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Breeding bird populations of Irish peatlands

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Capsule Peatlands are very important habitats for birds despite low species diversity.
Aims To describe the variation in breeding bird populations that occur on different types of Irish peatlands and their associated habitat characteristics.
Methods Bird abundance and diversity were compared between four peatland habitat types (fens, raised bogs, Atlantic blanket bogs and montane blanket bogs) at 12 study sites using transects. Various measures of habitat quality were also taken at each location.
Results Only 21 species were recorded during the study, with Meadow Pipit *Anthus pratensis* and Sky Lark *Alauda arvensis* accounting for over 80% of all birds recorded. Fens had greater bird species diversity and densities than the other three peatland types. Raised bogs, Atlantic blanket bogs and montane blanket bogs were very similar in terms of their avian diversity. Each of the recorded bird species was associated with different aspects of the peatland habitat.
Conclusion This study shows that despite the relatively low avian species diversity of Irish peatlands, they are of enormous conservation value due to the presence of species of high conservation concern such as Willow Ptarmigan (Red Grouse) *Lagopus lagopus* and Eurasian Curlew *Numenius arquata*.

Peatlands are one of the most characteristic landscape features in Ireland and cover about 17% of the total area, a percentage exceeded in Europe only by Estonia (22%) and Finland (30%) (Aalen *et al.* 1997, Lappalainen 1996). Intact peatlands are one of the few remaining pristine ecosystems in both an Irish and global context. Peatlands provide important habitats for bird communities and hold large proportions of the national populations of several species including Sky Lark *Alauda arvensis*, Meadow Pipit *Anthus pratensis*, Eurasian Curlew *Numenius arquata* and Willow Ptarmigan (Red Grouse) *Lagopus lagopus*. The main types of peatlands in Ireland are fens, raised bogs and blanket bogs (Hammond 1981).

Fens are peatlands that form from vegetation fed from nutrient-rich ground waters (Feehan & O'Donovan 1996). Raised bogs were formed where shallow lakes were overgrown by vegetation, which subsequently led to plant debris accumulating to form peat (Hammond 1981). Blanket bogs are characteristic of mountain areas in the west of Ireland. Blanket bogs are shallow peatlands and can be divided into two types in Ireland, Atlantic and montane blanket bogs (Hammond 1981). Atlantic blanket bogs occur along the Atlantic seaboard below the 150 m contour line and in areas where rainfall is greater than 1250 mm per annum (Feehan & O'Donovan 1996).

A high proportion of Irish peatlands have been damaged to various degrees in the last 60 years due to several factors, including the introduction of large-scale, mechanized turf extraction schemes in the 1940s for fuel and horticultural peat, afforestation programmes commencing in the 1950s, intensification of agriculture following Ireland's entry to the European Union (EU), and land reclamation (Feehan & O'Donovan 1996). The area of peatland suitable for conservation in Ireland has been seriously reduced in recent times, leaving less than a quarter of the peatland resource in relatively intact conditions (Foss *et al.* 2001).

Despite the substantial area of peatland in Ireland and its importance as a habitat for birds, especially during the breeding season, few published studies exist on the birds of peatland in Ireland. In general, previous surveys have focused mainly on recording the avian species richness and species abundances of a single peatland, with no density estimates given (Lack & Lockley 1935, MacLochlain 1984, Madden 1987a, 1987b). The results of these studies have found

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breeding season species richness to be very low on raised bog and blanket bog: Madden (1987a) found 12 species on an area of intact raised bog in Mongan Bog, Co. Offaly, with only four species being proven to have bred; Lack & Lockley (1935) found only three species present in a blanket bog site in Letterfrack, Co. Galway. Other studies have focused on single species in peatland such as Red Grouse (Watson & O'Hare 1973, 1979a, Lance & Mahon 1975, Murray & O'Halloran 2003), Hen Harrier *Circus cyaneus* (Norriss *et al.* 2002) and Common Redshank *Tringa totanus* (Nairn *et al.* 2004).

The importance of peatland as a habitat in an international and national context is illustrated by the inclusion of blanket bog, raised bog and fens in Annex I of the EU Habitats Directive, which affords peatlands special conservation status. Many important peatland sites in Ireland are allocated special protection through their designation as Nature Reserves, Special Areas of Conservation (SAC), Special Protection Areas (SPA) and Natural Heritage Areas (NHA). The main aim of this study was to determine avifaunal diversity, and the population density and habitat preferences of common breeding birds, at 12 Irish peatlands illustrating a range of peatland types.

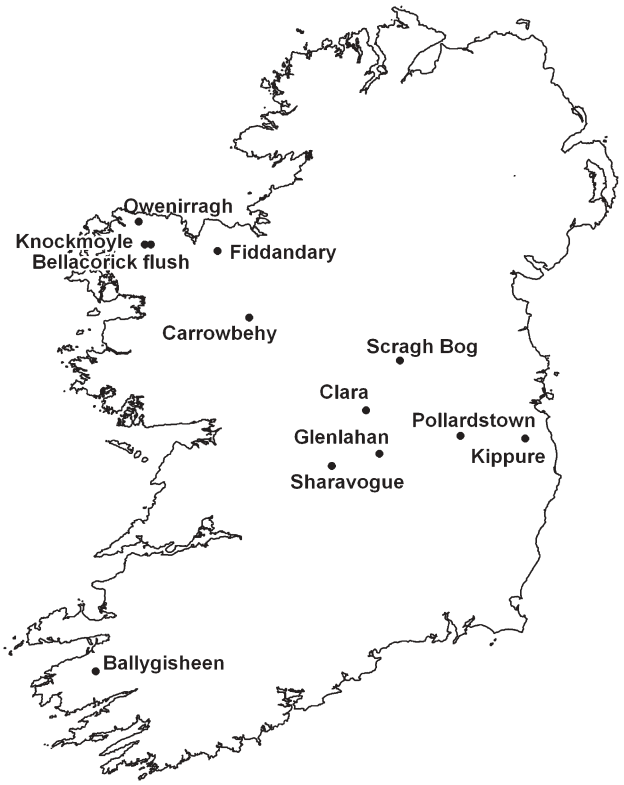

Figure 1. Locations of the 12 study sites.

METHODS

Study sites

Twelve study sites were surveyed during this study, with three sites in each of the four peatland habitat types: fens, raised bogs, Atlantic blanket bogs and montane blanket bogs. These sites were located throughout Ireland. The fens were at Scragh Bog (Co. Westmeath), Pollardstown Fen (Co. Kildare) and Bellacorick flush (Co. Mayo). The raised bogs of Sharavogue and Clara were located in Co. Offaly and the third, Carrowbehy, was situated in Co. Roscommon. Atlantic blanket bogs were located in Ballygisheen (Co. Kerry), Knockmoyle and Owenirragh (both Co. Mayo). Montane blanket bogs were in counties Sligo (Fiddandary), Wicklow (Kippure) and Laois (Glenlahan). The study site locations are illustrated in Fig. 1.

Within each site, two parallel 1 km transects 500 m apart were marked; however, many sites were too small or irregularly shaped to allow this exact layout of the transects, so some compromise occurred. For example, only single transects of 300 m in length were possible in both Bellacorick and Owenirragh.

Bird counts

Between late April and mid-June 2006, two visits were made to each sampling site. The first visits took place between 21 April and 16 May with the second visits between 23 May and 13 June. The line transect method is one of the most widely used methods for estimating numbers of birds and was deemed to be the most appropriate method to use in the difficult peatland terrain (Bibby *et al.* 2000). The methods used are based on the methods of the British Breeding Bird Survey (BBS) (Raven *et al.* 2007) and Irish Countryside Bird Survey (CBS) (Coombes *et al.* 2006). Transects were walked at a slow steady pace early in the morning on days with dry and reasonably calm weather conditions. Each bird within 100 m of the transect line, to both left and right, was recorded. Birds seen or heard more than 100 m from the transect were not recorded in this study as hedges and forest became confounding influences at this distance and detectability also decreased. The distance at which each bird was recorded was based on the perpendicular distance from the bird to the transect line. All adult birds seen or heard were recorded, provided that they were consid-

ered to be nesting within the site or were using the site for feeding or roosting. Each transect was divided into 100 m sections.

Habitat quality and vegetation structure

Various measures of habitat quality were taken for each transect. Within the 100 m transect sections, estimates of cover were made 25 m on either side of the transect line, so that the estimates for each section were made for an area of 100 m by 50 m. The percentage cover of Heather *Calluna* species, grasses/other vegetation, open water/pools and bare peat were estimated to the nearest 5%. The percentage cover of hummocks was also estimated for each section. Hummocks are small raised mounds found in peatland and are formed by the upward growth of sphagnum mosses.

A 'vegetation stratification profile', which involved estimating the cover of vegetation within predetermined height classes, was produced for each transect section. This was undertaken because many species of birds select their habitats on the basis of vegetation structure (MacArthur & MacArthur 1961). This involved dividing the vegetation into six height classes (or strata) on a geometrical scale. The strata used were 0 to 0.25 m (stratum 1), 0.25 to 0.5 m (stratum 2), 0.5 to 1 m (stratum 3), 1 to 2 m (stratum 4), 2 to 4 m (stratum 5), and greater than 4 m (stratum 6). For each stratum a visual estimation was made, to the nearest 5%, of the cover of all vegetation by a projection on a horizontal plane.

The vertical height of the vegetation and horizontal density was measured every 25 m along the transect. The vertical height of the vegetation at each recording location was measured as the height of the highest piece of vegetation. For estimates of horizontal density, a 50 cm quadrat was placed at the recording location and the percentage cover of all vegetation (*Calluna* and other vegetation) within the quadrat was estimated.

Finally, the distance to the nearest forest, hedge or clump of bushes/shrubs was estimated as less than 100 m, 100 m to 250 m, 250 m to 500 m, 500 m to 1 km, 1 km to 2 km or greater than 2 km.

Statistical analysis

To investigate how the bird communities varied in relation to different peatland types and habitat variables, ordination techniques were applied using CANOCO 4.5 (ter Braak & Šmilauer 2002). The 12 species most associated with peatlands were selected for more detailed analysis. These species were Eurasian Curlew, Common Grasshopper Warbler *Locustella naevia*, Mallard *Anas platyrhynchos*, Meadow Pipit, Reed Bunting *Emberiza schoeniclus*, Red Grouse, Sky Lark, Stonechat *Saxicola torquata*, Common Snipe *Gallinago gallinago*, Sedge Warbler *Acrocephalus schoenobaenus*, Winter Wren *Troglodytes troglodytes* and Willow Warbler *Phylloscopus trochilus*. For the breeding season the maximum number of these species showing signs of breeding (e.g. singing, displaying or feeding young) recorded on any of the two surveys was used, as this maximum number is still unlikely to overestimate potential breeding number. The total number of breeding birds is likely to be higher than the maximum recorded.

To standardize the variation between transect lengths that existed between sites, the average number of birds per 100 m transect per site was calculated. These figures for each species and site were used to analyse the variation in community assemblage structure. Detrended correspondence analysis (DCA) and redundancy analysis (RDA) were used to assess variations in assemblage structure. DCA is an indirect gradient analysis technique, i.e. an ordination technique that searches for major gradients in the species data irrespective of any environmental variables (ter Braak 1988). DCA determines the gradient length in the response variable (i.e. bird data). Gradient length is the length of the theoretical explanatory variable along an ordination axis. It is expressed in standard deviation units of species turnover. If the gradients are short (<3 sd) the linear methods of analysis (e.g. redundancy analysis) are more appropriate. However, if the gradients are long (>4 sd) then unimodal methods (e.g. canonical correspondence analysis) are more appropriate. If the gradients are in between then either method may be useful (ter Braak & Šmilauer 2002). In RDA the distinction is made between response (species) variables and explanatory (environmental) variables (ter Braak & Šmilauer 2002). RDA can be expressed as the constrained form of multiple regression of species' response on explanatory variables. Monte Carlo permutation tests can be used to evaluate the statistical significance of the relationship, given the covariables, between the species and the whole set of environmental variables (Jongman *et al*. 1987). DCA and RDA were carried out using CANOCO Version 4.5 (ter Braak & Šmilauer 2002).

RESULTS

When the maximum numbers between the two visits

were taken for each species and transect section, 1165 individuals were recorded between all 12 sites, representing 21 different species. Meadow Pipit was by far the most abundant species recorded, constituting 56.5% of the individuals seen (Table 1). Sky Lark was the next most abundant species making up 24.7% of the population (Table 1). Only four other species (Reed Bunting, Wren, Snipe and Sedge Warbler) constituted 1.8% or more of the individuals recorded (Table 1).

Meadow Pipit was the dominant species in each habitat type and Sky Lark was the second most abundant species in all peatland types except fen (Table 1). In fen, Meadow Pipit constituted 40% of the individuals sighted, followed by Reed Bunting (18%), Wren (9%), Snipe (9%) and Sedge Warbler (8%) (Table 1). The three commonest species in raised bogs were Meadow Pipit (62%), Sky Lark (30%) and Curlew (4%) (Table 1). Meadow Pipit and Sky Lark dominated Atlantic blanket bog, with 51% and 45% of the individuals, respectively (Table 2). Meadow Pipit (66%), Sky Lark (24%), Wren (4%), Red Grouse (3%) and Mallard (1.5%) were the main species in montane blanket bog (Table 1).

The densities of the key species in the different peatland types are presented in Table 2. The overall density of birds within all the peatland sites was 338.7 individuals per km^2, with fen having the highest density of 635 per km^2 and Atlantic blanket bog with the lowest density of 252.6 per km^2 (Table 2). Meadow Pipit occurred at the highest density of all species recorded with 191.3 birds per km^2 in all peatland habitat types (Table 2). Meadow Pipit density was highest in fen with 255 birds/ km^2 while Sky Lark density was highest in Atlantic blanket bog with 114.5 birds/ km^2 (Table 2).

DCA indicated that linear forms of ordination were appropriate for this data set (length of the first gradient = 1.915) therefore RDA was used to analyse the composition of the bird assemblages in the different peatland habitat types. RDA showed a significant difference between the four habitat types in bird assemblage composition; in particular the assemblage structure in fen habitats was different from those found in the other peatland types ($P < 0.01$ for first canonical axis) (Fig. 2). The second canonical axis divided raised bog on the positive half of the diagram from Atlantic and montane blanket bogs and fen on the negative half of the diagram. All of the canonical axes were significant ($P < 0.05$) and explained 70.1% of the variance of the species data and 100% of the variance of the species–environment relation. The assemblage

Table 1. Community proportion (%) of each bird species recorded in all sites and in the different peatland habitat types.

Common name	Scientific name	Species code	Fen	Raised bog	Atlantic blanket bog	Montane blanket bog	All bog types
Meadow Pipit	*Anthus pratensis*	MP	40.2	61.7	50.5	66.3	56.5
Sky Lark	*Alauda arvensis*	S	2.4	30.2	45.3	23.7	24.7
Reed Bunting	*Emberiza schoeniclus*	RB	17.7	0	0.5	0	3.9
Winter Wren	*Troglodytes troglodytes*	WR	9.1	0.5	1.0	4.4	3.6
Common Snipe	*Gallinago gallinago*	SN	9.1	1.3	0	0.6	2.6
Sedge Warbler	*Acrocephalus schoenobaenus*	SW	7.9	0.3	0	0	1.8
Eurasian Curlew	*Numenius arquata*	CU	0	3.7	0	0	1.2
Mallard	*Anas platyrhynchos*	MA	1.2	1.0	1.0	1.5	1.2
Willow Ptarmigan (Red Grouse)	*Lagopus lagopus*	RG	0	0.5	0	3.0	1.0
Willow Warbler	*Phylloscopus trochilus*	WW	4.3	0.3	0	0	1.0
Stonechat	*Saxicola torquata*	SC	2.0	0.3	0	0.6	0.7
Common Grasshopper Warbler	*Locustella naevia*	GH	2.0	0	0	0	0.4
Mute Swan	*Cygnus olor*	MS	1.6	0	0	0	0.3
Common Wood Pigeon	*Columba palumbus*	WP	1.2	0	0	0	0.3
Eurasian Teal	*Anas crecca*	T	0	0	1.0	0	0.2
Dunlin	*Calidris alpina*	DN	0	0	0.5	0	0.1
European Goldfinch	*Carduelis carduelis*	GO	0.4	0	0	0	0.1
European Greenfinch	*Carduelis chloris*	GR	0.4	0	0	0	0.1
Hooded Crow	*Corvus cornix*	HC	0	0.3	0	0	0.1
Common Moorhen	*Gallinula chloropus*	MH	0.4	0	0	0	0.1
Rook	*Corvus frugilegus*	RO	0.4	0	0	0	0.1

Numbers given are the percentages of the total number of individuals recorded in habitat type for each individual species based on maximum figures between the two visits, e.g. Meadow Pipit constitutes 45% of the raised bog community.

Table 2. Densities (individuals/km^2 ± se) for selected species and for all species combined, in the different peatland habitat types.

Species	Atlantic blanket bog	Fen	Montane blanket bog	Raised bog	All peatland sites
All species	252.6 ± 20	635 ± 44	281.7 ± 14.5	352.8 ± 17.5	338.7 ± 13
Curlew	0 ± 0	0 ± 0	0 ± 0	13.0 ± 4	4.1 ± 1.5
Grasshopper Warbler	0 ± 0	12.5 ± 5	0 ± 0	0 ± 0	1.5 ± 0.5
Mallard	2.6 ± 2.5	7.5 ± 5.5	4.2 ± 3	3.7 ± 2.5	4.1 ± 1.5
Meadow Pipit	127.6 ± 14	255 ± 34	186.7 ± 10	217.6 ± 13.5	191.3 ± 8
Reed Bunting	1.3 ± 1.5	112.5 ± 24	0 ± 0	0 ± 0	13.4 ± 4
Red Grouse	0 ± 0	0 ± 0	8.3 ± 3.5	1.9 ± 1.5	3.5 ± 1.5
Sky Lark	114.5 ± 10.5	15 ± 7.5	66.7 ± 8.5	106.5 ± 9.5	83.7 ± 5.5
Stonechat	0 ± 0	12.5 ± 7	1. 7 ± 1	0.9 ± 1	2.3 ± 1
Snipe	0 ± 0	57.5 ± 13	1.7 ± 1	4.6 ± 2	8.7 ± 2
Sedge Warbler	0 ± 0	50 ± 21	0 ± 0	0.9 ± 1	6.1 ± 2.5
Wren	2.6 ± 2	57.5 ± 15	12.5 ± 4	1.9 ± 2	12.2 ± 2.5
Willow Warbler	0 ± 0	27.5 ± 10	0 ± 0	0.9 ± 1	3.5 ± 1.5

structure of fen differed greatly from raised bog and the two blanket bog types, forming three different species groupings (Fig. 2).

Curlew was closely associated with raised bog (Fig. 2, see Table 1 for a list of all abbreviations). Many species showed an affinity to fens including Reed Bunting, Grasshopper Warbler, Sedge Warbler, Snipe, Stonechat, Wren and Willow Warbler. Red Grouse showed a preference for blanket bog. Neither Sky Lark nor Meadow Pipit were closely associated with any particular habitat type.

The initial RDA of the species data set and the habitat quality and vegetation structure data set yielded no significant result. Therefore RDA with forward selection was used, with a subsequent RDA performed using only the most significant variables as chosen by forward selection. RDA with forward selection selected

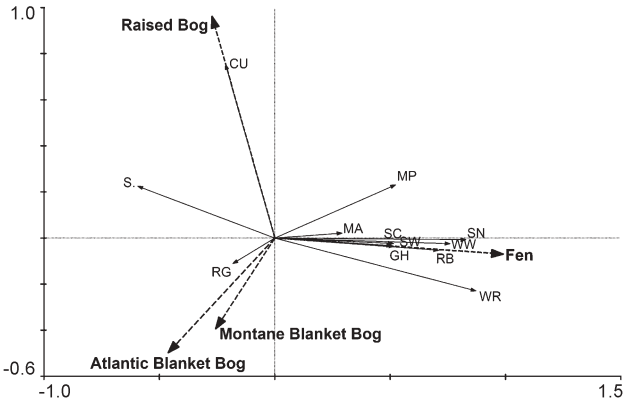

Figure 2. Redundancy analysis (RDA) of selected species in four types of peatland habitat. $P < 0.05$ for all axes. The first two axes account for 42.6% of the variance in the species data (see Table 1 for species codes).

stratum 2 (25–50 cm high vegetation cover) ($P < 0.05$), stratum 3 (50 cm to 1 m high vegetation cover) ($P < 0.01$) and stratum 6 (>4 m high vegetation cover) ($P < 0.05$) as the only significant habitat and vegetation variables. The second RDA included strata 2 to 6, horizontal density of vegetation, vertical height of vegetation, percentage cover of *Calluna* and distance to nearest group of trees in the analysis (Fig. 3). The first canonical axis divided the species preferring strata 2 to 6 and vertical height of vegetation on the positive side of the diagram from those showing a preference for cover of *Calluna*, distance to nearest trees and horizontal density on the negative side (Fig. 3). The first canonical axis was significant ($P < 0.01$) and accounted for 58.7% of the species inertia and 58.9% of the inertia between the species and the environment. The second canonical axis primarily divided strata 3, 4 and 6 and vertical height of vegetation on the positive half of the diagram from distance to nearest trees and horizontal density on the negative half. All of the canonical axes were also found to be significant ($P < 0.01$) and explained 94.5% of the species inertia and 94.9% of the species–environment inertia.

Curlew was strongly associated with peatlands with high horizontal density of vegetation cover (Fig. 3). Sky Lark also showed an association with peatlands that had dense vegetation (horizontal density). Red Grouse showed a weaker preference for areas with a high density of heather cover. Several species were associated with vertical height of vegetation and with strata 3 (0.5–1 m), 4 (1–2 m) and 6 (2–4 m), including Reed Bunting, Willow Warbler, Snipe, Sedge Warbler and Grasshopper Warbler. Mallard and Wren showed preferences for vegetation between 25 and 50 cm

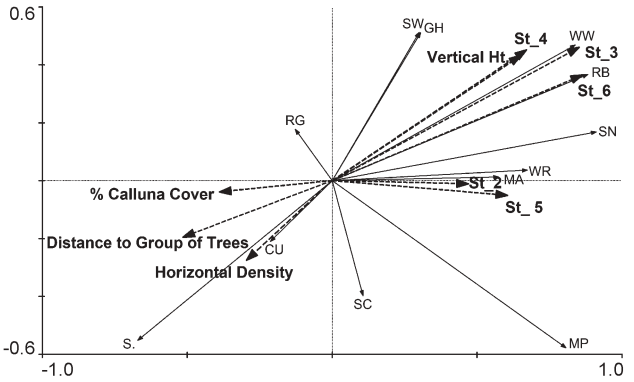

Figure 3. Redundancy analysis (RDA) of selected species with peatland habitat quality parameters. $P < 0.01$ for all axes. The first two axes account for 81.5% of the variance in the species data (see Table 1 for species codes).

(stratum 2) and between 2 and 4 m (stratum 5). Meadow Pipit showed no strong preference for any particular habitat or vegetation feature.

DISCUSSION

The most striking results from the study were the low number of species recorded and the dominance of two species, namely Meadow Pipit and Sky Lark, in Irish peatland habitats. These two species account for almost three-quarters of all birds recorded during this study. In the raised and blanket bog habitats these figures rose to over 90% in each case. Similarly in eastern Canada, studies have shown that while large numbers of birds were found on peatlands, four species made up the majority of the recorded birds (Desrochers & Van Duinan 2006). Wilson (2002) notes that Meadow Pipits nearly always outnumber Sky Larks and often by a factor of two to three on peatlands; this is consistent with the results of this study which found an overall ratio of 2.3:1 for Meadow Pipits to Sky Larks in all peatland habitats. However, in fens Meadow Pipits accounted for 45% of the population with Sky Larks making up only 2.5%. Reed Bunting, Wren, Snipe and Sedge Warbler were all far more abundant in fens than Sky Lark. Curlew was another important species of raised bog while Red Grouse, Wren and Mallard were often found in montane blanket bogs.

The overall results of the study showed that raised bogs, Atlantic blanket bogs and montane blanket bogs were similar in terms of their avian diversity, but the bird assemblages of fens were quite different. Fens had a more diverse avifauna than the other three peatland types. A number of the unique species found in fens were summer migrants such as Grasshopper Warbler and Sedge Warbler.

The four studied peatland habitat types all contained characteristic bird species assemblages. Many species were associated with fens including Reed Bunting, Grasshopper Warbler, Sedge Warbler, Snipe, Stonechat, Wren and Willow Warbler. Curlew showed a preference for raised bog. Red Grouse were found almost exclusively on Atlantic and montane blanket bog. The results suggest that Sky Larks avoid fens. In contrast, Meadow Pipits were found on all surveyed sites indicating that this species could be considered a peatland generalist in the breeding season.

The recorded bird species were associated with different aspects of the peatland habitat. Meadow Pipit showed no strong preference for any particular habitat or vegetation feature as it was the dominant species in all four habitat types. Sky Lark was more common in peatlands that had dense, low vegetation and was less common in the fens which generally had higher vegetation than the other peatland habitats. Stroud *et al.* (1987) found that the greatest numbers of Meadow Pipits occurred in heather-dominated areas in the blanket bogs of Caithness and Sutherland in Scotland, whereas Sky Larks were more abundant in grass-dominated areas. This result contrasts with Smith *et al.* (2001) who found that Meadow Pipit abundance declined with increasing heather but increased with grass cover on managed Red Grouse moors in Scotland. Watson & O'Hare (1979b) found that Meadow Pipits were most abundant on well drained, heather-dominated ground on a blanket bog at Glenamoy, Co. Mayo. Vanhinsbergh & Chamberlain (2001) suggested that a mosaic of heather, peatland and grassland may be the optimum habitat for Meadow Pipits in the uplands of Britain. Pearce-Higgins & Grant (2006) examined the relationships between bird abundance and the composition and structure of vegetation in moorland in southern Scotland and northern England. Their study found that Meadow Pipit densities were highest in graminoid–Heather *Calluna vulgaris* mixes and that Sky Larks, as in the other studies above, exhibited a positive association with short vegetation, in particular short grass.

Pohler (1996) conducted an in-depth study of dispersion patterns of breeding birds and their habitat relationships in Clara Bog, Co. Offaly. The study showed that Sky Larks and Meadow Pipits showed no distinct response to site-specific differences in habitat properties, indicating their unspecialized mode of habitat use in open raised bog habitats (Pohler 1996).

However, occupied Meadow Pipit areas of the peatland had higher and denser grass/sedge–dwarf shrub vegetation than unpopulated parts (Pohler 1996). There was very little difference between occupied and unoccupied areas of the peatland in the case of Sky Lark (Pohler 1996). Curlew were strongly associated with peatlands with high density of vegetation cover. Curlew seemed to prefer the wetter parts of Clara Bog and also areas with low and sparse grass/sedge–dwarf shrub vegetation (Pohler 1996).

Snipe showed a preference for low to medium height vegetation (25–100 cm). Stroud *et al.* (1987) found that the distribution of Snipe in Caithness and Sutherland was strongly determined by the distribution of suitable feeding habitat, i.e. wet, rank flushes with abundant cover of *Juncus* species. Snipe preferred a higher cover of lawn-forming sedges and areas with a higher proportion of open water in Clara Bog (Pohler 1996). Snipe were found to be most abundant in soft rushes and Bog Myrtle *Myrica gale* on a blanket bog in Co. Mayo (Watson & O'Hare 1979b). Pearce-Higgins & Grant (2006) found that Curlew and Snipe were most abundant where vegetation structure was relatively heterogeneous in moorland in southern Scotland and northern England.

Red Grouse showed a weak association with areas with a high density of heather cover. The association with *Calluna* is unsurprising as Red Grouse requires this plant as food, cover and nesting habitat (Wilson 2002). Red Grouse was one of only two species of high conservation concern, the other being Eurasian Curlew (Newton *et al.* 1999). Red Grouse is a particularly important species in an Irish context as it is the only bird species that is exclusively found on Irish peatlands. Watson & O'Hare (1973, 1979a) studied Red Grouse populations on a blanket bog in Co. Mayo and found that after application of fertilizers to a flat area of peatland, heather coverage increased and this led to an increase in grouse density. Another experiment involved fencing off an area of a heavily grazed hill which led to increased growth of heather and subsequent colonization by grouse (Watson & O'Hare 1973, 1979a). In moorland in southern Scotland and northern England, Red Grouse was associated with Heather *Calluna vulgaris*, although it favoured some heterogeneity in cover (Pearce-Higgins & Grant 2006).

Areas with vegetation of greater vertical height were attractive for Sedge Warbler; this vegetation often contained very tall sedges in fen habitats, which are especially important as song-posts for this species (Snow *et al.* 1998). Wren numbers were greater in areas where the vegetation was above 2 m in height as this species generally nests in shrubby vegetation or tall heather within peatland habitats (Snow *et al.* 1998).

Henderson *et al.* (2002) looked at population estimates and habitat associations of breeding Lapwing, Curlew and Snipe in Northern Ireland and showed that the preferred habitats of Curlew were upland peatlands and unimproved grassland. Snipe showed a strong selection for peatlands, fens and marshes while Lapwing preferred marshland and very few were recorded on peatlands or heather moorland (Henderson *et al.* 2002). Pearce-Higgins & Grant (2006) found that in northern British moorland Red Grouse density varied from 5 to 17 per km^2 depending on the cover of dwarf shrubs in the plots. Snipe densities were between 2 and 3 per km^2 and Curlew ranged from 4 to 6 per km^2 in moorland in northern England and southern Scotland (Pearce-Higgins & Grant 2006). Sim *et al.* (2005) found that Snipe densities varied from 0.4 to 2 per km^2 and Curlew from 0.6 to 10.2 individuals per km^2 in nine study areas of the British uplands. As in the current study, Pearce-Higgins & Grant (2006) found that Sky Lark and Meadow Pipit had the greatest densities, with 7–43 Sky Larks per km^2 and 102 to 157 Meadow Pipits per km^2. Watson & O'Hare (1979a, 1979b) found densities of Red Grouse in spring on blanket bog in Co. Mayo averaged 5 per km^2, ranging from 0 to 12 per km^2, Meadow Pipit ranged from 4 to 20 per km^2, Sky Lark from 0 to 7 per km^2 and Snipe from 1 to 11 per km^2.

In the current study density estimates in all peatland habitats showed that the densities of Meadow Pipit (191 individuals per km^2) and Sky Lark (84 per km^2) were higher than in the studies by Watson & O'Hare (1979a, 1979b). Red Grouse densities (3.5 per km^2) were substantially lower than on northern British moorland (Pearce-Higgins & Grant 2006) and slightly lower than found by Watson & O'Hare (1979a). Snipe densities (9 per km^2) were similar to that found in Co. Mayo (Watson & O'Hare 1979b) but more than three times the densities found by Pearce-Higgins & Grant (2006) and Sim *et al.* (2005). It would appear that densities of Snipe are higher within Irish peatlands compared to those found in the UK. The density of Curlew (4 per km^2) was very similar to the densities recorded on northern British moorland (Pearce-Higgins & Grant 2006) and was within the range recorded on other areas of British uplands (Sim *et al.* 2005). It should be highlighted that all sites in the previous studies were upland peatlands but in the

present study sites were composed of fen, upland etc. and therefore comparisons should be put in context. It should also be noted that densities of Red Grouse, Curlew and Snipe were recorded as pairs per km^2 in Sim *et al.* (2005) and Pearce-Higgins & Grant (2006) but were converted to individuals per km^2 so as to be comparable with the present study.

The results of this study should be put in context considering the limited sample size. There were a number of factors that contributed to this. Firstly, in order to standardize the survey the same observer carried out all the bird and habitat surveys. This obviously limited the surveyed sites within the breeding season. There are limited numbers of specific types of peatlands in Ireland, particularly raised peatlands and fens. In order to have representative sites of existing peatland habitats indicative of the geographical spread in Ireland and equal replicates, only a limited number of sites (three of each type) were used. This limitation on the number of available sites also indicates the dwindling areas of this extraordinary ecosystem within the Irish rural landscape.

Winter studies of the same sites may be useful to assess the differences in bird assemblages between the breeding and winter seasons. However, it is known that the avifauna of raised and blanket peatlands is poorer in winter as many species, including Meadow Pipit, Sky Lark and Reed Bunting, form migratory flocks and leave peatlands in search of food in the neighbouring countryside. There are some changes to bird diversity in winter, with wildfowl being important visitors.

Peatlands are one of the last large undisturbed ecosystems in the world but unfortunately there are many areas in western Europe and temperate North America where peatlands have completely disappeared (Desrochers & van Duinan 2006). No bird species from Eurasia or North America are found exclusively on peatlands, but well over 100 species and several families of birds are found in these ecosystems (Desrochers & van Duinan 2006). Most of the studies of birds in peatland are from North America (Desrochers *et al.* 1998, Wilson *et al.* 1998) and Fennoscandinavia (Berg *et al.* 1992), and it has been shown that species diversity is somewhat greater in North American peatlands compared to Fennoscandinavia. The main difference in bird diversity between Eurasian and North American peatlands would appear to be the dominance of shorebirds in Eurasian peatlands (Hakala 1971, Väisänen & Järvinen 1977) compared to the pre-eminence of songbirds in North American peatlands (Calmé *et al.* 2002). Many of the peatland studies from Britain have focused on moorland, in particular Red Grouse moors (Smith *et al.* 2001, Tharme *et al.* 2001), and on single species such as Red Grouse (Thirgood *et al.* 2000, Shaw *et al.* 2004) and European Golden Plover *Pluvialis apricaria* (Pearce-Higgins & Yalden 2004).

Of the 21 species recorded during this study, eight are of conservation concern in Ireland (Newton *et al.* 1999). Curlew and Red Grouse are species of high conservation concern and Eurasian Teal *Anas crecca*, Dunlin *Calidris alpina*, Snipe, Sky Lark, Stonechat and Grasshopper Warbler are species of medium conservation concern. This shows that despite the relatively low number of bird species found on Irish peatland habitats, they are of great importance in terms of conservation value. Thus it is vital that the remaining peatlands of Ireland are protected, conserved and managed so that important breeding habitats for birds are not damaged or destroyed. To date, a number of important peatlands in Ireland have been designated as SACs and SPAs due to their importance as national and international ecosystems.

In addition to highlighting these important habitats, management guidelines need to be established and implemented to ensure the survival of these ecosystems and the important avifauna they support. All new draining of peatlands should be ceased and restoration of existing drained peatlands could be implemented in certain areas. Livestock grazing on upland peatlands should be limited through sustainable stocking levels. This will help prevent overgrazing and erosion of these upland peatland habitats. Red Grouse is the only species in Ireland totally confined to peatlands and thus major efforts should be made to maintain populations in current breeding areas through preventing the degradation of existing habitats. In certain areas active habitat management may be appropriate (Murray & O'Halloran 2003). This would include such measures as heather burning and predator control (Allen *et al.* 2005). However, active management of all upland peatlands would not be encouraged as it is impractical, and also heather burning and predator control can have negative effects on other biodiversity including Meadow Pipit populations which decrease as a result (Smith *et al.* 2001). Tharme *et al.* (2001) found evidence that heather burning on heather-dominated moorland in upland areas of eastern Scotland and northern England had a positive effect on the density of Red Grouse and Golden Plover but a negative effect on Meadow Pipit. It is also important to conserve Ireland's peatlands so that common species such as Meadow Pipit and Sky Lark, which are now associated

with agricultural land, may be seen in a natural habitat (Madden 1987a).

Peatlands are a valuable ecosystem from a national, European and global perspective. Therefore it is vital that the remaining peatlands of Ireland are protected, managed and conserved to maintain the integrity of these habitats and ensure the survival of the unique avifauna that they sustain.

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