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Long-term effects of supplementary feeding of moose on browsing impact at a landscape scale

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ABSTRACT

Supplementary, or diversionary feeding of wildlife is a common management practice, increasingly used to reduce or divert herbivore impact from sensitive habitats, forestry or agriculture. The landscape-scale spatial distribution of herbivory in relation to diversionary feeding is relevant to wildlife and land management, yet has never been quantified. We considered multiple hypotheses, based on central-place foraging theory, to investigate how landscape-scale browsing impact changed as a function of distance from feeding stations and thereby test the effectiveness of diversionary feeding. We assessed the landscape-scale browsing impact of moose by quantifying browsing patterns and moose density in commercially-valuable young Scots pine stands in an area of South-East Norway with a long history of winter feeding. We also used positions from GPS-collared female moose to investigate the spatial distribution of individuals across the landscape. Moose density and browsing impact at the local spatial scale (<1 km) followed an exponential decrease with distance from diversionary feeding stations. However, at the landscape scale (1–10 km), browsing impact did not show any relationship with distance to feeding stations. Leader stem browsing on Scots pine trees was high at both the local (68 ± 12%) and landscape (59 ± 8%) scales. In addition, browsing on commercially valuable Norway spruce, which is normally avoided by moose, was locally high around feeding stations. Long-term diversionary feeding of moose is ineffective in diverting browsing impact from young pine stands at the landscape scale, as currently practiced. Browsing on commercially-important tree species was sufficiently high that economic consequences could be expected. To avoid further conflict, we suggest a combination of reducing moose density and increasing the availability of natural or higher quality supplementary forage.

1. Introduction

Supplementary feeding of wild large herbivores is often implemented as a management tool to increase wildlife productivity (Putman and Staines, 2004; Brown and Cooper, 2006) or carrying capacity (Smith, 2001), or to mitigate human-wildlife conflicts (Andreassen et al., 2005; Barrio et al., 2010; Kowalczyk et al., 2011). In terms of mitigation, the provision of supplementary feed may change animals' habitat use, diverting them away from sensitive habitats or attracting them to sacrifice areas or refuges (i.e. diversionary feeding). Alternatively, it may increase the overall availability of forage and so reduce consumption of sensitive natural vegetation, commercial forest or agricultural crops (Peek et al., 2002; Putman and Staines, 2004; Brown and Cooper, 2006). Diversionary feeding has been used to reduce grazing in agricultural fields by free ranging European bison (*Bison bonasus*) (Kowalczyk et al., 2011), to mitigate against traffic accidents and browsing on commercially valuable young forest by moose (*Alces alces*) in Scandinavia (Gundersen et al., 2004; Andreassen et al., 2005; van Beest et al., 2010a), and to reduce browsing in vineyards by rabbits (*Oryctolagus cuniculus*) (Barrio et al., 2010). However, many studies have shown that supplementary-fed animals continue to feed on natural vegetation in the proximity of feeding stations (Doenier et al., 1997; Smith, 2001; Gundersen et al., 2004; Cooper et al., 2006). Most of these studies have been carried out at small spatial scales, whereas management of forest and wildlife often takes place at a landscape scale.

Supplementary feeding stations can be seen as spatially concentrated key resources within an animal's home range, comparable to mineral licks, salt pools or water holes (Bailey et al., 1996; Laurian et al., 2008). Such point sources of essential resources in the landscape may create radial patterns of habitat use such as the disturbance zones (piospheres) around water sources in dry rangelands (Graetz and Ludwig, 1976; Andrew, 1988; Jeltsch et al., 1997). Central-place foraging theory, an application of the wider optimal

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foraging theory, describes space-use and foraging patterns by animals that frequently return to a focal place such as a den or a nest (Orians and Pearson, 1979). It has also been used as an effective tool to describe radial patterns of habitat use in a wide range of herbivores (Gallant et al., 2004; Bakker et al., 2005; Raffel et al., 2009; Shrader et al., 2012). Central-place foraging theory predicts a decline in space use and an increase in selectivity with increasing distance from the central place (Orians and Pearson, 1979; Rosenberg and McKelvey, 1999). Although feeding stations differ from dens or water points in offering concentrated food resources, it has been shown that fine-scale movements and browsing around feeding stations create space-use patterns and foraging decisions in accordance with the predictions of central-place foraging theory (van Beest et al., 2010a,b).

Numbers of large herbivores have increased across Europe and North America during recent decades (McShea et al., 1997; Côté et al., 2004), exacerbating human-wildlife conflicts (Austin et al., 2010; Kuijper, 2011; Putman et al., 2011). In Fennoscandia, moose numbers increased dramatically between 1950 and 1980, and have since stabilized at relatively high densities, often in the order of one moose per km^2 (Lavsund et al., 2003). As Scots pine (*Pinus sylvestris*) is an important winter forage for moose, but also an economically valuable timber species, moose browsing can lead to conflicts with commercial forestry (Hornberg, 2001). In Norway, diversionary feeding is practised in areas with high moose density to reduce browsing in young Scots pine stands. However, supplementary fed moose continue to browse on natural vegetation (Gundersen et al., 2004), and to select for young Scots pine stands (van Beest et al., 2010b). At feeding stations, browsing impact can be locally high, questioning the efficacy of diversionary feeding in reducing browsing in young Scots pine stands (van Beest et al., 2010a). The effectiveness of diversionary feeding depends on the ability of feeding stations to attract animals and so reduce browsing further away. The length and shape of the resource use gradient from a central-place, like a feeding station, varies with the resource utilised, animal species and population size, and the period of use (Jeltsch et al., 1997). This has not been quantified before in the context of supplementary feeding. If browsing impact in relation to distance from feeding stations can be predicted by central place foraging theory, it would be useful for evaluating the efficacy and placement of diversionary feeding stations.

In this study we quantified the landscape-scale spatial pattern of moose distribution and browsing up to 10 km from feeding stations, focusing on the diversionary aspect of supplementary feeding. This enabled us to characterise the spatial pattern of resource use as a function of distance from feeding stations, using hypotheses based on central-place foraging theory, and thereby assess whether diversionary feeding was an effective tool to reduce moose browsing on commercially valuable forests at the landscape scale. We tested three alternative hypotheses for the shape of the decline in resource use with increasing distance from the central place (feeding station) and compared them with a null-hypothesis.

H_0. Browsing intensity is unaffected by distance from feeding stations.

H_1. Browsing intensity decreases linearly with increasing distance from feeding stations (linear model; Rosenberg and McKelvey (1999)).

H_2. Browsing intensity is high up to a threshold distance from feeding stations, and then drops to a lower level following the sigmoid response curve (sigmoid model) described for piospheres (Andrew, 1988; Thrash, 2000).

H_3. Browsing intensity decreases rapidly with increasing distance from feeding stations (exponential decrease model) until a low background level is reached at the landscape-scale (Thrash and Derry, 1999; Nemeth et al., 2005).

If browsing impact can be predicted by Hypotheses 1–3, they may be used to recommend the positioning of diversionary feeding stations in relation to distance from young forest stands. If browsing impact is too high to sustain timber production within a certain distance to feeding stations, this may be considered a sacrifice area.

2. Material and methods

2.1. Study area

The study was carried out in Stor-Elvdal, Åmot and Rendalen municipalities in South-East Norway (~61°N, 11°E), situated between 250 and 1100 m.a.s.l. The vegetation was primarily boreal forest (Moen et al., 1999) below the commercial timberline at 700 m. It consisted of managed stands of pure or mixed Scots pine, Norway spruce (*Picea abies*), downy birch (*Betula pubescens)* and silver birch *(Betula pendula*), interspersed with grey alder (*Alnus incana*), rowan (*Sorbus aucuparia*), aspen (*Populus tremula*) and willows (*Salix* spp.). The field layer vegetation was dominated by dwarf shrubs such as *Vaccinium* spp. Weather data from the valley bottom showed 30 year mean summer (May–September) and winter (October–April) temperatures of 10.6 °C and −5.8 °C, respectively. The 30 year mean annual precipitation was 628 mm and the mean snow depth (October–April) was 39 cm (NMI, 2008).

Moose were the dominant large herbivore in the area, with a winter population density ranging between 1.1 and 3.4 moose per km^2 (Gundersen et al., 2004; Storaas et al., 2005; Milner et al., 2012a). Moose hunting is an important driver of the regional economy (Storaas et al., 2001). Simultaneously, the area is one of the most important regions for Scots pine forestry in Norway. There is therefore a conflict of interest between moose hunters and foresters. In the winter, the moose population concentrates in the lower valleys, leading to browsing damage to young pine stands. Landowners have been feeding moose with grass silage during winter since 1990, initially to divert moose away from the main road and railway but currently an estimated 60% of the moose population's winter food comes from supplementary feeding (Gundersen et al., 2004; van Beest et al., 2010a; Milner et al., 2012a). Supplementary feed is provided *ad libitum* for moose at fixed sites throughout the winter period (November–March). The amount supplied has increased from a few hundred kg in 1990 to around 200 tons in 1998 and almost 2000 tons in 2010. Simultaneously the number of feeding stations has increased to >100 in Stor-Elvdal alone, and the radius of the area with heavy browsing impact around feeding stations has expanded from 0.2 km in 1998 to 1 km in 2008 due to local browse depletion (van Beest et al., 2010a). During the same period, the moose density has remained relatively constant, while the number of moose shot per year was 550 in 1994–2005, and approximately 700 in 2006–2010 (Milner et al., 2012a).

2.2. Field procedures

We plotted 1 km interval zones around all feeding stations currently in use within the study area and surroundings ($n = 108$), up to a distance of 10 km, by creating buffers using ArcGIS software (ESRI 2012). The zones were overlaid on satellite maps of forest stands from the Norwegian Forest and Landscape Institute (Gjertsen, 2007), allowing us to identify young stands of pure and mixed Scots pine. We intended to sample a similar number of forest stands from each zone over 1 km from feeding stations but as 95% of the forested area was within 7 km of an active feeding station, fewer stands were sampled at distances ⩾7 km