Effects of wind farm construction and operation on mire and wet heath vegetation in the Monte Maior SCI, north-west Spain

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SUMMARY

As part of the environmental impact assessment for the construction of a wind farm within the Monte Maior Natura 2000 Site of Community Importance (SCI) in Galicia, north-west Spain, a complete analysis of the development site's important mire and wet heath plant communities was performed. The study included phytosociological characterisation, species-area metrics, calculation of α and β diversity, and analysis of physiognomical characteristics such as life forms, distribution ranges and phenology. Permanent quadrats were monitored for three years after construction of the wind farm in order to identify and describe any changes in floristic composition. Two phytosociological associations were recognised in mire habitat, namely *Eleocharitetum multicaulis* (Litorelletea uniflorae) and *Carici durieui-Sphagnetum papillosi* subas. *ericetosum mackaianae* (Oxycocco-Sphagnetea), whilst the wet heath was assigned to *Gentiano pneumonanthe-Ericetum mackaianae* (Calluno-Ulicetea). The two plant communities shared most physiognomical characteristics and 13–33% of species. Low values were obtained for α and β diversity, with about nine species per square metre for heathland and ten species per square metre for mire habitat. Hemicryptophytes dominated and no therophytes were recorded. The dominant plant families were Poaceae in heathlands and Cyperaceae in mires, and most of the species flowered in early or late summer. Both communities were stable and no change in any of the attributes investigated was observed during the study period. The results indicate that, so long as the traditional land use of low-intensity grazing can be maintained, there are no major hazards for these plant communities. However, some of the data suggest that the improvement of access to the area provided by the wind farm may result in an increase in human activity which could affect environmental conditions and thus the longer-term stability of the plant communities.

KEY WORDS: European Habitats Directive, Galicia, heathland, nature conservation, peatland, Viveiro.

INTRODUCTION

Viveiro Wind Farm was constructed in 2003. It is located in the northern part of Lugo province, Galicia (Spain) (Figure 1). The climate of northern Galicia, with low annual temperature range and absence of drought in summer, supports wet habitats and species which require conditions of constant humidity. Accordingly, some of the most important Spanish sites for mire and wet heath are located here. Indeed, the only blanket bogs on the Iberian peninsula are found nearby, within the "Serra do Xistral and Montes de Buio" nature conservation area (Martínez-Cortizas & García-Rodeja 2001). The environmental importance of the Viviero site and its habitats is such that several studies relating to nature conservation value were carried out in conjunction with its development as a wind farm.

The European Union (EU) Habitats Directive (43/92/CEE) provides for the conservation of endangered habitats and species, and for establishment of the NATURA 2000 network of Sites of Community Importance (SCIs) (EU 1992, 2007). In Galicia, 56 SCIs have been proposed for the Atlantic biogeographical region of NATURA 2000. The most important natural features are coastal communities, forests and various endemic and macaronesian species, but wet heaths and mires are also important because of their extensive representation and favourable condition.

The so-called "priority habitats" are considered to be closest to extinction. Habitat 4020 "Southern Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix*", a type of "Temperate heath and scrub", is listed as a priority habitat. Wet heath with *Erica mackayana* belongs in this category, although *E. tetralix* and *E. mackayana* are rarely found growing together. The priority habitats for the group "Raised bogs and mires and fens" are raised and blanket bogs. Other important habitats in this group are "Transition mires and quaking bogs" (7140) and "Depressions on peat substrates" (7150).

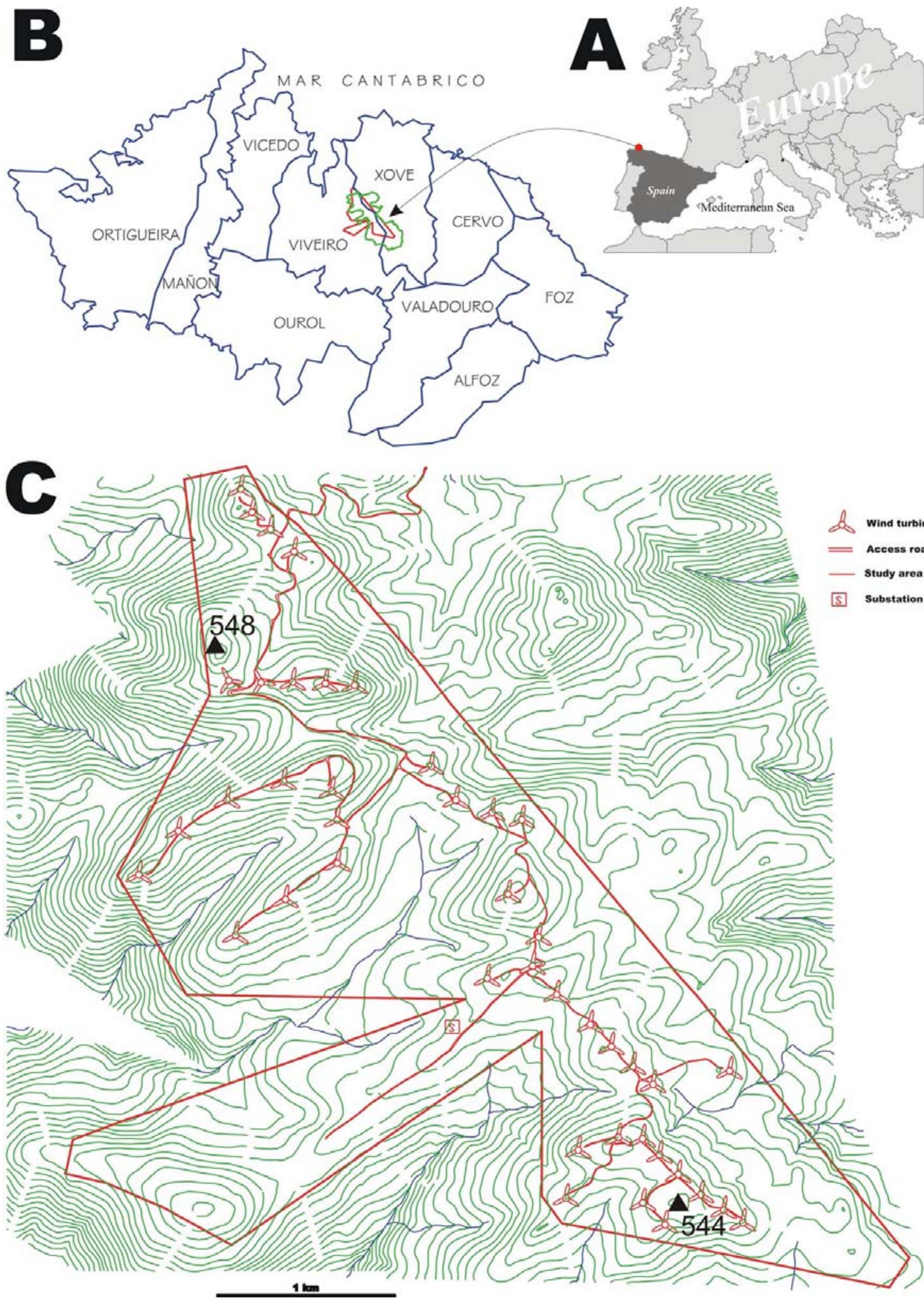

Figure 1. A: location of the study site in Europe; B: the study area (red boundary) and Monte Maior SCI (green boundary); C: layout of Viveiro Wind Farm superposed on topographical contours (altitude interval 10 m); spot heights are in metres a.s.l.

Aeolian energy and wind farm planning and construction have been major economic and social issues in Galicia for the last decade. The legislative requirements for the construction of wind farms state that "...the detail level of the environmental evaluation may vary according to the sensitivity of the area" (Xunta de Galicia 2004). For Viveiro Wind Farm, a detailed analysis of the impact on mires and wet heaths was required on account of their high nature conservation value. The impact study consisted of two major elements, namely a detailed floristic and vegetation analysis based on records of plant species presence and cover in permanent plots, and a general impact assessment of how wind farm construction affected the vegetation of the area. This paper presents the results of the first study and an outline of the second.

METHODS

Study site

The Monte Maior SCI (43º 38` N, 7º 32` W) is located in the north of Galicia, within the administrative areas of Viveiro and Xove Councils (Figure 1). It covers an area of 1,247 ha and reaches a maximum height of 552 m above sea level. Its designation was proposed by the Xunta de Galicia (Galician government) in 2001 and it was finally recorded as an EU SCI in 2004 (Community Decision 2004/813/EC). Its most important nature conservation feature is the extent of well-preserved mires and wet heathlands that it contains.

Viveiro Wind Farm was constructed by the company GAMESA ENERGÍAS RENOVABLES S.A. in 2003, and comprises 43 G-52 wind turbines (850 MW). The wind farm study area defined for the present work extends to 870 ha (Figure 1).

Habitat survey

For the initial general characterisation of the vegetation, plant communities (habitats) were identified and mapped at scale 1:5,000 according to the Braun-Blanquet phytosociological classification (Izco *et al*. 1999, 2000). For mire and wet heath, a conservation index (high, medium or low conservation status) was subjectively assigned on the basis of floristics and physiognomy. For wet heath, areas of medium conservation status were further categorised as being affected by forestry, by cattle grazing, or by both.

Complete floristic analyses were carried out for mire and wet heath, which were considered to be the most important plant communities present. Doubtful samples were collected and stored at the SANT herbarium (University of Santiago de Compostela).

Plot sampling

Different sampling strategies were adopted for mire and wet heath, in order to take account of the differences in their vegetation structure. For mire, a transect line was set out across the habitat patch and several plots (0.5 m x 0.5 m, separated by 1 m spaces) were marked along it. In total, 16 mire plots were established. For wet heath, expanding plots (Figure 2) were used because this is a more complex habitat than mire which displays small-scale heterogeneity. Nine plots were established on wet heath. For every plot sampled, each plant species was recorded and a cover value was assigned. Other data recorded were lichen and moss cover (*Sphagnum* cover on mire) and the extent of open water (on mire), along with total cover and maximum height of the vegetation.

All plots were permanently marked and the survey was repeated after construction of the wind farm and annually thereafter, in order to follow any temporal changes in vegetation.

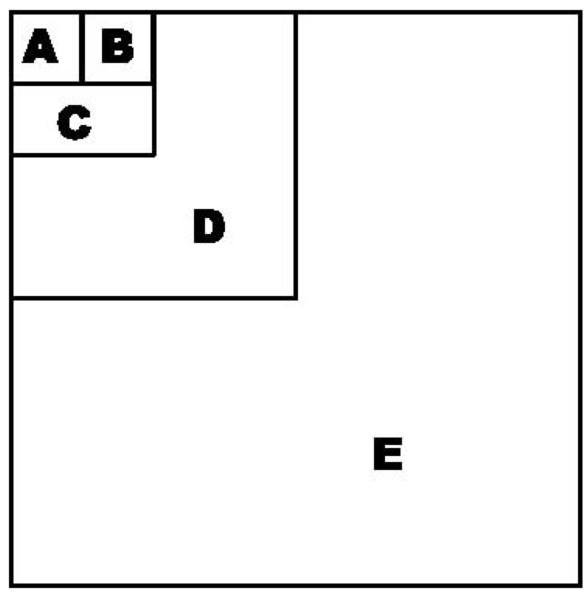

Figure 2. Expanding plot design for sampling heath vegetation. Species presence and cover was recorded first in Sub-plot A (0.5 m x 0.5 m). Any additional species were then recorded in Sub-plots B, C, D and E; and finally cover values were recorded for the whole plot (4 m x 4 m).

Numerical analyses

Floristic analysis was performed by constructing a species-site matrix for each habitat. The plant communities were identified using two-way indicator species analysis (TWINSPAN, ter Braak 1995). This ordination method permits the user to search for block structures of species and sites on the basis of cluster analysis. It was used for mire habitat only, because of the complexity of the communities that occur there. Two diversity indices were calculated. α diversity was calculated as the mean number of species per quadrat. β diversity was obtained as proposed by Fontaine *et al.* (2007), with values ranging from 0 (all plot species lists the same) to 100 (no repetition of species between plots). Species-area and average distance curves were calculated by the Jaccard method using SPSS for Windows and PC-ORD4 (McCune & Mefford 1999).

Impact analysis

A complete survey methodology, adapted from Conesa (1993), was designed to cover every type of impact on the target vegetation communities. Four sites were selected for each habitat type. Numerical values were calculated for 15 different impacts, grouped under the headings water, materials, emissions and (direct impacts on) vegetation (Table 1). When a new impact was detected, it was added to the table. The impact value for each issue and site was calculated as *Magnitude* (M) using the formula

$$M = (3 \times I) + (2 \times E) + D + P + R \qquad [1]$$

where I = *Intensity*, range of scores 1–3; E = *Extent*, >150% (score 1), >200% (score 2) or >400% (score 3) of the area directly affected by the activity in question; D = *Duration*, immediate (1), short

Table 1. Impact assessment system for mire and wet heath habitats, showing how partial and final total values for each of the sites assessed were derived from the individual impact scores. The letters *a – t* represent the values of M (Equation 1) which were calculated for each impact as described in the text. When the table was fully populated, Totals 1–4 and the Final Total for the site were calculated as shown.

	Habitat	Wet heath				Mire (enter M x 1.5)				**Total 1**	**Total 2**
Impact group	**Site** / **Impact**	**H.1**	**H.2**	**H.3**	**H.4**	**M.1**	**M.2**	**M.3**	**M.4**		
Water	Stream desiccation	$a_{H.1}$	$a_{H.2}$	$a_{H.3}$	$a_{H.4}$	$a_{M.1}$	$a_{M.2}$	$a_{M.3}$	$a_{M.4}$	Σa	sum of Σa–Σf
	Stream diversion	$b_{H.1}$	$b_{H.2}$	$b_{H.3}$	$b_{H.4}$	$b_{M.1}$	$b_{M.2}$	$b_{M.3}$	$b_{M.4}$	Σb	
	Turbid water	$c_{H.1}$	$c_{H.2}$	$c_{H.3}$	$c_{H.4}$	$c_{M.1}$	$c_{M.2}$	$c_{M.3}$	$c_{M.4}$	Σc	
	Dumping in water	$d_{H.1}$	$d_{H.2}$	$d_{H.3}$	$d_{H.4}$	$d_{M.1}$	$d_{M.2}$	$d_{M.3}$	$d_{M.4}$	Σd	
	Algal contamination	$e_{H.1}$	$e_{H.2}$	$e_{H.3}$	$e_{H.4}$	$e_{M.1}$	$e_{M.2}$	$e_{M.3}$	$e_{M.4}$	Σe	
	Loss of aquatic vegetation	$f_{H.1}$	$f_{H.2}$	$f_{H.3}$	$f_{H.4}$	$f_{M.1}$	$f_{M.2}$	$f_{M.3}$	$f_{M.4}$	Σf	
Materials	Loss of superficial soil layers	$g_{H.1}$	$g_{H.2}$	$g_{H.3}$	$g_{H.4}$	$g_{M.1}$	$g_{M.2}$	$g_{M.3}$	$g_{M.4}$	Σg	sum of Σg–Σk
	In situ alteration of superficial soil layers	$h_{H.1}$	$h_{H.2}$	$h_{H.3}$	$h_{H.4}$	$h_{M.1}$	$h_{M.2}$	$h_{M.3}$	$h_{M.4}$	Σh	
	Dumping	$i_{H.1}$	$i_{H.2}$	$i_{H.3}$	$i_{H.4}$	$i_{M.1}$	$i_{M.2}$	$i_{M.3}$	$i_{M.4}$	Σi	
	Material gathering	$j_{H.1}$	$j_{H.2}$	$j_{H.3}$	$j_{H.4}$	$j_{M.1}$	$j_{M.2}$	$j_{M.3}$	$j_{M.4}$	Σj	
	Accumulation of exogenous material	$k_{H.1}$	$k_{H.2}$	$k_{H.3}$	$k_{H.4}$	$k_{M.1}$	$k_{M.2}$	$k_{M.3}$	$k_{M.4}$	Σk	
Emissions	Dust on vegetation	$m_{H.1}$	$m_{H.2}$	$m_{H.3}$	$m_{H.4}$	$m_{M.1}$	$m_{M.2}$	$m_{M.3}$	$m_{M.4}$	Σm	Σm
Vegetation (enter M x 1.5)	Species loss	$n_{H.1}$	$n_{H.2}$	$n_{H.3}$	$n_{H.4}$	$n_{M.1}$	$n_{M.2}$	$n_{M.3}$	$n_{M.4}$	Σn	sum of Σn–Σq
	New species	$p_{H.1}$	$p_{H.2}$	$p_{H.3}$	$p_{H.4}$	$p_{M.1}$	$p_{M.2}$	$p_{M.3}$	$p_{M.4}$	Σp	
	Changes in cover	$q_{H.1}$	$q_{H.2}$	$q_{H.3}$	$q_{H.4}$	$q_{M.1}$	$q_{M.2}$	$q_{M.3}$	$q_{M.4}$	Σq	
Other	Impact 1	$r_{H.1}$	$r_{H.2}$	$r_{H.3}$	$r_{H.4}$	$r_{M.1}$	$r_{M.2}$	$r_{M.3}$	$r_{M.4}$	Σr	sum of Σr–Σt
	Impact 2	$s_{H.1}$	$s_{H.2}$	$s_{H.3}$	$s_{H.4}$	$s_{M.1}$	$s_{M.2}$	$s_{M.3}$	$s_{M.4}$	Σs	
	Impact 3	$t_{H.1}$	$t_{H.2}$	$t_{H.3}$	$t_{H.4}$	$t_{M.1}$	$t_{M.2}$	$t_{M.3}$	$t_{M.4}$	Σt	
	Total 3	Σ H.1	Σ H.2	Σ H.3	Σ H.4	Σ M.1	Σ M.2	Σ M.3	Σ M.4	**Final Total: Σ(Total 2) or Σ(Total 4)**	
	Total 4	sum of ΣH.1– ΣH.4				sum of ΣM.1– ΣM.4					

term (2) or long term (3) impact; *P* = *Persistence*, not permanent (1), permanent for a short (2) or long (3) time; *R* = *Reversibility*, easily reversible (1), hardly reversible (2) or irreversible (3). Because mire habitat was rare and the aim was to assess impacts on vegetation, scores for mire and for issues affecting vegetation were multiplied by 1.5. Alert values of *M* were set at 75% of the maximum value for any cell within the table, 50% of the maximum value for any of Totals 1–4 (Table 1), and 40% of the maximum Final Total. Ceiling values were set at *M* = 90% of the maximum value for any cell, 75% of the maximum value in 50% of cells, 75% of the maximum value for any of Totals 1–4 (Table 1), and 60% of the maximum Final Total. An alert or ceiling value would trigger a detailed study of the impacts and communication of the situation and results to the developer. The impact assessment was performed before and during construction of the wind farm, and is now being continued on an annual basis during operation of the facility.

RESULTS

Vegetation survey

Nine vegetation types (habitats) were identified and mapped within the study area (Figure 3). Pasture, dry heath with *Ulex*, oak forest and riparian forest occupied a small percentage of the total area. Chasmophytic vegetation, mire and regenerating forest were more widespread. Heath was the most extensive habitat, with some areas coded as highly conserved but most with medium conservation index (Figure 4). The main impacts were conversion of heathland to pasture, forestry (*Eucalyptus*, *Acacia* and *Pinus*), and drainage of mire associated with increased intensity of grazing by cattle. The floristic analysis recorded 46 species in the areas identified as mire and wet heath (see Appendix).

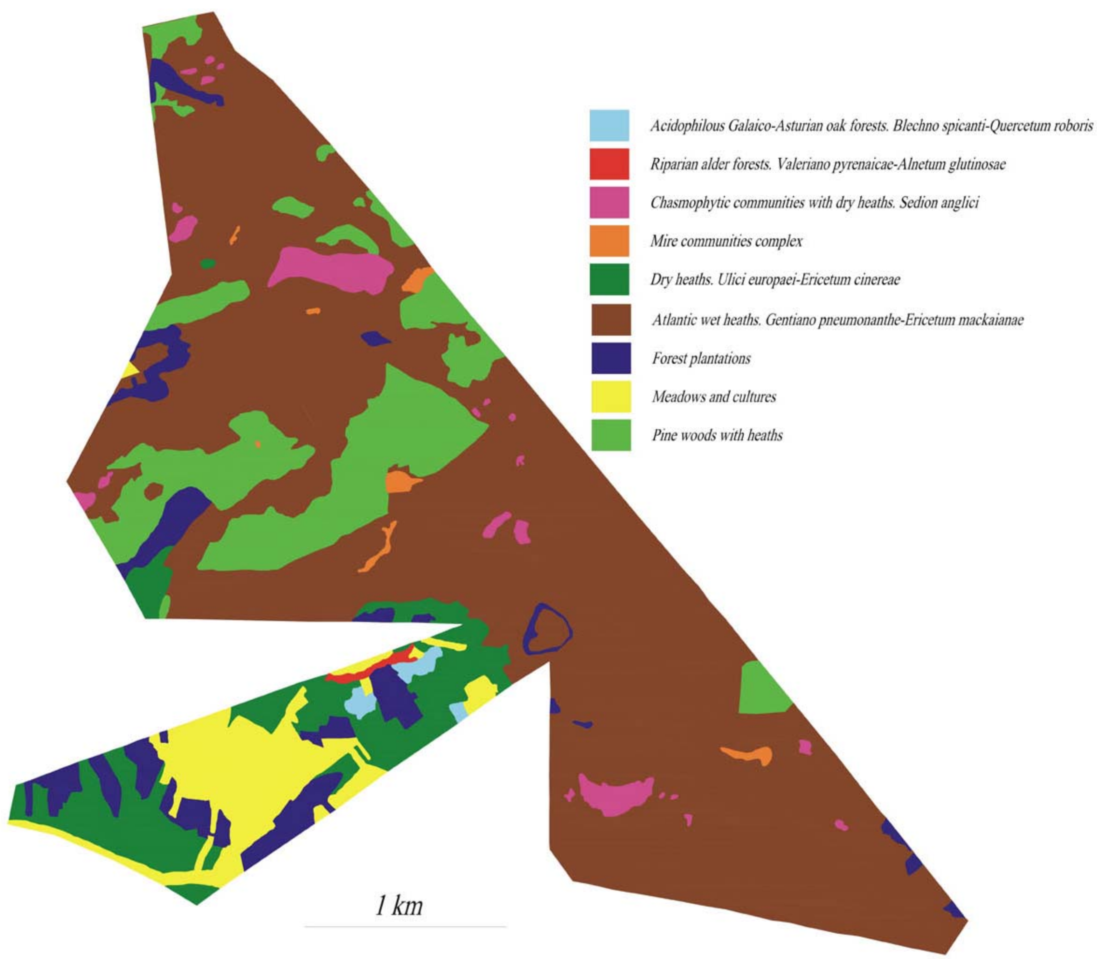

Figure 3. Map of the study area showing the distribution of vegetation types (habitats).

Figure 4. Conservation status of wet heath habitat in the study area. The map shows the distribution of the conservation index values (high, medium or low) assigned during the vegetation survey. The three sub-levels of the 'medium' category based on the cause of disturbance (forestry, cattle grazing or both) are also distinguished.

Syntaxonomy and diversity indices

For mire, 16 species were recorded in 16 plots (4 m^2) and the mean number of species per plot was 7.1. The most frequent species were *Molinia caerulea* (present in 15 plots) and *Erica mackayana* (11 plots), and the rarest were *Carex remota* and *Pedicularis sylvatica* (present in only one plot). The β diversity value was extremely low, at 8.4. This means that species turnover was low and most of the plots were similar. The TWINSPAN analysis did not yield a clear ordination for either presence (Table 2, left) or presence-abundance (Table 2, right). However, two extremes emerged, namely one community dominated by *Eleocharis multicaulis* with *Juncus bulbosus* or *Carum verticillatum* and a second community with the endemic *Carex durieui* accompanied by *Eriophorum angustifolium*, *Narthecium ossifragum* and high cover of *Erica mackayana*. The first community was assigned to the phytosociological association *Eleocharitetum multicaulis* (Litorelletea uniflorae). The second was placed in the *Carici durieui-Sphagnetum papillosi*, which is close to the *Carici durieui-Sphagnetum compacti* (Oxycocco-Sphagnetea) but distinguished by the high frequency of *Eriophorum angustifolium* and *Narthecium ossifragum* (Rodríguez-Oubiña 1986). The community at Viveiro belongs to the subassociation *ericetosum mackaianae*.

Table 2. TWINSPAN analysis of mire vegetation according to species presence (left) and presence-abundance (right). Species codes consist of the first three letters of the genus with the first three letters of the specific epithet appended (e.g. "junbul" means "*Juncus bulbosus*"). A full key is provided in the Appendix.

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                 1      11111 1                                 1111111
                 5142346890123675                      1234567890123456

 1  carrem       1---------------  00        5  droint   4-3444-44-------  11
 6  agrhes       --1--1----------  00        4  junbul   565544334-4-----  11
 8  desfle       -1111111-----1--  00        3  elemul   -653--5-------5-  11
 2  carech       1--1111-------1-  010       2  carech   -856544---------  11
 4  junbul       11-111111-1---1-  010       1  carrem   ----3-----------  11
 5  droint       11--11111-------  010       8  desfle   7433-4-4-----9-6  10
14  potere       -111---1-----1--  010       6  agrhes   ---3---------3--  10
 3  elemul       ---111--------11  011      11  erimac   353--24---434975  01
 7  naross       1---11-11111-11-  10       10  molcae   5635566-59587766  01
10  molcae       1111111-11111111  10        9  carver   ----3-3-3--3---3  01
11  erimac       -1111-1---111111  10        7  naross   --755-374434---3  01
 9  carver       1-------1--1-11-  110      16  eriang   -------577545--4  00
12  cardur       --1--11111111111  110      15  pedsyl   ---------------4  00
13  drorot       ------11-111-111  110      14  potere   33-----7-----4-4  00
15  pedsyl       -------------1--  111      13  drorot   -----323-332--32  00
16  eriang       -------1111111--  111      12  cardur   ---3-33545573684  00

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The wet heath was floristically homogeneous. Twenty-six species were recorded in the nine plots (total area 144 m^2). The mean number of species per plot was 10.6 (range 7–15). The β diversity value was higher than for mires, but still low at 12.4. β diversity was not compared statistically between the two habitats because the sampling designs were different. Seven species were common to all of the plots, namely *Agrostis curtisii*, *Calluna vulgaris*, *Erica cinerea*, *Erica mackayana*, *Potentilla erecta*, *Molinia caerulea* and *Ulex gallii* subsp. *breogani*. The high cover values of *Ulex gallii* subsp. *breogani* and *Erica mackayana*, the presence of species such as *Potentilla erecta*, *Carex* spp. and *Gentiana pneumonanthe* which require humid soil, and the absence of *Ulex europaeus* clearly demonstrate that the phytosociological association is *Gentiano pneumonanthe - Ericetum mackaianae* (Calluno-Ulicetea). In one plot, low presence of *Erica umbellata* and *Ulex europaeus* was recorded, probably due to microsite-level conditions of shallower, more intensely drained soil. Here, wet heath was substituted by the dry heath community *Ulici europaei - Ericetum cinereae* (Calluno-Ulicetea).

Minor temporal variations were observed in the permanent quadrats, but species presence and abundance did not change significantly. Two species changes were recorded in the mire quadrats only, where *Pedicularis sylvatica* was not recorded in the second year and *Viola palustris* was recorded in one plot in the second year. A long-term study would be desirable but problems arose with the markers, which were moved and/or removed by cattle or people.

The species-area curve for mire shows that 80% of species would be recorded in *ca.* five plots (Figure 5). The jacknife estimate of the total number of species was 17.9 (18), although 16 species were actually recorded. The Jaccard index average distance approached zero at 16 sub-plots.

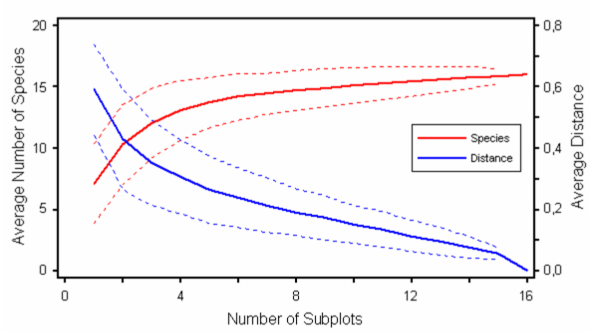

Figure 5. Species-area and average distance curves for mire vegetation, generated using the Jaccard method. The dimensions of each sub-plot are 0.5 m x 0.5 m. The dashed lines indicate confidence limits (± 2 x standard deviation).

Species attributes

Species attributes are shown in the Appendix and summarised in Figure 6. The Cyperaceae family (44%) dominated in mire, and Poaceae (35%) in wet heath. Ericaceae were important in both communities, whereas Compositae, Leguminosae and Umbelliferae were poorly represented. The main Raunkiaer type (Raunkiaer 1904, 1934) for both communites was hemicryptophyte (13 species) followed by phanerophyte (6 species) in heath and geophyte (2 species) in mire. The only therophyte recorded was *Cuscuta epithymum*.

Most species were confined to one or other of the the two habitats, but an important percentage (33% in heath and 13% in mire) was shared between them. A few species were also found in other habitat types such as meadow or hydrophytic habitat. A very small percentage of the species recorded are endemic to the north-west of the Iberian peninsula. *Carex durieui* and *Agrostis hesperica* are two endemic species with highly restricted habitat ranges that include peatlands. The rest of the species have either Atlantic or boreal distributions (Figure 6). Atlantic species dominate in heath, but in mire, which commonly provides habitat for species with wide geographic ranges, Eurosiberian species represent more than 60% of the total complement.

Impact analysis

Impact values are shown in Figure 7. The most important impacts were materials issues such as loss of superficial soil layers and deposition of exogenous material. The presence of an invasive plant species was recorded for first time in 2007 when *Helichrysum foetidum*, a therophyte from South Africa that is now common in Galicia (Fagúndez & Barrada 2007), was recorded on the verges of the wind farm road.

The initial impact values reflected baseline human impacts that were not related to the wind farm. The highest impact values were recorded during construction, but did not reach alert or ceiling levels at any time. In general, the impact values have not yet returned to baseline level, although this has occurred for some of the individual impact categories and sub-groups (Table 1, Figure 7). The most significant impacts of wind farm construction were indirect ones, such as new drainage and forestry - mostly on mires - which resulted from the improved access to the area. In particular, the use of heavy machinery for forest harvesting and re-planting close to one of the mire areas during 2005 affected the stability of the vegetation as well as hydrology, and increased the turbidity of draining water.

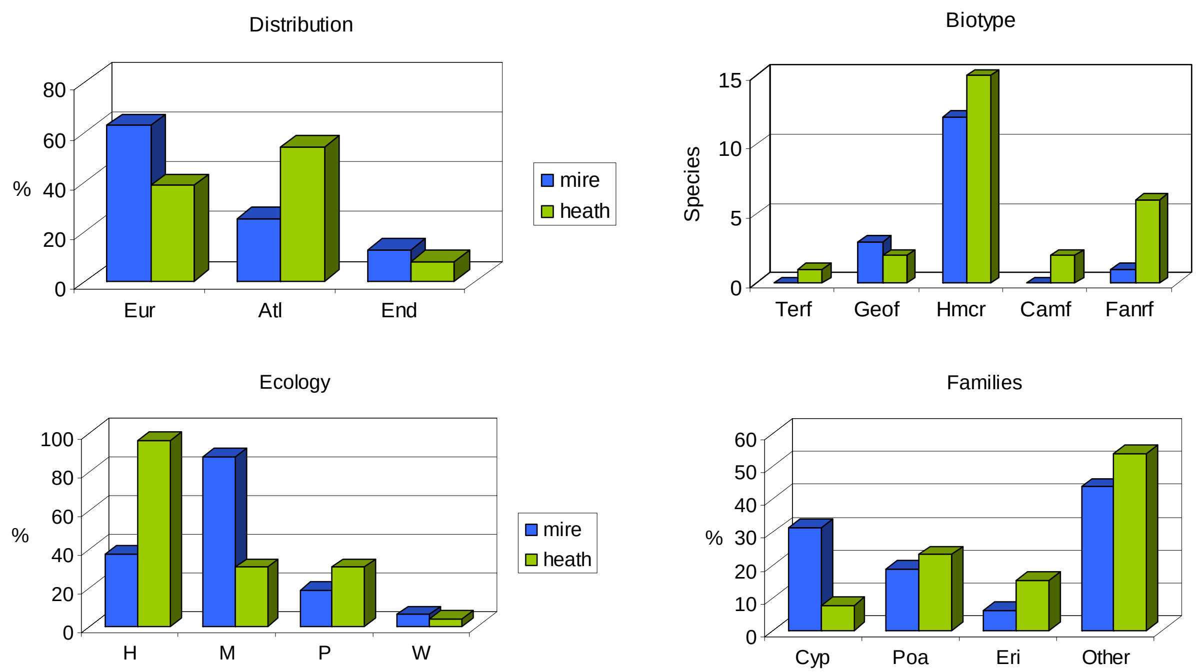

Figure 6. Geographic distribution, biotypes, ecology and families of the species recorded in mire and heath habitats. Ordinates are % of all species except for biotypes, which are expressed as total number of species. Plant distribution is classified as Eurosiberian (Eur), Atlantic (Atl) or Endemic (End). Raunkiaer plant types are therophyte (Terf), geophyte (Geof), hemicryptophyte (Hmcr), camaephyte (Camf) and phanerophyte (Fnfr). The main ecological types are heath (H), mire (M), pasture and meadow (P) and hydrophytic communities (W). The families represented are Cyperaceae (Cyp), Poaceae (Poa) and Ericaceae (Eri).

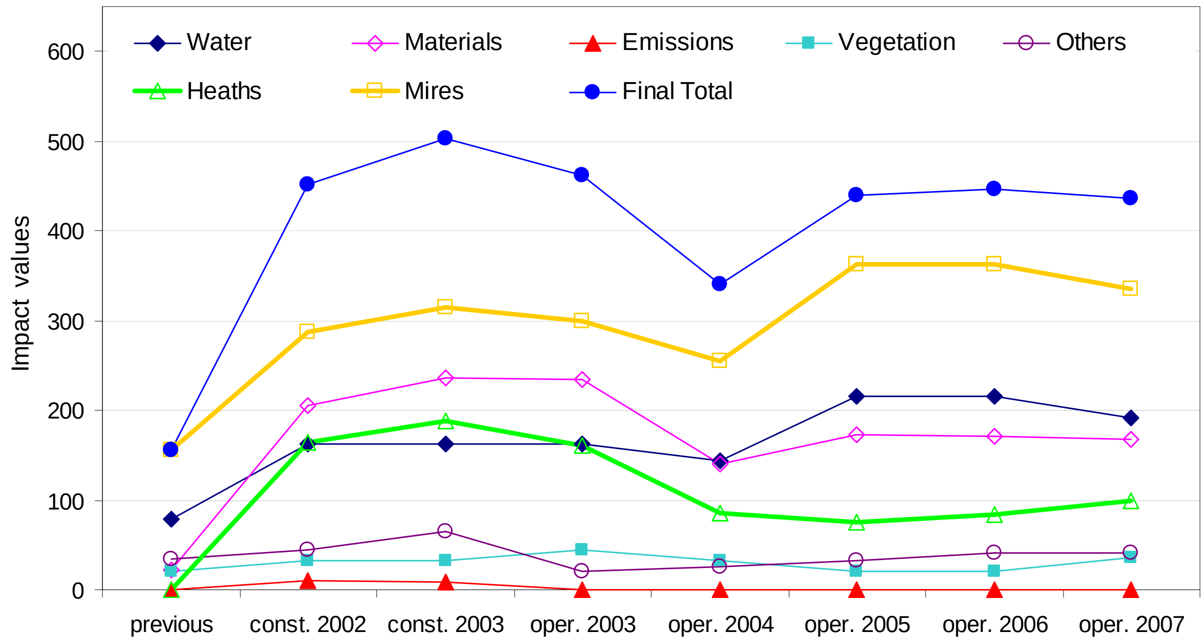

Figure 7. Results of impact analyses for mire and wet heath habitats before development (previous), and during construction (const.) and operation (oper.) of the wind farm. Totals 2 (for impact groups), 4 (for habitats) and Final (see Table 2) are shown. The 'construction' data were recorded in December 2002 and March 2003, and the 'previous' and 'operation' data in June–July each year from 2002 to 2007. Note that the impact on mire identified in 2005 was caused by forestry operations that were not directly associated with the wind farm (see text for further explanation).

DISCUSSION

The results of the plant attributes study indicates that these are mature, stable plant communities typical of constant environments with specific limiting conditions. Low α and β diversity values, late-flowering phenology, absence of therophytes and species with long-distance dispersal capability, together with specialised ecological requirements, are common in this habitat type. Future changes in species diversity, abundance of therophytes and/or opportunistic species, or major differences in any of the monitored variables, would indicate a loss of conservation status.

Annexes I and II of the EU Habitats Directive list the natural habitats and species that should be protected by inclusion in the SCI network. Habitats of priority interest are "...habitat types in danger of disappearance and whose natural range mainly falls within the territory of the European Union" (EU 2007). Wet heath including *Ulici gallii - Ericetum mackaianae*, which is now regarded as an invalid name for *Gentiano pneumonanthe - Ericetum mackaianae* (Izco *et al.* 1999), is the priority habitat type 4020. Special attention should be given to this habitat type, which occurs mostly in well-conserved areas at the north-west end of the Iberian peninsula. Heathlands are important biodiversity hotspots, but their extent in Galicia has been dramatically reduced during the last century (Izco *et al.* 2006). Mire and bog are also regarded as habitats of interest. Raised and blanket bogs (priority habitat if active) are rare in Galicia, being found only in the Sierra do Xistral and Montes de Buio SCI, but other types are also important for landscape, biodiversity and the water cycle (Martínez-Cortizas & García-Rodeja 2001).

The direct impact of wind farm construction on mire and wet heath habitat was moderate to low overall. There was no construction on mire habitat. Wet heath is extensive within the wind farm site (Figure 2) and only a small percentage of the total area of this habitat was replaced by access roads and turbine foundations. However, there is already some evidence of wider indirect impacts, such as the establishment of invasive species. Moreover, cattle grazing and forestry have intensified as a consequence of the improved access to these uplands.

ACKNOWLEDGEMENTS

GAMESA, IBERDROLA, Sistemas Energéticos Viveiro and Alen Ingeniería partially supported this study. B. Pereira and A. Aguilar helped with graphics design. A presentation based on this paper was delivered at the IMCG symposium *Wind Farms on Peatland* held in Santiago de Compostela, Spain, 27–30 April 2008.

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Submitted 31 Mar 2008, revision 16 May 2008
Editor: Olivia Bragg

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Appendix. List of plant species recorded in mire and wet heath habitats within the study area. Species in bold type were recorded in the permanent plots. CODE is given for the species listed in Table 2. COMM. (community type) indicates occurence in wet heath (H), mire (M) or both (H&M). DISTRIB. (plant distribution) is classified as Endemic (End), Atlantic (Atl) or Eurosiberian (Eur). BIOTP. (Raunkiaer plant biotypes) are therophytes (Terf), hemicryptophytes (Hmcr), geophytes (Geof), camaephytes (Camf) and phanerophytes (Fnfr). The main ecological (ECOL.) types are heath (H), mire (M), pasture and meadow (P) and hydrophytic communities (W). PHENOL. (flowering time) is coded as 1: January–February, 2: March–April, 3: May–June, 4: July–August, 5: September–October, 6: November–December.

SPECIES	CODE	COMM.	DISTRIB.	BIOTP.	ECOL.	PHENOL.
***Agrostis curtisii* Kerguélen**		H	Atl	Hmcr	H,P	3,4
***Agrostis hesperica* Romero, Blanca & Morales**	agrhes	M	End	Hmcr	M	3,4
***Agrostis stolonifera* L.**		H&M	Eur	Hmcr	H,M,P	2,3,4
Arnica montana L.		M				
***Avenula sulcata* (Gay ex Boiss.) Dumort.**		H	Atl	Hmcr	H	3,4
***Calluna vulgaris* (L.) Hull**		H&M	Eur	Fnrf	H	3,4,5,6
***Carex binervis* Sm.**		H&M	Atl	Hmcr	H,M,P	3,4
***Carex duriaei* Steudel**	cardur	M	End	Hmcr	M	4,5
***Carex echinata* Murray**	carech	M	Eur	Hmcr	M	3,4
***Carex panicea* L.**		H&M	Eur	Hmcr	H,M	2,3,4
***Carex remota* L.**	carrem	M	Eur	Hmcr	H,M,P	2,3,4
***Carum verticillatum* (L.) Koch**	carver	H&M	Atl	Hmcr	H,M,P	3,4,5
***Cirsium filipendulum* Lange**		H	Atl	Hmcr	H,P	3,4
***Cuscuta epythimum* (L.) L.**		H	Eur	Terf	H	3,4,5
Dactylorhiza maculata (L.) Soó		H				
***Danthonia decumbens* (L.) DC.**		H	Atl	Hmcr	H,P	3,4
***Deschampsia flexuosa* (L.) Trin.**	desfle	H&M	Eur	Hmcr	H	2,3,4,5
***Drosera intermedia* Hayne**	droint	M	Eur	Hmcr	M	4
***Drosera rotundifolia* L.**	drorot	M	Eur	Hmcr	M	4,5
***Eleocharis multicaulis* (Sm.) Desv.**	elemul	M	Atl	Hmcr	M	3,4
***Erica cinerea* L.**		H	Atl	Fnrf	H	3,4,5
***Erica mackayana* Bab.**	erimac	H&M	Atl	Fnrf	H,M	4,5
***Erica umbellata* L.**		H	Atl	Fnrf	H	1,2,3,4
***Eriophorum angustifolium* Honckeny**	eriang	M	Eur	Geof	M	2,3,4
Erythronium dens-canis L.		H				
Festuca gr. *rubra*		H				
***Gentiana pneumonanthe* L.**		H	Atl	Hmcr	H,M	4,5,6
***Juncus bulbosus* L.**	junbul	M	Eur	Geof	M	3,4,5
***Lithodora prostrata* (Loisel.) Griseb.**		H	Atl	Camf	H	1,2,3,4
***Molinia caerulea* (L.) Moench.**	molcae	H&M	Eur	Hmcr	H,M	3,4,5
Narcissus bulbocodium L.		H&M				
***Narthecium ossifragum* (L.) Hudson**	naross	M	Atl	Geof	M	3,4
***Pedicularis sylvatica* L.**	pedsyl	M	Eur	Hmcr	H,M,P	3,4,5
***Physospermum cornubiense* (L.) DC.**		H	Eur	Hmcr	H	3,4

SPECIES	CODE	COMM.	DISTRIB.	BIOTP.	ECOL.	PHENOL.
Pinguicula lusitanica L.		M				
***Polygala vulgaris* L.**		H	Eur	Hmcr	H,P	2,3,4
***Potentilla erecta* (L.) Raeuschel**	potere	H&M	Eur	Hmcr	H,M,P	1 to 6
Pseudarrhenatherum longifolium (Thore) Rouy		H				
Rhynchospora alba (L.) Vahl		M				
***Scorzonera humilis* L.**		H	Eur	Hmcr	H	2,3,4
***Serratula tinctoria* L. subsp. *seoanei* (Willk.) Laínz**		H&M	Atl	Geof	H,M,P	4,5
***Simethis mattiazzi* (Vandelli) Sacc..**		H	Atl	Geof	H	2,3,4
Thymelaea coridifolia (Lam.) Endl.		H	End	Camf	H	2,3
***Ulex europaeus* L.**		H	Atl	Fnrf	H	1,2,3,6
Ulex gallii* Planch. subsp. *breogani* (Castrov. & Valdés-Berm.) Rivas Mart. *et al.		H	End	Fnrf	H	4,5,6
***Viola palustris* L.**		M	Eur	Hmcr	M	2,3,4