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Ecological dimensions of airborne laser scanning — Analyzing the role of forest structure in moose habitat use within a year

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ABSTRACT

During the last decade, Airborne Laser Scanning (ALS) data has been used increasingly in numerous studies to assess e.g. bird habitats and biodiversity, but less often in studies focusing on ground dwelling mammals.

Here, we utilized ALS data to study the role of forest structure in moose habitat use. The data consisted of 18 GPS-collared moose in western Finland. ALS data was extracted around the moose locations. The aim was to examine the habitat selection patterns of moose within a year. Special attention was given: 1) to winter to detect when moose-related forest damages occur (when moose favor young forests) and 2) to the calving period to examine the possible role of forest structure in determining where females give birth and where they move with the newborn calves.

During calving, females were occupying forests with minimal amounts of vegetation below the height of five meters. Shortly after calving, the females and their calves moved to forests with dense vegetation under the height of five meters, which is explained by the increasing demand of food both for the growing calf and the lactating mother. In summer and autumn, all moose were found more often in mature forests with higher and denser canopies, which is explained by the fact that their most preferred food during autumn (e.g. berries and twigs) grows in mature forests. This trend diminished as autumn turned to winter and moose started to favor vegetation below five meters. In general, we were able to see clear patterns and differences in habitat use between sexes, as well as with calves, and we gained new and more accurate information about the role of the forest structure to calving females. The results show that ALS data alone can yield valuable additional information about wildlife ecology.

1. Introduction

A large number of studies conducted in the 21st century have advanced the use of Airborne Laser Scanning (ALS) in forest inventory and planning. Its usefulness is based on the fact that the height distribution of ALS data is related to the vertical structure of the tree canopy. Variables calculated from the data can then be linked to attributes, such as tree height, basal area and ultimately, growing stock and volume. However, when thinking about forest wildlife, attributes such as availability of food, shelter and cover are also very often determined by the structure of the surrounding forest. In the 1960s, MacArthur and MacArthur (1961) acknowledged the importance of three-dimensional (3D) vegetation structure in assessing habitat suitability of an area. As ALS produces detailed 3D data about vegetation structure, it can be highly useful in assessing habitats, organism–habitat relationships and biodiversity (Hill, Hinsley, & Broughton, 2014; Müller & Vierling, 2014). The range of species that can be studied with ALS includes marine and terrestrial as well as avian (Vierling, Vierling, Gould, Martinuzzi, & Clawges, 2008). Here, we tested how ALS data can be used to describe the role that forest structure has in moose habitat selection (*Alces alces*).

Moose is the most important game species in Fennoscandian area. It is also an important keystone species for the local forests, as it modifies the species composition through extensive browsing (McInnes, Naiman, Pastor, & Cohen, 1992). It also causes damage to forestry due to its tendency to browse in young seedling stands (Korhonen, Ihalainen, Miina, Saksa, & Viiri, 2010; Lavsund, 1987). In many cases (not always), moose are migratory and have different winter and summer habitats that they migrate between according to the seasonal cycle (Singh, Börger, Dettki, Bunnefeld, & Ericsson, 2012). During the summer, habitat selection of moose is diverse because summer provides moose with plenty of easy sources of food (both trees and green plants). Preferred foods include grasses, deciduous trees and shrubs, and certain water plants (Hjeljord, Hövik, & Pedersen, 1990; Bergstrom and Hjeljord, 1987). During autumn, moose start to eat more mushrooms, twigs and plants, such as blueberry (*Vaccinium myrtillus*) and common heather (*Calluna vulgaris*), which become a very common part of the

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diet. Thus, the selection of habitats favors areas with these kinds of food sources (i.e. more mature forests). During winter, the tree species and the age of the forest are the dominant factors affecting habitat selection. Winter habitats are typically characterized by Scots pine (*Pinus sylvestris*) dominated forests, peat lands, or shrub lands, and when compared to the surrounding landscape, they include more pine-dominated forests and forests of young successional stages (Nikula, Heikkinen, & Helle, 2004). Cassing, Greenber, and Grzegorz (2006) suggested that Scots pine stands that are 5–15 years old are most preferred. In Finland, pine is the most consumed source of food during winter due to its high availability (in the seedling stands) (Heikkilä & Härkönen, 1993).

Differences have been found in terms of moose habitat use between males and females (Cederlund et al., 1987; Cederlund & Sand, 1994; Nikula et al., 2004), but so far, few studies have assessed the effect of calves. Calving typically takes place in May or early June, but the exact moment varies due to factors, such as the timing of last autumn's rut, progress of spring, availability of food and the condition of the mother (Bowyer, Kie, & Ballenberghe, 1998; Keech et al., 2000; Saether, Andersen, Hjeljord, & Heim, 1996). Moose typically give birth to one or two calves. In addition to timing, the characteristics of calving sites vary within the landscape. Factors, such as elevation, slope, distance to water and islands have been described as affecting calving site selection (Addison, Smith, McLaughlin, Fraser, & Loachim, 1990; Bowyer et al., 1998; Chekchak, Courtois, Ouellet, Breton, & St-Onge, 1998; Poole, Serrouya, & Stuart-Smith, 2007). Forest structure also plays a major role; past studies have described favoring both for more dense and closed forests and for more open landscapes for calving sites (Bailey & Bangs, 1980; Bowyer et al., 1998; Chekchak et al., 1998; Langley & Pletscher, 1994).

Now, due to the ongoing changes that forest management causes in the forest structure (e.g. thinning, clear-cutting), it is important to understand the habitat requirements of moose in relation to forest structure (Markgren, 1974). As mentioned, ALS makes it easy to accurately measure this structure and so its potential has been widely realized and studied over the last decades (see, for instance, Graf, Mathys, and Bollmann (2009); Coops, Duffe, and Koot (2010); Goetz et al. (2010); Flaherty (2013); Palminteri, Powell, Asner, and Peres (2012)). Thorough reviews on recent studies have been provided by Davies and Asner (2014), Hill et al. (2014), and Müller and Vierling (2014). While ALS revolutionized the process of analyzing forests in 3D, Global Positioning System (GPS) based tracking collars revolutionized methods for tracking and locating wildlife. Moose has been a popular focus for these studies (Dettki, Löfstrand, & Edenius, 2003; Dussault et al., 2004; Lowe, Patterson, & Schaefer, 2010; van Beest, Rivrud, Loe, Milner, & Mysterud, 2011). Still, the method of integrating ALS data with exact animal locations from GPS-collars is relatively new. For moose, it has been tested by characterizing summer and winter habitats, in mapping the availability of forage, and in analyzing behavioral responses to thermal stress (Lone et al., 2014a,b; Melin, Packalen, Matala, Mehtätalo, & Pusenius, 2013; Melin, Matala, et al., 2014).

Here, we hypothesize that there are structural differences in the areas occupied by moose at different times of the year and that these differences can be identified from ALS data. Our aims were to use ALS to describe the role that forest structure has in habitat use of moose during different seasons, and to see how sex, and especially the presence of calves, affect it. Special attention will be given to two times of year, winter and the calving period, because these are the most crucial times regarding survival, especially to females and their calves.

2. Methods

2.1. Study area

The studied moose moved within an area of around 2000 km^2 on the west coast of Finland between the latitudes 62.254 N and 63.503 N. The topography of the study area is extremely flat. The overall topographical variation is less than 10 m in most parts of the study area. Scots pine is the most common species, but Norway spruce (*Picea abies*) and downy birch (*Betula pubescens*) are also present (METLA, 2013). The landscape is characterized by fields and peat lands and the proportions of downy birch can be relatively high in peat lands. The inland waters of the area are small lakes, ponds and rivers. A total of 48% of the inland waters are less than one hectare in size and 94% are less than 10 ha. The rivers flow steadily without large rapids and the majority are less than 20 m wide. The density of the moose population (after the hunting period) in the study area is around 3.5 moose per 1000 ha (RKTL, 2011), which is a typical density.

2.2. Data

2.2.1. Moose data

The data were obtained from 15 moose equipped with GPS-collars (Vectronic). Of these, 11 were female and four were male. Of the 11 females, five were calving during the study and the calf stayed with the mother during the whole study period. The status of the calving females was checked in early summer (were any calves born) and early winter (were the calves still alive after the hunting season). Each of the calving moose used in this study had one calf at heel during the study period. Moose locations were collected from January 2009 and until the winter of 2011. The collars measured the positions hourly, and every fourth hour, the information was sent to a database (WRAM 2011) via a GSM-network (Global System for Mobile Communications). This research focused on a 365-day period, so we selected a period that included the most moose individuals (i.e. a common period during which most of the moose were followed for the full time of 365 days). This period was between April 10 (2009) and April 11 (2010). An additional reason to delineate the period in this way was that now we were able to see how the calves born in the spring of 2009 affected the mother cows' behavior during the rest of the year.

The average fix rate of GPS-positioning was 99.61% (ranging from 98.9 to 99.8%). The times of no fix seemed to happen with no reference to season or time of day. However, problems with the GSM network caused periods of blackout, from 4 h up to even a few days during the late summer and early autumn of 2009 and especially in June (as noted in Melin et al. (2014)). Because of these reasons, not all the positions were usable.

2.2.2. ALS data

ALS data were provided by the National Land Survey of Finland (License no. TIPA/517/10-M) and were collected between April 24 and May 5, 2009 using a Leica ALS50 laser scanning system. The test site was measured from an altitude of 2000 m above ground level using a field of view of 40°. The nominal sampling density was about 0.8 measurements per square meter. The footprint of a single laser pulse was about 0.35 m at ground level. The National Land Survey of Finland had previously classified ALS points as ground and non-ground points. The Digital Terrain Model (DTM) was interpolated from the ground points using inverse distance weighted interpolation (Shepard, 1968). Next, the DTM was subtracted from the orthometric heights of the ALS echoes to scale the heights to above ground level (AGL). The laser scanner used in the study captured a maximum of four range measurements (echoes) for each emitted pulse. Here, only the echo categories “first of many” and “only” were used, because they represent surface hits.

2.3. Methods

2.3.1. Determining the calving period

Past studies have shown that the calving period typically occurs in May or June. In the Bertram and Vivion's (2002) study, the calving periods of moose in Alaska ranged between May 14 and June 9, with median dates of May 24 and 25. Whereas, in the Kostroma experimental moose farm (natural or near-natural environment), Bogomolova and