Assessing cumulative impacts of wind-power development on birds: a spatially-explicit deterministic index for decision support

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Background

Whereas each wind-power plant in itself may present little conflict, multiple wind-power plants may in sum, however, have serious impact on individual species or ecosystems as a whole. Internationally there has been signaled a growing need to establish common standards and methods of how issues related to cumulative effects of wind-power plants can be integrated in future research and monitoring practice (Masden et al. 2010). This spatially-explicit cumulative impacts index can contribute to sound decision making which may lead to improved legitimacy and accept for concession approvals.

Step-wise cumulative impacts index

The proposed cumulative impacts index incorporates both direct (through collisions) and indirect (through reduced reproduction) mortality, in addition to barrier effects. The single-species impacts (e_{ij}) are related to the energetic 'footprint' of each wind-power plant by multiplying the dimensionless effect-sum with the impact area (A_{ij}, in km^2) per capacity (C_j, in megawatt) (**step 1**). The overall impact of a single wind-power plant across species (E_j) equals the average of single-species impacts (e_{ij}) weighed by a species-specific vulnerability index (s_i) (**step 2**). The cumulative impact of several wind-power plants within a geographic region (CI) equals the sum of all wind-power plant impacts (E_j) while taking into account the effect of spacing of wind-power plants (D_j) (**step 3**).

Index components and data input

The index is derived using standard survey techniques. Direct (annual) mortality (m_{ij}), expressed per turbine (T_j), can be approximated by collision risk models (CRM, e.g. Band et al. 2007) based for example on vantage point observations (May et al. 2010) or telemetry data (May et al. 2011). Indirect mortality is approximated by the summed territory fractions (r_{ij}) lost through habitat loss and disturbance, expressed per km^2 of the impact area (A_{ij}). The number, placement and delineation of territories before construction can be assessed through breeding surveys. The impact area (A_{ij}) equals the envelope encompassed by all turbines and associated infrastructure including a species-specific disturbance buffer, derived from flight initiation distances (Ruddock & Whitfield 2007; Blumstein 2006). Possible barrier effects are approximated by the ratio of the actual perimeter of the impact area (P_{ij}) by the (minimal) perimeter of an equal-area circle (Forman & Godron 1986).

Implementation and verification

The cumulative impacts index is thus based on easily assessed pre-construction data, and may support consenting agencies for deciding on acceptable thresholds of cumulative impacts of wind-power development on birds within a geographical region. To verify the sensitivity of the proposed index for capturing cumulative impacts, it still requires to be implemented. **Please contact me for possible case studies we can cooperate on!**

Step 1. Single-species & single wind-power plant impact

$$e_{ij} = \left(\frac{m_{ij}}{T_j} + \frac{r_{ij}}{A_{ij}} + \frac{m_{ij} \cdot r_{ij}}{T_j \cdot A_{ij}} + \left[1 - \frac{2 \cdot \sqrt{\pi \cdot A_{ij}}}{P_{ij}}\right]\right) \cdot \frac{A_{ij}}{C_j}$$

- direct collision mortality, expressed per number of turbines
- indirect mortality (reduced breeding), expressed per impact area
- interaction term to take into account time-lag effects
- barrier effect, expressed as the area-circumference-ratio
- related to the 'energetic' footprint, expressed as impact area per MW

Step 2. Average over species for each wind-power plant

- Weighted average over all vulnerable species:

$$E_j = \frac{\sum e_{ij} \cdot s_i}{\sum s_i}$$

- s_i equals the species-specific vulnerability index (e.g. *Garthe & Hüppop 2004*)

Step 3. Sum over all wind-power plants within a geographical region

- Weighted sum over all wind-power plants:

$$CI = \sum \left(E_j \cdot D_j\right)$$

- D_j equals the spatial location of wind-power plants relative to the harmonic mean centre:

$$D_j = min_{j=1}^{n}\left(M_j\right)/M_j \qquad M_j = \left(\frac{1}{n-1} \cdot \sum_{k=1}^{n} d_{jk}^{-1}\right)^{-1}$$

(Dixon & Chapman 1980)

d_{jk} represents distance between wind-power plant j and all others

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