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Using environmental impact assessment and post-construction monitoring data to inform wind energy developments

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Abstract. Ecological data are routinely collected for Environmental Impact Assessments (EIAs) and post-consent planning requirements to assess potential negative impacts of developments on wildlife. Such data are almost always obtained from a single site and this often prohibits robust statistical analysis due to insufficient replication. Here, we integrate data collected during EIAs and post-construction monitoring from multiple sites to study the impact of wind energy developments on the distribution and abundance of black grouse. We show that the construction of wind turbines at these seven sites had no detectable effect on the abundance of lekking black grouse, but that leks within 500 m of the nearest planned wind turbine moved locally after construction (median distance before construction was 250 m and after was 803 m). This effect was not observed for leks greater than 500 m from a wind turbine. Although not examined within this study, there are several reasons which, individually or in combination, could underlie the localized movement of black grouse we report. These include the operation of the wind energy development, volume of visitors, changes in land management both within and surrounding the site, and habitat enhancement measures designed to attract black grouse to specific areas away from the wind energy development. We demonstrate that ecological data routinely collected by EIAs and post-construction surveys from multiple projects can be combined to provide a robust ecological evidence base on which to inform development decisions. We recommend that easily-accessible data repositories be maintained by regulatory authorities to enable the development of a robust ecological evidence base to guide planning decisions across a wide range of different wildlife.

Key words: biodiversity offsetting; black grouse; disturbance; mitigation; renewable energy; Scotland; Tetrao tetrix; wind farms.

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INTRODUCTION

Change in land-use has had a significant impact on biodiversity and continues to do so (Sala et al. 2000, Foley et al. 2005). Consequently, there is a need to synthesize the results from robust ecological studies in order to understand and predict the consequences of this change. Where the change is due to a development, the standard approach is to conduct an Environmental Impact Assessment (EIA), which is intended to minimize and, where necessary, mitigate the potential negative impacts of the development. EIAs are carried out globally and are subject to different regulations dependent on their location. For example, in the European Union (EU) the process was originally outlined in Council Directive 85/337/EEC on Environmental Impact Assessments in 1985 and subsequently amended (Council Directive 2011/92/EU). One recent estimate suggested that there are around 16,000 EIAs carried out across the EU each year (GHK 2010), with follow on post-construction monitoring required, under planning regulations, on a subset of these. Given how widely EIAs and post-construction monitoring are undertaken, there is a substantial amount of ecological data generated that are only used to address specific questions about a single development and are rarely used to address other questions, although there are some exceptions which use data from multiple sites (Ferrer et al. 2012, Pearce-Higgins et al. 2012).

The specific purpose for which EIA and post-construction monitoring data are gathered and the associated logistical issues of obtaining this data (despite being officially available in the public domain) mean that the data are rarely marshalled to help address significant questions at larger spatial and temporal scales. This is unfortunate given the difficulties in determining cumulative impacts of development on landscapes (e.g., Masden et al. 2010) and the uncertainty of the effect of EIAs on biodiversity conservation (Sutherland et al. 2009). Furthermore, the demand by both scientists (e.g., Sutherland et al. 2004) and policy makers (e.g., Parliamentary Office of Science and Technology 2011) for management and policy to be based on strong scientific evidence suggests that new ways of making data available for analysis would be very welcome. We explore the potential of data gathered during the EIA process and post-construction monitoring to answer such larger scale questions by asking what impact wind energy developments (or wind farms) have on the distribution and abundance of a species of conservation concern.

Based on data obtained from the Netherlands, the number of EIAs carried out due to wind energy development has increased significantly from 0.6% of all EIAs in 2006–2008 to 5.9% of the EIAs in 2013 (Commissie voor de milieueffectrapportage; www.commissiemer.nl). However, an estimation across Europe could not be made as there is no specific information on this. Wind energy, as all renewable energy production, is generally a more sustainable resource with a far lower carbon footprint than the burning of fossil fuels and consequently plays a role in mitigating climate change (IPCC 2012). There has been a rapid rise in its use over the last 15 years (IEA 2010). However, there are concerns on the potential effects of wind turbines on wildlife, especially birds and bats. Potential effects include displacement through direct or indirect habitat loss (e.g., Pearce-Higgins et al. 2009, Dahl et al. 2012), or fatality through collision with turbine blades (e.g., Orloff and Flannery 1992, Horn et al. 2008, Smallwood and Thelander 2008, de Lucas et al. 2012). Much focus has been on birds, with larger, less maneuverable, species tending to be at greatest risk; these include raptors, geese and gamebirds (Barrios and Rodríguez 2004, Hötker et al. 2006, Fijn et al. 2007, Smallwood and Thelander 2008, Zeiler and Grünschachner-Berger 2009, Garvin et al. 2011, Dahl et al. 2012, LeBeau et al. 2014). A better understanding of the risks posed by wind energy developments is important for at least two reasons: conservationists are concerned about the potential effects on vulnerable species, and at the same time planning applications from wind energy companies can be refused or subject to costly delays if wildlife is judged to be threatened. Potential effects like displacement and collision could be substantially reduced by careful placement of wind energy developments and their turbines, in particular by building them away from known breeding sites of vulnerable species (Drewitt and Langston 2006). Therefore, during the planning phase of a wind energy development, EIAs are carried out to advise about its potential effects. Ideally these decisions would be based on the most robust evidence base, including survey data collected in a consistent manner from a range of sites over a meaningful time period, in order to draw robust conclusions. However, the expense involved means that this kind of dataset is rarely, if ever, available and planning decisions are being made in its absence, and are typically based on collective experience or professional opinion (Hill and Arnold 2012).

In our paper, we explore the usefulness of data collected during EIAs and post-construction monitoring to study the possible impacts of wind energy developments on birds. We focus on black grouse, *Tetrao tetrix*, a species considered at risk from wind turbines (European Commission 2011). Although little research has been conducted on the impact of wind energy developments on black grouse, the one study that has been performed at a wind energy development in the Austrian Alps showed that the abundance of black grouse at a wind energy site decreased rapidly after construction (Zeiler and Grünschachner-Berger 2009). However, this decline also coincided with continued shooting of black grouse at the site and the construction of a major ski-lift operation with an associated large increase in human disturbance. Thus, in our opinion the cause of the black grouse decline at this site was far from clear. Here we aim to provide an evidence base of population changes across seven sites where wind energy developments have been constructed. Our data provides insight into both the abundance and distribution of black grouse from before and after the wind energy developments were constructed.

We address simple, yet fundamental, questions with our data set: is the construction of wind energy developments associated with a change in the (1) numbers and (2) the distribution of lekking black grouse in the surrounding area? The interpretation of our results is complicated by background declines of British black grouse populations, habitat enhancement aimed at benefitting black grouse at some of these wind energy sites (as mitigation for perceived impacts) and other changes in habitat (both within and adjacent to each site). We discuss our results in light of these factors and insights into the use of EIA and post-construction monitoring data to answer ecological questions.

METHODS

Gathering of data

We contacted six different wind energy developers active in Scotland to ask for data from wind energy sites where black grouse occur. From these only ScottishPower Renewables responded with data. In addition, we obtained data from one site through the Central Scotland Black Grouse Study Group.

Wind energy sites

Each year males gather at leks and display to attract a mate. Counting birds at these leks has been an established survey method and is a way to monitor population changes in this species (Hancock et al. 1999). We therefore surveyed seven sites for lekking black grouse during the breeding season (April–May) before and after construction of the wind energy developments. These data were covered by confidentiality restrictions and so the site names are not given here, but are referred to by numeric identifiers. We are also unable to provide information on the number of turbines or the year that each site became operational, although the earliest became operational in 1995 and the latest in 2010. In cases where plausible scientific concerns about environmental impacts have been raised, the Precautionary Principle states that the burden of proof falls on those in favor of the development to demonstrate safety (UNESCO COMEST 2005). As such, and despite the lack of a strong scientific consensus on the impacts of wind energy development, six of our study sites incorporated Habitat Management Plans (HMPs) as mitigation for potential impacts of wind energy development on black grouse (see Table 1). The habitat modifications on the sites consisted of tree planting (sites 1, 3, 4, 5 and 7), predator control (culling of foxes and crows) (sites 1 and 7), grazing restrictions (sites 1 and 7), removal of redundant fences (site 7), marking of existing fences (site 7), tree felling (sites 3, 6 and 7), creating small wet areas (sites 3 and 7) and blanket bog restoration (sites 3 and 6) in addition to the construction of the turbines. These modifications took place in the wind energy site area and/or areas immediately adjacent to, or within 400 m, of the wind energy site. The areas of modifications varied greatly between sites but at five of the six sites these expanded at least several square kilometers in size. The majority of this enhancement work took place at the end of the construction period. However, at sites 1, 3, 6 and 7 the habitat modifications are still on-going as the habitat is naturally changing as a result of felling and grazing restrictions. In addition, at site 6 blanket bog is being restored by ground treatments. These habitat changes are representative of the management and natural changes that take place throughout the uplands. Only at site 2 there was no HMP to mitigate for potential effects of wind energy development on black grouse.

Table 1. Overview of the habitat modifications at each site. Six of our study sites incorporated Habitat Management Plans (HMPs) as mitigation for potential impacts of wind energy development on black grouse. The habitat modifications on the sites consisted of tree planting, predator control (culling of foxes and crows), grazing restrictions, removal of redundant fences, marking of existing fences, tree felling, creating small wet areas and blanket bog restoration in addition to the construction of the turbines. These modifications took place in the wind energy site area and/or areas immediately adjacent to, or within 400 m of, the area containing the wind turbines. The areas of modifications varied greatly between sites but at five of the six sites these extended at least several kilometer squares in size. The majority of this enhancement work took place at the end of the construction period.

Habitat modification	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Tree planting	X		X	X	X		X
Predator control	X						X
Grazing restrictions	X						X
Removal or marking of existing fences							X
Tree felling			X			X	X
Creating small wet areas			X				X
Blanket bog restoration			X			X	

Data collection

Data on black grouse distribution and abundance were obtained from the Central Scotland Black Grouse Study Group and ScottishPower Renewables. Data collection was shared between several different ecological consultancy companies and the RSPB (see Table 2). The sites were surveyed both before and after construction of the wind energy development for any displaying black grouse (see Table 2). Survey methods followed the methods described in Gilbert et al. (1998). In short, a number of visits, varying from one to six, were undertaken to count the total number of birds attending suitable areas for lekking. It is possible that the number of visits altered before and after turbine construction: to test for this we carried out a paired t-test with number of visits per year before and after construction as a treatment. There were significantly fewer visits per year post-construction (overall before mean $= 2.76$, overall after mean $= 1.69$, $t = 2.37$, $df = 36.25$, $p = 0.02$). We used the mean number recorded per visit (see below) but the imbalance between before and after construction data collection is more likely to result in fewer records after construction (due to fewer

Table 2. Overview of the data collection at the seven study sites. We surveyed seven sites for lekking black grouse during the breeding season (April–May) before and after construction of the wind energy developments. These data were covered by confidentiality restrictions and so the site names are not given here, but are referred to by numeric identifiers. The seven study sites were in Scotland in the United Kingdom.

	No. years data collected			
Lek†	Before construction‡	Post-construction‡	Survey area	Surveyed by
1	1	8	Known lek was visited	3 EC
2	2	2	500 m around the proposed wind energy development	2 EC
3	2	7	500 m around the proposed wind energy development and the habitat management area	3 EC + RSPB
4	2	3	200-300 m around the proposed wind energy development and the planned track of the wind energy development	2 EC
5	1	3	Known lek was visited	2 EC
6	3	4	Known lek was visited and 500 m around the proposed track of the wind energy development	2 EC
7a	7	2	Known lek was visited	RSPB
7b	6	3	Known lek was visited	RSPB
7c	5	3	Known lek was visited	RSPB

† We identified nine leks for analysis: groups of birds found more than 1.5 km apart were regarded as separate leks. Site 7 therefore had three leks.

‡ The years of data collection before or after construction were not necessarily in consecutive years.

visits). This contrasted with the pattern shown in the data (see *Results*).

Surveyors used visual scanning and audible sounds to detect black grouse, carefully counting birds while making an effort not to double count if birds were flushed. The location and behavior of each black grouse was marked on a map and the grid reference recorded. Across all sites there were 64 survey years; in 29 survey years there was one visit, in 17 survey years there were two visits and in 18 survey years there were more than two visits to the site.

All observations were digitized in GIS and their distance to the nearest turbine was calculated in GIS.

Analysis

Number of lekking male black grouse.—We compared the abundance of lekking males before the construction of the wind energy development with the abundance of lekking males after construction. For the analysis we used the maximum number of lekking males per visit for each year in the breeding season for each site. While it is common practice to use the maximum count of lekking males per lek across all visits per year in an analysis, we used the maximum number of lekking males per visit. This is due to the number of visits varying between years and sites, as a result of which there would be a greater chance of a higher maximum count in the years with more visits than in the years with fewer visits. We used Bayesian generalized linear mixed models (GLMMs) with a Poisson error distribution with the maximum number of lekking males per visit per lek as a response variable and before or after construction as a categorical fixed effect. We used lek as a categorical random effect as there were large differences in number of birds between the leks (for example lek 2 had around two males lekking while lek 7a had between 10 and 30 males lekking). We used a Bayesian approach because it accounted for the overdispersion that we found when fitting a Poisson model using conventional frequentist methods. Although there are methods to account for high overdispersion using conventional frequentist methods (such as using a negative binomial distribution), we chose the Bayesian approach as this model best fitted our data; assessment of model fit was visually checked with QQ-plots of the residuals.

We identified nine leks for analysis: groups of birds found more than 1.5 km apart were regarded as separate leks. As our aim was to establish whether population numbers have changed, we investigated the whole population at the site. We therefore chose to treat groups of birds found more than 1.5 km apart as separate leks, because lekking males within this area are most likely to belong to the same population (Cayford 1993, Warren and Baines 2004). Site 7 was therefore split up into three leks.

We ran the model with three chains for 65000 iterations. We found that autocorrelation within the chains was reduced sufficiently when every 50th iteration was saved (thinning rate of 50). In addition, the chains converged after 15000 iterations; therefore these first 15000 iterations of the Markov chains were discarded (burn-in). This resulted in a sample size of 1000 saved iterations from which our posterior estimates were drawn.

Distribution of lekking male black grouse.—To determine whether the distribution of lekking males changed in relation to the construction of the wind energy development, we calculated the distance in meters to the nearest wind turbine from each lekking male or lekking group. For each visit, these distances were either calculated from each individual lekking male or, when lekking males were within 100 m of each other (as our data were at 100-m resolution), from each group of lekking males. We used a total of nine leks in the analysis (the same leks as in the previous section, *Number of lekking male black grouse*). We performed Bayesian GLMMs with Gaussian error with lek as a random effect. The distance to the nearest turbine was used as a response variable, with before/after construction as a categorical fixed effect. The distance values were square-root-transformed so the residuals from the model conformed to a Gaussian distribution. We ran the models with three chains for 13000 iterations with a thinning rate of 10 and a burn-in of 3000, resulting in a sample size of 1000.

In addition, to investigate whether the distribution of lekking males only changed relatively near to the planned wind energy development, we split data into two groups: (1) leks where the median distance of the lekking male black grouse to the nearest planned wind turbine before construction was less than 937 m (937 m was the median distance calculated from all recorded distances of lekking male black grouse to the nearest wind turbine before construction across all leks); (2) leks where the median distance of the black grouse to the nearest planned wind turbine before construction was above this value. Before construction, over 80% of the lekking males in group 1 were within 500 m of the nearest wind turbine, while almost 80% of the lekking males in group 2 were over 900 m away. We then performed the above Bayesian GLMM on these subsets of data with lek as a random effect. The square-root transformed distance values were used as a response variable and we used before or after construction as a categorical fixed effect. Group 1 included data collected at leks 2, 4, 5 and 6 and group 2 included data from the other five leks (1, 3, 7a, 7b and 7c). For both models, we ran three chains for 65000 iterations with a thinning rate of 50 and a burn-in of 15000, resulting in a sample size of 1000.

All statistical tests were performed in R (version 3.0.0) (R Core Team 2013). The GLMMs were performed with package MCMCglmm version 2.17 (Hadfield 2010). For all Bayesian GLMMs convergence was assessed by a graphical check of adequate mixing of the three chains as well as the Gelman-Rubin diagnostic. We did not specify any priors and therefore the models used the default priors. This means that the priors for the fixed effects were centered on 0 and had large variance and for the variance components a flat improper prior was used. Results were regarded as significant when the 95% credibility interval of the posterior distribution excluded 0.

RESULTS

Black grouse were recorded at seven different sites both before and after the construction of wind energy developments of varying sizes. Males continued to lek at six of the seven sites (Fig. 1).

Changes in abundance of lekking male black grouse following the construction of wind energy development.—Overall, the abundance of lekking males did not change significantly after the wind energy developments were constructed (mean = −0.03, 95% CI = −0.51–0.48) (see Table 3 and Fig. 1). There was strong support for variability between leks as the posterior distribution of the random effect term 'lek' was centered well away from zero (mean = 1.20, 95% CI = 0.47–4.56). In addition, the random effect term 'lek' explained the majority of the variation in the data (mean = 63%, 95% CI = 39–87%). This is not surprising given the difference in the number of lekking males between the leks.

Distribution of lekking male black grouse.—The distribution of lekking males was farther away from the wind energy development after construction than before, across all sites (mean = 3.16, 95% CI = 0.57–5.86). As the data were square-root-transformed this means that the average square root distance between the lekking males and turbines increased by 3.16. It is difficult to interpret the exact quantity of this figure because back-transformation of the data is not possible. However, as an approximate guide the median distance of lekking males from wind turbines before construction was 937 m and after was 1331 m.

When we split the data into two groups based on those that were initially closer to the turbines before construction, only the distribution of lekking males in group 1 changed after construction (group 1 mean = 7.51, 95% CI = 2.78–12.24, group 2 mean = 0.94, 95% CI = −2.13–4.29; see also Table 3 and for the raw data Fig. 2). Again as an approximate guide the median distance of lekking males from wind turbines in group 1 before construction was 250 m and after was 803 m. For group 2 the median distance of lekking males from wind turbines before construction was 1380 m and after was 1624 m.

DISCUSSION

This study demonstrates that data from EIA studies and post-construction monitoring can be used to answer important scientific questions and provide an evidence base for land management decisions. Using data from seven sites collected by a range of companies we have been able to show that black grouse persisted on all seven wind energy sites for the duration of our study period, which ranged between two and fifteen years post-construction. While, across all sites, the abundance of black grouse did not

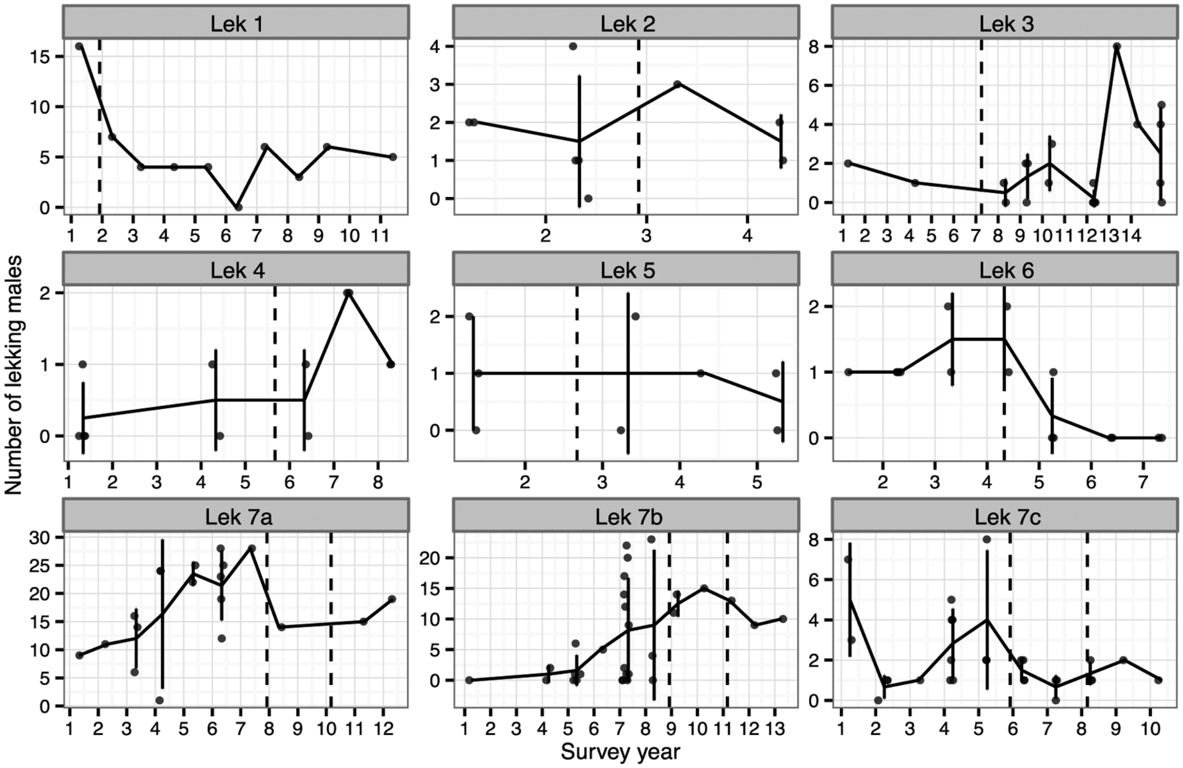

Fig. 1. The number of lekking male black grouse per site per year. Seven sites were surveyed for lekking black grouse during the breeding season (April–May) before and after construction of the wind energy developments. The line is the mean number of lekking males in each year, the dots show the total number of lekking males per visit. The dashed vertical line indicates the year that the wind energy development or extension was constructed. The habitat modifications on the sites consisted of tree planting (sites 1, 3, 4, 5 and 7), predator control (culling of foxes and crows) (sites 1 and 7), grazing restrictions (sites 1 and 7), removal of redundant fences (site 7), marking of existing fences (site 7), tree felling (sites 3, 6 and 7), creating small wet areas (sites 3 and 7) and blanket bog restoration (sites 3 and 6) in addition to the construction of the turbines.

change in the areas around the wind energy developments, we did find evidence that black grouse leks generally within 500 m of the nearest planned wind turbine moved locally after construction.

Currently, conservationists assess the potential effects of wind energy developments on black grouse largely on expert opinion and potentially taking into account the one peer-reviewed scientific study in the Austrian Alps that showed that black grouse left the wind energy site (Zeiler and Grünschachner-Berger 2009). In contrast to that study, our results indicated that the *abundance* of black grouse was not significantly affected by wind energy developments. This might be contrary to expectations as a decrease in the abundance of black grouse at wind energy sites in Scotland might even be expected regardless of the wind energy development. Firstly, due to the fact that the British black grouse populations have declined during the period of the study. The last national survey in 2005 found black grouse in Britain, especially in southern Scotland, were still in decline (Sim et al. 2008). Secondly, because small leks seem more susceptible to change (Geary et al. 2012) and therefore a change in black grouse numbers would first be expected at the leks with observed low numbers. However, we found that even at these leks (lek 2, 3, 4, 5, 6 and 7c) we did not observe consistent declines. This coupled with the fact that the majority of the variation in the data was

Table 3. Upper and lower 95% credibility intervals of the posterior distribution from the different models run via MCMCglmm. The table shows values of the intercept and the fixed effect. In addition, it also gives the proportion of data that is explained by the random effect. For example: if looking at the first model (abundance lekking males) it shows that there was no change in the abundance after the wind energy development was constructed as the 95% credibility interval overlapped with zero; the random effect mean shows the proportion of the deviance or variance (depending on model) explained by the lek effect, in this case on average 63% of the variation was explained by differences between leks.

Model	Term	Mean	95% lower	95% upper
Abundance of lekking males	Intercept	0.60	−0.32	1.36
	Before/after	−0.03	−0.51	0.48
	Random effect†	0.63	0.39	0.87
Distribution all lekking males	Intercept	30.67	21.83	40.93
	Before/after	3.16	0.57	5.86
	Random effect†	0.79	0.63	0.96
Distribution lekking males: group 1	Intercept	17.87	11.63	24.20
	Before/after	7.51	2.78	12.24
	Random effect†	0.23	<0.01	0.74
Distribution lekking males: group 2	Intercept	39.60	28.34	49.01
	Before/after	0.94	−2.13	4.29
	Random effect†	0.71	0.42	0.96

† The proportion of data that is explained by the random effect: lek.

explained by the difference between the leks (the random effect) and black grouse are still in decline in the region, strengthens the case that the abundance of black grouse is not affected by wind energy developments over the duration of our study. However, it could be that we did not find a significant change in black grouse abundance due to mitigation measures in the form of

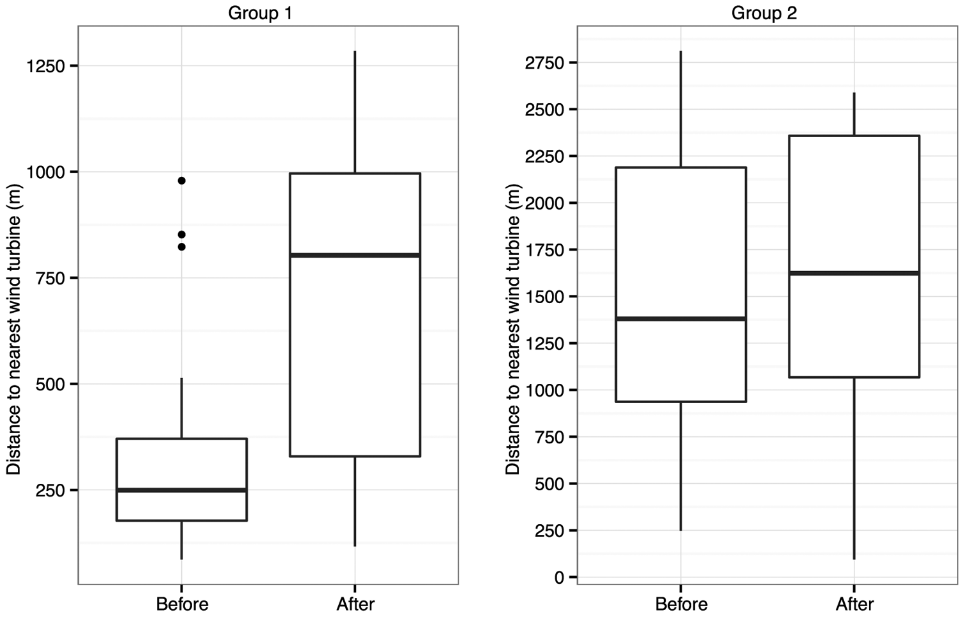

Fig. 2. A boxplot of the distance from lekking males to the nearest wind turbine. Group 1 includes the leks where the mean distance of black grouse records was below 937 m (n = 4 leks, left plot), Group 2 includes the sites where the mean distance of black grouse records was above 937 m (n = 5 leks, right plot). On the x-axis of each plot the data before wind energy development is displayed on the left and on the right the data after wind energy development.

habitat enhancement aimed to benefit black grouse at six out of the seven sites. Although it is interesting to note that black grouse persisted on all seven sites so even where no mitigation occurred black grouse populations remained extant.

We found some evidence of localized movement by black grouse leks which were generally within 500 m of the proposed turbines. The movement of lek sites could be driven by several causative factors. These include the operation of the wind energy development, volume of visitors, changes in land management both within and surrounding the site, and habitat enhancement measures designed to attract black grouse into specific areas. As black grouse require a range of habitat throughout the year which includes heathland, young and open forests, pastures and meadows (Bernard 1981, Picozzi and Hepburn 1986, Baines 1994, Angelstam et al. 2000), any change in the distribution of black grouse could be due to one or more of these factors mentioned above.

Even though we found that black grouse leks moved at some sites, it does not necessarily mean that they did not use the wind energy site area at all. At one of the study sites additional records were obtained during the winter months and any evidence of black grouse presence such as feathers, droppings and footprints were recorded during all surveys at this site. These extra records indicated frequent use of the area within 500 m of the turbines and occasional use of the area underneath the turbines (unpublished data). Further study is needed to determine how much and when black grouse use the wind energy site area.

Our results could have implications for planning applications as the information to assess potential effects of a planned wind energy development on black grouse is limited. For example, the SNH guidance stipulates that all leks within 1.5 km of a proposed onshore wind energy development should be surveyed (SNH 2010) and the RSPB buffered black grouse leks by a similar distance when producing its sensitivity guidance and maps in 2008 (Bright et al. 2008). Warren and Baines (2004) suggested suitable habitat should extend for 200–500 ha from a lek (which corresponds to 0.8–1.3 km buffer) and Cayford (1993) suggested that 500–700 ha may be enough to sustain one lek (which corresponds to 1.3 km and 1.5 km buffer). Our results show that black grouse found generally within 500 m of planned turbines moved locally after construction. Therefore detectable effects may be defined within 500 m of planned turbines. However we would suggest survey boundaries up to 1.5 km from wind turbines to gather information on local population change, especially if EIA and post-construction data from multiple sites are to be used for this species.

Insights into use of EIA data.—Our study provides an important example of how data that is gathered during EIAs and post-construction monitoring can be used to inform wider issues of potential effects of wind energy developments on wildlife and in turn inform planning decisions. In addition, we showed how researchers and developers could work together to provide an evidence base for land management decisions. Nonetheless, there are limitations with this type of data. Firstly, the data is not readily accessible. We had to contact six different wind energy developers as there is no central repository for this type of data. However, only one contact replied and provided data sets. Recently, there has been effort in Scotland to create a central repository for data from EIAs and post-construction monitoring by the Scottish Windfarm Bird Steering Group (www.swbsg.org). This is positive but ideally there should be a data repository across many countries so scientists and consultants could access this data for research and planning decisions. This would in turn mean that scientists can carry out studies that would include all sites where their species of interest is occurring and therefore make more robust conclusions about potential effects.

A second limitation of this data is that the proximate cause of an effect at a single site is not possible because the data are observational. However, if these data were more widely available this would be less of an issue.

Thirdly, survey effort differed between sites and between years which introduces variance. More consistency would have provided more power to detect effects of interest. For example, in our case the number of visits reduced after construction, and therefore if we had found a decline in the abundance of black grouse at wind energy developments we would not have known if this would have been due to reduced survey effort or if there really is a decline. A greater consistency in survey effort would make the data more useful, without necessarily increasing the cost or difficulty of data collection.

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