Can airborne laser scanning or satellite images, or a combination of the two, be used to predict the abundance and species richness of birds and beetles at a patch scale?

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1. Introduction

Management of forests for biodiversity conservation requires knowledge on the habitat needs of forest-dwelling species. Important habitat factors include local stand conditions such as forest structure and tree species composition as well as the amount and distribution of suitable local habitats in a surrounding landscape. Information at both these scales can be efficiently derived from remotely sensed data.

Focusing on the European boreal forest, this paper presents an analysis of the relation between the local-scale abundance and species richness of forest-dwelling birds and beetles on the one hand, and information derived from airborne laser scanning (ALS) data and satellite images on the other. The aim is to answer the following questions: 1. Can ALS-data or satellite image data or a combination of the two be used to identify important habitats for forest dwelling beetles and birds in boreal forest? 2. Which type of remote sensing data can best explain biodiversity patterns for beetle and birds species in boreal forest? 3. How accurate can different remote sensing methods predict biodiversity patterns at different spatial scales?

2. Materials

2.1 Study area and field data

The study area is a 30 × 40 km large forest landscape in the middle boreal zone (Ahti et al. 1968) in northern Sweden (64°05’ - 64°10’N, 19°05’ - 19°30’ E; Figure 1). During the summers of 2009 and 2010, we sampled stands in three age classes: young (10-25 years), middle-aged (40-60 years) and old (>80 years). The young and middle aged stands are regenerated with conifers after clear cutting, mostly Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). The trees in the young stands are 1-6 m high. The middle aged stands include the oldest available stands which have been regenerated after clear-cutting, mostly in the 1950s-1960s. The older managed stands have been subjected to selective felling and thinning, but have never been clear-cut. In each study stand, three groups of species were sampled: birds (surveyed using fixed-radius point counts), flying beetles (captured using flight interception traps of the Polish IBL type) and ground-dwelling beetles (captured using pitfall traps). The species sampling was done at the scale of a 1 ha square. The correlation was high (0.67 - 0.81) between the observations of flying beetles and ground-dwelling beetles, suggesting that the two groups of beetles benefit from similar forest conditions. However, the correlation was lower (-0.04 - 0.28) between the observations of birds and the two groups of beetles.

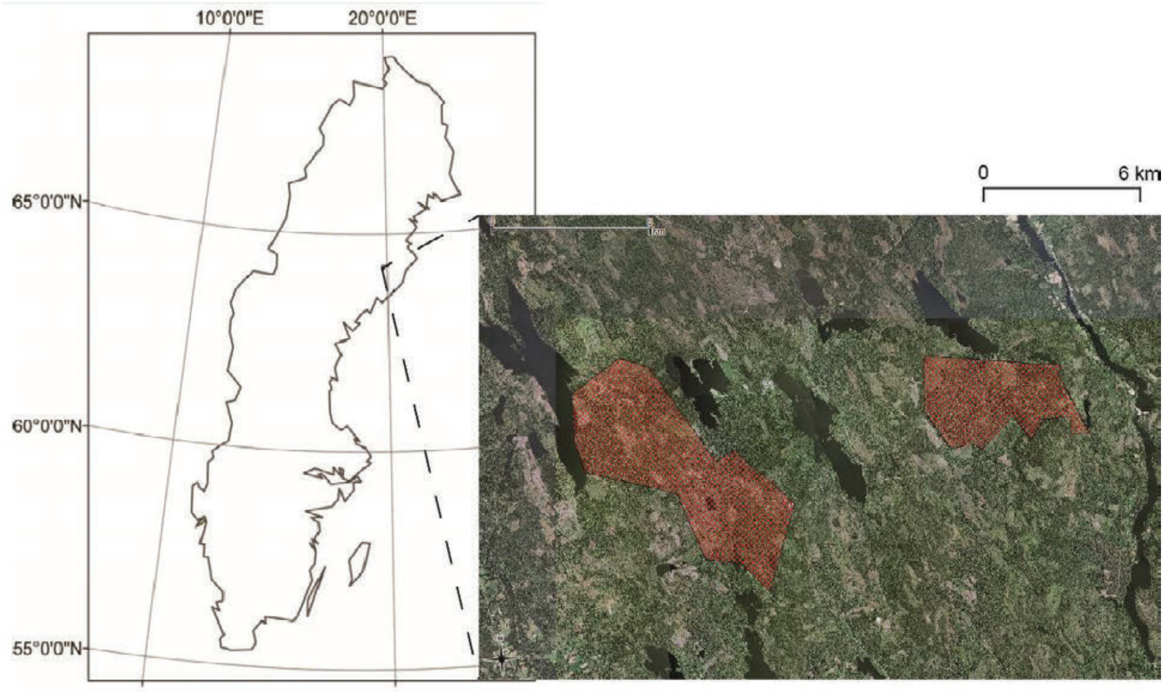

Figure 1: The position of the study area in Sweden and an orthophoto with the laser-scanned areas drawn in red.

2.2 Remotely sensed data

We extracted data from kNN-Sweden 2010, which provides information on forest age, tree height, total stem volume, and tree species composition in a raster with a resolution of 25×25 m (i.e., as a map). kNN-Sweden is based on forest data from the Swedish national forest inventory (NFI) combined with satellite images from SPOT 4 and SPOT 5 (Reese et al. 2003). Variables describing the forest conditions were derived as mean values of the 25×25 m raster cells in circles with 50 m and 200 m radius centred on the middle of the stands.

The ALS data were acquired on 3 and 5 August 2008, using a TopEye system S/N 425 with a wavelength of 1064 nm and a flying altitude of 500 m above the ground. The first and last returns were saved for each laser pulse and the average density of returns was 5 m^{-2}. Laser returns were classified as ground or non-ground and the ground returns were used to derive a Digital Elevation Model (DEM) with 0.5 m raster cells. Only study stands in the laser-scanned area were used for further analysis (Table 1).

Table 1. Number of study stands in different strata in the laser-scanned area; total number of study stands in brackets.

	Young forest	Middle-aged forest	Old forest	Total
Birds	17 (20)	16 (20)	14 (20)	47 (60)
Flying beetles	12 (14)	11 (14)	10 (14)	33 (42)
Ground-dwelling beetles	12 (14)	11 (14)	10 (14)	33 (42)

Metrics describing the height and density of the vegetation were calculated from the ALS data for each 10×10 m raster cell and the mean values were calculated within the 50-m and 200-m radii (Table 2).

Table 2. Summary description of the variables derived from kNN and ALS.

Variable	Description
kNN-based variables	
KNN_A	Mean forest age
KNN_H	Mean tree height
KNN_V	Mean total stem volume
KNN_P	Mean proportion of pine stem volume
KNN_S	Mean proportion of spruce stem volume
KNN_D	Mean proportion of deciduous (i.e. broadleaved) stem volume
ALS-based variables	
ALS _H95	Mean of the 95th percentile of height above the ground
ALS_HIGHR	Mean of the fraction of returns ≥ 3 m above the ground of all returns (higher vegetation ratio). This represents a general measure of higher-level foliage density, excluding bushes, short trees and branches below 3 m.
ALS_LOWR	Mean of the fraction of returns ≥ 0.5 m above the ground of all returns ≤ 3 m above the ground (lower vegetation ratio). This represents a general measure of lower-level foliage density.
ALS_SHANH	Mean of Shannon's diversity index for height. This provides an index of foliage height diversity (*sensu* MacArthur and MacArthur 1961).

3. Methods

Regression models were created for abundance and species richness as functions of variables derived from kNN and ALS data. For each response variable, three regression models were created for each of the two radii (50 m and 200 m): one with variables derived only from kNN, one with variables derived only from ALS, and one with variables derived from both sources. The independent variables for the final models were selected based on the Akaike information criterion corrected for finite sample sizes (AICc).

4. Results and discussion

Several of the regression models with the lowest AICc included the variables ALS_H95 or KNN_H (Table 3). These variables describe the mean height of the forest within the area, which generally increases with the age of the forest. The variables HIGHR and LOWR were also included in some regression models. They describe the mean density of the forest. The variable KNN_V was included in some regression models for the 200 m-radius. It describes the mean stem volume.

At the 50-m radius, all of the selected models included variables derived from ALS only. At the 200-m radius, 4 of the 6 best models included variables derived from ALS only, and 2 included kNN variables. The reason might be that the ALS data describe the forest better than the kNN data, especially for smaller areas.

For each of the 6 response variables, the model based on variables derived within the 50-m radius had lower AICc and better explanatory power than the model based on the 200-m radius. One possible explanation is that the habitats of the studied species depend mostly on local forest conditions (i.e., within the 50-m radius). However, other possible explanations could be that the forest conditions change too much within the 200-m radius and the derived variables don't characterize the factors that are important at this scale.

Table 3. Regression models with lowest AICc.

	50 m radius			200 m radius		
	Regression model	Adjusted R2	AICc	Regression model	Adjusted R2	AICc
Bird abundance	~ALS_HIGHR_50	0.35	37.7	~ALS_H95_200 + ALS_LOWR_200	0.21	47.9
Bird species richness	~ ALS_H95_50 + ALS_LOWR_50	0.37	32.2	~ALS_HIGHR_200	0.18	43.8
Flying beetle abundance	~ALS_HIGHR_50 + ALS_LOWR_50	0.43	39.7	~ ALS_H95_200	0.28	46.0
Flying beetle species richness	~ALS_H95_50	0.38	9.4	~ALS_H95_200	0.24	16.3
Ground-dwelling beetle abundance	~ALS_HIGHR_50	0.53	73.7	~KNN_V_200	0.45	78.9
Ground-dwelling beetle species richness	~ALS_HIGHR_50	0.60	29.8	~KNN_V_200 + KNN_H_200	0.56	34.3

These preliminary results suggest that ALS data can provide a useful complement to satellite images for describing patterns of beetle and bird diversity in boreal forest. The best regression models for the different response variables were all based on variables derived from ALS data, meaning that variables derived from ALS data had a greater explanatory power than the variables derived from satellite images.

The best regression models were achieved for a smaller radius, suggesting that the effects of local conditions override those of the landscape surroundings in this system.

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