. 2007, Thompson et al. 2008), supplementary feeding may result in spreading diseases due to the concentrated distribution of food. If food is replenished following consumption, animals may concentrate at the location and there will be an increased digestion of faeces and saliva (Thompson et al. 2008). The results from our study at an individual level indicate that the disease threat should be of minor concern given the absence of any temporal overlap in usage, implying few animals at the site at the same time. However, at larger scales, i.e. at the population level, this may be important in management terms.

The pattern of increased usage near feeding sites found by pellet group counts was not confirmed on an individual basis as the GPS-data showed variation among individuals in how individual moose responded to the supplementary forage. The pellet group counts reflect population-level distribution if conducted at the landscape scale, however, from the perspective of moose winter activity area (11.5 ± 13.9 km^2; Sweanor et al. 1992), the pellet count in this case might be considered as a local spatial scale. In that sense, the increased usage close to feeding sites might reflect that some individuals used the site intensively, as we also conclude from GPS-collared individuals. However, we do not know whether the droppings came from several or few individuals. Using the GPS data and pellet group counts combined, we show that some individuals probably utilise feeding sites more than others. Other studies have concluded that moose show antagonistic behaviour within winter concentration areas (Sweanor & Sandegren 1985), and this might be one of the mechanisms behind our observed pattern from the pellet group counts and GPS data combined.

Silage grass is not a natural food resource for moose (Hofmann 1985), and a difference in time to adaptation to a new food source among individuals might also be a mechanism explaining the difference among individuals. A time lag in utilisation of similar feeding sites (silage grass) was reported by Gundersen et al. (2004) where use of feeding sites increased with the number of years since the supplementary forage had been provided. Such a pattern might imply that moose need some time to adapt to the fodder.

We monitored moose in Höbäcken as they left their summer areas and were moving towards the line of supplementary forage, and we were expecting them to stop and try the food. Our data showed that moose just walk around the silage grass. To verify this, we used a helicopter to check the fresh snow for tracks. When we flew over all of the sites, and later landed, we could verify that moose just passed by all the feeding stations without feeding. Later, during the winter, we went back and verified that no moose had used the feeding stations. Gundersen et al. (2004) also concluded that feeding sites placed at the end of the migration route attracted moose once they had arrived at their wintering areas, rather than getting them to stop during the migration from summer to wintering areas (Gundersen et al. 2004).

Conclusion/management implications

The pattern found in our study demonstrates both

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the potential of supplementary feeding as a management tool to redistribute animals at their wintering areas, but also the risk of establishing feeding sites close to forest stands or crops sensitive to damage. Compared to e.g. hunting and fencing, one should consider this as a slow management method. The placement of feeding sites may be integrated in forestry planning and moved, spatially and temporally, in conjunction with the growth of the forest. In terms of moose-vehicle collisions, there is a possible opportunity to utilise feeding sites to steer animals away from road sides where the risk of accidents is high. However, supplementary feeding, as a tool to change a migration route, to stop moose in their summer area or to prevent moose entering their wintering areas is unlikely to achieve its desired aim.

Acknowledgements - we acknowledge financial support from the EU/Interregional IIIA project Moose in Mid-Scandinavia, the EPA Program of Adaptive Management of Fish and Wildlife, the SLU thematic program Wildlife and Forestry, and the Swedish Environmental Protection Agency. We thank Eric Andersson, Nils-Olov Eklund and Åke Nordström for their help with fieldwork. The project was approved by the Animal Care Committee for Northern Sweden at Umeå (Dnr A124-05 2005-11-15) and was carried out in accordance with the Swedish laws concerning animal research ethics. All personnel handling animals were certified according to the standards by the Swedish Animal Welfare Agency and the Swedish Board of Agriculture.

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