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Modelling golden eagle habitat selection and flight activity in their home ranges for safer wind farm planning

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ABSTRACT

Onshore wind farm development may impact vulnerable large eagles at both individual and population levels and requires appropriate assessment under the EU Bird and Habitat Directives. The present conservation policy (e.g. fixed safety zones around nest sites) improves species conservation but may not prevent habitat loss or reduce collision risk in the best possible way because this policy may not consider habitat-specific effects on eagle behaviour. Here, we develop a method for estimating habitat use and flying time distribution within Golden Eagle (*Aquila chrysaetos*) home ranges. Location data retrieved with GPS-transmitters (Global Positioning system) in Finland indicated that these large raptors used vast areas (mean 297 km^2, 95% Minimum Convex Polygon), reaching up to 14 km, but not uniformly around their nests. The best resource selection function models (cross-validation performance 83%) revealed that flying Golden Eagles preferred the vicinity of their nests, steep slopes, and old forests in their home range. They avoided human settlements and neighboring territories. GPS data indicated short flying times per day (mean 2.2 h) and about 30% of the flying time within collision risk heights (50–200 m). Together with information on habitat selection, flying times can be used for predicting airspace use of birds and in assessing the collision risk at particular wind farm locations. Thus, our method can be applied in planning wind farm locations that enable a safer co-existence of large territorial birds and wind power plants in the same landscape.

1. Introduction

Human activities often lead to conflicts between land use interests and biodiversity conservation (Young et al., 2005). These conflicts and potential impact on biodiversity may be prevented or made less harmful if the potential negative effects of land use on biodiversity can be foreseen already in the planning phase. Reaching this goal, however, requires detailed information of the ecology, especially habitat use for the species in question. This knowledge will provide useful tools for ecologically relevant land use planning without causing significant harm to nature and endangered species (López-López et al., 2011; Miller et al., 2014; Watson et al., 2014a).

The increasing building of wind power plants all over the world threatens biodiversity and nature protection (Santangeli et al., 2018). Large wind power plants are typically placed in areas where their negative effects on humans are minimal, i.e. far from cities and towns. These same areas are typically favoured by animal species that require large, undisturbed and continuous natural habitats. A good example of such species are large raptors (e.g. the Golden Eagle, *Aquila chrysaetos* and the White-tailed Eagle, *Haliaeetus albicilla*), which are also susceptible to negative impacts by wind power plants (Smith and Dwyer, 2016). Some locations for wind power plants have proven to be much more problematic areas for migrating and/or breeding eagles than others (Barrios and Rodríguez, 2004; Smallwood and Thelander, 2008; Bevanger et al., 2010). Especially the location of wind power plants at the core of an eagle's home range may dramatically increase the probability of collision with wind turbines (May et al., 2011; Watson et al., 2014a). Collisions are more common in areas where wind power plants are numerous. One example of this is the Island of Gotland in Sweden where a wind energy project causes annually an estimated 10 collisions of either Golden Eagles or White-tailed Eagles (Hjernquist, 2014).

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Importantly, Golden Eagles may avoid wind power plants by moving their hunting areas elsewhere (Fielding and Haworth, 2010) or by raising their flight height at wind power plants to vertically avoid collisions (Hedfors, 2015). Similar patterns have been found in migrating Golden Eagles (Johnston et al., 2014). On the other hand, White-tailed Eagles on Smøla failed to show any sign of behavioural in-flight changes (Dahl et al., 2013) but did show partial displacement (May et al., 2013). However, even a few collisions can have dramatic consequences for long-lived species, where the most sensitive demographic parameter for population growth is adult survival (Sæther and Bakke, 2000), and a relatively minor increase in adult mortality (3–5%) can lead to significant population declines over time (Whitfield et al., 2004).

This is worrying because wind power is increasingly used as a source of energy. For example, the Finnish government aims to increase wind power capacity from 1000 MW (2016) to 3000 MW by the year 2025 (Ministry of Employment and the Economy, 2013). In Finland, the areas reserved for wind power plants overlap many Golden Eagle home ranges and may thus constitute a serious threat for this species which is classified as a vulnerable in Finland (Tiainen et al., 2016) and listed in Annex 1 (species needing special habitat conservation measures) of the EU Birds Directive (European Commission, 2009). At present, most common approaches to limit negative impacts of wind power plants include land use restrictions that forbid the building of wind turbines, such as in Sweden where protection buffers of 2 km from known Golden Eagle nests are established (Birdlife Sweden, 2016), moreover protective distance of 4 km has been proposed for the productive territories in this country (Alatalo and Bernhold, 2010).

Ideally, land use planning around the territories of protected and susceptible species should be based on detailed habitat use information. Many studies have modelled territory and nest site selection of Golden Eagles at the landscape level (Tapia et al., 2007; Vittorio and López-López, 2014; Tack and Fedy, 2015). Alternatively, habitat use can be studied within a territory with models that consider the location of nests and several relevant environmental factors, e.g. landscape topography, distance to human settlements and forest structure (the RIN-model, commonly known as the series of Research Information Notes where it was published, and the Predicting Aquila Territory model (PAT); (McGrady et al., 1997; McLeod et al., 2002a, 2002b).

Resource selection functions (RSFs) can be used to map the suitable habitat of a species based on predicted probability of use (Meyer and Thuiller, 2006; Manly et al., 2002; Miller et al., 2014; Watson et al., 2014a). These habitats use models can be applied to predict the areas preferred or avoided by animals within their home ranges. Therefore, these models provide useful ecological information for planning more environmentally friendly land use, which has been applied e.g. in forestation and wind power plants (McGrady et al., 2002; Fielding et al., 2006; Singh et al., 2016).

To estimate the actual collision risk at wind power plants, information on flight activity in different parts of the home range or the studied areas is needed. Different collision risk models (CRM) have been developed for predicting the numbers of collisions at wind power plants (Tucker, 1996; Band et al., 2007; Holmstrom et al., 2011; New et al., 2015). CRM's consider several possible factors, e.g. the physical characteristics of birds, weather conditions, technical specifications of wind turbines, and particularly the flight activity of birds. Reliable estimates for flight activity at particular points or areas are the bottleneck of these models.

Predictive modelling to forecast risk, while considering spatio-temporal variability, can guide the mitigation of wildlife impacts at wind power plants (May et al., 2017). In this study, we use GPS-observation data retrieved from territorial adult Golden Eagles from Finland throughout the year to model habitat selection. We construct a general RSF that describes the habitat use of resident Golden Eagles in their home ranges by coupling GPS-observation data of flying Golden Eagles and land cover data. We use cross validation to study how the general RSF model fits the observed patterns of habitat use. In addition, we calculate the average flight activity and height distributions for Golden Eagles and connect this to the knowledge on habitat use. We use the model in predicting airspace use of Golden Eagles in different parts of the territory, enabling the estimation of collision risk at any point in the area. We also discuss how this spatial risk distribution can be taken into account in the land use planning of wind power plants to avoid conflicts between Golden Eagles and the interests of humans.

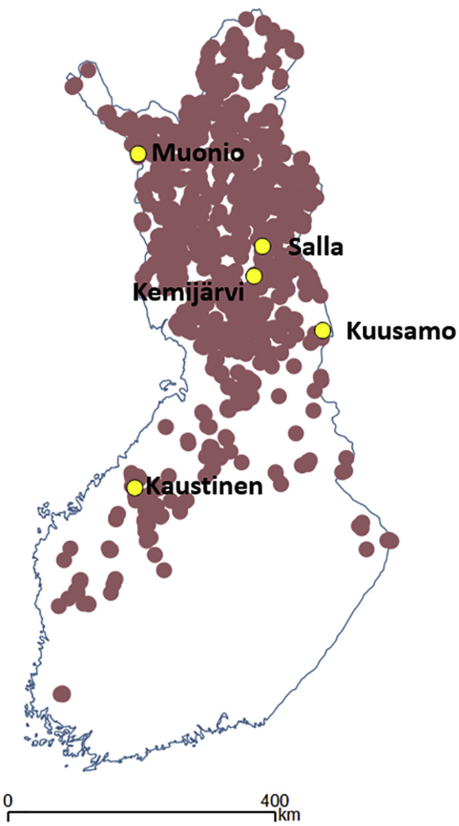

Fig. 1. Distribution of the study areas (open yellow circles) among the known Golden Eagle nesting locations (solid circles) in Finland (data from Metsähallitus/Tuomo Ollila). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Methods

2.1. Study area and land cover data

The study areas were located in Finland in mid-boreal (Kaustinen) and north-boreal zones (Kuusamo, Kemijärvi, Muonio and Salla; Fig. 1). Kaustinen is flat lowland (mean elevation was 70 m at the studied home range) characterized by large bogs and spruce-pine forests. The northern areas are characterized by higher topography (mean elevation 170–237 m) and typical boreal forest landscape with pine and spruce forests. These home ranges represent typical Finnish territories of Golden Eagles both environmentally and geographically (Fig. 1). During 2011–2015, there were 442 active territories in Finland (Ollila, 2016).

2.1.1. Land cover data

The geographic information analyses were carried out with programs QGis and MapInfo by using the following open access data sets: Multi-source National Forest Inventory (MS-NFI) data from 2012 (the National Research Institute Finland), Corine Land Cover data from 2012 (the Finnish Environment Institute) and basic and topographic maps (the National Land Survey of Finland).