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A spatial explicit agent based model approach to evaluate the performance of different monitoring options for mortality estimates in the scope of onshore windfarm impact assessments

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ABSTRACT

Despite the environmental benefits associated with wind energy, studies have confirmed the occurrence of significant levels of bat and bird fatalities at windfarms, which raise concerns about the long-term effects of these infra-structures on these populations. Reliable estimates of windfarm fatalities are fundamental for accurate environmental assessment studies and supporting management actions. A spatially explicit agent-based model (ABM) was developed to investigate how searcher "controlled" variables, i.e., different field monitoring protocols, monitoring periods and periodicities influence the success of carcasses detection in field trials and estimator accuracy. Different rates of bat mortality due to collision, scavenger pressures and habitat complexity were simulated in order to reproduce variable conditions that might take place at onshore wind facilities. Based on our findings we propose a reduction in the monitoring periods and a shortening in the periodicity of searches in order to reduce bias in the estimations and increase the confidence limits of impact assessments associated with mortality estimates at onshore windfarms.

1. Introduction

Wind energy facilities can be responsible for changes in animal behaviour and direct mortality of birds and bats (e.g. Santos et al., 2010, 2016a; Ferreira et al., 2015; Bastos et al., 2016). High fatality rates for birds and bats are associated with specific types of wind energy facilities, specific seasons and prevailing regional environmental conditions (Bernardino et al., 2013). Most methods used to estimate animal fatalities at windfarms and to assess impacts on populations are supported by data from carcass searches carried out around the wind turbines. Several variables are critical to mortality estimator accuracy in contexts of deficient detection (e.g. Bernardino et al., 2013). The existing estimators include different adjustment approaches that use correction factors and a variety of implicit assumptions to improve accuracy (e.g. Korner-Nievergelt et al., 2011; New et al., 2015; Huso et al., 2016). Recent development in the evolution of estimators integrate survival analysis, complex statistical methods and modelling among other approaches (see Péron et al., 2013; Korner-Nievergelt et al., 2015). Although these estimators are considered more precise, the range of assumptions they are based on makes them complex and dependent on the uncertainty of pre-determined distributions (e.g. Bastos et al., 2013). On the other hand, field monitoring protocols used to assess mortality at windfarms have barely changed

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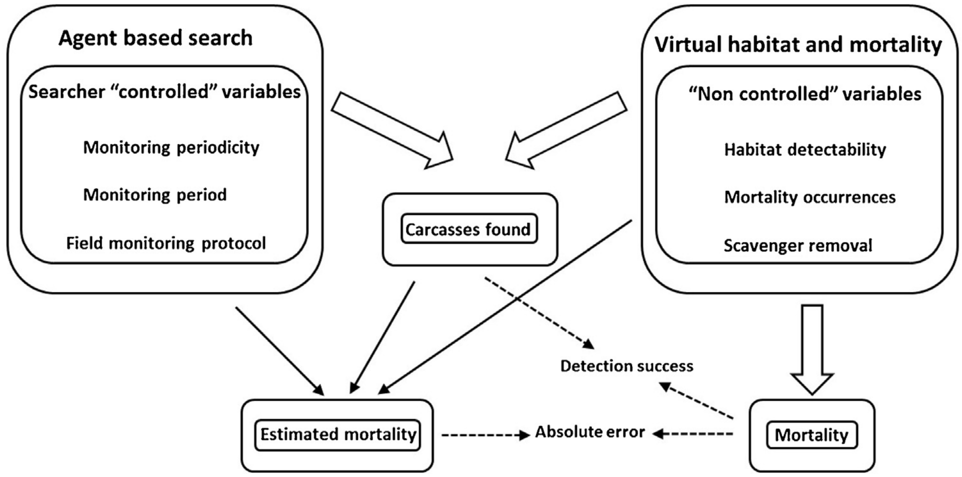

Fig. 1. Conceptual diagram of the agent based model used to reproduce and investigate how the interaction of several variables (i) determines the number of Carcasses found by searchers in field trials around a wind turbine and (ii) their influence on the accuracy of the Estimated mortality. Bold arrows represent the mechanistic processes that originate Mortality and Carcasses found, thin arrows represent direct influences on the calculus of the Estimated mortality and dashed thin arrows link the accuracy variables used to compare Mortality with the Estimated mortality (Absolute error) and Mortality with the Carcasses found (Detection success).

over the last few decades, although the implications of changes in the field monitoring protocols were never properly addressed (Bernardino et al., 2013). The development and implementation of spatiotemporal models, using agent-based modelling platforms (ABM), is a promising and realistic way to gain insight into mortality found/estimated versus specific circumstances (e.g. Eichhorn et al., 2012). ABMs are computer simulation tools that can incorporate intelligence, learning and adaptation by using basic system components (i.e. individual agents) to demonstrate how systemic properties emerge from their main interactions (Wilensky, 1999). ABMs have been widely used in environmental studies, particularly interdisciplinary approaches relating interactions between humans and wildlife (e.g. Topping and Petersen, 2011; Ferreira et al., 2015; Santos et al., 2016b).

To evaluate the effects of monitoring strategies in animal mortality estimates at windfarms, we developed a spatially explicit ABM by generating bat mortality occurrences and simulating carcass searches around a wind turbine. The use of a spatially explicit ABM in this context is valuable since the interaction between agents and their environment is readily incorporated into the different simulated conditions. The major objectives of this study were: a) to investigate the influence of the searcher "controlled" variables, i.e., different field monitoring protocols, monitoring periods and periodicities on carcass detection success (number of carcasses found/total mortality) for field trials at onshore windfarms, b) to evaluate the accuracy of five widely used mortality estimators, considering eventual changes in the detection success of carcass searches associated with the searcher "controlled" variables, and c) to propose monitoring strategies that overcome some of the previously identified problems (e.g. Korner-Nievergelt et al., 2015).

2. Material and methods

2.1. Virtual site description

The model simulates a landscape surrounding a small sized wind turbine with a hub height of 65 m and rotor sweep diameter of 66 m (Hull and Muir, 2010). The virtual landscape was parametrised to mimic characteristic landscapes associated with onshore windfarms, reproducing land use/land cover patterns dominated by grasslands and scrublands of diverse complexity and biomass (Eurobats, 2012).

2.2. Modelling procedure

The conceptual description of the model follows the specifications of the standard protocol ODD (Overview, Design Concepts and Details) to describe ABMs, proposed by Grimm et al. (2010). Netlogo 5.3 software (Wilensky, 1999) was used to perform the simulations and to calculate estimators' outcomes.

2.2.1. Overview

2.2.1.1. Purpose. The model investigates how the interaction of several variables determines the number of bat carcasses found by searchers in field trials around a wind turbine. We used this context as a demonstration to reproduce rates of mortality by collision, scavenger pressures, habitat complexity and searcher monitoring requirements in order to assess the accuracy of the estimated mortality obtained from five commonly used mortality estimators (Johnson et al. (2003), Erickson et al. (2005), Huso (2011), Korner-Nievergelt et al. (2011) and Bastos et al. (2013)). We were especially interested in understanding the combined effects of searcher "controlled" variables, i.e., different field monitoring protocols, monitoring periods and periodicities of searches in the detection success of bat carcasses and in the estimated mortality associated (Fig. 1). Although it was not in our objectives to assess the impact of the spatial distribution of habitats on the mortality patterns and its influence on the estimated mortality, this could be implemented by specific parametrization and connexion with previous works addressing this problematic (e.g. Ferreira et al., 2015).

2.2.1.2. Entities, state variables and scales. The model included three types of conceptual entities (Table 1): the patches (unit cells) that form the landscape of the searching area (4 ha; Hull and Muir, 2010), the wind turbine (distinct type of patches in the model), the carcasses and the searcher (the only mobile entity in the model). All state variables associated with these entities are described in Table 1. The time unit used during simulations was the second, as it is the discrete unit that best fits the carcass search process as virtual human individuals scan in small time intervals. Each simulation represents a monitoring period and all activity was updated and recorded discretely, allowing outputs to be obtained for every second of the simulation, if necessary.

2.2.1.3. Process overview and scheduling. Each simulation followed a sequence of steps to replicate a period where: 1) carcasses distri-