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Diversionary feeding can reduce red deer habitat selection pressure on vulnerable forest stands, but is not a *panacea* for red deer damage

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ABSTRACT

Diversionary feeding implies strategic food provisioning to wildlife to lure animals away from undesired areas, and is a common forest management practice throughout Europe and North America. Within forestry, diversionary feeding typically targets cervids, and aims to reduce browsing damage and bark-stripping in vulnerable forest stands (young and mid-aged forest stands). Because these stands are most vulnerable during winter, diversionary feeing is often restricted to that season. Despite being widely applied, clear evidence on the effectiveness of diversionary feeding of cervids is lacking. The aim of this study was to evaluate the effectiveness of diversionary winter feeding as a tool to lure away a large cervid, red deer (*Cervus elaphus*), from vulnerable forest stands. First, we hypothesized (H1) that diversionary feeding is among the most important factors explaining differences in red deer habitat selection between summer (i.e., no food supply at feeding stations) and winter (i.e., food supply *ad libitum* at feeding stations). Second, we hypothesized (H2) that diversionary feeding releases red deer habitat selection pressure in forest stands vulnerable for browsing or bark-stripping, and that this release decays with distance to the nearest feeding station. We tested our hypotheses using red deer relocation data (11 individuals & 3 years) and resource selection functions in an intensively managed Austrian forest. As expected, variation in red deer habitat selection between summer and winter was best explained by a different response to supplementary feeding stations between the seasons (H1). During winter, red deer strongly selected for areas close to feeding stations, whereas feeding stations did not strongly affect their habitat selection during summer. We found that diversionary feeding during winter released red deer habitat selection pressure on vulnerable forest stands, but limited to distances of about 1.3 to 1.5 km from the feeding station, this accounts for 39% of the study area (H2). Our results show that diversionary feeding can indeed be an effective tool to mediate habitat selection behavior and to lure cervids away from vulnerable forest stands. However, habitat selection is not necessarily a good proxy for damage, and whether or not diversionary feeding reduces forestry damage in the long-term remains unclear, as it can positively feed-back into survival, reproduction, and eventually population growth and densities. We suggest that forest managers also consider silvicultural measures, population control (i.e., hunting) or spatial planning as means to minimize red deer induced forestry damage.

1. Introduction

Supplementary feeding wildlife is a common but controversial management practice, because it can influence wildlife in many, sometimes unexpected ways (Putman and Staines, 2004; Robb et al., 2008). Supplementary feeding can alter behavior, life history, and demography in wildlife (Boutin, 1990; Robb et al., 2008). Further, it can affect species assemblages and distribution (Redpath et al., 2001),

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social organization and intraspecific interactions (Craighead et al., 1995), and it can enhance parasite and pathogen transmission (Bradley and Altizer, 2007). Furthermore, supplementary feeding can mediate human-wildlife conflict through food conditioning and human habituation (Kavčič et al., 2013; Steyaert et al., 2014).

Diversionary feeding implies strategic food provisioning to wildlife to lure animals away from undesired places or habitats (Kubasiewicz et al., 2016). It is common in forest management throughout Europe and North America, and typically targets cervids (e.g., red deer *Cervus elaphus*, moose *Alces alces*) to reduce browsing damage and bark-stripping (Putman and Staines, 2004; van Beest et al., 2010). Its effectiveness regarding reducing red deer damage on forests is not unambiguous and appears to be context dependent (Kamsker, 1979; Ueckermann, 1986; Schmidt and Gossow, 1991; Náhlik et al., 2005). The underlying reasons for the effectiveness of diversionary feeding of deer are not fully understood as they are highly complex and depend on many factors, such as habitat, winter severity, feeding site characteristics, as well as type, quality and quantity of provided food and its arrangement at feeding sites, as well as local history of its use (Pheiffer, 1983; Nopp-Mayr et al., 2011; Jerina, 2012; Gerhardt et al., 2013; Ossi et al., 2017).

Red deer is an intermediate feeder with a tendency towards roughage eater (Hofmann, 1989). From spring to autumn, red deer diet consists predominantly of protein rich forage such as grasses and herbs (Schröder, 1977; Trdan and Vidrih, 2008), and deer inflict little damage to commercial forest stands (Gill, 1992). During winter, when grasses and herbs lignify and become unavailable by snow and ice, twigs and buds of trees and shrubs with high fiber content become important food resources (Schröder, 1977). In alpine habitats, red deer prefer coniferous trees as foods during winter (e.g., silver fir *Abies alba,* Norway spruce *Picea abies*) (Schröder, 1977), which are also commercially the most interesting species. Hence, diversionary feeding is typically only conducted during the winter months.

Red deer is a conflict-rich game species for forestry (Reimoser and Reimoser, 2010). It can negatively affect forest productivity by browsing or bark-stripping. For example, in Austria, herbivores (red deer, roe deer *Capreolus capreolus*, and chamois *Rupicapra rupicapra*) can cause damage by browsing and/or bark-stripping of up to about 218 million Euro per year in at least 10.000 km^2 or 25% of the total forest area per year (Reimoser, 2000; Reimoser and Putman, 2011). In addition, they cause minor damage to tree regeneration because of fraying and trampling. By feeding on apical buds and shoots, tree growth can be suppressed or be hampered, and red deer browsing can prolong or pause forest cycles. Selective feeding affects species composition and turnover (Lilleeng et al., 2016). By bark-stripping, fungi can enter the wounds and destroy lignin, leading to economic losses and higher susceptibility of trees to abiotic impacts such as snow damage or windthrow. Unequivocally, by browsing and bark-stripping, red deer has direct impacts on commercial trees and forest vegetation in general (Gill, 1992; Reimoser et al., 1999). Red deer-induced forestry damage is of growing concern for forest managers in Europe (Verheyden et al., 2006; Jerina et al., 2008; Kiffner et al., 2008; Klopcic et al., 2010). Diversionary feeding during winter is the most widely applied tool in forestry and wildlife management to lure red deer away from vulnerable sites (Putman and Staines, 2004). Red deer show an opportunistic feeding strategy, selecting for easy available food resources in their home ranges. Artificial food resources, such as supplementary winter feeding, may alter red deer spatio-temporal behavior (Luccarini et al., 2006; Jerina, 2012).

There is a lack of empirical studies examining the efficiency of diversionary feeding regarding browsing and bark-stripping. To our knowledge, no study so far has tested the mechanisms of selection for specific habitat types in relation to winter feeding schemes. Here, we assess the effectiveness of diversionary feeding during winter to keep red deer away from forest stands that are vulnerable for browsing and bark-stripping. First, we compare red deer habitat selection between the period of diversionary feeding (hereafter 'winter', when feeding stations are supplied with food *ad libitum*) and no diversionary feeding (hereafter 'summer', when feeding stations are not supplied with food). We hypothesize (H1) that red deer response to feeding stations is the most important factor that distinguishes red deer habitat selection between winter and summer, and that red deer selects for areas close to supplementary feeding stations during winter but not during summer. Secondly, we zoom in on red deer habitat selection during winter, and hypothesize (H2) that forest stands that are vulnerable for browsing or bark-stripping become increasingly released from red deer habitat selection pressure the closer to supplementary feeding stations. We test our hypotheses based on red deer GPS relocation data and resource selection functions (RSFs) in an intensively managed forest in Styria, Austria.

2. Materials and methods

2.1. Study area

The study area is located in the Eastern Central Alps in the upper part of the river Mur valley in the federal state of Styria, Austria. The region is located between 46°59′12″ und 47°04′20″ latitude and 13°53′59″ and 14°00′27″ longitude, and covers a total area of 131 km^2. Average annual temperature in our study area is 5 to 6 °C and the precipitation varies in average between 60 and 160 mm per month, with minima during winter. Although precipitation is low during winter months, mean temperatures below zero maintain a snow layer from around December to March. Summer months are warm and wet. Shielded valleys have a pronounced continental climate, whereas overall the climate is milder inner alpine (Kilian et al., 1993). The study area comprises a wide altitudinal gradient (850–2200 m.a.s.l.), and habitat types range from submontane to high subalpine habitat. The study area consists of a privately owned forest, managed for timber production as well as for hunting, maintaining high densities of red deer stags older than 10 years. Large carnivores, such as grey wolf (*Canis lupus*) or Eurasian lynx (*Lynx lynx*) are observed only occasionally (Erwin Lick, personal communication). Forest vegetation is characterized by a transitional zone of silver fir *(Abies alba)* – Norway spruce *(Picea abies)* forests with a predominance of the latter. In lower altitudes, broadleaved species such as sycamore *(Acer pseudoplatanus)* and European beech *(Fagus silvatica)* are admixed. The higher subalpine consists mostly of European larch *(Larix decidua)* and stone pine *(Pinus cembra)*. Economically important is the harvest of Norway spruce and European larch. Overall, the area is managed with a small clear-cut regime and therefore has a patchwork-like structure, intersected with forest roads. The study area suffered from heavy windthrows in 2002, when about 7.3 km^2 hectares of forest was completely wind-thrown. These areas were afforested afterwards. These windthrows resulted in a heterogeneous pattern of old forest stands and regenerating forests.

Red deer density varies between forest beats. According to simultaneous counts at the winter feeding stations of the forest enterprise, densities vary from 7 to 12 animals per 1 km^2 (Lick, 2013), in average 9 animals per 1 km^2 (Arnold and Hackländer, 2014). Red deer hunting season starts, depending on sex and age, on 15th May and lasts until 15th January. Winter feeding occurs outside the growing seasons and depends on weather conditions. Roughage (hay) is provided *ad libitum* and daily complemented with succulent feed (mainly apple pomace) at seven active feeding stations (1 per 18.7 km^2) in the study area from October to May. Exact start and end of food provisioning depended on onset of winter and start of growing season. Feeding stations are located on clearings in thinned old growth forest stands, ranging from 1680 to 1810 m.a.s.l. Damage induced by ungulates is at a critical level: A comprehensive sampling plot procedure in 2009 and 2010 showed that about 33.5% of apical buds of spruce regeneration (trees < 0.2 to < 1.80 m) being browsed annually, and the bark of about 2.3% of all stems in spruce pole wood stands (aged 20–39 years) being stripped from bark each year. Bark-stripping damage amounts to