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Estimating habitat loss due to wind turbine avoidance by bats: Implications for European siting guidance

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ABSTRACT

Wind energy is rapidly growing as a renewable source of energy but is not neutral for wildlife, especially bats. Whereas most studies have focused on bat mortality through collision, very few have quantified the loss of habitat use resulting from the potential negative impact of wind turbines, and none of them for hub heights higher than 55 m. Such impacts could durably affect populations, creating a need for improvement of knowledge to integrate this concern in implementation strategies. We quantified the impact of wind turbines at different distances on the activity of 11 bat taxa and 2 guilds. We compared bat activity at hedgerows (207 sites) located at a distance of 0–1000 m from wind turbines (n = 151) of 29 wind farms in an agricultural region in the autumn (overall 193,980 bat passes) using GLMMs. We found a significant negative effect of proximity to turbines on activity for 3 species (*Barbastella barbastellus*, *Nyctalus leisleiri*, *Pipistrellus pipistrellus*), 2 species-groups (*Myotis* spp., *Plecotus* spp.) and 2 guilds (fast-flying and gleaner). Bat activity within 1000 m of wind turbines by gleaners and fast-flying bats is reduced by 53.8% and 19.6%, respectively. Our study highlighted that European recommendations (at least 200 m from any wooded edge) to limit mortality events likely strongly underestimate the loss of bat activity. The current situation is particularly worrying, with 89% of 909 turbines established in a region that does not comply with recommendations, which themselves are far from sufficient to limit the loss of habitat use.

1. Introduction

Land consumption due to the development of projects (e.g., transport infrastructure, power generation infrastructure, and urbanization) is a major driver of biodiversity loss (Maxwell et al., 2016). Project developers should avoid and reduce their negative impacts on biodiversity as much as possible and implement offset measures when residual effects persist (mitigation hierarchy, EC, 2007). Assessment studies before projects are set up aim to quantify impacts (i.e., direct loss of individuals and future habitat losses) in order to apply the mitigation hierarchy. Most of these studies mainly focus on habitat losses; however, wind farms are an exception because of weak covered area in the construction stage and growing concerns about impacts to wildlife issues in the post-construction stage (Gibson et al., 2017).

A large number of studies summarized by Arnett et al. (2016) have shown that wind farms have adverse effects on bats through mortality events from collisions in the post-construction stage and could threaten population viability (Frick et al., 2017). Whereas many studies have focused on bat mortality through collision with wind turbines, few have studied activity loss in the post-construction stage resulting from the potential impact on habitat use around wind farms. Habitat availability, notably foraging habitat, is nevertheless recognized as a major driver of population dynamics for most taxa (Ney-nifle and Mangel, 2000; Rybicki and Hanski, 2013)). This is especially the case for one in-

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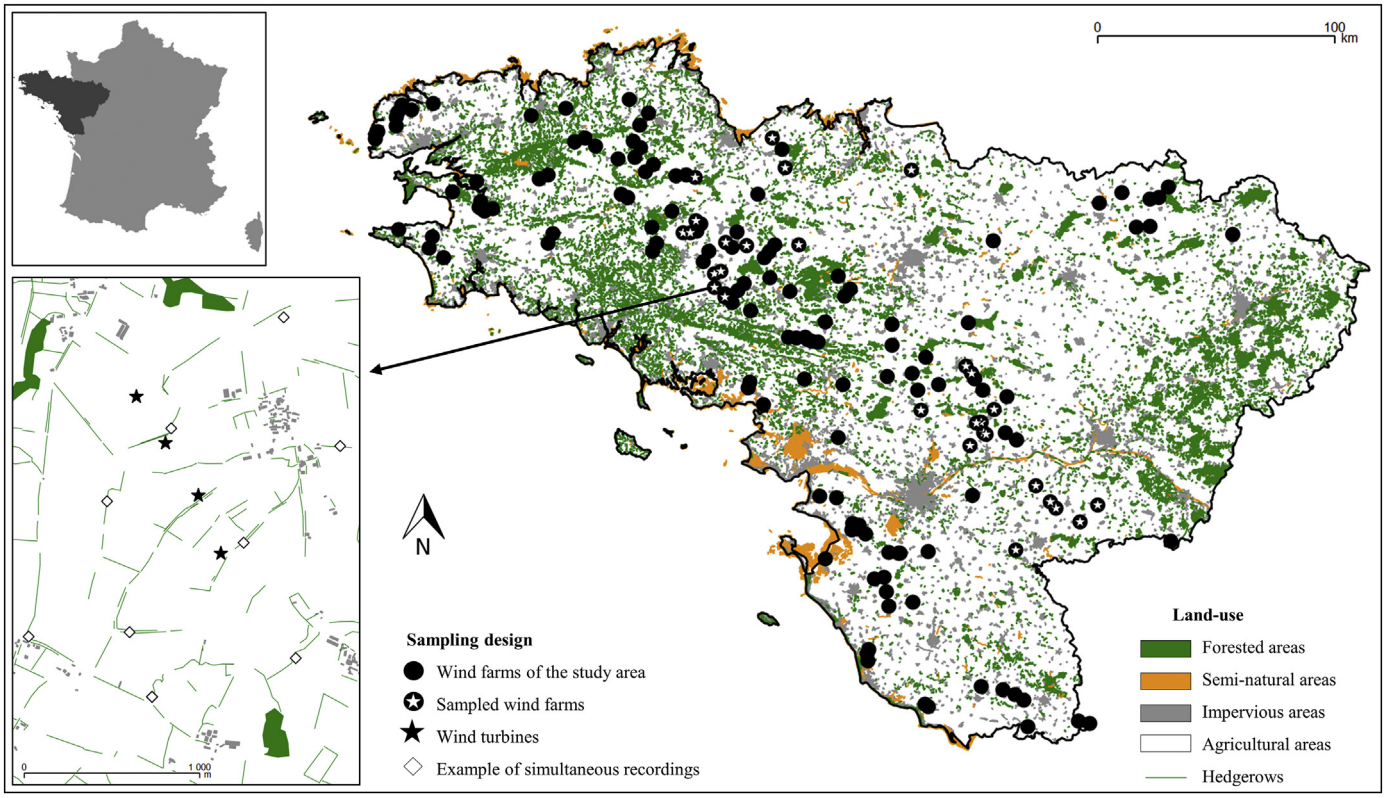

Fig. 1. Map of the land use, total and studied wind turbines in the study region, showing an example of sampling with simultaneous recordings of bat activity over one night.

sectivorous bat species, *Rhinolophus ferrumequinum*, whose colony size strongly depends of the density of hedgerows surrounding the roosts (Froidevaux et al., 2017). The establishment of wind farms, by modifying environmental conditions, may thus durably affect the habitat use of such long-lived species with high survival rates (e.g. 0.80 for *Pipistrellus pipistrellus* and 0.91 for *R. ferrumequinum*; Sendor and Simon, 2003; Schaub et al., 2007) and low fecundity (e.g. 0.72 for *P. pipistrellus* and 0.74 for *R. ferrumequinum*; Webb et al., 1996; Schaub et al., 2007). Moreover, agricultural landscapes are widely used by bats as foraging areas (Boyles et al., 2011; Wickramasinghe et al., 2004). Indeed, some widespread habitats in agricultural areas are known to be essential for bats, such as wetlands (Sirami et al., 2013) and hedgerows (Lacoeuilhe et al., 2016), structuring the landscape used by bats (Boughey et al., 2011a; Frey-Ehrenbold et al., 2013).

To our knowledge, only 2 studies have dealt with the impact of the distance of wind turbines on the attractiveness of foraging habitat, and they studied small turbines (< 25 m hub height). Minderman et al. (2012, 2017) found a significant reduction of activity for *P. pipistrellus* and no effect for *Pipistrellus pygmaeus* (2 species studied) up to 400 m from the turbines (between 6 and 25 m hub height). Two other studies have shown a strong reduction in bat activity with proximity to wind turbines without account for impact distances. First, Millon et al. (2015) showed a significantly lower global bat activity within European intensive agricultural fields under wind turbines of 100 m hub height than in fields 35 km away from any turbine. Then, the same authors showed a significantly lower activity (20 times in mean) at wind turbine sites (between 50 and 55 hub height) than paired sites 1 km away from any turbine for *Miniopterus* sp. and *Chalinolobus* sp. in an island tropical context (Millon et al., 2018). Thus, concerning the standard turbines (> 55 m hub height), there has been no accurate assessment of the distance and the magnitude of the wind turbine impact on the attractiveness of foraging habitat. In addition, overall very few species have been studied in relation to these questions. Another great issue is the reduction of the mortality risk by setting up wind turbines far from attractive habitats such as wooded edges, including hedgerows (Boughey et al., 2011a; Lacoeuilhe et al., 2016). Hedgerows in agricultural landscapes concentrate most of the activity for the majority of bat species, which becomes very low at > 200 m from hedgerows in open areas (Kelm et al., 2014). Guidelines of the Agreement on the Conservation of Populations of European Bats (UNEP/EUROBATS; Rodrigues et al., 2015) have recommended since 2008 that turbines should not be installed closer than 200 m to any types of wooded edges (forests and hedgerows) due to the high risk of fatalities. However, these recommendations only consider the avoidance of collision and are based on the observation of reduced activity with increased distances to wooded edges. Reduction of activity in habitats close to turbines as well as the threshold distance of this impact are not considered in recommendations.

Moreover, the installed capacity of wind energy has grown as a renewable energy source over the last 10 years by a factor of 6.6 (Global Wind Energy Council, 2016). This strong positive trend is expected to continue. Indeed, the 2015 United Climate Change Conference (COP