Spatial overlap of wind farms on peatland with sensitive areas for birds

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SUMMARY

The UK Government has set stringent targets for renewable energy generation, prompting a substantial increase in proposals for wind farms, notably in the Scottish uplands which have a particularly high wind resource. These upland areas also support many bird species of conservation concern, leading to potential conflict. To help minimise this conflict, a map has been created indicating areas in Scotland where especially careful planning of wind farms will be necessary to avoid adverse impacts on vulnerable bird species. This map is based on the locations of statutorily protected Special Protection Areas, plus eighteen bird species of conservation priority. It is used here to assess the proportion of current and proposed wind farms on peatland, whether these coincide with mapped sensitive areas for birds, and which species are most likely to be affected. A high proportion of wind farms are on peatland (by stage in planning process: scoping 40%, application 38 %, approved 23%, installed 55%), although the area of peatland is only *ca*. 12% that of Scotland. Peatland also contains a high proportion of sensitive areas for birds. Of the 1 km squares from the sensitivity map whose centres fall within peatland, 52% are high sensitivity, 32% medium sensitivity and 17% low/unknown sensitivity. This compares with figures of 37%, 31% and 32% respectively for Scotland overall. Species on the map that are associated with peatland are red-throated diver, black-throated diver, common scoter, hen harrier and arctic skua. Of these, hen harrier is the species most likely to coincide with current and future wind farm developments, and cumulative effects of peatland wind farms on this species require assessment.

KEY WORDS: bird conservation, bird sensitivity map, renewable energy, Scotland, wind turbine.

INTRODUCTION

Climate change is regarded as the greatest long-term threat to birds and other wildlife, with mid-range climate warming scenarios predicting that 15–37% of species world-wide will be 'committed to extinction' by 2050 (Thomas *et al.* 2004). In response to the threats posed by climate change, the proposed European Union Renewable Energy Directive has set a target of 20% of energy generation across member states to come from renewable sources by 2020, with the UK allocated a target of 15% (EU 2008). The Scottish Government's target is for 50% of electricity from renewables by 2020 (Scottish Executive 2008). Wind is currently one of the cheapest and most technologically advanced forms of renewable energy, and thus these targets have resulted in an increase in wind farm proposals. Scotland has one of the best wind resources in western Europe, and as a result, 42% of the UK's wind farm proposals are in Scotland, notably in upland habitats (BWEA 2008). The Scottish uplands also support many bird species of conservation importance including species listed in Annex I of the EU Birds Directive (EC 1979). Some of these species are concentrated in statutory Special Protection Areas (SPAs), but others are widely dispersed. Only 15% of the UK breeding population of golden eagle occurs within SPAs (Stroud *et al*. 2001).

Collision and disturbance displacement are the main adverse effects of wind farms on birds (see Langston & Pullan 2003, Hötker *et al.* 2006 and Drewitt & Langston 2006 for reviews). Effects can be site- and species-specific, but remain relatively poorly understood. Low collision rates have been recorded at many wind farms (e.g. reviews by Erickson *et al.* 2001, Langston & Pullan 2003, Percival 2005, Drewitt & Langston 2006), but there are notable exceptions where collision mortality has been high (e.g. Barrios & Rodríguez 2004, 2007, Everaert & Stienen 2006, Smallwood & Thelander 2008) and meta-analysis found reduced abundances at wind farm sites of wildfowl and waders in particular, but also of raptors and songbirds (Stewart *et al.* 2007).

Careful location of wind farms is key to minimising negative effects on birds (Langston &

Pullan 2003, Percival 2005, Langston *et al.* 2006, Stewart *et al.* 2007). Given the increasing demand for wind energy in the UK and particularly in Scotland, a strategic approach to locating wind farms is necessary to safeguard species of conservation concern. To aid this, a map of bird sensitivity to onshore wind farms was created for use as a planning tool, based on SPAs plus the distributions of eighteen bird species of conservation concern with known or suspected vulnerability to wind turbines (Bright *et al*. 2006, 2008). This map was used to assess the overlap of wind farms with occurrences of different bird species (Bright *et al*. 2008). Here, the distributions of peatland and wind farms are overlaid on the sensitivity map to assess the potential impact on peatland birds of planned wind farms in Scotland.

METHODS

Creation of the sensitivity map

The map was based on locations of SPAs, plus eighteen bird species of conservation concern (Table 1). SPAs are defined under Article 4 of the EU Birds Directive (EC 1979) as "most suitable territories" to deliver conservation of Annex I and regularly occurring migratory bird species. In particular, SPAs were used as surrogates for areas occupied by congregational species of wintering geese and other waterbirds, and colonial nesting seabirds, as a high proportion of their populations occur within SPAs (Stroud *et al.* 2001).

The SPA network accommodates only small proportions of the populations of some dispersed species, and so the distributions of a further eighteen species were included on the map. Fourteen of these were Annex I species for which the literature indicates sensitivity to collision risk or disturbance, particularly in relation to wind farms. Four additional species were included because, although not listed in Annex I, their UK distributions are very localised or they are undergoing rapid population decline and are not well represented within the SPA network.

Fairly comprehensive national surveys of many of these species take place at regular intervals, under the Statutory Conservation Agency/RSPB Breeding Bird Scheme (SCARABBS, Baker *et al.* 2006). For a few species, however, national survey data were supplemented with data from regional surveys. The most recent datasets available were used, but age of survey varied; and for some species - for example those using alternative breeding locations in different years - the data were from a span of years. Most national surveys are based on the locations of nests or birds in the breeding season, but survey units varied.

The map was created in a Geographical Information System (GIS). Distributional data were mapped separately for each bird species. These data were buffered according to species, e.g. with circles of fixed radius centred on nest locations or polygons including set margins around loch (lake) shorelines, and sensitivity ratings were applied to these buffered areas. Buffer radii and sensitivity ratings were determined following reviews of literature relating to territory size, foraging ranges, sensitivity to disturbance, collision risk and other relevant features of behavioural or population ecology for each species. Full details of data sources and buffer distances are provided elsewhere (Bright *et al*. 2006, 2008).

Buffered areas were assigned a rating of high or medium sensitivity for each species. Maps of buffered areas for each species were converted to 1 km square grids, and the individual species maps were then combined to produce a composite map by choosing the highest sensitivity rating of any species for each 1 km square. No weighting was given to the number of species occurring in each square, because the legal basis for recognising species of conservation concern does not distinguish between priority species. Sensitivity ratings on the composite map are defined as follows:

1. high sensitivity with respect to one or more species, or within an SPA - these areas merit particular care when locating wind farms;
2. medium sensitivity for one or more species; and
3. low/unknown sensitivity - not sensitive for any of the species on the basis of available data.

Assessing the sensitivity of peatlands

The sensitivity map was used to assess:

1. the extent to which current and proposed wind farms overlap with peatland;
2. the extent to which peatland areas correspond with sensitive areas for birds; and
3. which bird species are most likely to be affected.

BGSDiGMap-62 5000 (British Geological Survey 2008) data were used to form a layer of peat soils in Scotland. Wind farm locations were obtained from the Scottish Natural Heritage (SNH) renewable energy database (February 2007 version, SNH unpublished). Wind farms were at one of four stages in the planning process, namely installed (operational), approved (planning consent granted), application (planning permission sought), or scoping (registered with the planning authority in order to seek direction for environmental assessment).

Table 1. Overlap of different bird species with peatland and peatland wind farms.

Species	**Total locations plotted (number)**	**Number (%) of centres of locations that fall within peatland**	**Number of peatland locations for which buffers overlap wind farm footprints (% of total locations plotted)**		**Scottish population estimate**
			Installed wind farms	**All[1] wind farms**	
Red-throated diver *Gavia stellata*	2,021	845 (42)	4 (<1)	48 (2)	935 breeding pairs (Gibbons *et al*. 1997)
Black-throated diver *Gavia arctica*	305	57 (19)	0 (0)	6 (2)	180 summering pairs (Whyte *et al*. 1995)
Slavonian grebe *Podiceps auritus*	56	5 (9)	0 (0)	0 (0)	44 pairs (RSPB unpublished data 2005)
[2]**Bean goose** *Anser fabalis*	1	0 (0)	n/a	n/a	300 birds in 2005/06 (M. Trubridge, pers. comm.)
[2]**Common scoter** *Melanitta nigra*	88	43 (49)	0 (0)	0 (0)	95 pairs (Underhill *et al*. 1998)
Red kite *Milvus milvus*	166	0 (0)	n/a	n/a	82 pairs (RSPB unpublished data)
White-tailed eagle *Haliaeetus albicilla*	37	1 (3)	0 (0)	0 (0)	Over 30 pairs (Evans & Wilson unpublished)
Hen harrier *Circus cyaneus*	499	171 (34)	10 (2)	29 (6)	633 breeding pairs (Sim *et al*. 2007)
Golden eagle *Aquila chrysaetos*	438	41 (9)	0 (0)	8 (2)	430 breeding pairs (Eaton *et al*. 2007a)
Peregrine falcon *Falco peregrinus*	609	30 (5)	0 (0)	5 (1)	542 breeding pairs (Banks *et al*. 2003)
[2]**Black grouse** *Tetrao tetrix*	1,444	84 (6)	0 (0)	19 (1)	3,344 displaying males (Sim *et al*. unpublished)

continued ….

Table 1 continuation

Species	**Total locations plotted (number)**	**Number (%) of centres of locations that fall within peatland**	**Number of peatland locations for which buffers overlap wind farm footprints (% of total locations plotted)**		**Scottish population estimate**
			Installed wind farms	**All[1] wind farms**	
Capercaillie *Tetrao urogallus*	3,231	37 (1)	0 (0)	0 (0)	1,980 males (Eaton *et al*. 2007b)
Corncrake *Crex crex*	797	30 (4)	0 (0)	0 (0)	1,067 calling males (O'Brien *et al*. 2006.)
[2]**Arctic skua** *Stercorarius parasiticus*	84	25 (30)	0 (0)	1 (1)	2,136 apparently occupied territories (Mitchell *et al*. 2004)
Nightjar *Caprimulgus europaeus*	17	2 (12)	0 (0)	0 (0)	27 churring males (Conway *et al*. 2007)
Chough *Pyrrhocorax pyrrhocorax*	82	4 (5)	0 (0)	0 (0)	83 pairs (Finney & Jardine 2003)

[1] This category includes scoping, application, approved and installed wind farms.
[2] Species not listed in Annex I of the EU Birds Directive (EC 1979).
For golden plover *Pluvialis apricaria* and dunlin *Calidris alpina schinzii* the only comprehensive data available were at the 10 km square level of resolution. For this reason, squares containing high densities of these species were denoted as 'medium sensitivity' on the map in order to highlight possible hotspots for planners, but they were not included in the analyses because of the coarse resolution of data.

Locations of wind farms in the database were given as single central point references. For analysis, the footprints of the wind farms were estimated from their output capacities. The relationship was quantified using turbine locations extracted from available Environmental Statements for 46 wind farms in the UK. The turbine locations were plotted and buffered by 100 m to prevent linear arrays or single turbines from having zero area. The outer edges of buffers within 1 km of each other were then joined to create a footprint for each wind farm. The following predictive relationship ($R^2 = 0.98$) between footprint F (km^2) and output capacity O measured in MW was derived using linear regression:

$$F = (7E\text{-}05 \times O^2) + (0.0505 \times O) + 0.0295 \qquad [1]$$

This relationship was used to estimate the footprints of all wind farms in the SNH database, and a circular buffer of the appropriate area was then drawn around each central point to represent footprint size. In cases where the output capacity of the wind farm was not given (installed 6/38, approved 4/39, application 73/159, scoping 42/91), the median value for wind farms at the same stage of planning was used (installed = 7.5 MW, approved = 17.5 MW, application = 30 MW, scoping = 33 MW). Wind farms with output capacities below 1 MW (n = 18, generally single turbines) were excluded from the analyses.

The sensitivity map was overlaid with the peatland and wind farm maps in GIS in order to calculate the statistics listed below.

1. The number of estimated footprints of wind farms at each stage in the planning process intersecting with the peatland area (i.e. how many wind farms overlapped with peatlands).
2. The proportions of 1 km squares whose centres fell within peatland with, respectively, high, medium and low/unknown sensitivity ratings (i.e. what proportion of squares of each sensitivity ranking coincided with peatland). These were compared with the proportions of different sensitivity ratings amongst non-peatland squares using a Chi-square test.
3. The proportion of bird locations for each species included in the sensitivity map that fell within peatland (i.e. which species showed significant associations with peatland), and which of these were most likely to be affected by current and potential future wind farm development (i.e. to what extent buffered bird distributions overlapped with wind farm footprints). In order to assess the association of different species with peatland, the number of species for which the centre of the buffered area coincided with peatland was calculated. These central points represented different features for different species (e.g. nest site location, centre of breeding territory, centre of breeding loch). They were used as an index of the number of birds on peatland, which was compared with the number expected by chance (taken to be 12% of the total number of locations, this being the percentage of Scotland's area that is peatland) using a Chi-square test to test for significance of associations. To test which species might be affected by wind farms on peatland, either currently or in the future, the number of buffered locations for each species that intersected with footprints of (a) installed wind farms, and (b) wind farms at all stages in the planning process (installed, approved, application and scoping) was calculated. Again, the buffered areas represented different features according to species, for example approximating foraging range for some and a breeding loch plus disturbance distance for others (see Bright *et al*. 2006 for full details). Where a species had both high and medium sensitivity buffered areas, only the high sensitivity buffers were used for this analysis (representing either the core range, or more recent data).

RESULTS

Proportion of wind farms on peatland

The peat soils layer for Scotland had a total area of 9,720 km^2, comprising approximately 12% of the total area of the country. Overall, 40% of all wind farms at the scoping stage, 38% of wind farm applications, 23% of approved wind farms and 55% of installed wind farms were on peat soils (Figure 1).

Bird sensitivities to peatland wind farms

The sensitivity map is presented at the tetrad (2 km square) scale of resolution in Figure 2. This version is based on the 1 km square map, but the underlying 1 km square sensitivity ratings are not presented in order to protect locations of species that are vulnerable to persecution. If a tetrad contained any high sensitivity 1 km squares it was shaded red, and if it contained no high sensitivity but one or more medium sensitivity squares, it was shaded yellow. Colour intensity increases with increasing number of high or medium sensitivity squares within the tetrad. Low/unknown sensitivity areas are unshaded.

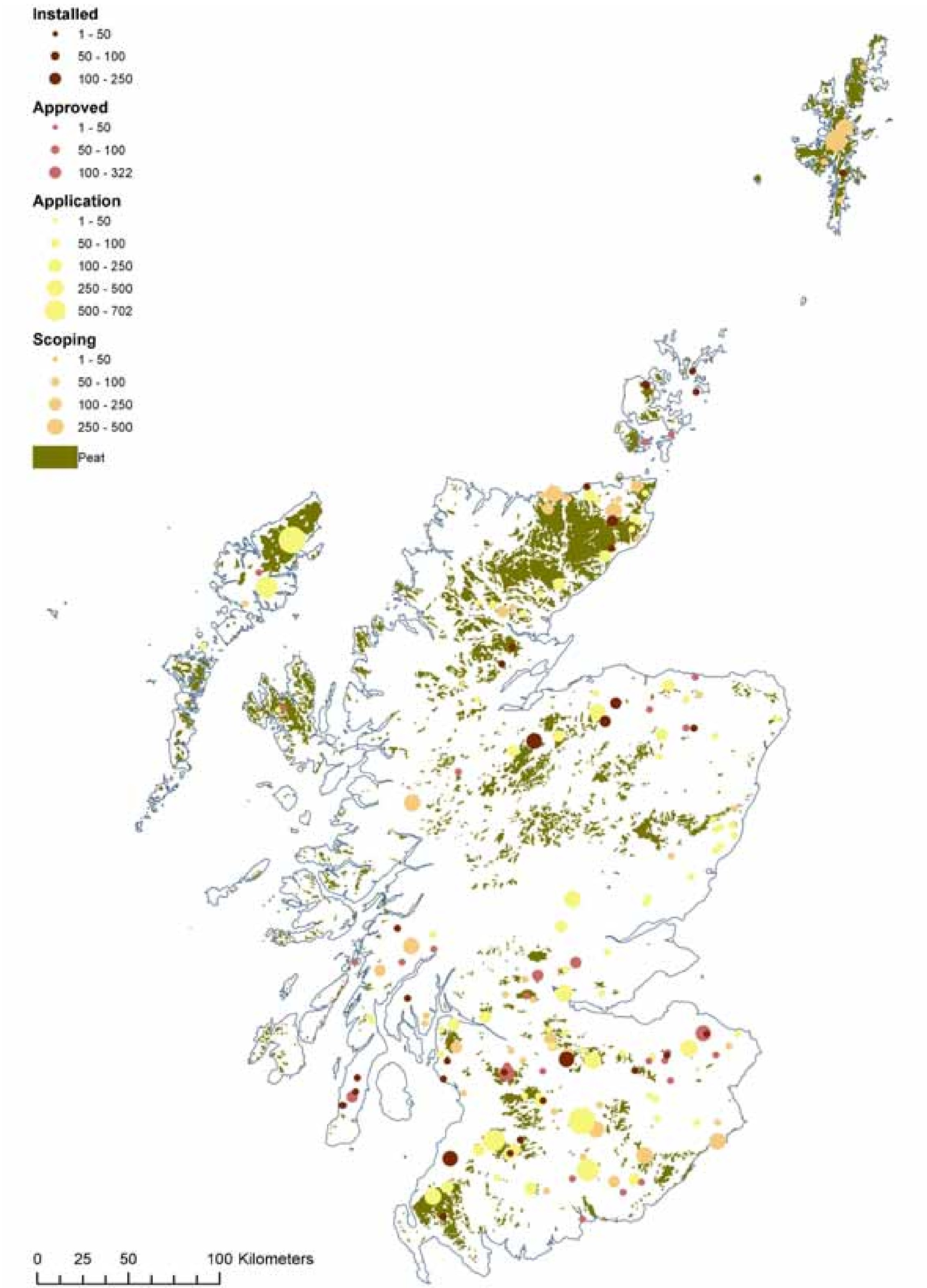

Figure 1. Wind farms at different stages of the application process (SNH unpublished, February 2007) overlaid on the distribution of peat drift in Scotland (British Geological Survey 2008), which is used to indicate the distribution of peat soils and peatland. The sizes of the circles indicate energy output capacities in MW.

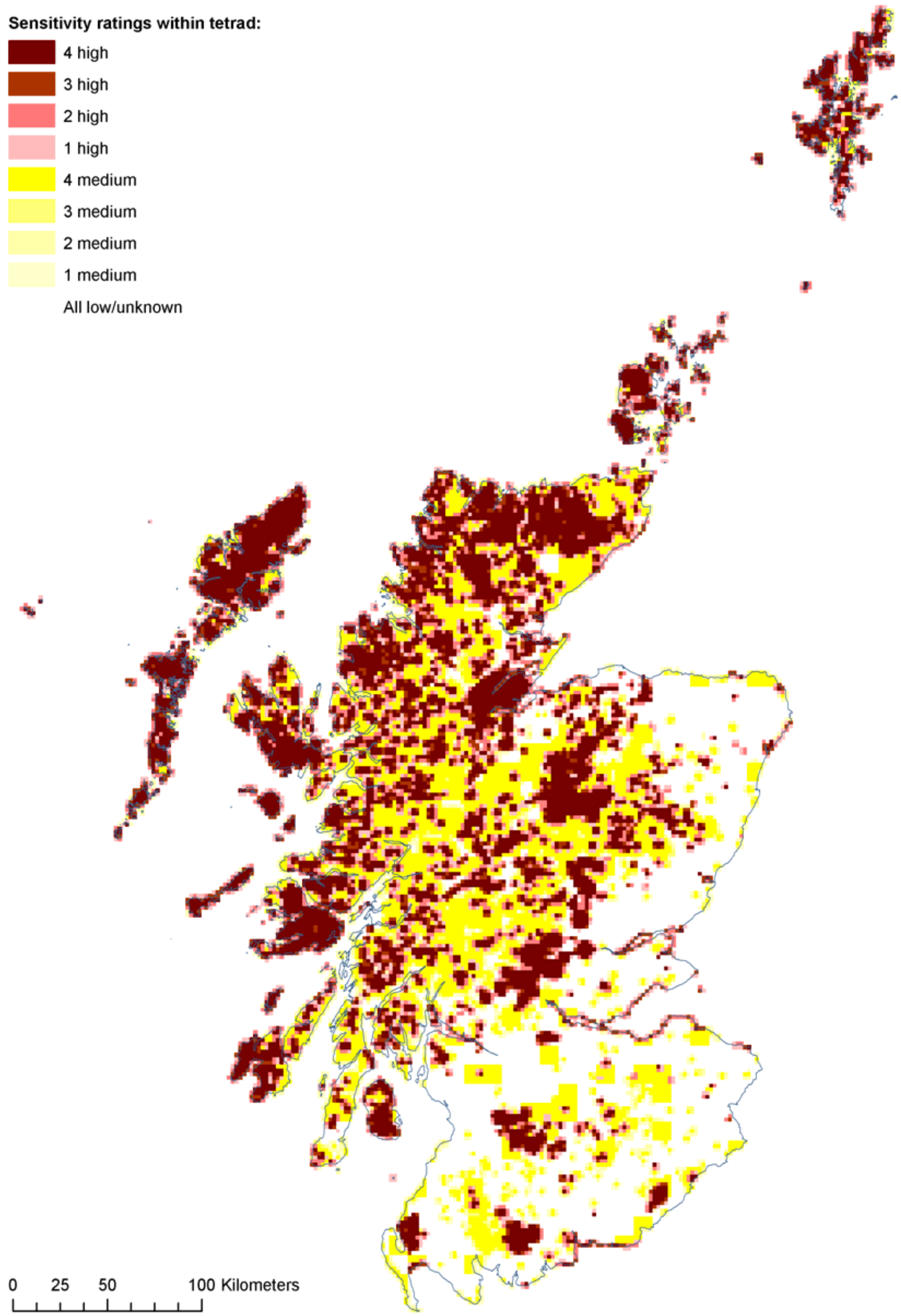

Figure 2. Map of sensitive areas for birds in the context of onshore wind farm development in Scotland, presented at the tetrad (2 km x 2 km) level of resolution to protect locations of vulnerable species.
This Figure was published in *Biological Conservation* (2008), Bright, J., Langston, R., Bullman, R., Evans, R., Gardner, S. and Pearce-Higgins, J. Map of bird sensitivities to wind farms in Scotland: A tool to aid planning and conservation. Copyright Elsevier.

Overall, the overlap between 1 km squares from the bird sensitivity map and peatland was as follows: 52% of squares had a rating of high sensitivity, 32% medium sensitivity, and 17% low/unknown sensitivity. For non-peatland squares, 35% were high, 31% medium and 34% low/unknown sensitivity, with the figures for Scotland overall being 37%, 31% and 32% respectively. Significantly more peatland than non-peatland squares had a rating of high sensitivity (χ^2_1 = 525.05, $p < 0.0001$). Of the high sensitivity squares on peatland, 53% were within SPAs, compared with 28% of high sensitivity non-peatland squares (χ^2_1 = 2061.88, $p < 0.0001$).

Sensitive bird locations in peatland areas

Five of the sixteen species showed significant associations with peatland. These were red-throated diver (χ^2_1 = 1700.81, $p < 0.0001$), black-throated diver (χ^2_1 = 12.92, $p < 0.0001$), common scoter (χ^2_1 = 113.24, $p < 0.0001$), hen harrier (χ^2_1 = 234.33, $p < 0.0001$) and arctic skua (χ^2_1 = 25.09, $p < 0.0001$). Five species showed neither preference for nor avoidance of peatland; these were Slavonian grebe (χ^2_1 = 0.50, $p = 0.479$), bean goose (χ^2_1 = 0.14, $p = 0.712$), white-tailed eagle (χ^2_1 = 3.03, $p = 0.08$), golden eagle (χ^2_1 = 2.89, $p = 0.09$) and nightjar (χ^2_1 = 0.0009, $p = 0.98$). The remaining six species were found on peatland less often than expected by chance; these were red kite (χ^2_1 = 22.64, $p < 0.0001$), peregrine falcon (χ^2_1 = 28.86, $p < 0.0001$), black grouse (χ^2_1 = 52.27, $p < 0.0001$), capercaillie (χ^2_1 = 360.51, $p < 0.0001$), corncrake (χ^2_1 = 51.19, $p < 0.0001$) and chough (χ^2_1 = 3.94, $p < 0.0001$).

The species occurring most commonly on peat soils were common scoter, red-throated diver and hen harrier, with 49%, 42% and 34% of the locations plotted on the map occurring on peat soils. Thirty percent of locations for arctic skua and 19% for black-throated diver were on peat soils.

Of the bird locations on peat soils, buffered areas (i.e. areas within which birds may be vulnerable to effects of wind farm development) intersected with estimated installed wind farm footprints only for hen harrier and red-throated diver. For hen harrier, ten of the buffered areas (2% of all buffered areas) overlapped with an installed wind farm footprint; for red-throated diver the figure was four (0.2% of all buffered areas). Considering wind farms at all stages in the planning process, overlap with buffered areas for birds was relatively low for most species, the highest overlap being 6% of all buffered areas for hen harrier.

DISCUSSION

Wind farms in Scotland are disproportionately more likely to be sited on peatland than on other soil types. This is not unexpected, as peatlands often occur in upland areas, which have high wind resources; although there are also considerable wind resources outside these areas (Figure 3). However, it could place peatland birds under greater pressure from wind farm development than birds of other habitats.

Peatlands are also more likely to contain sensitive bird areas. The bird data used to produce the sensitivity map represent different attributes for different species (e.g. a nest site or sighting of a bird showing evidence of breeding behaviour). Data from more than one year were used for some species, and in other cases not all locations were breeding locations (Bright *et al*. 2006). However, the proportion of locations on peat for each species was used as an index of association with peatland. Species that have significant associations with peatland are red-throated diver, black-throated diver, common scoter, hen harrier and arctic skua.

Given the large number of proposed wind farms on peatland and the association with peatland of several bird species of conservation concern, there is potential for conflict between bird conservation and wind energy. However, the analysis shows that at present there is little or no overlap between installed wind farms on peatland and most bird species. The highest overlap was for hen harrier, with 2% of all buffered areas overlapping with the estimated footprints of currently installed wind farms on peatland. For wind farms at all stages of the planning process (installed, approved, application and scoping), 6% of buffered areas for hen harrier or 17% of hen harrier locations on peatland overlap with the estimated footprints of existing or proposed wind farms. Previous analysis to assess the overlap of all wind farms with all hen harrier buffers (i.e. both on and off peatland) found that 13% of hen harriers were potentially affected (Bright *et al*. 2008). The proportion affected by wind farms on peatland will be a subset of this (given that only approximately 12% of Scotland's area is peatland), hence the 6% figure. However the fact that 17% of hen harrier buffers on peatland overlapped with wind farms suggests a closer correspondence between hen harriers and wind farm development on peatland than in non-peatland habitats. Therefore, cumulative effects of wind farms on peatland in particular need to be considered for this species.

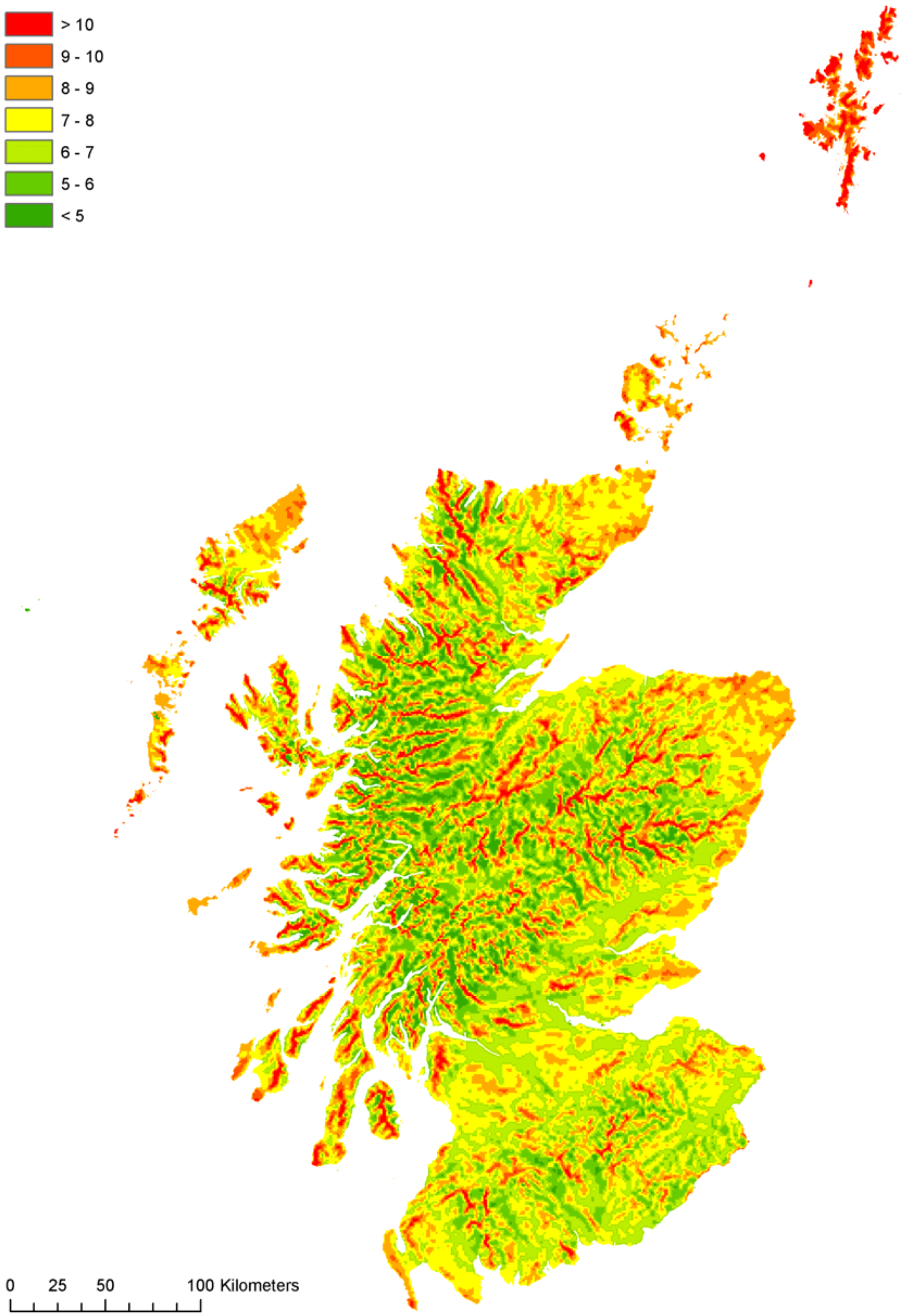

Figure 3. Map of Scotland showing annual mean wind speed (m s^{-1}) at 45 metres above ground level by 1 km square (BERR 2007).

Generally, current and potential wind farm developments occur outside the most sensitive areas for birds (Figures 1 and 2). It is hoped that the sensitivity map will help to maintain this situation, and will facilitate careful planning within peatland areas to help balance future wind farm development and bird conservation.

The map was created using the best currently available data and information, but there are inevitably caveats that apply to its use. Unfortunately, data deficiency and gaps in survey coverage ruled out a distinction between low and unknown sensitivity squares. Some peatland species, such as dunlin and golden plover, could not be included due to data deficiency (but see Pearce-Higgins *et al*. (2008) for a coarser-scale assessment of the likely impacts of wind farms on golden plover in Scotland). Thus, the map is intended as an indicative tool, and is not a substitute for site-specific Environmental Impact Assessment. The level of information on which buffer distances and sensitivity ratings were based also varied, being fairly comprehensive for some species but sparse for others. The map should be updated as new information becomes available.

The bird sensitivity map can be used by consenting authorities, in combination with other constraints to wind farm development, to identify preferred areas for wind farm development within a region. An example may be found in the Highland Renewable Energy Strategy (Aquatera 2006). The map is also intended to aid developers during site selection.

Scotland was considered a priority within the UK for sensitivity mapping, as it has the highest number of onshore wind farm proposals. The approach is currently being extended to England and could be exported to other countries. Furthermore, a similar approach could be used to highlight areas of high bird sensitivity to other types of development.

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