Landscape and Urban Planning 177 (2018) 251–258

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Assessing space use by pre-breeding white-tailed eagles in the context of wind-energy development in Finland

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ARTICLE INFO

Keywords:
Raptors
Turbine
Renewable energy
Conservation
Landscape ecology
Land use

ABSTRACT

The expansion of wind energy over large areas may be accompanied by major conflicts with birds, including birds of prey. Hence, it is desirable that the space use of species known to be vulnerable to wind energy be assessed in light of current and future developments. Here, we report on the large-scale dispersal movements of pre-breeding white-tailed eagles (*Haliaeetus albicilla*) in Finland, where a currently modest wind-energy capacity is expected to increase in the near future. We studied white-tailed eagle space use with a particular focus on the potential for annual power production (GWh) at specific locations, as estimated by the Finnish Wind Atlas. Also, we aimed to detect a potential human-wildlife conflict by assessing white-tailed eagle space use against the spatial distribution of existing and recently proposed wind farms. We found that, despite visiting a large proportion of the country, the eagles stayed primarily within coastal areas and islands, restricted to where human infrastructure was present only at very small amounts. Because of the distribution of wind resources, such areas were found to contain considerable potential for power production. The eagles visited most of the areas targeted for wind-energy development. However, these areas did not coincide with a higher-than-average eagle relocation frequency, suggesting that the existing and recently proposed wind farms do not represent an elevated threat to dispersing eagles. Caution should nevertheless be taken against interpreting that co-occurrence poses no threat at any given site, as site selection is paramount to avoid conflicts with avian conservation.

1. Introduction

The use of wind energy is recognised as an important means to help reduce the consumption of fossil fuels, thereby contributing to the mitigation of climate change (Wiser et al., 2011). The wind industry continues to expand at a rapid pace, especially in Asia, Europe, and North America. In 2015, new wind energy installations accounted for nearly half of global electricity growth (Global Wind Energy Council, 2015).

Despite its benefits, wind energy can be detrimental to birds in terms of collision mortality, displacement, habitat loss, and barriers to movements (Drewitt & Langston, 2006). As regards collision, comparisons with other man-made structures (*e.g.* buildings, communication towers, power lines) suggest the impact of wind turbines to be minor (Erickson, Johnson, & Young, 2005; Loss, 2016). However, wind energy increases worldwide and concerns have been raised about development in areas inhabited by species of high conservation value. Large soaring raptors, together with *e.g.* swans, geese, ducks, waders and owls, appear to be at greatest risk of collision (Tosh, Montgomery, & Reid, 2014). Golden eagles and other raptors have suffered high fatality rates at the Altamont Wind Resource Area in the USA (Smallwood & Thelander, 2008), and griffon vultures in southern Spain (de Lucas, Ferrer, Bechard, & Muñoz, 2012). Given that raptors have long generation times and low reproductive output, additive mortality may prove harmful to population persistence (Drewitt & Langston, 2006). Furthermore, the indirect effects produced by displacement, habitat loss or barriers to movements, difficult to assess in conjunction with direct mortality due to observational limitations, may lead to negative changes in survival and breeding success (Masden, Fox, Furness, Bullman, & Haydon, 2010).

Site selection and strategic planning are critical to avoid or minimise undesirable impacts of wind energy on birdlife (Drewitt & Langston, 2006). At the landscape scale, mapping avian distribution or space use allows the identification of areas containing vulnerable species, priority habitats or major flight paths (Hayes, Gove, & Whitaker, 2015), providing guidance to developers early in the planning stage (see Bright et al., 2008; Fargione, Kiesecker, Slaats, & Olimb, 2012; Fielding, Whitfield, & McLeod, 2006; Miller et al., 2014). Early

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https://doi.org/10.1016/j.landurbplan.2018.05.012
Received 9 December 2016; Received in revised form 8 December 2017; Accepted 14 May 2018
0169-2046/

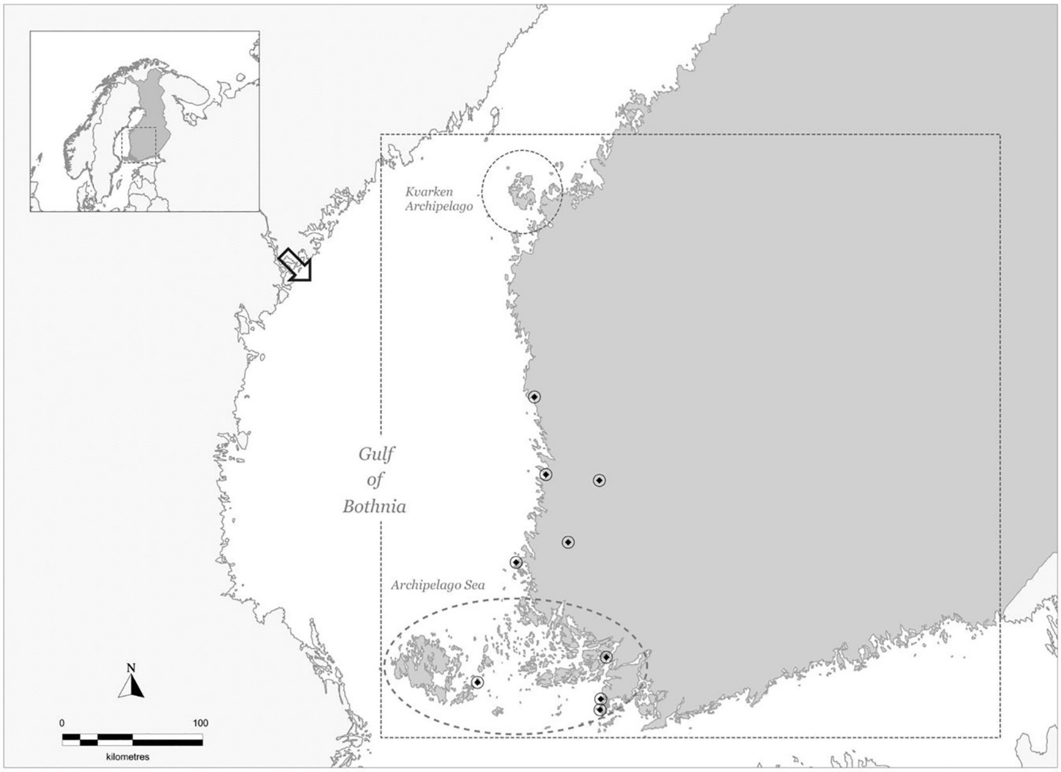

Fig. 1. Approximate nest locations of the satellite-tagged white-tailed eagles. The dashed circle around the Kvarken Archipelago indicates the area containing five nests which are undiscernible at the used scale due to the short distances between them. The Archipelago Sea is a stronghold of the species in Finland.

locational guidance, though not a substitute for Environmental Impact Assessment (EIA), may enable developments to be sited where risk of conflict is presumably lower.

Wind energy is an integral part of Finland's National Energy and Climate Strategy, with a goal to supply 8TWh of wind-derived electricity by 2030 (Government report, 2017). In 2016, an installed capacity of *ca.* 1500 MW accounted for 3.5% (3 TWh) of the country's electricity consumption (Finnish Energy Industries, 2017). In 2011, a new Finnish Wind Atlas was produced to facilitate site selection by providing estimates of wind-energy potential (Tammelin et al., 2011). The Finnish Wind Atlas identified a 30-km wide coastal strip (including an extension to offshore zones), highlands, large lakes and fields as the most favourable areas for electricity generation. The coastal-offshore strip is the largest of such areas and contains most of the existing wind farms and development proposals (Finnish Wind Power Association., 2016). Coastal areas encompass a large extent of the white-tailed eagle (*Haliaeetus albicilla*) range in Finland, supporting an estimated 80–90% of its breeding population (Herrmann, Krone, Stjernberg, & Helander, 2011).

The white-tailed eagle is classified as a vulnerable species in the Finnish Red List (Tiainen et al., 2016), and is listed in Annex I of the EU's Birds Directive (Directive, 2009). The species can be negatively affected by wind farms. On the Norwegian island of Smøla, collision mortality and displacement of breeding pairs have been associated with a reduction in breeding success (Bevanger et al., 2010; Dahl, Bevanger, Nygård, Røskaft, & Stokke, 2012). Collisions have also been reported in Germany (Krone & Scharnweber, 2003), Poland (Zieliński, Bela, & Marchlewski, 2011), and Japan (Ueta, Fukuda, & Takada, 2010), adding to the mortality attributed to other anthropogenic causes (*e.g.* lead poisoning; Krone, Langgemach, Sömmer, & Kenntner, 2003). In Finland, white-tailed eagles appear to be more likely to breed successfully when their territory is located farther from a facility (F. Balotari-Chiebao, Brommer, Niinimäki, & Laaksonen, 2016).

Adult white-tailed eagles of the Western Palaearctic are typically sedentary (Hardey et al., 2013), though breeding adults from *e.g.* inland territories in Northern Europe winter on the Baltic Sea coast; (Forsman, 1999). Young birds disperse during their first years of life and may cover long distances before reaching maturity (*ca.* 5 yr.; Hardey et al., 2013). Bevanger et al. (2010) reported that juveniles from Smøla moved extensively along the coast of Norway, following a seasonal pattern in their return to the natal sites. Little is known of the dispersal movements of Finnish white-tailed eagles, especially in relation to wind energy. Here, we use long-term satellite telemetry data (1) to report on the large-scale movements of pre-breeding white-tailed eagles with a special reference to wind energy. In particular, we assess their space use in relation to site-specific annual power production potential (GWh), a relevant measure for wind-energy developers. Also, we (2) assess their space use against the spatial distribution of existing and recently proposed wind farms. Based on these two objectives, we provide information to developers and planning authorities on how to better consider the species in the planning process.

2. Materials and methods

2.1. Study species and turbine-related mortality

The white-tailed eagle is a diurnal raptor that breeds along sea coasts and by large rivers, lakes and reservoirs, feeding primarily on fish and waterfowl (Cramp & Simmons, 1980). In Finland, despite being widely distributed, the species breeds in three main areas: the Archipelago Sea, the Quark, and Lapland (Stjernberg, Koivusaari, Högmander, Ollila, & Ekblom, 2005). In 2016, nearly 400 occupied territories were confirmed (Stjernberg et al., 2016). White-tailed eagles are exposed to direct mortality due to collision with wind turbines. In Finland, at least 10 fatalities have been reported based on opportunistic observations made by the general public (T. Stjernberg, personal communication, December 8, 2016). While this figure appears negligible, it underestimates the true impact of Finnish facilities, because a