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Underpinning the precautionary principle with evidence: A spatial concept for guiding wind power development in endangered species' habitats

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ABSTRACT

The precautionary principle is an essential guideline in decision making, particularly for regulating novel developments with unknown or insufficiently proven environmental impact. However, due to the inherent component of uncertainty it has been widely criticized for being "unscientific", i.e. hindering progress without sufficient evidence. The consequential postulation, that precautionary measures are only justified if the addressed threats are plausible and the measures reasonable, calls for methods to guide action in the face of uncertainty. Using the example of species conservation versus wind-farm construction, an expanding development with hypothesized – but unexplored – effects on our model species the capercaillie (*Tetrao urogallus*), we present an approach that aims at compensating the lack of knowledge about the threat itself by making best use of the available knowledge about the object at risk. By systematically combining information drawn from population monitoring and spatial modelling with population ecological thresholds, we identified areas of different functionality and importance to metapopulation persistence and connectivity. We integrated this information into a spatial concept defining four area-categories with different implications for wind power development. Highest priority was assigned to areas covering the spatial and functional requirements of a minimum viable population, i.e. sites where the plausibility for threat is highest, the uncertainty as regards importance for the population is lowest, and thus the justification for precautionary measures is strongest. This gradated approach may also enhance public acceptance, as it attempts to avoid either error-minimization bias (i.e. being too restrictive or permissive) the precautionary principle is frequently criticized for.

Introduction

The precautionary principle is an established guideline applied to environmental policy and considered a fundamental tool for sustainable development (Cooney, 2004; Kriebel et al., 2001; Myers, 1993). It is based on the idea of "better safe, than sorry", in more detail described as "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Raffensperger & Tickner, 1999). The precautionary principle is usually applied when decision makers have an obligation to respond while there are indications of a negative impact, which are expected to be serious or irreversible and when there exists scientific uncertainty to the nature and severity of the threat (LILC, 2000; Prato, 2005). As this often applies to new developments, which are in potential conflict with species conservation, the precautionary principle has become a common element in environmental impact assessments in relation to endangered species. Nevertheless, the precautionary principle is often criticized for being not entirely "science based" (i.e. even though an activity or development has not been shown to be harmful it might still be prohibited) and is therefore accused of hindering progress or innovation (Kriebel et al., 2001; Sandin, Peterson, Hansson, Rudén, & Juthe, 2002).

The recent increase of wind energy use in Central Europe and the consequential necessity to evaluate wind farm projects with regard to conservation targets provides a good example of how the precautionary principle is applied in the field of endangered

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species protection. There are three main effects wind turbines may have on wildlife: firstly, increased mortality due to collisions; secondly, habitat fragmentation or reduced population connectivity when animals avoid passing through wind turbine areas; and thirdly, habitat loss due to construction works and avoidance of the disturbed area. Both birds and bats are known to collide with wind turbines causing increased adult mortality (Drewitt & Langston, 2008; Johnson et al., 2002; Kuvlesky et al., 2007; Langston & Pullan, 2003; Rydell et al., 2010). Although in most cases the effects at population-level are unclear (Stewart, Pullin, & Coles, 2007), increased adult mortality in long lived, slow reproducing species can rapidly affect population numbers (Sæther & Bakke, 2000). Moreover, a wide range of animal species have been shown to avoid areas around wind turbines, effectively causing habitat loss or acting as barriers to movement (Bach & Rahmel, 2004; Drewitt & Langston, 2006; Pearce-Higgins, Stephen, Langston, Bainbridge, & Bullman, 2009). Yet, the effects of wind turbines on wildlife seem to be highly species and site specific and the mechanisms behind certain effects remain poorly understood (Anderson et al., 2008; Kuvlesky et al., 2007). Besides, most studies on this subject are case studies, making it difficult to draw general conclusions. This lack of knowledge induces policy makers to apply the precautionary principle, which usually results in defining buffer zones around sites with ascertained species presence, for example nesting sites, where wind turbines are prohibited (Bright et al., 2008). The extent of this buffer zone is often based on expert opinion (Bright et al., 2008) and is therefore highly debated. Moreover, this approach is static and often based on data collected in a short time-window (e.g. a single breeding season), thus neglecting spatial and temporal fluctuations as well as minimum required areas or functional connectivity at the population level. One may argue that the lack of knowledge precludes a more complex approach. However, even if the effect of wind turbines on a species is unknown, evidence-based information on species' habitat selection and spatial requirements is often largely available or can be generated with relatively low effort from existing data sources. We state that this knowledge should be applied to determine prohibition zones for wind turbine development and advocate that the precautionary principle is used to protect viable populations of species and not only individuals. Here we provide an approach illustrating how a systematic combination of available data and knowledge can be applied to minimize – within the framework of the precautionary principle – the potential impact of wind power development on an endangered species population, even though knowledge about the actual effects of wind turbines on the species is lacking. Using the example of capercaillie (*Tetrao urogallus*) in the Black Forest, Germany, we identified areas of different functionality and importance with regard to reproduction, metapopulation persistence and connectivity, which were combined with population-related thresholds to define area categories with different levels of vulnerability and consequential implications for wind power development.

Methods

Model species

Due to its specific habitat and extensive area requirements, and its high sensitivity to human disturbance, the capercaillie is considered an indicator of undisturbed mountain forest ecosystems rich in structural diversity (Cas & Adamic, 1998; Klaus et al., 1989; Simberloff, 1998; Storch, 1995) and an umbrella species for the underlying species community (Pakkala, Pellika, & Lindén, 2003; Suter, Graf, & Hess, 2002). The same attributes, along with a limited dispersal capacity, renders the species highly vulnerable to habitat degradation and fragmentation. In Central Europe capercaillie is listed in most national red data books and in Annex I of the EU Birds Directive (EU Directive 2009/147/EC on the conservation of wild birds, The European Parliament and the council of the European Union, 2009), and its presence was one of the main criteria for the designation of special protected areas (SPA) for birds in the Natura 2000 network. However, the proportion of the capercaillie range that is covered by protected areas is far from sufficient to support self-sustaining, viable populations in most countries (Storch, 2007).

As the Central European populations are mostly confined to mountain regions, with distributions largely overlapping the areas suitable for wind energy development, capercaillie became a focal species for impact regulations. However, although a wide array of knowledge is available on behaviour and habitat requirements, it is still unclear how the species is influenced by wind turbines. The main impact is expected from turbine construction and operation triggering avoidance behaviour and thus effective habitat loss (González & Ena, 2011; Horch, Bruderer, Keller, Mollet, & Schmid, 2003; Horch, Graf, Liechti, Mollet, & Schmid, 2006; Langston & Pullan, 2003), but none of these effects have been scientifically proven yet. The only published study on the Cantabrian subspecies *T. urogallus cantabricus* shows a significant decrease of capercaillie signs in winter, one year after turbine construction (González & Ena, 2011). As capercaillie is highly sensitive to human presence (Thiel, 2007), road construction in the forefront of wind-turbine erection, followed by an increased human use of the area, is highly likely to reduce habitat suitability (Thiel, Jenni-Eiermann, Braunisch, Palme, & Jenni, 2008). Moreover, being a prey species to raptors, the flickering shadows elicited by the turbines blades may affect vigilance behaviour, a hypothesis that requires further research (Lovich & Ennen, 2013). Capercaillie are known to collide with many different man-made structures (Baines & Andrew, 2003; Baines & Summers, 1997; Bevanger & Brøseth, 2004; Catt et al., 1994) and occasional collisions with wind turbines have been reported from Sweden (Göran Rönning, pers. comm.). Despite case studies suggesting negative effects of wind turbines on capercaillie, it is impossible to draw general conclusions at the population level. In the case of the small and fragmented Central European capercaillie populations however, any additional impact may affect long-term population viability, which is why the precautionary principle is applied to handle conflicts between wind turbine construction and capercaillie protection.

Study area

The study area encompassed the Black Forest (i.e. the ecoregions "Black Forest" and "Baar-Wutach", Aldinger et al., 1998), a forested mountain range of about 7000 km^2 in south-western Germany. It was selected as it hosts the largest Central European capercaillie population outside the Alps (Storch, 2007) and, at the same time, is one of the Federal State's primary regions for wind energy development due to favourable wind conditions along the mountain ridges. The capercaillie population is distributed over 520 km^2 in the forested regions of the highest altitudes (Braunisch & Suchant, 2006), isolated from neighbouring populations (Storch and Segelbacher, 2000) and forms a metapopulation system consisting of four main subpopulation clusters (Segelbacher, Manel, & Tomiuk, 2008) (Fig. 1a). Since the beginning of the 20th century the population has declined greatly, from an estimated 3000–4000 males (Suchant in Lieser & Roth, 2001) to a low of 250 males counted in 2003. Since then the population has slightly recovered to approximately 300 males, which translates to a conservatively estimated minimum size of 600 individuals (Braunisch & Suchant, 2006), which exceeds only marginally the estimated size of a minimum viable population (MVP) of 500 birds (Grimm & Storch, 2000). Consequently, the loss or isolation of any sub-population is expected