BTO Research Report No. 566

Multi-scale Relationships between Vegetation Pattern and Breeding Birds in the Upland Margins (ffridd) of North Wales

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for Countryside Council for Wales and Joint Nature Conservation Committee

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Executive Summary

The marginal uplands of Wales are typified by complex mosaics of vegetation, broadly referred to as ffridd, that are increasingly recognised as valuable for biodiversity, especially birds and invertebrates. This report presents a detailed examination of how bird distributions at site, habitat patch, territory and individual bird scales relate to vegetation structure and composition within the ffridd. This assessment of bird-habitat preferences is based on work undertaken in 2008 and 2009 in Snowdonia and the Berwyn, north Wales. The results should also be relevant to the management of similar upland fringe environments in western and northern Britain. The data gathered create a baseline against which future changes in vegetation and birds within ffridd habitats can be assessed. This is relevant to understanding the biodiversity implications of any future reform of livestock grazing regimes under the CAP that might lead to widespread neglect of the ffridd. On the other hand, it is also possible that there could be extension of managed land within the ffridd, either for agriculture or through tree planting.

A total of 25 sites were selected, each embracing a gradient of vegetation and land-uses. The sites were stratified using an existing classification of four ffridd types to ensure that the sites were broadly representative of ffridd vegetation. Birds were mapped using a four-visit territory mapping method. A multi-scale method was used to map and sample vegetation composition and structure. Distinct habitat patches and locations of scatted trees were initially determined from colour aerial photographs, which were then ground-truthed. These habitat patches and tree locations were digitised to provide a spatially referenced habitat polygon layer. The 47 distinct patch types were combined into 10 simplified habitat types based on habitat structure. A range of site metrics and mosaic structure was generated using the FRAGSTATS algorithms; these metrics mainly provided information on the configuration and spatial pattern of habitat patches. A total of 26 habitat variables was examined at the site level, including the cover of the 10 habitat types and the variables derived from FRAGSTATS. Bird densities were calculated for all individual habitat patches potentially large enough to support territories. Habitat associations were also assessed by using the cover of different habitat types together with patch density, patch diversity and density of small trees within buffers of 50 m, for territory centres, and 25 m, for individual bird locations. For each of these variables, mean values, with 95% confidence intervals, were compared with ‘availability’ of each variable as derived from a regular grid of points at each site.

There were many relationships between the 26 habitat variables. Examination of inter-relationships for site metrics, indicated that patch density and diversity of patch types were useful summary measures of spatial and habitat complexity in ffridd mosaics. Higher altitude sites tended to have less complex mosaics than lower altitude sites. Bracken-dominated sites tended to be spatially complex in their configuration of habitat patches and have higher densities of scattered trees compared with sites that had relatively little bracken. Differences between the four ffridd sub-classes in habitat characteristics and bird assemblages were examined. One sub-class was relatively rich in woodland birds and another in moorland birds. There was no difference in bird assemblages between the two regions. The main variation in bird assemblages across sites was associated with a gradient from woodland species, through open woodland/scrub/bracken species to open habitat species.

Analysis of bird densities by habitat type showed that 12 out of 26 species reached relatively high abundance in woodland. However, less expected was the general association that 16 species showed with bracken or bracken mixtures. Tree Pipit, Stonechat, Whinchat and Linnet reached high densities in bracken or mosaics of low vegetation. At the territory and registration scales, many statistically significant patterns of association or avoidance were detected. As expected, woodland was selected by several species. More surprising was the large number of species (11) that selected bracken or mixtures of vegetation including bracken and the general lack of significant association with small tree density. Four species consistently selected areas where gorse was a strong feature at both territory and registration scales. Locations with high diversity of patch types were selected by 12 species at the territory scale and 15 species at the registration scale. This study provides evidence that some bird species are ‘keying into’ certain types of mosaics of vegetation. This is supported by

the fact that many species selected locations with high patch diversity. Mosaics involving bracken seem to be especially favoured by several species, although it appears there is much detailed species-specific variation in preferred mosaics. Gorse is a component of preferred mosaics of four species. The implications for these bracken and gorse mosaics of (a) long-term successional change arising from reduced grazing pressure and (b) different approaches to conservation management are discussed.

Four areas of potential future research are identified: (1) establishing a better understanding of relationships between land-uses and vegetation pattern, (2) more detailed analysis of pattern in the vegetation, (3) modelling of bird species responses to mosaics and vegetation volume, including analysis of non-linear relationships, (4) behavioural studies of resource use. The second and third of these areas could be examined using the data available from this study.

1. INTRODUCTION

Ffridd is increasingly recognised as an important component of Welsh upland landscapes for biodiversity, especially for invertebrates and birds. It typically occupies an intermediate zone on hillsides, lying between higher altitude open moorland and more intensively managed and relatively fertile lower land. Ffridd is highly variable in vegetation composition, ranging from uniform grass or bracken to complex mixtures of grass, bracken *Pteridium aquilinum*, scrub and trees. These mosaics are maintained largely through extensive grazing and intermittent small-scale clearance and burning, especially of gorse *Ulex* spp.. Areas with high spatial heterogeneity are likely to be richest in biodiversity but it is unclear exactly which types of mosaics, in terms of habitat composition and scale, will bring the greatest benefits. There is a need to define what constitutes the most desirable type of ffridd in conservation terms so that appropriate habitat management policies can be developed. Although these complex moorland-edge vegetation mosaics are especially extensive in Wales, similar habitats also occur in parts of south-west England, the Pennines, the Lake District, and southern and central Scotland.

Ffridd has probably always been a dynamic zone of land-use. Changes in the economy of livestock farming have for centuries influenced numbers of animals grazing on the ffridd and the character of the landscape. Many farmers have traditionally used the ffridd as a holding area for livestock before they are moved onto moorland for summer grazing. Since the 1950s, but especially between the mid 1970s and 1990s, numbers of sheep increased in Wales, though there was considerable local variation in trends (Fuller & Gough 1999). Between 1980 and 1990, overall numbers of sheep increased by 0.99 million in North Wales and by 0.84 in central Wales (Fuller & Gough 1999). Grazing pressure intensified in many areas of ffridd during this period and there was probably widespread conversion of semi-natural vegetation to grassland. In the coming years, there may be something of a reversal of this process as a result of Common Agricultural Policy (CAP) reform and economic pressures on hill farmers. If reduction of grazing, and withdrawal from active management more generally, were to become widespread within ffridd, there would be large consequences for vegetation types, habitat structures and the associated biodiversity. The expectation would be that many areas would undergo a contraction of the open ffridd vegetation mosaics, due to increased tree, and possibly bracken, colonization and the gradual development of closed woodland. However, other trajectories of change in land-use are possible. Woodland planting could occur in some areas in response to policy drivers including carbon sequestration, woodfuel production and timber production. With climate warming there could even be an uphill expansion of managed land.

Conservation policy in Wales has recently emphasized the importance of increasing spatial linkages between habitat patches to enhance dispersal of species. So far this has focused mainly on woodland (Latham *et al*. 2004, Latham 2006). Ffridd could potentially form an important element of functional networks of semi-natural habitats in Wales. These networks can form a focus for habitat creation and habitat management initiatives. Such networks may contribute to future population viability in the face of changing climate by allowing species to move into more favourable environments.

In order to predict effects of possible future changes in land-use, and to appreciate how ffridd might best play a part in habitat networks, relationships between habitat structure and biodiversity need to be better understood. An extensive analysis of bird-habitat relationships for 120 ffridd sites has been reported by Fuller *et al*. (2006). This demonstrated that the main spatial variation in breeding bird communities was associated with vegetation composition; for example the presence of trees, even at low densities, appear to have a large effect. However, the analysis provided little information on the preferred vegetation mosaics for the characteristic bird species of ffridd, such as Whinchat and Tree Pipit (Note: scientific names of birds are given in appendix 7).

The broad objective of the work reported here is to provide further, more detailed, information that will assist CCW in developing conservation policy in upland Wales, both with respect to habitat creation and habitat management. This information should also be relevant to the management of similar upland fringe environments in western and northern Britain. The report has three major aims:

(1) To examine how bird species are distributed in the breeding season in relation to vegetation structure and composition on a sample of ffridd sites. This complements earlier work (Fuller *et al*. 2006) by providing a more spatially explicit and finer-scale understanding of bird responses to vegetation in these dynamic environments. It therefore, helps to define the preferred vegetation mosaics of bird species.

(2) To provide an analysis of the habitat characteristics and bird densities of the four main sub-classes of ffridd recognized by CCW.

(3) To provide an insight to the consequences for bird communities of a long-term reduction in active management of ffridd and resulting successional changes.

The project also creates a baseline against which future changes in vegetation and birds within ffridd habitats can be assessed at these sample sites. This is especially relevant to understanding the biodiversity implications of any future reform of livestock grazing regimes under the CAP.

2. METHODS

2.1 Site Selection

A total of 25 sites was selected and surveyed, consisting of 13 in the Snowdonia area (studied in 2008) and a further 12 sites in the Berwyn area (studied in 2009) (Table 1). Each site embraces a gradient of vegetation and land-uses including relatively intensively farmed land (typically lower slopes / valley floor), ffridd (mid slopes) or open moorland (upper slopes / plateau), and five of the sites contained woodland (Table 1).

Nineteen sites were selected as a random stratified sample, which included a representative number of each of four ffridd sub-classes (Blackstock *et al*. 2010), in proportion to their availability. Six further sites were added, based on local knowledge, as being typical examples of ffridd. Site areas ranged between 31 and 74 hectares, with a mean area of 53 hectares (Table 1).

2.2 Bird Survey Methods

2.2.1 Field methodology

Birds were mapped on 1:2500 scale maps using a territory mapping method based on the methodology of the Common Birds Census (CBC), (Marchant 1983, Bibby *et al*. 2000). Four visits were made to each site during the breeding season, for the purposes of bird mapping. All species occurring within the sites and adjacent habitats were plotted and recorded using CBC activity codes and methodology, with particular emphasis on identifying simultaneously singing or observed individuals. With the aid of aerial photographs, major vegetation patches were mapped (see below) before bird fieldwork was undertaken and included on the survey maps to ensure that birds were accurately located within the relevant vegetation patches. The timing of visits occurred within the following periods:

Visit 1: April 20th – May 11th　　Visit 3: May 29th – June 15th
Visit 2: May 8th – May 28th　　Visit 4: June 16th – July 2nd

There was a slight overlap between the first two visit periods due to delays in obtaining access to some sites. All sites received at least two morning and one afternoon visit. Morning visits started no earlier than half an hour after sunrise and finished by 1200 hrs. Afternoon visits commenced after 1500 hrs and finished at least two hours before sunset, coinciding with the peaks of bird activity at the beginning and end of the day. The afternoon visits were also used to collect records of confirmed breeding during the latter half of the survey period. On each visit the entire area of the plot was systematically searched, approaching all areas to within approximately 50 m, though some of the very open grassland was covered to 100 m. Different routes were used on individual visits to avoid biasing distribution of records due to variation in bird activity with time of day. Birds were mapped outside the plot boundary up to a minimum distance of 50 m.

2.2.2 Assessment of territory numbers and locations

All species records and activity codes from all four visits were taken from the field maps and plotted using a geographical information system (GIS) in ArcGIS v9.2 (ESRI). Each record was coded with the relevant site number and visit date. Territory cluster interpretation was then applied to the registrations (i.e. individual bird records) from all four visits; each cluster of points being contained within a single polygon, which was coded with the species. Central points of territories were identified for subsequent analysis by using the ET Geowizards Tool in ArcGIS v9.2.

The number of territories for each species was determined for each site using criteria based on that of the CBC methods (Marchant 1983). This used the field-based relationships between individual registrations recorded simultaneously, which were therefore known to be different, the same individual or probably different individuals. These relationships were used to define territory clusters.

However, it was necessary to modify the territory criteria to account for our 4-visit method rather than the typical 8-12 visits in a similar way to that adopted recently for extensive national surveys of woodland birds (Hewson *et al.* 2007). All records of birds only noted in active flight, moving directly over sites, were excluded (e.g. gulls, Grey Heron and Swift). Criteria used to define a territory cluster included:

1) A singing male, or pair, or two individuals on one or more visits
2) Single non-singing individuals on two or more visits
3) Raptors and corvids: a displaying bird on a single visit, or single birds in flight on at least two visits or a pair on a single visit.

To standardise the assessment of territory clusters, where no information on simultaneous registrations was available, a minimum distance threshold was applied (Appendix 2) to define separate territories. These criteria were adapted from Hewson *et al*. 2007 for woodland species and an assessment, from known different individuals, was applied to species occupying open habitats. A registration or group of registrations, which were separated by a distance exceeding the minimum threshold, was counted as a separate territory. In cases where a territory cluster included individuals from outside the site boundary, a territory was counted if half, or more, of the registrations were located within the site boundary. Territory clusters with the majority of registrations falling outside the site boundary, or possible clusters not meeting the minimum acceptable criteria, were not counted as territories and excluded from subsequent analyses.

2.3 Habitat Survey Methods

2.3.1 Field methodology

A multi-scale method was used to map and sample vegetation composition and structure. Distinct habitat patches (i.e. areas within which vegetation appeared to be relatively uniform in appearance with no obvious discontinuities) and boundaries were initially determined from colour aerial photographs taken in 2006 provided by CCW. It was possible to identify certain vegetation types (see categories below) from the photographs but the locations and boundaries of distinct habitat patches were subsequently ground-truthed for all sites to ensure that spatial variation in vegetation was as accurate as possible. These distinct habitat patches were digitised from the aerial photographs, using Arc Map v9.2, to provide a spatially referenced habitat polygon layer.

The locations and density of scattered trees (non-woodland), with crowns greater than approximately 2 m diameters, as determined from aerial photographs taken in summer 2006, were plotted throughout the entire site using ArcMap v9.2. Tree locations were confirmed in the field and additional trees were plotted as necessary (mainly those with crowns less than 3 m diameter), and the species of each determined and recorded. Trees were divided into two categories based on tree canopy diameter; small (less than 6 m) including mainly hawthorn *Crataegus monogyna*, and large (greater than 6 m) trees including oak *Quercus petraea* and rowan *Sorbus aucuparia*.

Detailed measures of vegetation structure and coverage were also collected at 40 sample points on each site. Details of the methods used to gather these sample point data are given in Appendix 1. A detailed analysis of the sample point data is not presented here due to lack of resources (see Discussion). This report concentrates on an analysis of the habitat patch and tree data which were collected over the entire extent of each site and are therefore especially appropriate for assessing spatial pattern in the ffridd mosaics. All vegetation recording, with the exception of the sample points in 2009, were undertaken by one observer (GC) to achieve consistency of approach.

2.3.2 Derivation of habitat patches and habitat types

A large number of individually distinct habitat patch types, many of which consisted of particular mixtures of the dominant plants, were determined from the aerial photographs and field assessments. To simplify the analysis, it was necessary to reduce the different patch types to a more manageable number. Our approach was to combine patch types that were of similar structural composition (knowledge gained from the sample point data was helpful in this process). By 'structure' we mean the average height, density and canopy structure of vegetation. The rationale for adopting a predominantly structural approach was that we thought it most likely that fine-scale bird distributions would be determined more by physical structure than by floristics per se. Initially, all patches containing bare rock (i.e. contributing minimal structural elements) were combined with their counterpart patches, not containing a bare rock component. This resulted in 47 distinct patch types which were then combined into 10 simplified habitat types based largely on habitat structure. These are subsequently referred to as 'habitat types' and individual spatial patches, irrespective of their habitat type, are referred to as 'habitat patches'. The 10 habitat types, differing in micro- or macro-structure are (see also Table 2):

1) G - Grass dominated (including *Juncus*)
2) B - Bracken dominated
3) H - Heather dominated
4) BG - Bracken and Grass dominated mixture
5) BH - Bracken and Heather dominated mixture
6) GH - Grass and Heather dominated mixture
7) GHV - Grass, Heather and Vaccinium dominated mixture
8) GORSE - Strong Gorse component
9) WOOD - Woodland
10) OTHER - Additional habitats, including farm yards, rock and open water

Note that wet grassland and flushes are included within the grass dominated category; most of these wet patches were small and appeared to show rather little effect on bird communities, though this would merit closer examination. The gorse category includes both *Ulex europaeus* and *U.gallii* so there is some variation in physical structure within this category. Areas within heath that are dominated by *U.gallii* have been classified as gorse.

2.3.3 Landscape, site and patch metrics

Site metrics and spatial mosaic structure were summarized using Fragstats 3.3 (McGarigal *et al.* 2002). The habitat polygon layers for each site, consisting of the ten habitat types, were converted to raster files, with a cell size of 1 m x 1 m, using ArcMap v9.2, prior to analysis in Fragstats. Eleven site-level metrics derived from Fragstats were: number of habitat patches, patch density, largest patch index, landscape shape index, mean patch area, median patch area, mean patch shape, median patch shape, mean nearest neighbour distance, Simpson's diversity index and Simpson's evenness index. Median altitude and altitude range was calculated for each site, along with the tree density, classified as total, small and large trees. Abbreviations for the metrics are given in Table 2 and a summary of each metric is provided in Appendix 3.

2.3.4 Species habitat associations

The general associations of breeding bird species with each of the ten habitat types was examined by simple calculation of the mean territory density and standard error for all species with more than 20 territories across all the sites. In calculating densities for habitat types, only individual habitat patches potentially large enough to support breeding bird territories were used i.e. with an area greater than one hectare. Territories were allocated to habitat patches according to the location of the central point.

Within a landscape, each species is expected to show selection (= preference) for, or avoidance of, or neutrality towards particular habitat types, mosaics or structural features. Selection or avoidance imply stronger or weaker occupancy respectively of a feature, than one would expect from its availability. This may involve selection of habitat at the level of the entire territory or, smaller units or features, particularly in landscapes containing a fine-grained mosaic of habitats. To investigate species–specific habitat selection we considered two spatial scales, the territory and the individual registration locations. Territory level habitat was assessed by placing a 50 m radius buffer around the territory centre point. A 50 m radius buffer was considered to provide a representative, yet conservative, measure of the habitat within the core of the territory. Sub-territory level habitat was assessed by placing 25 m radius buffers around individual registration locations of each individual within a defined territory cluster. For each size of buffer the proportion of area of each of the ten habitat types was calculated, as well as Simpson's indices of habitat diversity (Simpson 1949) and evenness, patch density and density of small trees. The association of individual species with the ten habitat types was assessed by comparing the habitat composition at territory and registration locations with the availability of each habitat type across all sites.

Available habitat was examined using a standardised selection of locations generated at the intersections of all 100 m grid cells (based on the British National Grid), falling within the site boundary. These are termed 'regular' points and are used to provide a measure of habitat availability at each site with which actual use can be compared to give an assessment of association (i.e. selection or avoidance). Each regular point, registration point and territory centre point, was buffered with 25 m and 50 m radius buffers to create polygons. These polygons were then intersected using, the Intersect tool in ArcGIS v9.2 (ESRI), with the habitat polygon layer for the site and the percentage area of each habitat type within each buffer was calculated.

A habitat profile for each species was generated by bootstrapping (Efron 1982). A mean value and 95% confidence interval for the proportion of each habitat type, number of small trees, patch density and diversity index was derived for each species (equal to the number of records) from random selections of the regular points, with replacement and 1000 iterations. Habitat preference, or avoidance, for each species was assessed by comparing the 95% confidence intervals for the usage of each habitat type with that of the available habitat (from the regular points). Where the 95% confidence intervals of both the species and available habitat type did not overlap, a significant relationship was indicated - either avoidance or selection depending on whether the usage mean was lower or greater respectively than the availability mean.

Habitat composition and diversity measures might differ depending on the size of buffer for a given sample point. Therefore, to investigate whether there were systematic differences between 25 m and 50 m buffers that might affect the conclusions, the mean and 95% confidence intervals for each habitat type and the diversity indices were compared using the regular points only (i.e. at the intersections of the 100 m grid within sites).

2.3.5 Statistical approach

The Kruskal-Wallis test (Sokal & Rohlf 1981), a non-parametric method in lieu of single classification ANOVA, was used to examine whether there were differences among the four ffridd sub-classes in patch metrics, area of each of the ten habitat types and the density of breeding bird species. Correlation matrices with non-parametric Spearman coefficients were used to examine relationships between all the habitat variables, patch metrics and altitude.

Breeding bird assemblages among sites, ffridd sub-classes and study regions, were examined in relation to landscape metrics and percentage areas of the ten habitat types, using a detrended correspondence analysis (DCA). Canoco 4.5 (ter Braak & Smilauer 2002) was used for the analysis; species data was not transformed, the detrending method was by segments and rare species were down weighted.

3. RESULTS

3.1 Relationships Among Landscape, Patch and Habitat Variables at the Site Level

With so many patch and habitat variables, it is to be expected that there will be correlations between many of them. Here we summarise the extent of correlations between these variables to identify which tend to be associated, which can be effectively regarded as surrogates, and to seek patterns in the characteristics of the sites.

For the landscape and patch metrics, there were strong correlations between several of the patch metrics (Table 3). Here we emphasize correlations greater than 0.60. Overall tree density was, not surprisingly, correlated with the density of both small and large trees. The Simpson's diversity and evenness indices were strongly correlated ($r = 0.87$). Patch density was highly correlated ($r > 0.90$) with both mean patch area (-ve) and landscape shape index (+ve), indicating that as the number of patches per unit increased so their average area decreased and the spatial configuration became more complex. The diversity index was also moderately strongly correlated ($r = 0.55$ to 0.66) with these three patch metrics indicating that diversity of habitat types as well as complexity in their spatial attributes tend to be associated. Patch density and patch diversity, therefore, appear to be useful measures of spatial and habitat complexity in the ffridd mosaics. We therefore incorporate these variables into the analyses of habitat selection at territory and registration scales presented below.

Largest patch index is related to the two Simpson indices, to tree density (negatively) and to mean altitude (+ve) (Table 3). Nearest neighbour distance and mean patch shape are not correlated with other variables (with two exceptions) and are rather difficult to interpret (Table 3). Median altitude is moderately strongly correlated ($r > 0.50$) with patch density (-ve), largest patch index (+ve), landscape shape index (-ve) and mean patch area (+ve). This suggests a tendency for higher altitude sites to have less complex mosaics. There were no other correlations with altitude with the exception of a weak negative correlation with the diversity index and tree density (Table 3).

Correlations between cover values of the ten habitat types showed relatively few strong and statistically significant relationships (Table 4). By far the strongest was a negative correlation between gorse and bracken/heather mixtures.

Relationships between the landscape and patch metrics and the cover values of the ten habitat types are detailed in Table 5. The main patterns that we draw attention to here are that bracken dominated sites tend to be spatially complex (i.e. have relatively high patch density, landscape shape index and low mean patch area). They are also relatively rich in scattered trees. Sites with relatively large areas of bracken/grass mixtures also tend to be rich in trees, whereas sites with much heather tend not to be.

3.2 Comparison of the Four ffridd Sub-classes: Habitat Attributes and Bird Densities

The sample sizes for the individual ffridd subtypes were small so the power to detect differences between them was limited. For this reason we report statistical differences significant at $P < 0.10$. Significant differences between the landscape and patch metrics among the four ffridd sub-classes were evident for Simpson's diversity index, altitude range (both at $P < 0.05$), and for large tree density at $P < 0.10$ (Table 6). Differences between the four ffridd sub-classes in terms of percentage cover of the ten habitat types were only evident for bracken/grass mixture (Table 7). Note that patch metrics and habitat cover values for individual sites are given in Appendices 4 and 5 respectively.

The mean territory density, for each each of the ffridd subtypes is shown in Table 8.

A total of 67 bird species was recorded holding territory on at least one of the 25 sites comprising 13 red and 25 amber listed as UK birds of conservation concern (BoCC) (Eaton *et. al.* 2009). In terms of Welsh birds of conservation concern, 16 species were red listed and 21 species were amber listed (Johnstone *et al.* 2010). There were statistically significant differences in mean breeding bird territory density between the four ffridd subtypes for two 'open' habitat species, Meadow Pipit and Tree Pipit, and fifteen 'woodland' species (Table 8). The densities for each species on each of the 25 sites are given in Appendix 6.

Ordination of the bird assemblages by DCA (Figure 2) indicates that there is some separation between the ffridd sub-classes on axis 1 (Figure 2). In terms of bird assemblages, sub-classes 1 and 4 lie at opposite ends of a gradient (one sub-class 4 site is an exception). Sub-class 1 sites are richest in woodland birds while sub-class 4 sites appear to be typified more by moorland species such as Red Grouse, Wheatear and Meadow Pipit. Sub-classes 3 and 4 are intermediate and probably tend to be typified more by complex mixtures of open habitats.

3.3 Species Assemblages and Habitat Gradients Illustrated by Ordination

Ordination of the species assemblages associated with each site by DCA, showed no difference between the Snowdonia and Berwyn survey regions (Figure 1). There was a very high overlap of sites from the two regions within the ordination space. Therefore, it was considered safe to pool the bird and habitat data from both regions.

The species scores show a clear pattern along Axis 1 (eigenvalue of 0.38) and indicate a gradient across three distinct ecological groups, comprising 1) woodland, 2) open woodland/scrub and 3) non-woodland species (Figure 2). It is not clear that axis 2 represents any meaningful ecological gradient in terms of bird assemblages.

Figure 3 shows site scores derived from the bird species ordination. Axis one clearly represents a gradient (negative to positive) from woodland and high tree density to larger sites dominated by large patches. To some extent the latter sites were associated with heather and heather/bracken mixtures. Gorse is something of an outlier – although it is positioned at the positive end of axis 1 it has a very negative score on axis 2, unlike any other variable. Sites with intermediate scores on axis 1 appear to be characterized by vegetation mixtures and complex mosaics (note that patch density is not shown because it appears very close to the centre of the diagram). Correlation coefficients between the site scores and the individual variables are shown in the shaded columns in Tables 3 and 4. These emphasise that there are especially strong gradients in the overall composition of bird assemblages associated with low values of tree density, woodland and bracken, but with high values of heather and patch area. This suggests a major gradient in bird assemblages from more wooded / bracken covered sites to ones with much open heather and vegetation occurring in relatively large patches. There were no direct effects of altitude on bird community composition but indirect effects were likely to operate through effects of altitude on vegetation e.g. through the relationships between altitude and patch density and patch area (Table 3).

3.4 Broad Scale Habitat Associations at the Patch Level

The mean territory densities, and standard error, within large patches (greater than one hectare) of the ten habitat types, for species with 20 or more territories are shown in Figure 4. A diversity of broad habitat associations is evident across the 26 species. As expected, a high proportion of the species (12 out of 26) show highest or second highest densities in woodland.

Perhaps more surprisingly, a considerable number of species also show general associations with bracken or bracken mixtures. These include Chaffinch, Cuckoo, Coal Tit, Great Tit, Garden Warbler, Linnet, Lesser Redpoll, Meadow Pipit, Tree Pipit, Robin, Stonechat, Song Thrush, Whinchat, Willow Warbler, Dunnock and Wren. In some of these cases, the presence of scattered trees and bushes within bracken and bracken mixtures will be an important element of habitat suitability (see below). Four species, in particular, reach highest densities in bracken or mosaics of low vegetation: Tree Pipit, Stonechat, Whinchat and Linnet.

Habitat associations are examined from a smaller-scale and bird-centred, rather than patch-centred, perspective below. These following analyses give a more detailed assessment of habitat selection at scales that are meaningful for individual birds.

3.5 Fine Scale Habitat Associations at the Territory and Registration Level

The proportion of each of the ten habitat types measured within 25 m and 50 m buffers placed around the territory centres, across all standardised habitat sample points, did not show significant differences (Figure 5). However, Simpson indices for habitat diversity and evenness, patch density and density of small trees showed larger values within 50 m buffers compared to the corresponding 25 m buffer. It was therefore decided that the 50 m radius buffer would be used to compare habitat at the territory centre, being more representative of the territory extent, and the 25 m radius buffer be used to compare habitat at the registration location, to focus on very fine-scale use of habitat within the territory.

3.5.1 Habitat associations: territory centre locations

Proportional habitat use by species, as indicated by 50 m radius buffers located around territory centres, compared to the actual availability of each habitat type is shown in Figure 6. The species showing significant preferences for a particular habitat type, above the level of availability across all sites were examined as follows with especially strong selection shown in bold:

Grass dominated: Skylark, Wheatear
Bracken and Grass dominated mixtures: Chaffinch, Tree Pipit and Willow Warbler
Bracken dominated: Redstart, Robin, **Tree Pipit**, **Wren** and **Willow Warbler**.
Bracken and Heather dominated mixtures: Whinchat
Grass, Heather and Vaccinium dominated mixtures: Meadow Pipit
Heather dominated: Meadow Pipit
Gorse mixtures: Wren, **Stonechat**, **Linnet**, and **Dunnock**
Woodland: **Blackbird**, **Blue Tit**, **Chaffinch**, **Garden Warbler**, **Great Tit**, **Pied Flycatcher**, **Redstart, Song Thrush**, **Robin**, **Willow Warbler** and **Wren**.

It should of course, be noted that there are also many examples of species avoiding particular habitats. All of the species selecting woodland or gorse, with the exception of Blackbird, avoided grass and many of them avoided heather and heather mixtures.

Twelve out of the 23 species selected locations with a relatively high patch diversity (Simpson Index) and five species selected high patch density. Only one species, Skylark, selected low patch diversity and density.

Density of small trees was not a selected feature by any species, although Tree Pipit and Lesser Redpoll showed a non-significant tendency to select territories with more small trees. Several species appeared to avoid locations with small trees including several woodland species (e.g. Blackbird, Blue Tit, Great Tit, Pied Flycatcher) and the two open country specialists Meadow Pipit and Skylark. Interestingly the four gorse specialists – Stonechat, Linnet, Dunnock and Wren – all tended to avoid areas with high density of small trees, perhaps simply because their preferred habitat rarely contained many small trees.

3.5.2 Habitat associations: registration locations

Patterns of habitat use within a 25 m radius buffer of the registration locations (Figure 7) show similar associations as for the territory centres (Figure 6). There were, however, some differences. Most strikingly, at the scale of registration, bracken and bracken mixtures were associated with more species than at the territory scale. Bracken associations (especially strong in bold) were evident for Chaffinch, **Garden Warbler**, **Lesser Redpoll**, **Reed Bunting**, Robin, **Song Thrush**, **Tree Pipit**, Whinchat, Willow Warbler and Wren (Figure 7). Not all the 'woodland associated' species at the territory scale, showed a woodland association at the registration scale e.g. Garden Warbler, Great Tit and Song Thrush.

The only other notable differences in preference for registration locations compared to territory habitat was for patches of gorse in Wheatear, grass / heather / Vaccinium in Whinchat and grass in Carrion Crow.

Fifteen species selected high habitat type diversity locations at the registration scale, compared with 12 species at the territory scale. At the registration scale, there was no evidence that any species was selecting high patch density but two species (Blackbird and Blue Tit) avoided high patch density.

Two of the species that avoided small trees at the territory scale showed the opposite relationship at the registration scale – Blackbird and Blue Tit (Figure 7). However, there were no other species selecting small trees at this scale, and in fact there was an overwhelming avoidance of them.

4. GENERAL DISCUSSION

4.1 Context of the Current Study in Space and Time

The previous study of ffridd bird communities (Fuller *et al*. 2006) was based on a sample of 120 sites spread throughout Wales whereas the current study examined 25 sites in the north of Wales. The former study provided a broad overview of ffridd bird communities and their general relationships with topography, geographical location and vegetation. However, the bird data and vegetation data collected in that study were considerably less detailed than in the current study and did not, for example, allow assessment of habitat preference, as opposed to simply describing habitat occupancy. Nor did they establish a sufficiently detailed baseline for any of the sites against which future changes in ffridd habitats (in terms of vegetation cover and the spatial arrangement of broad vegetation types) could be assessed and the responses of breeding birds measured. The present study, therefore, represents a substantial step forward in our ability to understand how different species of birds key into these complex environments.

The results in this report should have wider general applicability in Wales because geographical location was relatively unimportant compared with vegetation type as an explanatory factor of overall variation in bird communities in the 1980s (Fuller *et al*. 2006). Nonetheless, in the 1980s some species tended to be less abundant on ffridd in the north of Wales including Skylark, Meadow Pipit, Wheatear and Tree Pipit. Some of this regional variation in the 1980s sample may have arisen because the sites were not sampled at random, or in a random stratified manner. In the present study the four CCW ffridd sub-classes were used as a basis for stratifying site selection. Although the sample sizes in each of the ffridd sub-classes were small, there were clear differences in the bird assemblages of the subtypes (Table 8, Fig.2). Additionally there were several significant differences between the sub-classes in patch and landscape metrics and habitat variables (Tables 6 and 7). The use of the sub-classes has helped to ensure that a representative range of ffridd conditions has been included in the analysis.

It is difficult to draw comparisons between this study and the 1980s study in terms of the bird communities and changes in abundance of individual species. The current study was not designed to assess changes in abundance in bird species since the 1980s: the sampling rationale was different, samples sizes differ greatly and there were differences in field methodology. Nonetheless, it is worth noting changes in site frequency for several of the ffridd specialists. These are as follows with percentage of occupied sites in the 1980s followed by that in the 2000s:

> Meadow Pipit 100% - 100%; Tree Pipit 81% - 60%; Wheatear 79% - 60%; Whinchat 73% - 60%; Yellowhammer 62% - 4%; Skylark 45% - 68%; Linnet 44% - 56%; Stonechat 6% - 88%.

The most striking of these changes are for Yellowhammer and Stonechat. Yellowhammer was recorded on 73 (62%) of the sites in the 1980s and was the sixth most frequent and abundant species in that sample. Yellowhammer showed no evidence of being scarcer in the north of Wales (see Fig. 3 in Fuller *et al*. 2006) so it seems quite likely that it has greatly declined on the ffridd in the last two decades. Stonechat, however, appears to have greatly increased on the ffridd over the last two decades and this is borne out by the expansion shown by this species in the uplands of Wales and England by the two national bird atlases between approximately 1990 and 2009 (Dawn Balmer pers. comm.). These findings are consistent with the national trends for Wales which show Stonechat numbers to have increased by 168% and Yellowhammer to have decreased by 40% between 1995 and 2008 (Risely *et al.* 2010). It is also worth noting that Ring Ouzel was recorded at 8% of sites in the 1980s and 4% of sites in the 2000s.

4.2 Responses to Vegetation Mosaics

The ffridd is typified by patchworks of different vegetation types occurring in different spatial configurations and compositions. The approach taken in this study is to define mosaics in terms of habitat types (i.e. broad vegetation types) that are likely to be meaningful to birds. A strictly floristic approach would probably define individual patch types on a different basis, as would a purely structural approach based on remote sensing (e.g. LiDAR – see below). It should also be recognised that there is a fractal dimension to mosaics (Dolman & Fuller 2003) which has not been analysed here (see below). This is probably especially true for the presence of gorse and trees that may be nested within certain patch types. Mosaic attributes were defined in several ways including patch density and habitat diversity. These two measures appear to be especially useful in defining spatial vegetation heterogeneity.

The concept that complex habitat mosaics may enhance biodiversity is based on the following assumption. Imagine two defined areas containing exactly the same proportions of habitat types. In one of these areas each habitat type exists as one regular shaped patch. In the other area, each habitat type exists as several smaller patches of irregular shape. The mosaic hypothesis predicts that biodiversity will be higher where habitat pattern is closer to the latter arrangement. There are at least two potential mechanisms by which complex mosaics may benefit species. Firstly, some species may preferentially use habitat boundaries especially for foraging, possibly because microstructures and invertebrate availability are likely to be different there. Secondly, the landscape or resource complementation concept may operate whereby a species derives one resource (e.g. suitable vegetation for nest sites) from one habitat type and a different resource (e.g. food) from another habitat type (Dunning *et al*. 1992).

There are several pieces of evidence from the present study that bird species in ffridd are 'keying into' particular mosaics. There are summarised as follows:

(1) Several species select more than one habitat type. In the case of the 50 m buffers around territory centres, seven out of 23 species were significantly associated with more than one habitat type (Fig. 6) and in the case of 25 m buffers around registrations, nine out of 21 species were significantly associated with more than one habitat type (Fig. 7). This is not strong evidence of the importance of mosaics because species may have more than one preferred habitat type and do not necessarily need them present in combination. However, the fact that several species are associated with multiple habitats at such small spatial scales is consistent with the mosaic hypothesis.
(2) Many species were selecting areas of high patch diversity as measured by Simpson's Diversity Index. For territory centres 12 out of 23 species (Fig. 6) patch diversity was significantly higher than in the overall available habitat. For registrations the equivalent figures were 15 out of 21 species (Fig. 7). Only Skylark avoids patches of high diversity. Interestingly, these relationships were not evident for patch density, suggesting that patch composition, rather than merely configuration, may be important to birds.

The evidence from patch diversity is especially compelling - a substantial proportion of species are selecting areas where the spatial composition of vegetation is relatively complex. Can we identify especially important mosaic types for birds? To some extent these are species-specific (see information in Figs. 6 and 7). However, some general observations can be made. Firstly, mosaics involving Bracken seem especially favoured by several species. This is consistent with the findings of Fuller *et al*. (2006).

The functional basis of these relationships with bracken is unclear. In particular, to what extent does bracken itself provide critical resources for different species or does it effectively act as a surrogate for a complex of attributes that birds key into? Pure bracken stands are widely regarded as poor in biodiversity, including bird diversity. However, it seems likely that mixtures of bracken with other habitat types may be important to many species. Table 5 indicates that at the site level, bracken is correlated with patch density (+ve), landscape shape index (+ve), nearest neighbour index (-ve) and with tree density (+ve). The selection for bracken-rich areas may in some way be related to the presence of trees and elements of spatial complexity in habitat availability. However, it is surprising that tree density was rarely selected as a habitat feature (Figs. 6 & 7). It is possible that some species actually avoid patches with high densities of trees but do require a small number of trees in their territories. The possibility that many of these relationships are of complex non-linear forms needs to be explored further (see below).

The present study is interesting in relation to earlier suggestions that bracken may be an important habitat for Whinchats in particular (Allen 1995). The selection for pure bracken was only evident at the registration scale and was not as strong as that shown by several other species. However, both at territory and registration scales, Whinchats were selecting mixtures of bracken with other vegetation and indeed was the only species with the exception of Meadow Pipit to select bracken mixtures.

Gorse emerges as a selected habitat feature for several species: Dunnock, Linnet, Stonechat, Wren and Wheatear. The latter is a very surprising result which is not readily explained. Fuller *et al.* (2006) also found that Gorse was an important feature for Dunnock, Linnet and Stonechat. Although at the territory and registration scales, scattered trees appear not to emerge as an important selected feature (Figs. 6 and 7) they were the most strongly correlated variables ($r > 0.70$) with the axis 1 scores summarising variation across sites in bird assemblages. The cover of woodland was also an important explanatory variable of axis 1 but was only correlated at $r = 0.61$. This suggests either that scattered trees may have some function in determining the types of bird assemblages or that they are acting as a surrogate for some other, either unmeasured or poorly measured, feature of sites that is important.

The most useful information on bird-habitat relationships in the ffridd emerged at the finest scales i.e. the territory and registration analyses in Figs. 6 and 7. These are scales at which relationships between bird distribution, vegetation composition and spatial pattern can be most meaningfully explored.

The patterns of habitat association that emerged from the analysis of bird density (Fig. 4), the territory scale analysis (Fig. 6) and the registration scale analysis (Fig. 7) were somewhat different. The bird density analysis gives an indication of associations that exist with relatively large blocks of more or less uniform habitat. Therefore, it has little capacity to provide information about mosaic effects. The bird-centred analyses at the territory and registration scales, however, are informative about fine-scale mosaic effects; they also indicate how sensitive results can be to the choice of scale even at this fine level. In particular, the registration-focused analysis revealed considerably more relationships with bracken and bracken mosaics.

4.3 Successional Change – Likely Consequences

If ffridd habitats were to fall into widespread agricultural neglect through withdrawal of grazing, there would obviously be large consequences for the composition and pattern of vegetation. The rate of change would presumably vary spatially depending on seed sources and regeneration patterns within different types of vegetation – grass and bracken with deep litter layers may, for example, inhibit regeneration.

The long-term consequences for birds are fairly clear, though it should be borne in mind that future habitat associations may not necessarily remain the same due to wider environmental changes, especially in climate. Those species that depend on the open habitats, including the mosaics containing gorse and scattered trees, would gradually disappear and woodland species would come to dominate. This is the general pattern of avifaunal change that has occurred in many Mediterranean areas where abandonment of traditional livestock regimes has occurred (Sirami *et al*. 2007, 2008). The broad changes in species composition can be predicted from the ordination analysis (Fig. 2) which represents a gradient on axis 1 from sites with relatively large amounts of trees and woodland to sites with relatively little. The analysis of territory densities (Fig. 4) is useful in this context. It indicates that the specialist species of the open ffridd – notably Stonechat, Whinchat, Linnet, Reed Bunting and to some extent Tree Pipit and Lesser Redpoll – would be gradually squeezed out.

These broad-scale predicted changes are obvious and not especially interesting – if there is large scale change in habitat towards woodland it is inevitable that woodland birds will benefit and open country species decline. Somewhat more interesting – and perhaps more realistic – would be the consequences of episodic periods of tree regeneration (for example due to a fluctuating hill farming economy). The dynamics of relationships between grazing pressure and the structure and composition of vegetation mosaics is an area of research that needs more attention (Fuller & Gough 1999). Exactly how ffridd mosaics consisting of bracken, heather, grass, gorse and scattered trees would respond to different levels of grazing pressure is unknown. In addition, it would be potentially useful to assess responses of bird communities to landscapes with varying proportions of different seral stages.

4.4 Management Implications

This study illustrates, for one taxonomic group, that individual species vary greatly in their preferred habitat types and preferred mosaics within the ffridd. Maintaining complexity of habitat structure would therefore seem to be a priority for future management. A fundamental feature of ffridd environments that underpins their biological value is that they are dynamic in space and time. Local variation in grazing pressure, burning and possibly in traditional patterns of use have generated great complexity of pattern in the composition and structure of vegetation. In a strictly bird context, the bracken mosaics including scattered trees, and gorse dominated areas contribute key habitats and it is highly desirable that these should continue to form a major and widespread component of ffridd. Further work is needed to characterise these 'high priority' mosaics more fully (see below) before refined management actions could be established.

Conservation of species and habitats in Britain often adopts an interventionist, target-led and prescription-based approach. In the ffridd one could imagine this might take the form of identifying the preferred mosaic structures and implementing very precise management at specific locations with the aim of creating those structures. The techniques that might be used could include the tried and tested conservation armoury - cutting, mowing, spot treatment with chemicals, tightly controlled grazing etc. This approach would, however, go against the grain of past land-use and would risk losing some of the unpredictable diversity of pattern and vegetation structure that is so evident in the ffridd and that provides niches for a wide range of animal species. A landscape outlook founded on temporally variable, low intensity grazing seems more appropriate, possibly supplemented by occasional intervention in areas where there is a case for maintaining especially interesting features.

Recent thinking developed in Australia about how the dynamics of semi-natural landscapes interact with biodiversity could have real relevance to the ffridd. These concepts embrace the biodiversity value of scattered trees (Manning *et al*. 2009a), the notion that elements of the landscape are not static and may shift spatially (Manning *et al*. 2009b) and the idea that landscapes provide continua of resources for biodiversity (Fischer *et al*. 2006). The ffridd is a western European landscape that has to some extent been functioning for centuries in ways that are consistent with these emerging concepts.

If there was a shift in land-use within the ffridd environment, either in the direction of neglect or alternatively in the direction of more systematic land-use (agriculture or forestry), this dynamism would be reduced for an indeterminate period. Such land-uses, if applied on a large scale, would not be compatible with maintaining the vegetation mosaics that are currently characteristic of much ffridd.

4.5 Future Research Directions

This report has given insights into habitat selection by birds breeding on the ffridd and has considerably advanced our earlier understanding (Woodhouse *et al*. 2005, Fuller *et al*. 2006) especially by relating habitat occupancy to habitat availability. Several areas of further work would be especially valuable in helping to understand the dynamics of ffridd and how birds and other taxa respond to the variability of structure and vegetation that it embraces:

(1) *A better understanding of relationships between land-uses and vegetation pattern.* Particular questions concern how temporal variation in grazing pressure, seasonal patterns of grazing, and frequency of burning affect vegetation mosaics. This information would be invaluable in assessing what type of extensive grazing regimes might best maintain the diverse character of ffridd.

(2) *More detailed analysis of pattern in the vegetation.* The approach taken to the description of pattern in this report is only one of several possible approaches and, to some extent, it has been developed from the perceived habitat needs of birds. It would be valuable to develop a more data-driven assessment of structural pattern and gradients, some of which may be fractal in nature. The current data could be examined in greater depth to identify the extent to which certain patch types and habitat features (e.g. scattered trees) are nested within other patch types. If this were complemented with entirely independent assessment of spatial pattern derived from LiDAR it would be possible to characterise more clearly how species fitted onto spatial gradients and discontinuities represented by vegetation height. This approach has been shown to work in lowland woodland where individual bird species have been found to select fairly consistent profiles of canopy height and openness (Hinsley *et al*. 2009). Two specific questions concerning vegetation type that would merit further investigation are (a) the use of wet flushes and grassland by birds relative to drier areas and (b) the effect of different gorse structures on bird assemblages.

(3) *Clearer characterisation of bird species responses to mosaics and vegetation volume.* Modelling species responses to habitat composition to take account of nonlinearities is important. It is very likely that for some species there are 'optimum quantities' of different vegetation components so that the occupancy of individual locations would show a 'hump-backed' or quadratic relationship. As noted above, this would be especially useful for bracken, gorse and scattered trees. In addition, this analysis could make more use of the structural data collected from the stratified random points at each site (Appendix 1).

(4) *Behavioural studies of resource use.* To really understand the functional significance of habitat mosaics it would be necessary to undertake very detailed observations of how individual birds used the various components of vegetation available to them (plant species, particular structures, edges etc.) This would be difficult and would probably require use of radio tracking and / or other more advanced technologies to quantify use of space, coupled with direct observation of behaviour. Appropriate species might be Whinchat, Stonechat and Tree Pipit. We suggest this may be appropriate for student projects.

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Table 1 Location and classification of sites surveyed in 2008 (Snowdonia) and 2009 (Berwyn).

Site number	Study area	Site name	Central grid reference	Ffridd subtype	Selection	Area (ha)
1	Snowdonia	Cefn yr Orsedd	SH635647	1	Stratified Random	41
6	Snowdonia	Llyn Ffynhonnau	SH523552	2	Stratified Random	74
8	Snowdonia	Tanygrisiau Reservoir	SH678431	2	Stratified Random	40
10	Snowdonia	Waen Bryn-gwenith	SH744676	3	Stratified Random	74
11	Snowdonia	Betws Garmon	SH541575	3	Stratified Random	40
13	Snowdonia	Cwm Penmachno	SH750480	3	Stratified Random	58
16	Snowdonia	Cors Gwaun y Gwiail	SH647661	4	Stratified Random	48
18	Snowdonia	Tyn-y-mynydd	SH534604	4	Stratified Random	48
19	Snowdonia	The Ricks and Racks	SH703577	4	Stratified Random	52
20	Snowdonia	Nantgwynant*	SH622494	4	Stratified Random	50
23	Snowdonia	Tyn-y-maes Farm	SH637636	3	Local knowledge	68
24	Snowdonia	Bwlch ym Mhwll-le	SH635684	4	Local knowledge	65
25	Snowdonia	Hafod-lwyfog*	SH658523	1	Stratified Random	37
3_4	Berwyn	Tyn-y-fron*	SH913255	3	Stratified Random	43
1_1	Berwyn	Pentre-tai-yn-y-cwm	SH954406	1	Stratified Random	46
2_2	Berwyn	Alltforgan*	SH970246	2	Stratified Random	31
2_3	Berwyn	Rhiwaedog-is-afon	SH986329	2	Local knowledge	61
3_6	Berwyn	Rhanneg	SJ003337	3	Local knowledge	58
4_3	Berwyn	Llechwedd Groes	SJ032314	4	Stratified Random	65
3_5	Berwyn	Llandrillo	SJ045355	3	Local knowledge	63
1_2	Berwyn	Llwyn Onn*	SJ073264	1	Stratified Random	51
2_1	Berwyn	near Deeside Quarry	SJ132397	2	Stratified Random	61
4_6	Berwyn	Foel Gôch	SJ133327	4	Local knowledge	68
3_2	Berwyn	Graig Fawr	SJ134356	3	Stratified Random	33
4_2	Berwyn	Tuhwntir Afon	SJ145355	4	Stratified Random	55

* High component of woodland.

Table 2 Abbreviations of landscape, patch and habitat variables. Note that abbreviations of bird names are in Appendix 6.

Landscape and patch metrics	
NPATCH	Number of habitat patches
PDENS	Patch density
LPI	Largest patch index
LSI	Landscape shape index
PAREA1	Mean patch area
PAREA2	Median patch area
PSHAPE1	Mean patch shape
PSHAPE2	Median patch shape
NND	Mean nearest neighbour distance
SDI	Simpson's diversity index
SEI	Simpson's evenness index
ALTM	Median altitude
ALTR	Altitude range
TDENS	Tree density (total)
STDENS	Small tree density (< 6 m crown diameter)
LTDENS	Large tree density (> 6 m crown diameter)
Habitat type variables	
G	Grassland dominated (incl. *Juncus*)
B	Bracken dominated
H	Ericaceous (typically Heather) dominated
BG	Bracken-grass dominated mixture
BH	Bracken-heather dominated mixture
GH	Grass-heather dominated mixture
GHV	Grass-heather-Vaccinium dominated mixture
GORSE	Strong gorse component
WOOD	Woodland
OTHER	Additional habitats, incl. farmyards and open water

Table 3 Correlation matrix for patch and landscape metrics for the 25 sites (Spearman coefficients; significance levels: NS not significant *P <0.05-0.001, ** P <0.001-0.0001, *** P <0.0001 and '()' indicate marginally non significant 0.05 –0.07). Note that the first, shaded, column, relates to correlations between the individual metrics and the Axis1 Scores derived from the detrended correspondence analysis of the bird assemblage data (see Figure 3).

	DCA bird Axis1 Score	ALTM	ALTR	TDENS	LTDENS	STDENS	SEI	SDI	NND	PSHAPE1	PAREA1	LSI	LPI
Patch Density (PDENS)	-0.49 *	-0.52 *	-0.19 NS	0.44 *	0.41 *	0.45 *	0.32 NS	0.56 **	-0.36 NS	0.02 NS	-0.94 ***	0.92 ***	-0.37 (*)
Largest Patch Index (LPI)	0.61 *	0.61 *	-0.14 NS	-0.60 *	-0.55 *	-0.52 *	-0.61 *	-0.66 **	0.01 NS	-0.06 NS	0.452 *	-0.29 NS	
Landscape Shape Index (LSI)	-0.31 NS	-0.55 *	-0.04 NS	0.40 *	0.29 NS	0.46 *	0.36 *	0.59 **	-0.50 *	0.21 NS	-0.77 ***		
Mean Patch Area (PAREA1)	0.65 **	0.55 *	0.14 NS	-0.56 *	-0.58 *	-0.51 *	-0.28 NS	-0.55 *	0.27 NS	0.06 NS			
Mean Patch Shape (PSHAPE1)	-0.07 NS	0.05 NS	0.31 NS	0.14 NS	-0.14 NS	0.34 NS	0.24 NS	0.15 NS	-0.34 NS				
Mean Nearest Neighbour Distance (NND)	0.26 NS	0.31 NS	-0.34 NS	-0.43 *	-0.23 NS	-0.49 *	-0.02 NS	-0.18 NS					
Simpson's Diversity Index (SDI)	-0.37 (*)	-0.44 *	-0.05 NS	0.38 (*)	0.33 NS	0.39 *	0.87 ***						
Simpson's Evenness Index (SEI)	-0.17 NS	-0.20 NS	0.01 NS	0.24 NS	0.17 NS	0.29 NS							
Small Tree Density (STDENS)	-0.70 ***	-0.39 (*)	0.38 (*)	0.94 ***	0.65 **								
Large Tree Density (LTDENS)	-0.17 ***	-0.40 *	0.19 NS	0.84 ***									
Total Tree Density (TDENS)	-0.77 ***	-0.42 *	0.35 NS										
Altitude range (ALTR)	-0.11 NS	-0.09 NS											
Median Altitude (ALTM)	0.32 NS												

Table 4 Correlation matrix for percentage area of cover of the ten habitat types for the 25 sites (Spearman coefficients; significance levels: NS not significant *P <0.05-0.001, ** P <0.001-0.0001, *** P <0.0001 and '()' indicate marginally non significant 0.05 –0.07) . Note that the first, shaded, column, relates to correlations between the habitat variables and the Axis1 Scores derived from the detrended correspondence analysis of the bird assemblage data (see Figure 3).

	DCA bird Axis1 Score	B	BH	BG	H	GH	GHV	G	GORSE	WOOD	OTHER
Other (OTHER)	-0.27 NS	0.04 NS	-0.36 NS	0.25 NS	-0.21 NS	0.14 NS	-0.34 NS	-0.04 NS	0.54 **	0.23 NS	.
Woodland (WOOD)	-0.61 **	0.04 NS	-0.11 NS	0.30 NS	-0.47 *	-0.04 NS	0.07 NS	0.17 NS	-0.16 NS	.	
Strong gorse component (GORSE)	-0.02 NS	-0.15 NS	-0.72 ***	0.23 NS	_0.23 NS	-0.08 NS	-0.33 NS	0.15 NS	.		
Grass dominated (including Juncus) (G)	0.09 NS	0.03 NS	-0.47 *	0.28 NS	-0.44 *	-0.26 NS	-0.22 NS	.			
Grass-Heather-Vaccinium dominated mixture (GHV)	0.11 NS	-0.47 *	0.39 (*)	-0.43 *	0.08 NS	-0.28 NS	.				
Grass-Heather dominated mixture (GH)	0.13 NS	0.06 NS	0.07 NS	-0.14 NS	0.57 **	.					
Heather dominated (H)	0.45 *	-0.10 NS	0.37 (*)	-0.52 **	.						
Bracken-Grass dominated mixture (BG)	-0.37 (*)	0.30 NS	-0.48 *	.							
Bracken-Heather dominated mixture (BH)	0.16 NS	0.18 NS	.								
Bracken dominated (B)	-0.51 **	.									

Table 5 Correlation matrix for percentage area of cover of the ten habitat types and patch metrics for the 25 sites (Spearman coefficients; significance levels: NS not significant *P <0.05-0.001, ** P <0.001-0.0001, *** P <0.0001 and '()' indicate marginally non significant 0.05 –0.07) .

	Bracken dominated (B)	**Bracken-Heather dominated mixture (BH)**	**Bracken-Grass dominated mixture (BG)**	**Heather dominated (H)**	**Grass-Heather dominated mixture (GH)**	**Grass-Heather-Vaccinium dominated mixture (GHV)**	**Grass dominated (including Juncus) (G)**	**Strong gorse component (GORSE)**	**Woodland (WOOD)**	**Other (OTHER)**
Patch Density	0.54	-0.05	0.23	-0.01	0.38	-0.30	-0.11	0.04	0.21	0.53
(PDENS)	*	NS	NS	NS	(*)	NS	NS	NS	NS	*
Largest Patch Index	-0.32	0.06	-0.40	0.32	0.17	0.18	0.25	-0.22	-0.35	-0.48
(LPI)	NS	NS	*	NS	NS	NS	NS	NS	NS	*
Landscape Shape Index	0.54	-0.07	0.25	0.02	0.44	-0.39	0	0.16	0.04	0.59
(LSI)	*	NS	NS	NS	*	(*)	NS	NS	NS	*
Mean Patch Area	-0.55	0.06	-0.24	0.08	-0.27	0.25	0.19	-0.01	-0.34	-0.47
(PAREA1)	*	NS	NS	NS	NS	NS	NS	NS	NS	*
Mean Patch Shape	0.24	0.02	-0.18	-0.10	-0.17	0.01	0.29	0.05	-0.21	0.01
(PSHAPE1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean Nearest Neighbour	-0.61	0.04	-0.25	0.10	-0.21	0.40	-0.31	0.09	-0.06	0.04
Distance (NND)	*	NS	NS	NS	NS	*	NS	NS	NS	NS
Simpson's Diversity	0.33	0.12	0.15	0.11	0.40	-0.12	-0.32	-0.27	0.28	0.53
Index (SDI)	NS	NS	NS	NS	*	NS	NS	NS	NS	*
Simpson's Evenness	0.13	0.10	0.04	0.19	0.22	-0.04	-0.34	-0.01	-0.01	0.40
Index (SEI)	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Small Tree Density	0.43	-0.33	0.48	-0.50	-0.03	-0.25	0.12	0.12	0.30	0.23
(STDENS)	*	NS	*	*	NS	NS	NS	NS	NS	NS
Large Tree Density	0.39	-0.26	0.49	-0.31	-0.06	-0.15	-0.21	0.15	0.37	0.19
(LTDENS)	(*)	NS	*	NS	NS	NS	NS	NS	(*)	NS
Total Tree Density	0.46	-0.34	0.57	-0.50	-0.11	-0.23	0.02	0.16	0.36	0.25
(TDENS)	*	NS	*	*	NS	NS	NS	NS	NS	NS
Altitude range	0.26	-0.06	0.23	-0.09	-0.14	-0.25	0.19	0.04	-0.11	-0.10
(ALTR)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Median Altitude	-0.20	0.21	-0.26	0.02	-0.46	0.56	0.10	-0.26	-0.35	-0.53
(ALTM)	NS	NS	NS	NS	*	*	NS	NS	NS	*

Table 6 Mean site and landscape metrics for 25 ffridd sites, grouped by ffridd sub-class, with Kruskal-Wallis Tests between ffridd sub-classes. Significant differences between sub-classes are shown in bold * = P < 0.05, (*) = P < 0.10. Values for individual sites are given in Appendix 4.

	Ffridd sub-class				
Site metrics	**1**	**2**	**3**	**4**	**Kruskal-Wallis Test**
Number of Patches (NPATCHES)	34.25	33.60	20.88	21.75	H=4.10 d.f. 3NS
Patch Density (PDENS)	15.23	14.93	9.28	9.67	H=3.17 d.f. 3 NS
Largest Patch Index (LPI)	5.21	8.71	10.73	10.06	H=5.22 d.f. 3NS
Landscape Shape Index (LSI)	3.18	2.86	2.47	2.44	H=1.25 d.f. 3NS
Mean Patch Area (PAREA1)	2.23	1.87	3.66	4.00	H=4.36 d.f. 3NS
Median Patch Area (PAREA2)	1.24	0.25	1.05	1.04	-
Mean Patch Shape (PSHAPE1)	2.05	1.95	2.08	1.87	H=3.12 d.f. 3NS
Median Patch Shape (PSHAPE2)	1.86	1.78	1.83	1.64	-
Mean Nearest neighbour distance (NND)	41.30	66.04	80.49	66.54	H=3.25 d.f. 3NS
Simpson's Diversity Index (SDI)	0.73	0.72	0.62	0.63	**H=8.40 d.f. 3***
Simpson's Evenness Index (SEI)	0.88	0.85	0.76	0.79	H=6.45 d.f. 3NS
Total Tree Density (TDENS)	9.03	2.13	3.12	2.85	H=5.76 d.f. 3NS
Small (<6m diam.) Tree)Density (STDENS	5.34	1.19	1.93	2.12	H=6.45 d.f. 3NS
Large (>6m diam.) Tree Density (LTDENS)	3.69	0.94	1.19	0.74	**H=7.02 d.f. 3(*)**
Median Altitude (ALTM)	348.13	359.00	371.56	346.56	H=0.21 d.f. 3NS
Altitude Range (ALTR)	223.75	132.00	233.13	169.38	**H=8.16 d.f. 3***
Site Area	44.33	53.50	54.30	55.85	-

Table 7 Mean percentage covers for ten habitat types on 25 ffridd sites, grouped by ffridd sub-class, with Kruskal-Wallis Tests between ffridd sub-classes. The one significant difference (at P < 0.05) is shown in bold. Values for individual sites are given in Appendix 5.

	Ffridd sub-class				**Kruskal-Wallis**
Habitat type	**1**	**2**	**3**	**4**	**Test**
Bracken dominated (B)	18.13	16.40	5.66	10.63	H=4.10 df 3 NS
Bracken- Heather dominated mixture (BH)	0.13	8.94	6.38	2.99	H=5.10 df 3 NS
Bracken-grass dominated mixture (BG)	23.93	2.32	5.21	16.29	**H=8.34 df 3 ***
Heather dominated (H)	0.00	17.38	1.90	6.55	H=6.53 df 3 NS
Grass-heather dominated mixture (GH)	0.08	11.78	7.95	6.56	H=2.18 df 3 NS
Gass-heather-Vaccinium dominated mixture (GHV)	0.33	16.00	15.03	5.51	H=2.56 df 3 NS
Grassland dominated (G)	31.78	16.10	35.80	34.64	H=5.16 df 3 NS
Strong gorse component (GORSE)	8.75	4.26	18.56	12.93	H=2.06 df 3 NS
Woodland (WOOD)	15.73	6.02	2.91	3.58	H=3.83 df 3 NS
Additional habitats (OTHER)	1.15	0.76	0.58	0.36	H=1.61 df 3 NS

Table 8 Mean breeding territory density (territories/hectare) and, standard error (se) and Kruskal-Wallis tests, for four ffridd types, comprising 25 sites from the Snowdonia and Berwyn regions. Bold and italics indicate Red and Amber-listed UK BoCC species, respectively. Significance levels are as follows: NS not significant *P <0.05-0.001, ** P <0.001-0.0001, *** P <0.0001 and '()' indicate marginally non significant 0.05 –0.07). Appendix 6 gives details for individual sites.

	Ffridd sub-classes												Kruskal-Wallis Test
	1			2			3			4			
Species	**mean**	**se**	**n**	**mean**	**se**	**n**	**mean**	**se**	**n**	**mean**	**se**	**n**	
Mallard				*0.014*		*1*	*0.016*		*1*				H=1.84 df 3 NS
Goshawk							0.031		1				H=1.99 df 3 NS
Common Buzzard	0.023	0.001	4	0.022	0.004	4	0.020	0.002	8	0.021	0.004	7	H=2.25 df 3 NS
Kestrel				*0.021*	*0.004*	*2*	*0.023*	*0.008*	*2*	*0.016*		*1*	H=2.36 df 3 NS
Merlin										*0.016*		*1*	H=1.84 df 3 NS
Red Grouse				*0.023*	*0.010*	*2*				*0.015*		*1*	H=3.61 df 3 NS
Lapwing										**0.055**		**1**	H=1.84 df 3 NS
Common Snipe										*0.041*		*1*	H=1.99 df 3 NS
Curlew										*0.118*		*1*	H=1.84 df 3 NS
Common Sandpiper				*0.019*	*0.006*	*2*				*0.020*	*0.001*	*2*	H=3.71 df 3 NS
Stock Dove							*0.031.*		*1*				H=1.84 df 3 NS
Wood Pigeon	0.046	0.003	4				0.025.		1	0.021		1	H >30.00 df 3 ***
Cuckoo	**0.051**	**0.027**	**2**	**0.026**	**0.004**	**4**	**0.014**	**0.001**	**2**	**0.024**	**0.005**	**4**	H=5.87 df 3 NS
Tawny Owl	0.026		1	0.102	0.017	4							H=6.23 df 3 NS
Short-eared Owl										*0.015*		*1*	H=1.84 df 3 NS
G. S. Woodpecker	0.037	0.011	2							0.020		1	H=10.71 df 3 *
Skylark	**0.023**	**0.001**	**2**	**0.130**	**0.114**	**2**	**0.090**	**0.015**	**7**	**0.148**	**0.022**	**6**	H=6.08 df 3 NS
Sand Martin	*0.020*		*1*										H=6.23 df 3 NS
Swallow	*0.021*	*0.001*	*2*	*0.025*		*1*	*0.029*	*0.007*	*6*	*0.021*	*0.000*	*3*	H=4.19 df 3 NS
House Martin	*0.024*		*1*	*0.032*		*1*	*0.033*	*0.018*	*2*				H=2.25 df 3 NS
Tree Pipit	**0.188**	**0.076**	**4**				**0.045**	**0.013**	**5**	**0.203**	**0.122**	**2**	H=9.52 df 3 *
Meadow Pipit	*0.107*	*0.031*	*4*	*0.446*	*0.055*	*5*	*0.453*	*0.057*	*8*	*0.433*	*0.052*	*8*	H=10.44 df 3 *
Grey Wagtail				*0.025*		*1*				*0.042*		*1*	H=1.64 df 3 NS
Pied Wagtail	0.022		1	0.036	0.010	3	0.060	0.023	4	0.045	0.017	3	H=1.36 df 3 NS
Wren	0.567	0.218	4	0.320	0.100	5	0.240	0.080	8	0.228	0.071	8	H=3.54 df 3 NS
Dunnock	*0.120*	*0.060*	*3*	*0.059*	*0.025*	*3*	*0.123*	*0.036*	*6*	*0.083*	*0.022*	*6*	H=1.54 df 3 NS
Robin	0.270	0.076	3	0.117	0.069	4	0.095	0.028	5	0.080	0.042	3	H=5.19 df 3 NS
Common Redstart	*0.170*	*0.044*	*4*	*0.087*	*0.067*	*4*	*0.076*	*0.033*	*3*	*0.057*		*1*	H=10.56 df 3 **
Whinchat	*0.063*	*0.017*	*3*	*0.136*	*0.056*	*4*	*0.056*	*0.012*	*4*	*0.069*	*0.019*	4	H=2.56 df 3 NS
Stonechat	0.051	0.011	4	0.067	0.036	4	0.101	0.024	7	0.058	0.020	7	H=2.20 df 3 NS
Wheatear	*0.024*		*1*	*0.138*	*0.039*	*2*	*0.031*	*0.007*	*7*	*0.093*	*0.043*	*5*	H=1.91 df 3 NS
Ring Ouzel				**0.014**		**1**							H=6.23 df 3 NS
Blackbird	0.088	0.026	3	0.062	0.044	4	0.048	0.019	7	0.038	0.008	5	H=1.66 df 3 NS
Song Thrush	**0.085**	**0.010**	**3**	**0.064**		**1**	**0.029**	**0.005**	**5**	**0.038**	**0.013**	**4**	H=7.32 df 3 (*)
Mistle Thrush	*0.044*	*0.013*	*3*				*0.020*	*0.003*	*2*	*0.039*	*0.009*	*4*	H=8.63 df 3 *
Grasshopper Warbler				**0.033**		**1**	**0.032.**		**1**	**0.020**		**1**	H=2.38 df 3 NS
Whitethroat	*0.020*		*1*	*0.094*	*0.020*	*2*	*0.034.*		*1*				H=6.23 df 3 NS
Garden Warbler	0.074	0.045	4	0.128		1	0.020	0.004	2	0.141		1	H=7.65 df 3 (*)
Blackcap	0.023	0.002	3	0.032		1				0.019		1	H=9.45 df 3 *
Wood Warbler	**0.077**	**0.053**	**2**										H=6.23 df 3 NS
Chiffchaff	0.030	0.005	3	0.032		1							H=10.49 df 3 *
Willow Warbler	*0.327*	*0.123*	*4*	*0.234*	*0.047*	*4*	*0.113*	*0.030*	*8*	*0.164*	*0.106*	*5*	H=7.56 df 3 (*)
Goldcrest	0.037	0.011	2	0.032		1	0.014.		1	0.020		1	H=5.76 df 3 NS
Spotted Flycatcher	**0.020**		**1**										H=6.23 df 3 NS
Pied Flycatcher	*0.066*	*0.032*	*3*	*0.160*		*1*	*0.070.*		*1*	*0.081*		*1*	H=2.71 df 3 NS

Table 8 Continued.

Species	Ffridd sub-classes 1			2			3			4			Kruskal-Wallis Test
	mean	se	n	mean	se	n	mean	se	n	mean	se	n	
Long-tailed Tit	0.026		1										H=6.23 df 3 NS
Coal Tit	0.077	0.027	4	0.096		1	0.036	0.011	2	0.081		1	H=9.25 df 3 *
Blue Tit	0.137	0.048	4	0.072	0.056	2	0.052	0.033	3	0.080	0.061	2	H=11.52 df 3 **
Great Tit	0.067	0.032	4	0.072	0.056	2	0.035	0.012	4	0.038	0.023	2	H=7.12 df 3 (*)
Nuthatch	0.077	0.053	2				0.018	0.005	2	0.020		1	H=7.63 df 3 (*)
Treecreeper	0.051	0.027	2	0.064		1							H=6.68 df 3 NS
Jay	0.024		1	0.032		1				0.040		1	H=1.30 df 3 NS
Magpie	0.029	0.006	4				0.029	0.008	5	0.021		1	H=13.48 df 3 **
Chough							*0.025*	*.*	*1*				H=1.84 df 3 NS
Jackdaw	0.024		1	0.033		1	0.025	.	1	0.041		1	H=0.89 df 3 NS
Carrion Crow	0.057	0.011	4	0.032	0.010	5	0.049	0.010	8	0.021	0.003	8	H=10.44 df 3 *
Raven							0.023	.	1				H=0.89 df 3 NS
House Sparrow				**0.027**		**1**	**0.031**	**0.014**	**2**				H=0.89 df 3 NS
Chaffinch	0.250	0.055	4	0.107	0.048	5	0.098	0.025	6	0.068	0.028	7	H=9.37 df 3 *
Greenfinch										0.041		1	H=1.84 df 3 NS
Goldfinch	0.020		1				0.076	.	1	0.020		1	H=3.76 df 3 NS
Siskin	0.038	0.014	2	0.032		1	0.023	.	1	0.040		1	H=3.64 df 3 NS
Linnet	**0.050**	**0.005**	**3**	**0.023**	**0.010**	**2**	**0.091**	**0.037**	**5**	**0.103**	**0.057**	**4**	H=2.42 df 3 NS
Lesser Redpoll	**0.026**		**1**	**0.030**	**0.003**	**3**	**0.051**	**0.013**	**4**	**0.059**	**0.022**	**3**	H=1.01 df 3 NS
Bullfinch										*0.015*		*1*	H=1.84 df 3 NS
Yellowhammer	**0.098**		**1**										H=6.23 df 3 NS
Reed Bunting	*0.045*	*0.021*	*2*	*0.074*	*0.009*	*2*	*0.031*	*0.001*	*3*	*0.039*	*0.015*	*4*	H=1.18 df 3 NS

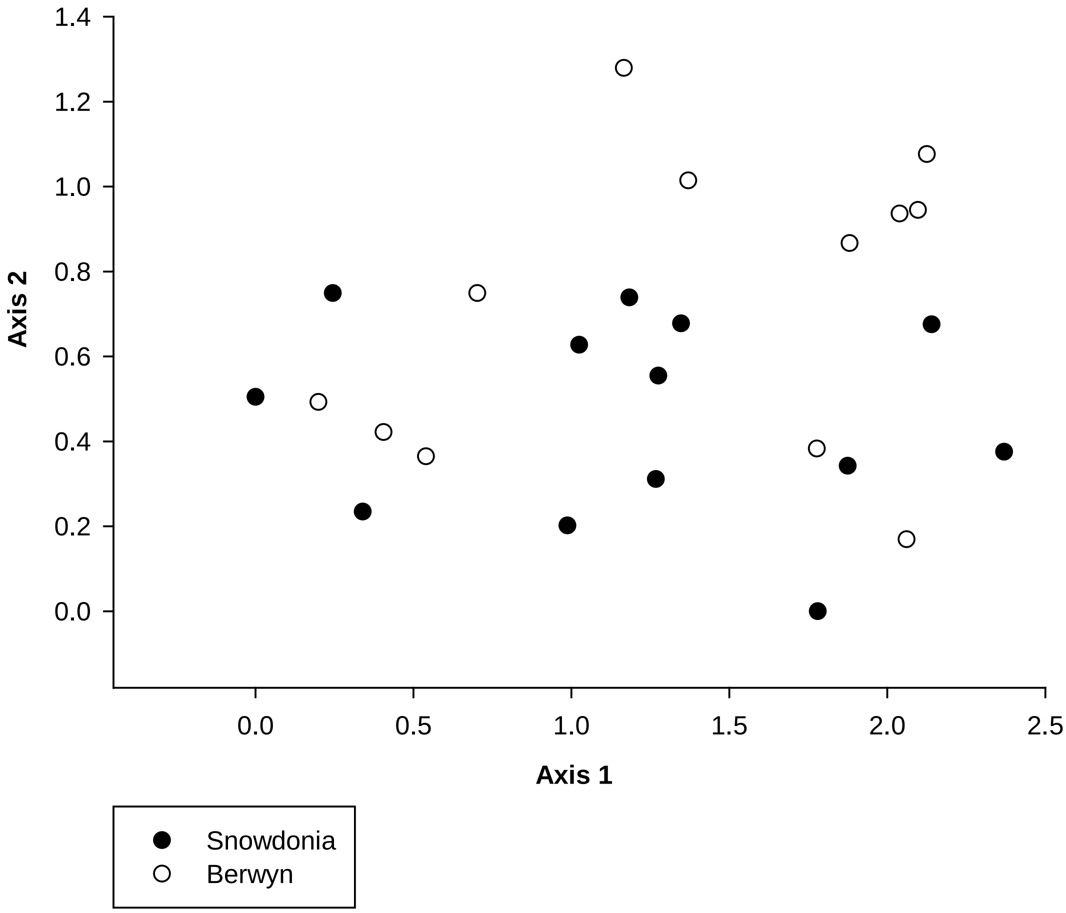


Figure 1 DCA plot for 25 ffridd sites defined by species assemblages in the two regions.

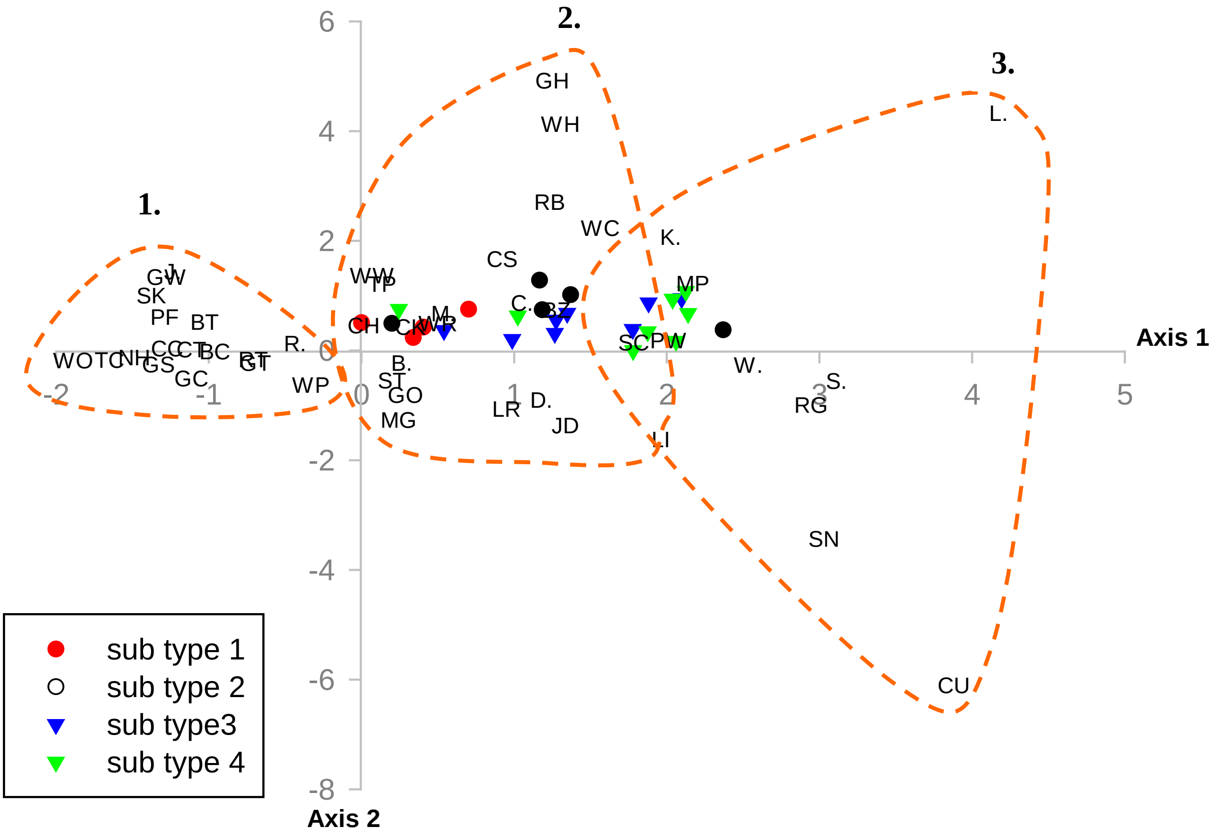


Figure 2 DCA plot of 25 ffridd sites (comprising 4 sub-classes) categorised by species assemblages with species scores. The three sets of dashed lines indicate distinct ecological groups of species: 1) Woodland, 2) Scrub and open habitat with structural features and 3) open habitat. Species symbols are defined in Appendix 6.

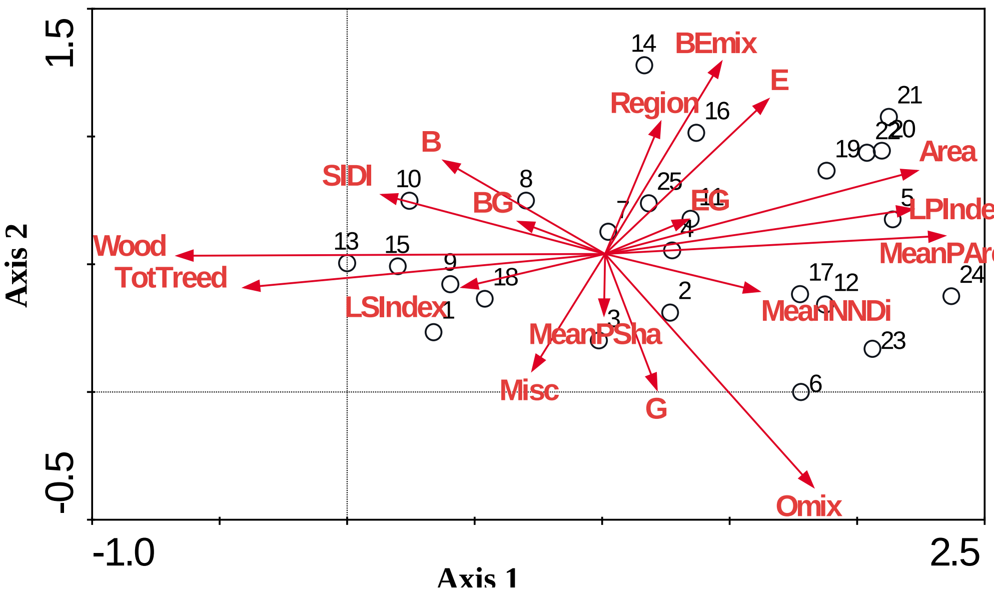


Figure 3 Site scores based on DCA ordination of bird assemblages. The strength and direction of relationships of landscape, patch and habitat type variables (symbols are defined below) are shown by arrows from the mean scores of sites. Note that not all variables are shown. For the sake of clarity the following variables, all of which are strongly intercorrelated with other variables (see Tables 3 and 4) are not plotted: patch density, Simpson's evenness index, small tree density and large tree density. Where symbols differ from those in Table 2 they are as follows: AREA = site area, E = H, EG = GH, LPIndex = LPI, LSIndex = LSI, MeanNNDi = NND, MeanPArea = PAREA1, MeanPSha = PSHAPE1, Misc = OTHER, SIDI = SDI, TotTreed = TDENS.

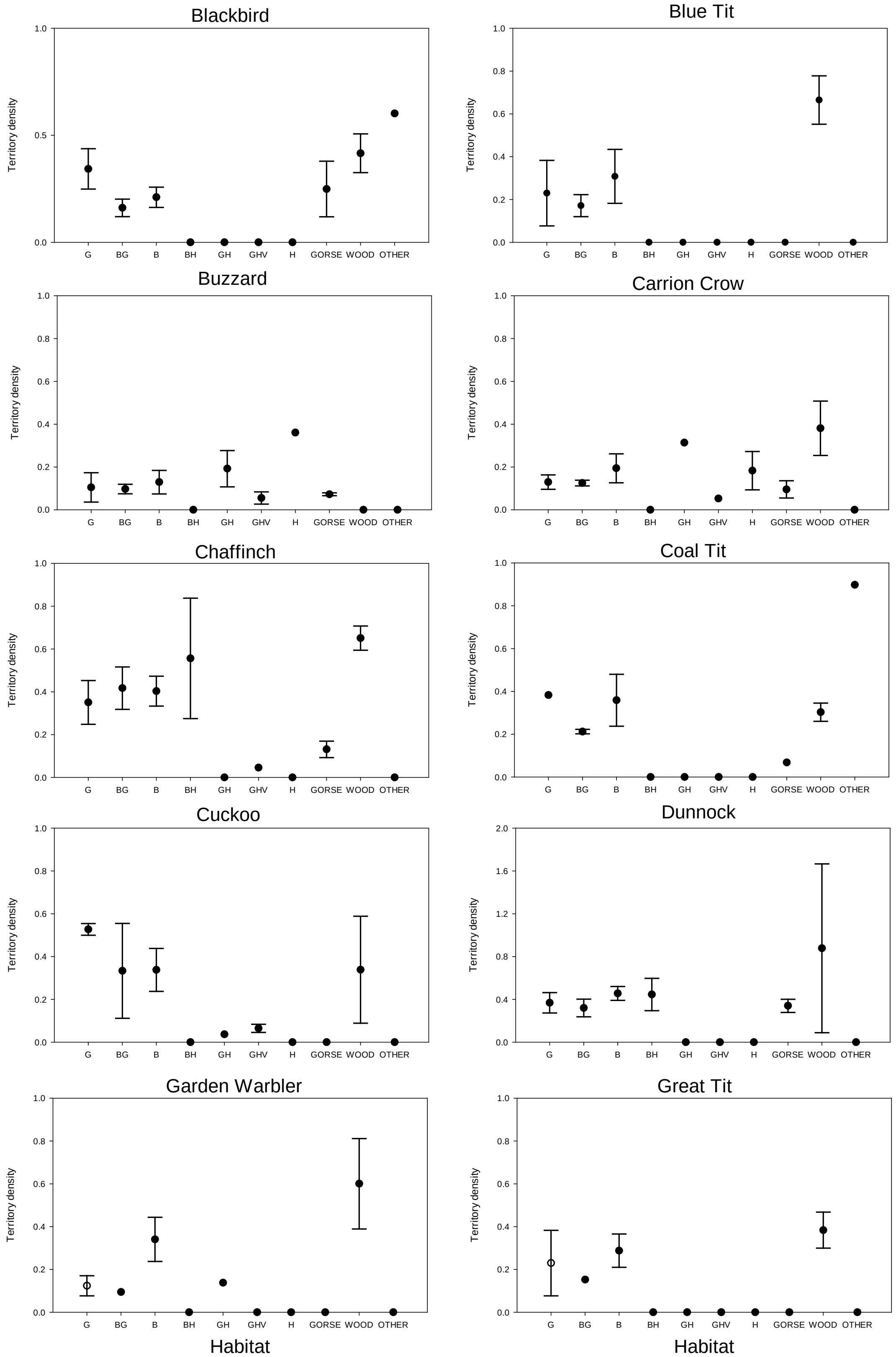


Figure 4 Mean territory densities (territories per hectare) and standard error, across 25 sites, for each habitat type (based on individual patches > 1 hectare), for species with more than 20 territories (or more than ten territories within a single habitat class.

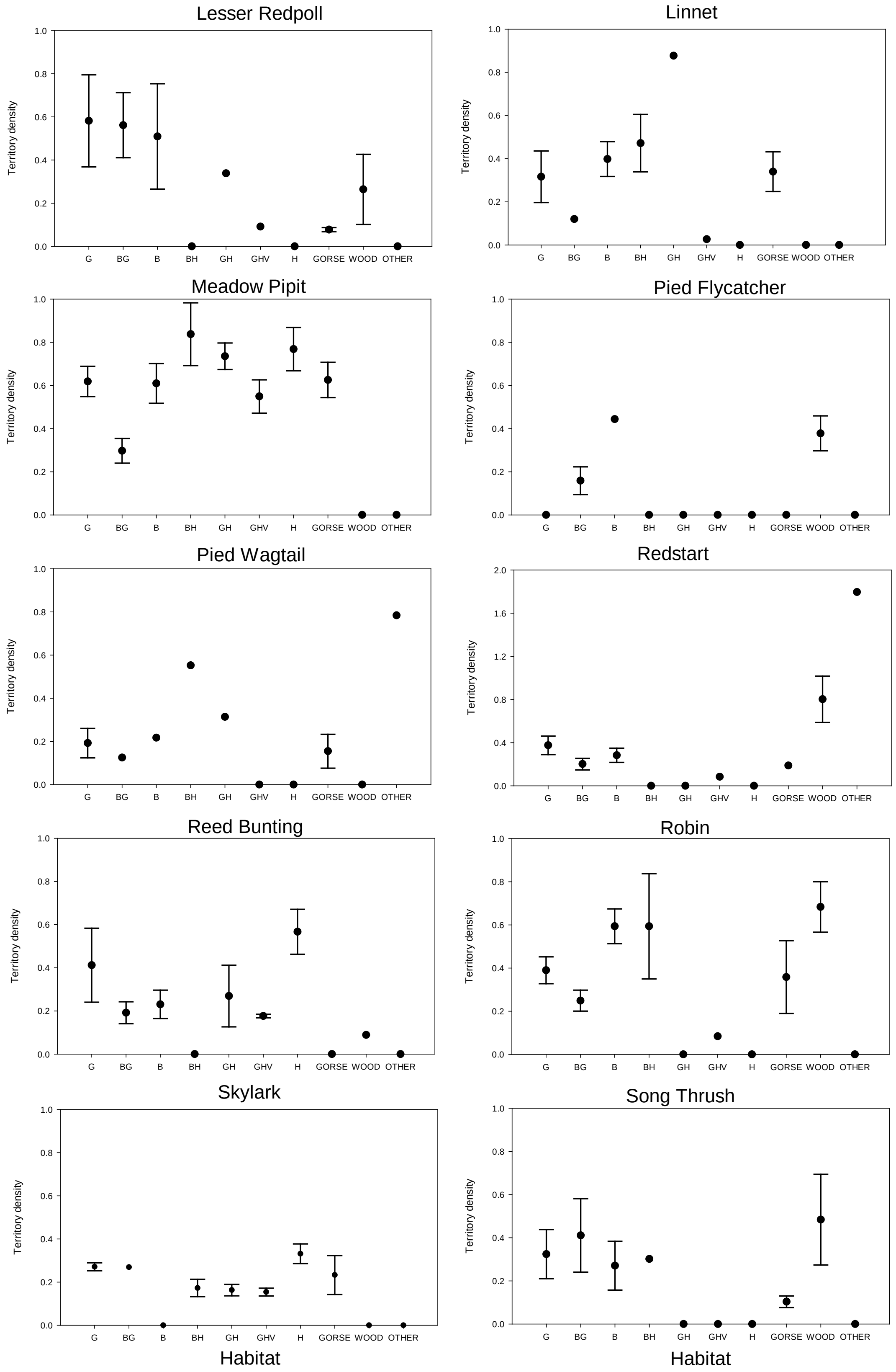
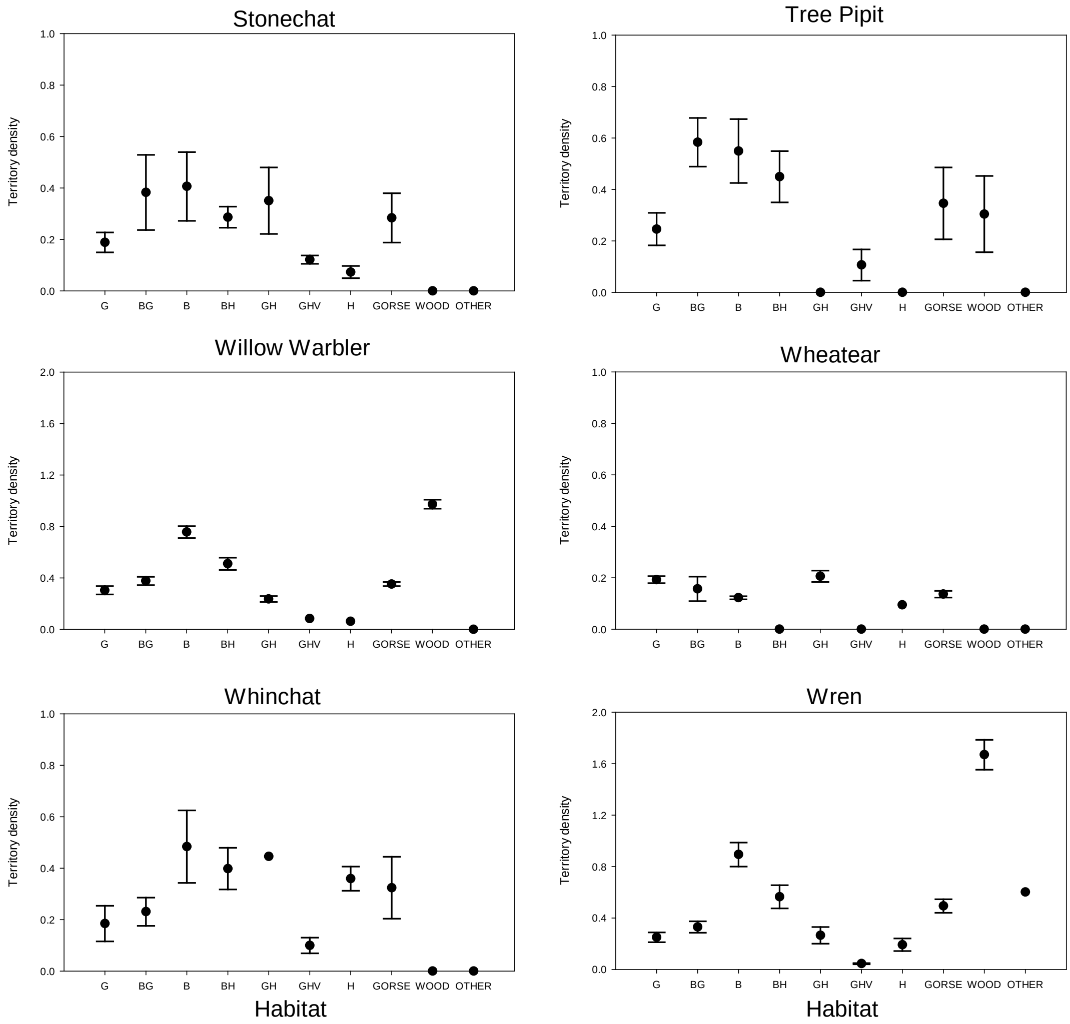


Figure 4 Continued.



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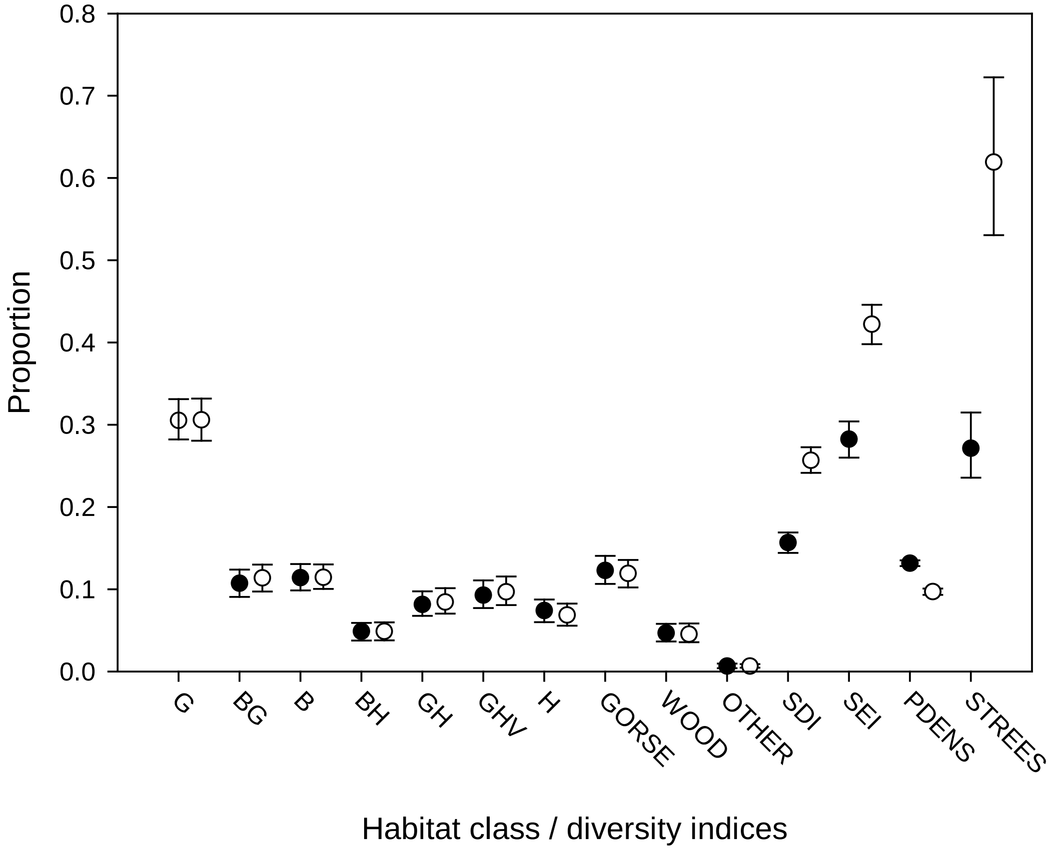

Figure 5 Mean proportions and 95% confidence intervals, from bootstrapping, for availability of habitat types and diversity indices from the sampling of 25 m (solid circles) and 50 m (open circles) radius buffers at regular points i.e. at the intersections of 100 m grid squares within site boundaries. Symbol definitions are as follows: G = grass dominated, BG = bracken/ grass mix, B = bracken dominated, HB mix = heather / bracken mix, GH = grass / heather mix, GHV = grass / heather / Vaccinium mix, H heather dominated, GORSE = strong gorse component, WOOD = woodland, SDI = Simpson's diversity index, SEI = Simpson's evenness index, PDENS = patch density and STREES = number of small trees (canopy diameter <6 m).

Note that for scaling purposes (i) patch density PDENS has been plotted as area / number of patches so that low values indicate high patch density and vice versa and (ii) density of small trees STREES is shown at 0.1 of actual values.

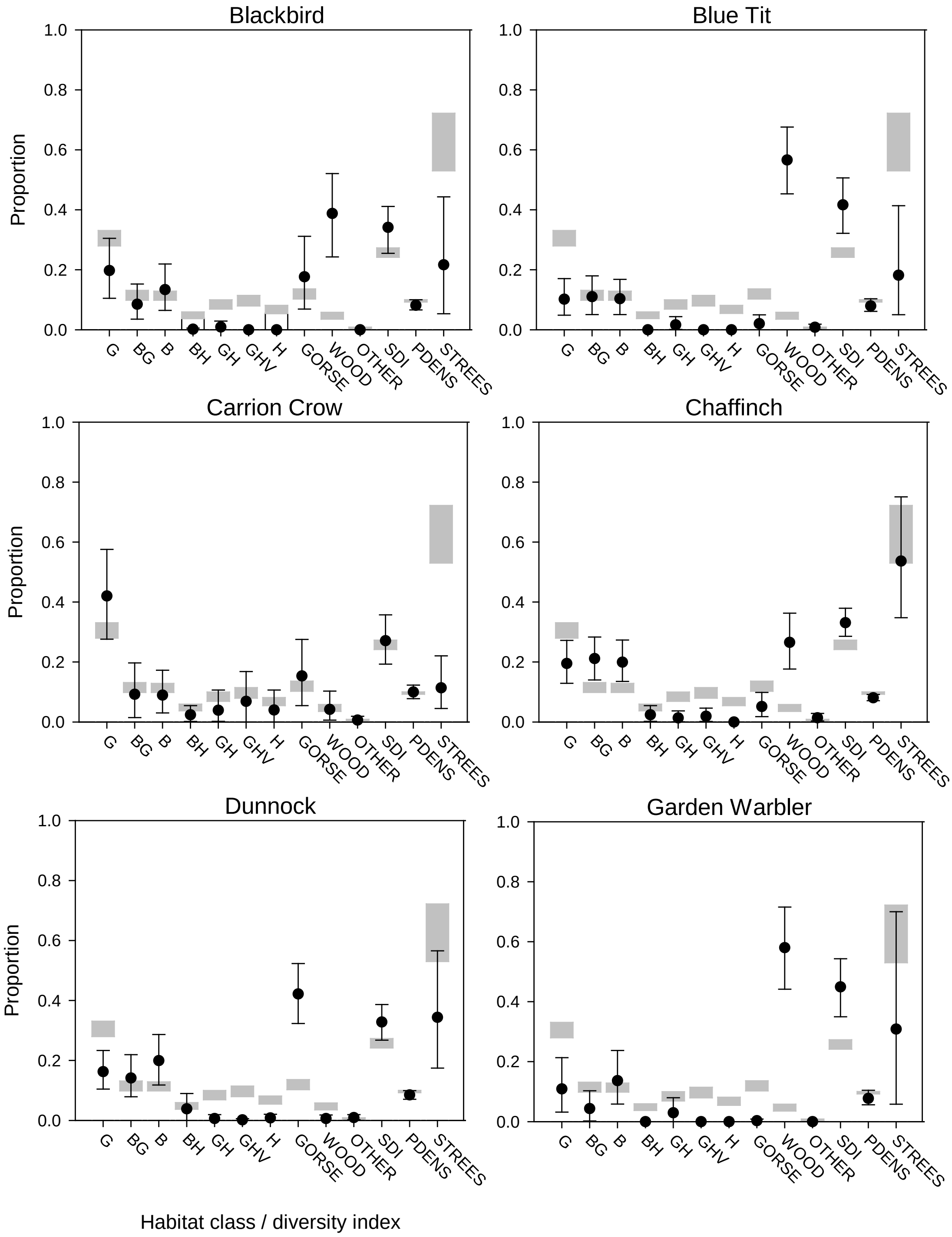

Figure 6 Plots of territory centre habitat profiles (bootstrap mean and 95% CI) from 50 m buffers around territory centres, compared to 95% CI for available habitat (grey bars), derived from 50 m buffers at 100 m grid intersections. See Table 2 for definitions of variables. Note that for scaling purposes (i) patch density PDENS has been plotted as area / number of patches so that low values indicate relative selection of areas with high patch density and vice versa and (ii) density of small trees STREES is shown at 0.1 of actual values.

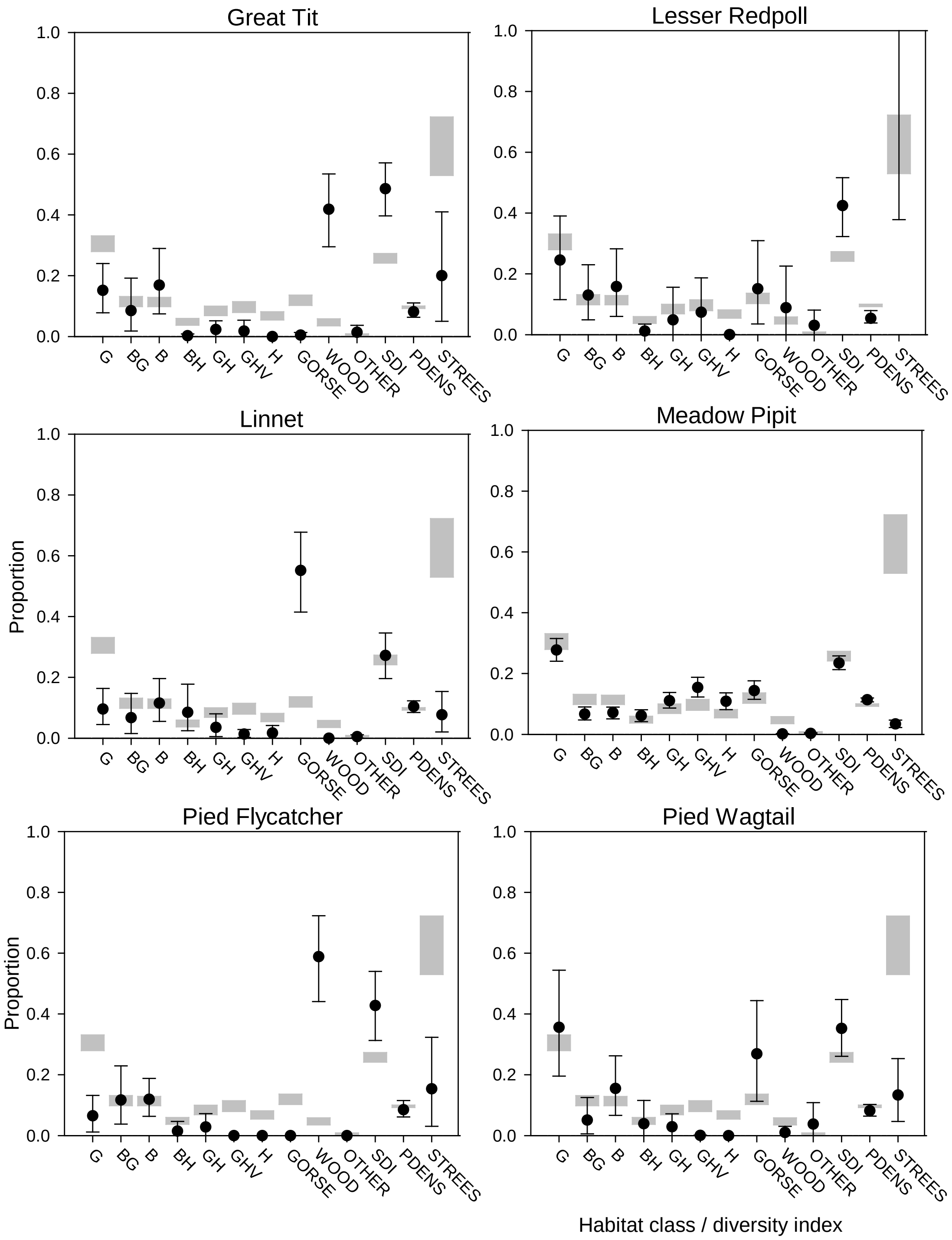

Figure 6 Continued.

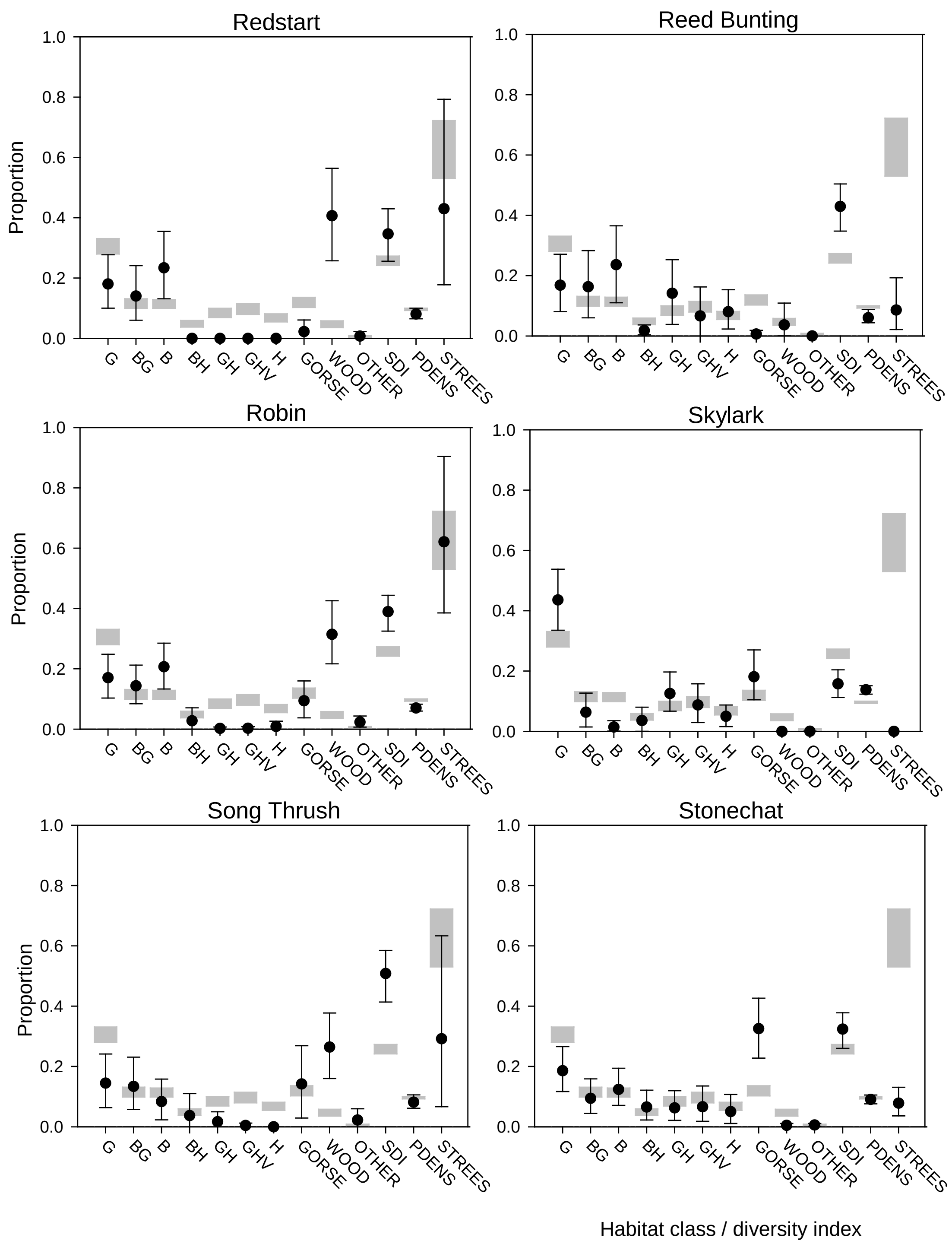

Figure 6 Continued.

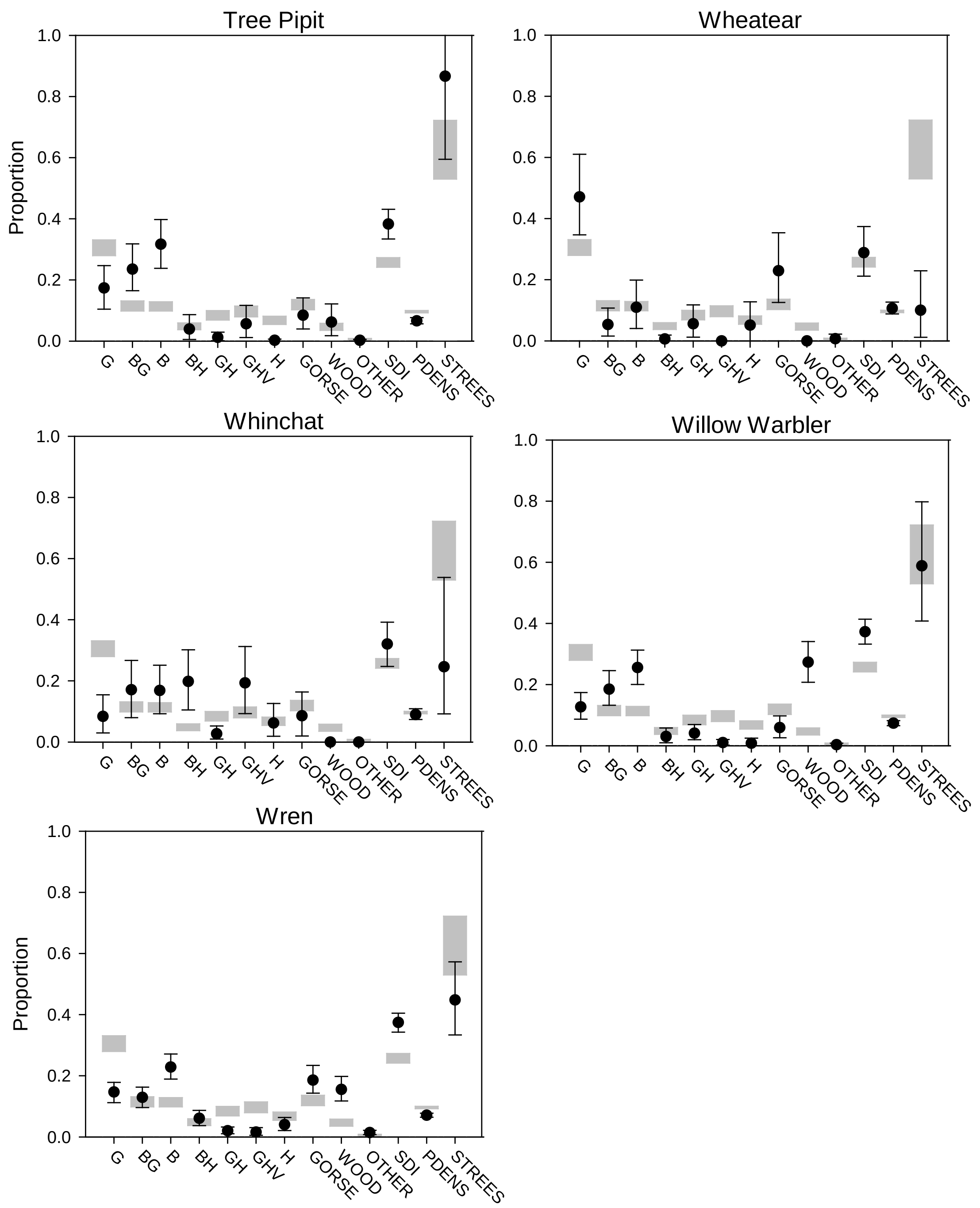

Figure 6 Continued.

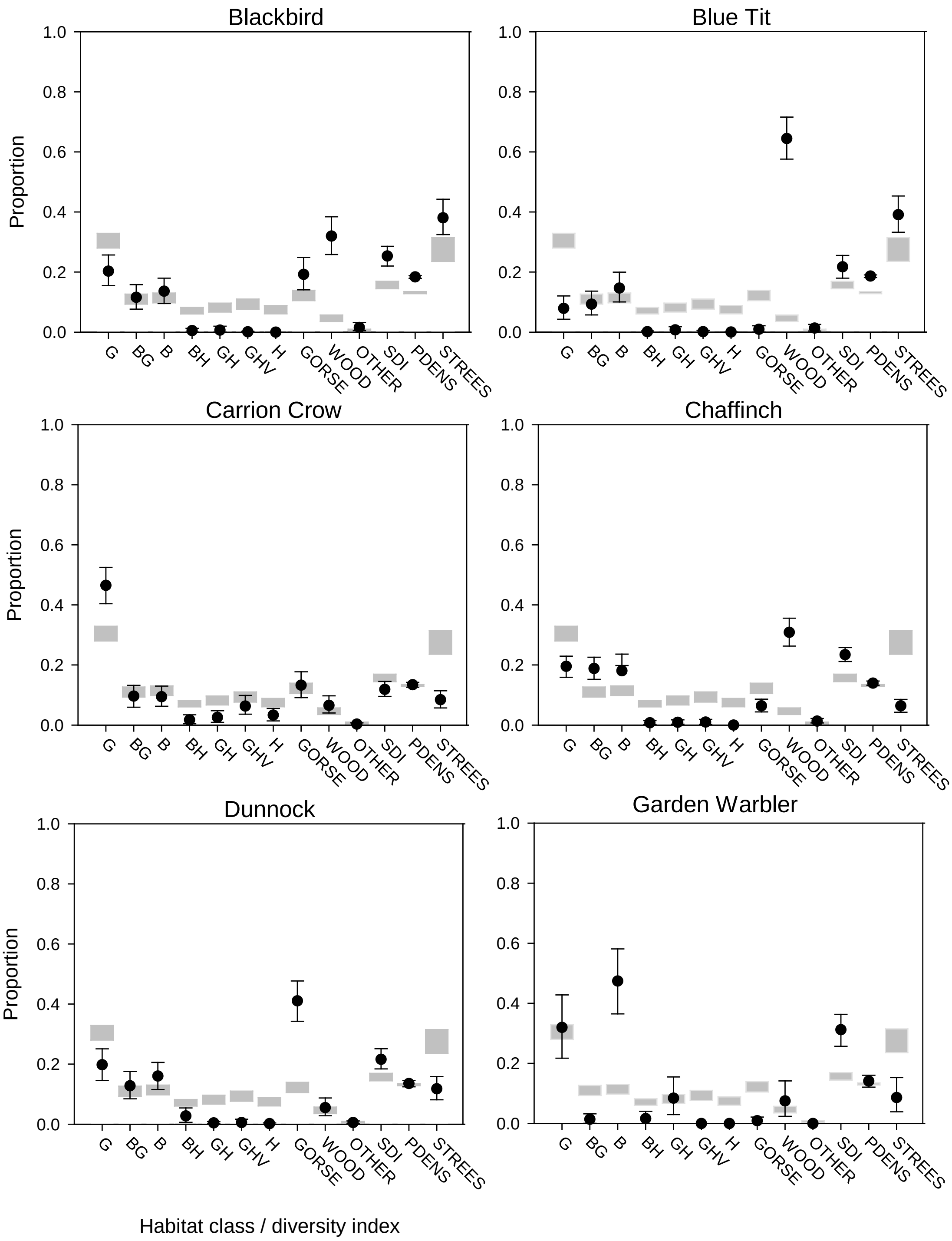

Figure 7 Plots of species habitat profiles (bootstrap mean and 95% CI) from 25 m buffers around individual registration locations, compared to 95% CI for available habitat derived from 25 m buffers at 100 m grid intersections. See Table 2 for definitions of variables. Note that for scaling purposes (i) patch density PDENS has been plotted as area / number of patches so that low values indicate relative selection of areas with high patch density and vice versa and (ii) density of small trees STREES is shown at 0.1 of actual values.

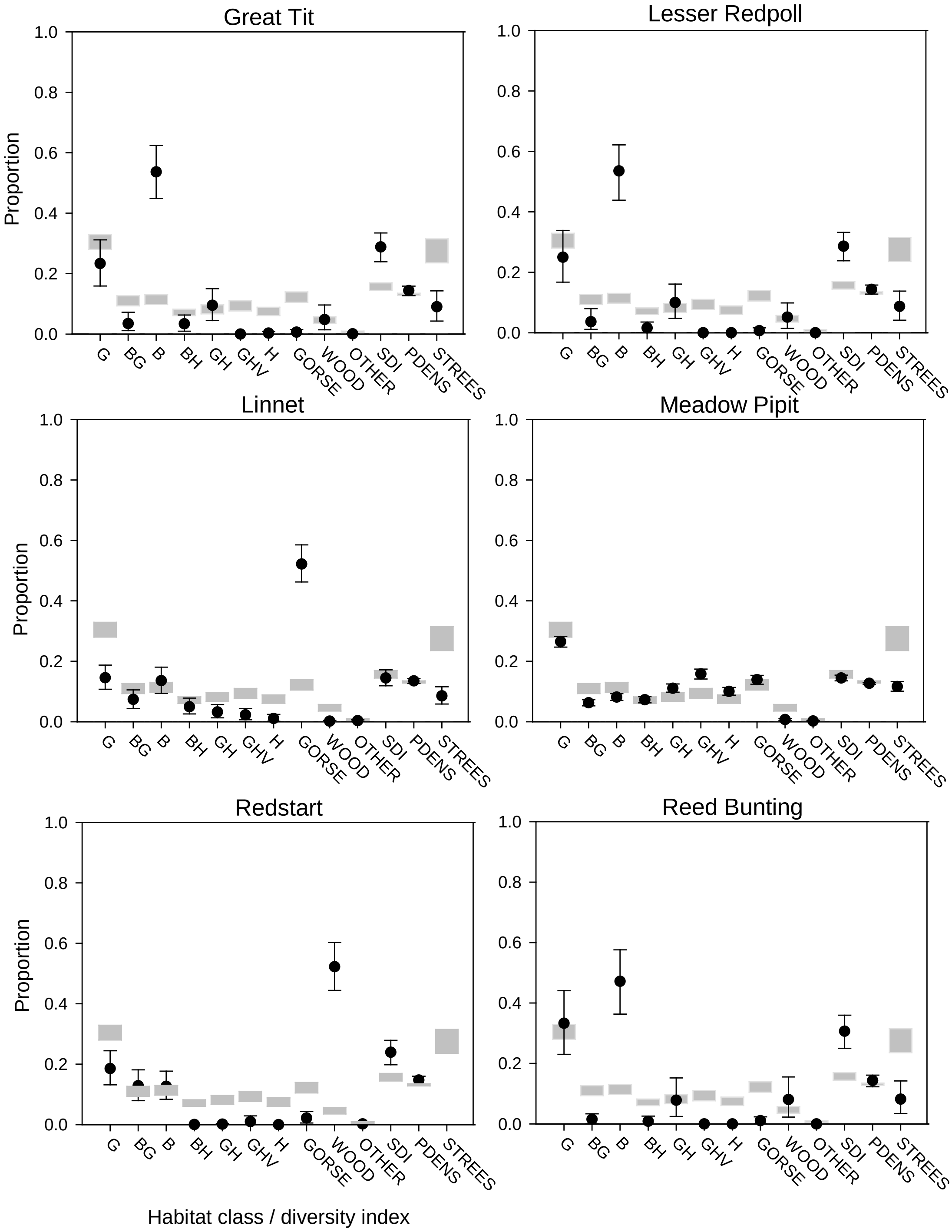

Figure 7 Continued.

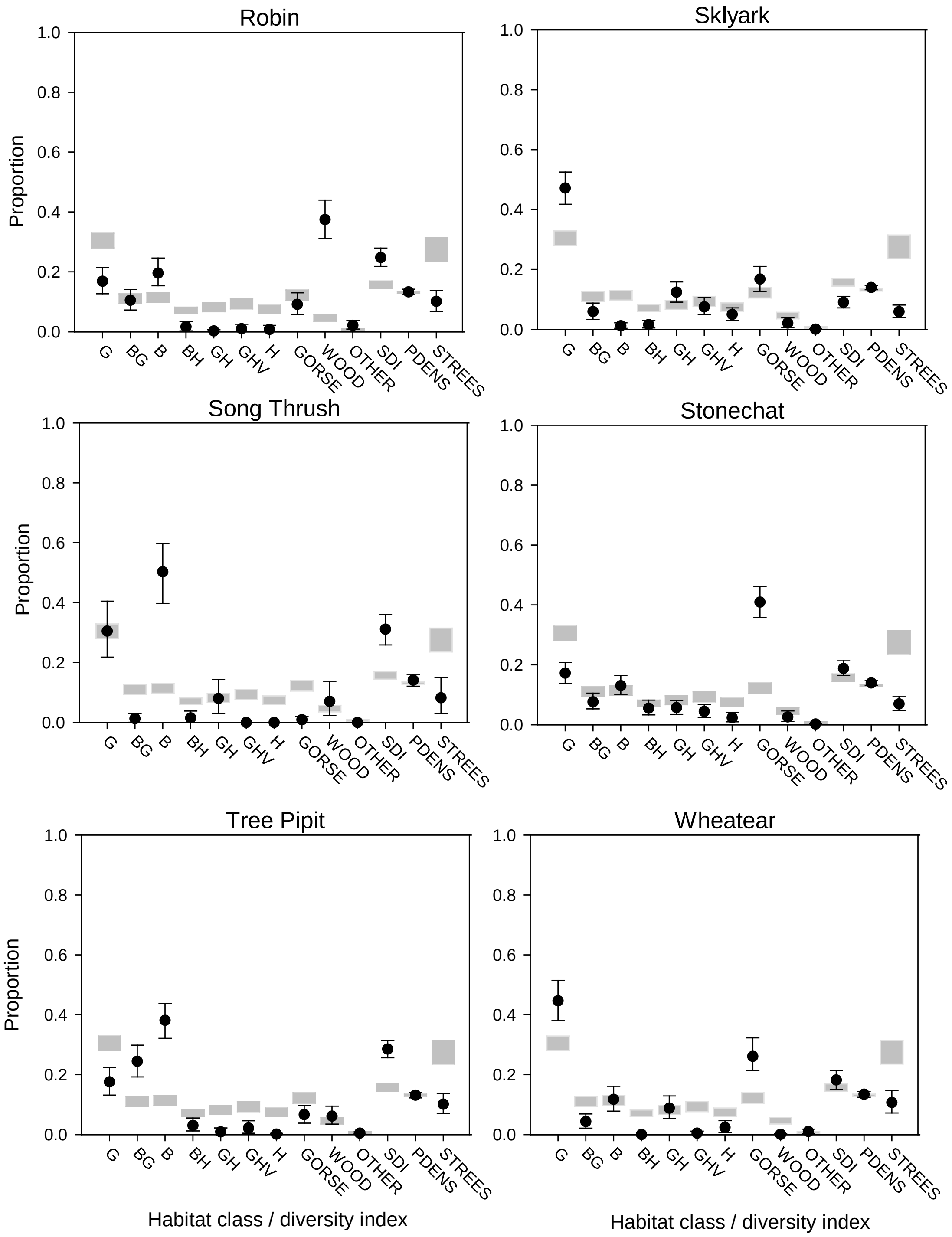

Figure 7 Continued.

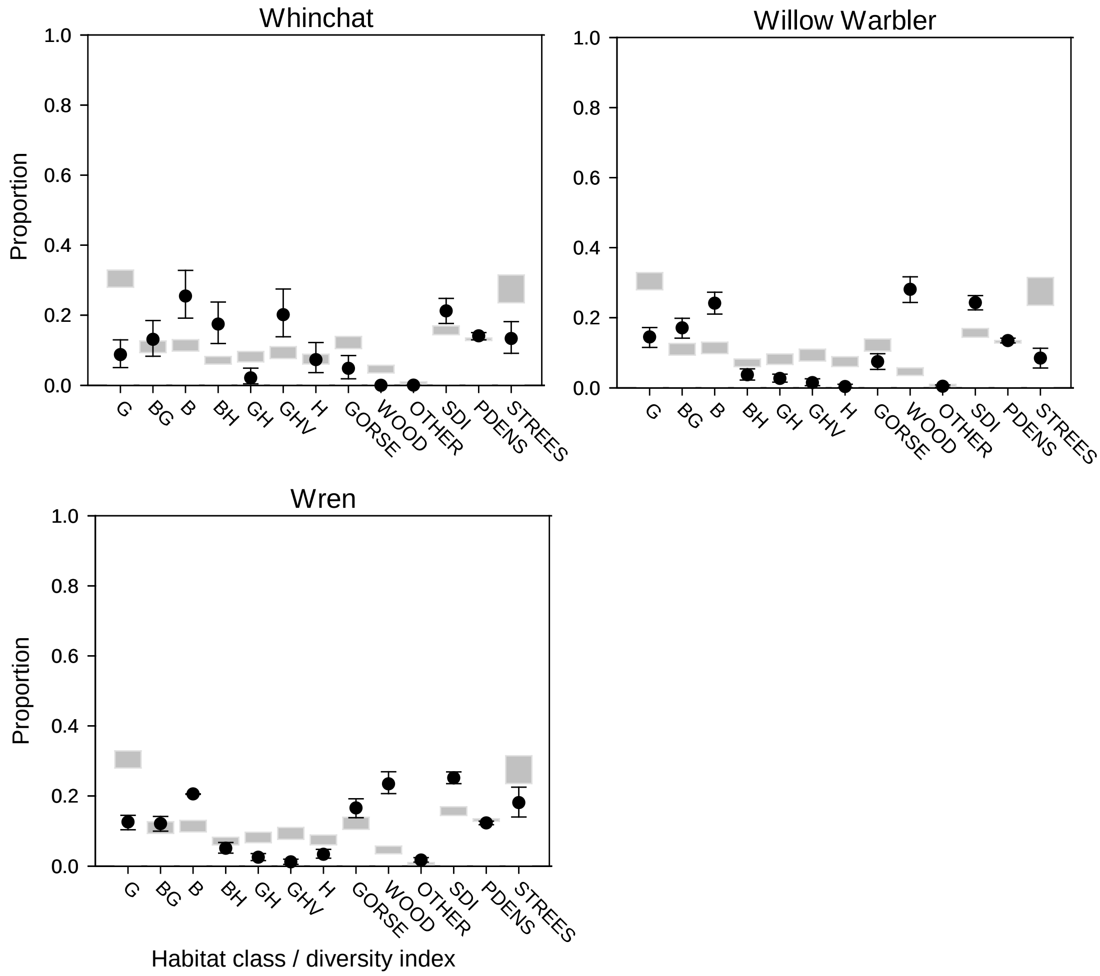

Figure 7 Continued.

Appendix 1 Structural Data Collection

For habitat measurements, a random stratified sample of 40 points was selected (the points were allocated to habitat types in proportion to the availability of each at the site, avoiding small patches of < 0.06 ha) at each of the 25 sites, covering a representative sample of all habitats present. These data were collected after the breeding season between August and mid-October.

At each point (see figure below), within a 5m radius, vegetation height, tree height, tree species, tree diameter at breast height (DBH), canopy density, grazing intensity and wet habitats were recorded. Within a 2.5m radius the % cover of a range of vegetation types was estimated to the nearest 5%.

Four sub-plots (see figure below) were located at 5m from the centre point, on the cardinal compass points. At each sub-plot, a measure of vegetation volume (vegetation present within 10cm radius of pole within 10cm bands up to 2.5m above ground level) and % cover of all vegetation (in categories of vegetation type) within a 1m radius was estimated to the nearest 5%.

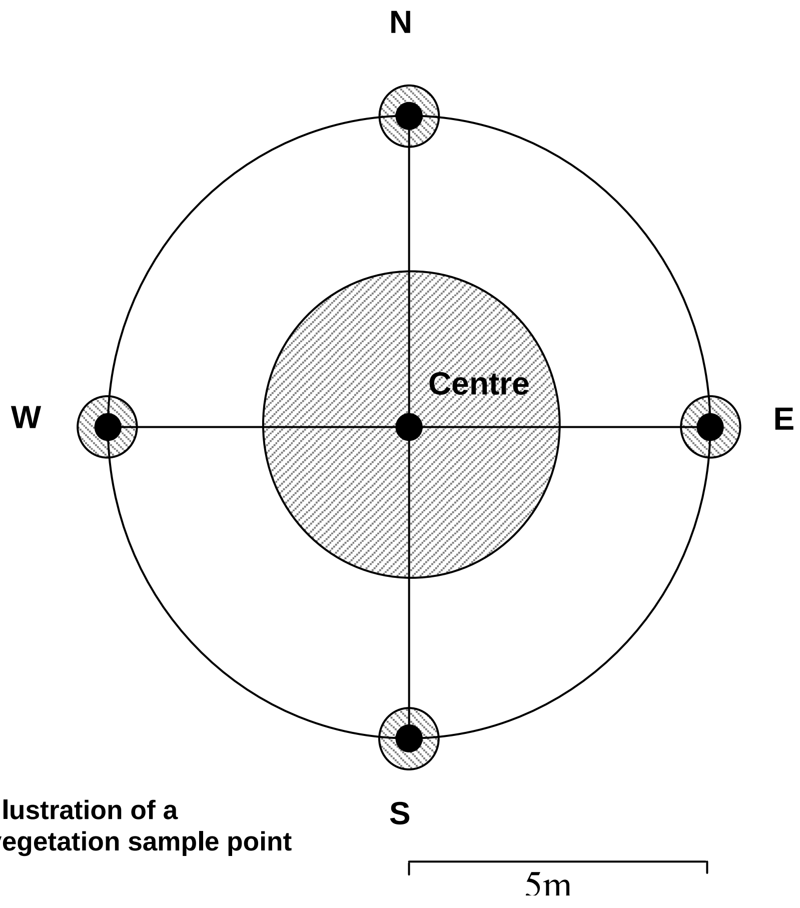

Illustration of a vegetation sample point

Appendix 2 Typical inter-territory distances (metres), as determined from breeding birds data from this study and published data (indicated by *). Where no information for relationships between registrations was available the registrations were deemed to belong to separate territories if the distance exceeds the threshold distance.

Species	Typical (m)	Threshold (m)
Blackbird	100-150	200
Blackcap	100-200	300
Blue Tit	50-100	150
Buzzard	>1000*	2000
Carrion Crow	300-400	550
Chaffinch	70-160	200
Chiffchaff	100-200	200
Chough	200-300	300
Coal Tit	40-100	150
Common sandpiper	300*	500
Cuckoo	160-500	500
Curlew	400	600
Dunnock	80-120	150
Garden Warbler	150-170	200
Goldcrest	50-100	200
Goldfinch	80-100	200
Grasshopper Warbler	160	200
Great Spotted Woodpecker	200-400	400
Great Tit	100-150	200
Greenfinch	300	400
Grey Wagtail	200	300
Jackdaw	300-400	400
Jay	200	300
Kestrel	>1000*	2000
Lesser Redpoll	75-200	225
Linnet	100-150	200
Long-tailed Tit	100-150	200
Magpie	300-400	400
Meadow pipit	45-100	125
Merlin	>1000*	2000
Mistle Thrush	100-200	300
Nuthatch	200	400
Peregrine	>1000*	2000
Pied Flycatcher	100-150	150
Pied Wagtail	200	200
Raven	300-400	1000
Redstart	80-120	150
Reed Bunting	60-180	200
Ring Ouzel	100-200	300
Robin	80-120	150
Siskin	100-200	225
Skylark	100-160	180
Song Thrush	100-200	300

Species	Typical (m)	Threshold (m)
Sparrowhawk	>1000*	2000
Stock Dove	100	200
Stonechat	150	150
Tawny Owl	300-400*	400
Tree Pipit	50-100	100
Treecreeper	200	400
Twite	100-150	200
Wheatear	80-130	200
Whinchat	100-150	200
Whitethroat	80-150	150
Willow Warbler	60-100	150
Wood Warbler	80-100	150
Woodpigeon	100	200
Wren	50	90
Yellowhammer	200	200

Appendix 3 Definitions of site and landscape metrics (following McGarigal *et al.* 2002).

Metric	Definition
Number of Patches (NPATCH)	Equals the number of patches within the site boundary.
Patch Density (PDENS)	Equals the number of patches with in the site boundary, divided by total site area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares).
Largest Patch Index (LPI)	Equals the area (m^2) of the largest patch within the site divided by total site area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percent of the landscape that the largest patch comprises.
Landscape Shape Index (LSI)	Equals the total length of edge within the site, given in number of cell (1m x 1m) surfaces, divided by the minimum total length of edge possible, also given in number of cell surfaces, which is achieved when the landscape consists of a single patch.
Mean Patch Area (PAREA1)	Equals the mean area (m^2) of the patch, divided by 10,000 (to convert to hectares).
Median Patch Area (PAREA2)	Equals the median area (m^2) of the patch, divided by 10,000 (to convert to hectares).
Mean Patch Shape (PSHAPE1)	Equals the mean of the patch perimeter (given in number of cell (1m x 1m) surfaces) divided by the minimum perimeter (given in number of cell surfaces) possible for a maximally compact patch (in a square raster format) of the corresponding patch area.
Median Patch Shape (PSHAPE2)	Equals the median of the patch perimeter (given in number of cell (1m x 1m) surfaces) divided by the minimum perimeter (given in number of cell surfaces) possible for a maximally compact patch (in a square raster format) of the corresponding patch area.
Mean Nearest neighbour distance (NND)	Equals the distance (m) to the nearest neighbouring patch of the same type, based on shortest edge-to-edge distance. Note that the edge-to-edge distances are from cell centre to cell centre.
Simpson's Diversity Index (SDI)	Equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared (Simpson 1949).
Simpson's Evenness Index (SEI)	Equals 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared, divided by 1 minus 1 divided by the number of patch types.
Total Tree Density (TDENS)	Equals the total number of trees divided by the total sites area (hectares)
Small (<6m diam.) Tree Density (STDENS)	Equals the total number of small trees divided by the total sites area (hectares)
Large (>6m diam.) Tree Density (LTDENS)	Equals the total number of large trees divided by the total sites area (hectares)
Median Altitude (ALTM)	Equals the midpoint (measured vertically) between the highest and lowest point within the site boundary
Altitude Range (ALTR)	Equals the difference in metres between the highest and lowest point within the site boundary.
Site Area	Equals the total site area in hectares.

Appendix 4 Site and landscape metrics for 25 ffridd sites, grouped by ffridd sub-class.

	Ffridd subtype 1				**Ffridd subtype 2**					**Ffridd subtype 3**								**Ffridd subtype 4**							
Site code	**1**	**25**	**1_1**	**1_2**	**6**	**8**	**2_1**	**2_2**	**2_3**	**10**	**11**	**13**	**23**	**3_2**	**3_4**	**3_5**	**3_6**	**16**	**18**	**19**	**20**	**24**	**4_2**	**4_3**	**4_6**
Number of Patches (NPATCH)	72	36	10	19	26	52	25	15	50	47	34	25	22	9	13	8	9	8	16	41	51	9	10	28	11
Patch Density (PDENS)	32.02	16.00	4.44	8.44	11.56	23.11	11.11	6.67	22.22	20.89	15.11	11.11	9.78	4.00	5.78	3.56	4.00	3.56	7.11	18.22	22.67	4.00	4.44	12.44	4.89
Largest Patch Index (LPI)	1.97	5.66	5.79	7.41	12.12	1.98	14.34	5.33	9.76	12.96	6.60	9.90	8.37	7.64	13.33	10.07	17.00	9.92	10.26	4.71	5.02	5.86	8.36	17.18	19.16
Landscape Shape Index (LSI)	5.76	2.59	2.12	2.26	2.79	3.59	2.52	1.82	3.57	3.55	3.09	2.72	2.73	1.67	1.96	2.14	1.88	1.37	2.20	3.77	3.30	2.12	1.84	2.73	2.19
Mean Patch Area (PAREA1)	0.58	1.07	4.59	2.68	2.84	0.78	2.44	2.08	1.21	1.58	1.16	2.31	3.07	3.61	3.28	7.85	6.45	5.96	3.02	1.28	0.97	6.83	5.49	2.31	6.16
Median Patch Area (PAREA2)	0.23	0.28	3.86	0.60	0.18	0.30	0.29	0.27	0.21	0.30	0.20	0.34	1.56	0.21	0.28	4.53	0.97	0.90	0.98	0.27	0.23	2.52	2.72	0.23	0.50
Mean Patch Shape (PSHAPE1)	2.54	1.77	2.14	1.75	1.96	1.97	1.91	1.93	2.00	1.95	2.16	2.04	1.89	1.84	2.20	2.54	2.00	1.55	1.78	2.09	1.74	2.08	1.89	1.87	1.99
Median Patch Shape (PSHAPE2)	2.31	1.55	1.99	1.59	1.69	1.70	1.73	2.01	1.79	1.58	1.89	1.79	1.76	1.57	1.78	2.44	1.86	1.55	1.48	1.79	1.51	1.72	1.91	1.67	1.52
Mean Nearest neighbour distance (NND)	40.1	31.4	46.5	47.2	56.2	64.6	44.0	108.2	57.2	37.9	50.4	37.6	92.4	241.6	69.6	33.4	81.0	98.1	84.2	36.2	54.0	53.4	123.8	39.1	43.5
Simpson's Diversity Index (SDI)	0.77	0.70	0.72	0.71	0.74	0.77	0.62	0.72	0.76	0.68	0.65	0.69	0.71	0.56	0.45	0.74	0.50	0.52	0.67	0.72	0.76	0.63	0.69	0.60	0.45
Simpson's Evenness Index (SEI)	0.92	0.82	0.96	0.83	0.88	0.87	0.75	0.86	0.88	0.78	0.82	0.83	0.83	0.66	0.54	0.86	0.75	0.65	0.83	0.86	0.87	0.85	0.92	0.72	0.61
Total Tree Density (TDENS)	9.08	14.70	6.91	5.43	0.30	0.69	2.59	2.95	4.14	3.86	9.21	4.30	2.88	1.08	1.41	1.34	0.91	1.81	1.10	11.34	5.82	2.23	0.16	0.31	0.03
Small (<6m diam.) Tree Density (STDENS)	6.81	8.54	4.88	1.14	0.24	0.17	0.93	2.05	2.54	2.34	4.43	3.20	2.45	0.09	1.22	1.05	0.67	0.61	0.66	10.61	2.84	1.89	0.02	0.26	0.03
Large (>6m diam.) Tree Density (LTDENS)	2.27	6.16	2.03	4.30	0.05	0.52	1.65	0.90	1.60	1.53	4.78	1.09	0.43	0.99	0.19	0.29	0.24	1.20	0.44	0.73	2.98	0.34	0.15	0.05	0.00
Median Altitude (ALTM)	297.5	235	470	390	327.5	245	377.5	430	415	352.5	280	342.5	370	450	400	322.5	455	337.5	272.5	305	107.5	345	485	415	505
Altitude Range (ALTR)	235	250	260	150	95	130	245	120	70	125	300	255	340	160	130	335	220	165	125	240	105	200	210	200	110
Site Area	41.8	38.6	45.9	51.0	73.8	40.4	61.1	31.2	61.0	74.1	39.3	57.7	67.4	32.5	42.6	62.8	58.0	47.6	48.3	52.3	49.6	61.4	55.0	64.8	67.8

Appendix 5 Percentage covers for ten habitat types on 25 ffridd sites, grouped by ffridd sub-class.

	Ffridd subtype 1				**Ffridd subtype 2**					**Ffridd subtype 3**								**Ffridd subtype 4**							
Site code	**1**	**25**	**1_1**	**1_2**	**6**	**8**	**2_1**	**2_2**	**2_3**	**10**	**11**	**23**	**13**	**3_2**	**3_4**	**3_5**	**3_6**	**16**	**18**	**19**	**20**	**24**	**4_2**	**4_3**	**4_6**
Bracken dominated (B)	18.6	21.0	25.8	7.1	0.1	38.6	28.8	4.3	10.2	2.4	16.2	2.9	16.2	0.8	2.2	4.6	.	0.2	.	39.7	9.4	.	.	13.4	22.3
Bracken-grass dominated mixture (BG)	16.3	8.7	27.1	43.6	.	6.0	3.7	.	1.9	9.5	2.3	19.3	6.0	0.6	4.0	.	.	54.2	.	22.5	24.4	18.3	.	10.9	.
Bracken-heather dominated mixture (BH)	.	0.5	.	.	.	17.3	10.3	8.4	8.7	.	.	.	.	0.7	.	30.8	19.5	.	.	3.5	2.9	.	10.5	0.9	6.1
Heather dominated (H)	.	.	.	.	17.3	7.4	52.8	.	9.4	.	.	.	0.6	0.4	.	14.2	.	.	18.2	.	.	.	25.7	8.5	.
Grass-heather dominated mixture (GH)	.	0.3	.	.	37.3	10.6	0.9	.	10.1	0.6	.	5.5	44.9	.	.	12.6	.	.	15.7	.	30.3	.	.	6.5	.
Gass-heather-vaccinium dominated mixture (GHV)	.	.	.	1.3	.	.	.	38.5	41.5	11.0	.	.	.	39.4	2.5	0.5	66.8	.	.	.	.	.	44.1	.	.
Grass dominated (G)	36.8	28.2	35.5	26.6	24.0	15.9	3.5	19.0	18.1	48.6	40.9	42.1	28.0	5.2	71.8	36.1	13.7	43.3	15.2	26.2	4.2	38.5	19.7	59.8	70.2
Strong gorse component (GORSE)	13.4	0.1	11.6	9.9	19.4	1.9	.	.	.	24.7	39.0	27.0	4.3	52.9	0.6	.	.	1.0	50.3	7.3	0.4	42.9	.	.	1.5
Woodland (WOOD)	12.0	41.2	.	9.7	.	0.6	.	29.5	.	2.6	.	0.6	.	.	18.9	1.2	.	1.2	.	.	27.4	.	.	.	.
Additional habitats (OTHER)	2.9	.	.	1.7	1.9	1.7	.	0.2	.	0.5	1.6	2.5	.	.	.	.	.	.	0.6	0.9	1.0	0.4	.	.	.

Appendix 6 Estimated territory density (territories per hectare) for each of the 25 sites, categorised by four ffridd subtypes. Bold and italics indicate Red and Amber-listed BoCC species, respectively (note – this is the UK BoCC list).

	Ffridd subtype 1				**Ffridd subtype 2**					**Ffridd subtype 3**								**Ffridd subtype 4**							
Species	**1**	**25**	**1_1**	**1_2**	**6**	**8**	**2_1**	**2_2**	**2_3**	**10**	**11**	**13**	**23**	**3_2**	**3_4**	**3_5**	**3_6**	**16**	**18**	**19**	**20**	**24**	**4_2**	**4_3**	**4_6**
Mallard					*0.01*											*0.02*									
Goshawk														0.03											
Common Buzzard	0.02	0.03	0.02	0.02	0.01	0.03	0.02	0.03		0.01	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02		0.02	0.02
Kestrel						*0.03*	*0.02*						*0.02*	*0.03*								*0.02*			
Merlin																						*0.02*			
Red Grouse					*0.01*				*0.03*															*0.02*	*0.02*
Lapwing																							**0.06**		
Common Snipe																			*0.04*						
Curlew																									*0.12*
Common Sandpiper					*0.01*	*0.03*														*0.02*	*0.02*				
Stock Dove														*0.03*											
Wood Pigeon	0.05	0.05	0.04	0.04							0.03								0.02						
Cuckoo	**0.04**	**0.08**			**0.01**	**0.03**		**0.03**	**0.03**	**0.01**			**0.02**						**0.02**	**0.02**	**0.04**	**0.02**			
Tawny Owl		0.03																							
Short-eared Owl																									*0.02*
G. S. Woodpecker	0.05	0.03																			0.02				
Skylark	**0.02**		**0.02**		**0.24**				**0.02**	**0.14**	**0.03**	**0.07**		**0.09**	**0.09**	**0.14**	**0.07**	**0.21**	**0.21**			**0.11**	**0.07**	**0.12**	**0.16**
Sand Martin				*0.02*																					
Swallow			*0.02*	*0.02*		*0.03*				*0.01*	*0.03*	*0.04*	*0.02*	*0.06*	*0.02*			*0.02*	*0.02*		*0.02*				
House Martin	*0.02*							*0.03*			*0.05*		*0.02*												
Tree Pipit	**0.05**	**0.39**	**0.22**	**0.10**		**0.15**	**0.07**	**0.10**	**0.10**	**0.08**	**0.03**	**0.07**	**0.03**				**0.02**			**0.33**	**0.08**				
Meadow Pipit	*0.14*	*0.05*	*0.17*	*0.06*	*0.45*	*0.30*	*0.48*	*0.39*	*0.63*	*0.28*	*0.38*	*0.43*	*0.53*	*0.59*	*0.24*	*0.45*	*0.72*	*0.63*	*0.58*	*0.42*	*0.16*	*0.49*	*0.31*	*0.46*	*0.41*
Grey Wagtail						*0.03*												*0.04*							
Pied Wagtail			0.02		0.04	0.05			0.02		0.05	0.05	0.02	0.12				0.04		0.08		0.02			
Wren	0.65	1.14	0.13	0.35	0.08	0.64	0.20	0.45	0.23	0.19	0.76	0.26	0.24	0.22	0.14	0.10	0.02	0.08	0.17	0.52	0.56	0.23	0.07	0.12	0.07
Dunnock	*0.24*		*0.04*	*0.08*	*0.01*	*0.10*		*0.06*		*0.11*	*0.23*	*0.04*	*0.13*	*0.22*		*0.02*		*0.02*	*0.17*	*0.08*	*0.06*	*0.13*			*0.04*
Robin	0.24	0.41		0.16		0.05	0.08	0.32	0.02	0.04	0.20	0.09	0.07		0.07			0.02		0.06	0.16				
Common Redstart	*0.19*	*0.29*	*0.09*	*0.12*		*0.03*	*0.02*	*0.29*	*0.02*	*0.05*		*0.04*			*0.14*					*0.06*					
Whinchat	*0.05*		*0.04*	*0.10*		*0.25*	*0.05*	*0.03*	*0.22*				*0.04*	*0.03*		*0.06*	*0.09*			*0.10*			*0.07*	*0.09*	*0.02*
Stonechat	0.07	0.03	0.07	0.04	0.01	0.17	0.03		0.05	0.12	0.20	0.04	0.03	0.15		0.08	0.09	0.02	0.12	0.02		0.15	0.04	0.03	0.03
Wheatear	*0.02*				*0.18*	*0.10*					*0.03*	*0.02*	*0.02*	*0.06*	*0.05*	*0.03*	*0.02*	*0.02*	*0.02*	*0.13*		*0.24*			*0.04*
Ring Ouzel					**0.01**																				
Blackbird	0.05	0.08		0.14	0.01	0.03	0.02	0.19		0.01	0.13	0.02	0.02	0.03	0.12	0.02			0.06	0.04	0.04	0.03			0.02
Song Thrush	**0.07**	**0.10**		**0.08**				**0.06**		**0.03**	**0.03**			**0.03**	**0.05**		**0.02**		**0.06**		**0.06**	**0.02**			**0.02**

Appendix 6 Continued.

	Ffridd subtype 1				Ffridd subtype 2					Ffridd subtype 3								Ffridd subtype 4							
Species	**1**	**25**	**1_1**	**1_2**	**6**	**8**	**2_1**	**2_2**	**2_3**	**10**	**11**	**13**	**23**	**3_2**	**3_4**	**3_5**	**3_6**	**16**	**18**	**19**	**20**	**24**	**4_2**	**4_3**	**4_6**
Mistle Thrush	*0.05*		*0.07*	*0.02*								*0.02*			*0.02*			*0.04*		*0.02*	*0.06*	*0.03*			
Grasshopper Warbler							**0.03**									**0.03**					**0.02**				
Whitethroat				*0.02*		*0.07*	*0.12*										*0.03*								
Garden Warbler	0.05	0.21	0.02	0.02				0.13							0.02	0.02					0.14				
Blackcap	0.02	0.03		0.02				0.03												0.02					
Wood Warbler	**0.02**	**0.13**																							
Chiffchaff	0.02	0.03		0.04				0.03																	
Willow Warbler	*0.10*	*0.67*	*0.28*	*0.26*		*0.12*	*0.25*	*0.35*	*0.22*	*0.14*	*0.31*	*0.10*	*0.09*	*0.09*	*0.12*	*0.05*	*0.02*		*0.06*	*0.12*	*0.58*	*0.02*			*0.04*
Goldcrest	0.05	0.03						0.03		0.01											0.02				
Spotted Flycatcher				**0.02**																					
Pied Flycatcher	*0.05*	*0.13*	*0.02*					*0.16*							*0.07*						*0.08*				
Long-tailed Tit		0.03																							
Coal Tit	0.12	0.13	0.02	0.04				0.10			0.03				0.05						0.08				
Blue Tit	0.17	0.26	0.04	0.08			0.02	0.13		0.01	0.03				0.12					0.02	0.14				
Great Tit	0.07	0.16	0.02	0.02				0.13	0.02	0.01	0.03		0.03		0.07						0.06				0.02
Nuthatch	0.02	0.13								0.01					0.02						0.02				
Treecreeper	0.02	0.08						0.06																	
Jay	0.02							0.03													0.04				
Magpie	0.05	0.03	0.02	0.02						0.01	0.05	0.02	0.02		0.03				0.02						
Chough											*0.03*														
Jackdaw	0.02								0.03		0.03								0.04						
Carrion Crow	0.05	0.05	0.09	0.04	0.01	0.05	0.02	0.06	0.02	0.03	0.05	0.02	0.03	0.09	0.09	0.03	0.05	0.02	0.04	0.02	0.02	0.02	0.02	0.02	0.02
Raven															0.02										
House Sparrow					**0.03**							**0.02**	**0.04**												
Chaffinch	0.22	0.41	0.17	0.20	0.01	0.05	0.07	0.30	0.12	0.05	0.15	0.10	0.06		0.19	0.03		0.02	0.04	0.19	0.16	0.03		0.02	0.02
Greenfinch																			0.04						
Goldfinch				0.02							0.08										0.02				
Siskin	0.02	0.05						0.03							0.02						0.04				
Linnet	**0.05**		**0.04**	**0.06**	**0.01**				**0.03**	**0.03**	**0.20**	**0.02**		**0.15**			**0.05**	**0.02**	**0.27**			**0.03**			**0.10**
Lesser Redpoll		**0.03**				**0.03**		**0.03**	**0.03**	**0.07**	**0.08**	**0.02**	**0.04**						**0.06**	**0.10**	**0.02**				
Bullfinch																									*0.02*
Yellowhammer				**0.10**																					
Reed Bunting	*0.02*		*0.07*				*0.07*		*0.08*				*0.03*	*0.03*		*0.03*		*0.04*			*0.08*		*0.02*		
Total species	38	31	24	30	18	22	17	27	19	23	27	21	23	19	23	16	13	16	21	21	29	18	8	9	19

Appendix 7 List of species names and two-letter codes

Blackbird	*Turdus merula*	B.
Blackcap	*Sylvia atricapilla*	BC
Blue Tit	*Parus caeruleus*	BT
Bullfinch	*Pyrrhula pyrrhula*	BF
Carrion Crow	*Corvus corone*	C.
Chaffinch	*Fringilla coelebs*	CH
Chiffchaff	*Phylloscopus collybita*	CC
Chough	*Pyrrhocorax pyrrhocorax*	CF
Coal Tit	*Periparus ater*	CT
Common Buzzard	*Buteo buteo*	BZ
Common Redstart	*Phoenicurus phoenicurus*	RT
Common Sandpiper	*Actitis hypoleucos*	CS
Common Snipe	*Gallinago gallinago*	SN
Curlew	*Numenius arquata*	CU
Cuckoo	*Cuculus canorus*	CK
Dunnock	*Prunella modularis*	D.
Garden Warbler	*Sylvia borin*	GW
Goldcrest	*Regulus regulus*	GC
Goldfinch	*Carduelis carduelis*	GO
Goshawk	*Accipiter gentilis*	GH
Grasshopper Warbler	*Locustella naevia*	GH
Great Spotted Woodpecker	*Dendrocopos major*	GS
Great Tit	*Parus major*	GT
Greenfinch	*Carduelis chloris*	GR
Grey Heron	*Ardea cinerea*	H.
Grey Wagtail	*Motacilla cinerea*	GL
House Martin	*Delichon urbica*	HM
House Sparrow	*Passer domesticus*	HS
Jackdaw	*Corvus monedula*	JD
Jay	*Garrulus glandarius*	J.
Kestrel	*Falco tinnunculus*	K.
Lapwing	*Vanellus vanellus*	L.
Lesser Redpoll	*Carduelis cabaret*	LR
Linnet	*Carduelis cannabina*	LI
Long-tailed Tit	*Aegithalos caudatus*	LT
Magpie	*Pica pica*	MG
Mallard	*Anser platyrhynchos*	MA
Meadow Pipit	*Anthus pratensis*	MP
Merlin	*Falco columbarius*	ML
Mistle Thrush	*Turdus viscivorus*	M.
Nuthatch	*Sitta europaea*	NH
Pied Flycatcher	*Ficedula hypoleuca*	PF
Pied Wagtail	*Motacilla alba*	PW
Raven	*Corvus corax*	RN
Red Grouse	*Lagopus lagopus*	RG
Reed Bunting	*Emberiza schoeniclus*	RB
Ring Ouzel	*Turdus torquatus*	RZ
Robin	*Erithacus rubecula*	R.
Sand Martin	*Riparia riparia*	SM
Short-eared Owl	*Asio flammeus*	SE
Siskin	*Carduelis spinus*	SK
Skylark	*Alauda arvensis*	S.
Song Thrush	*Turdus philomelos*	ST

Appendix 7 Continued.

Spotted Flycatcher	*Muscicapa striata*	SF
Stock Dove	*Columba oenas*	SD
Stonechat	*Saxicola torquata*	SC
Swallow	*Hirundo rustica*	SL
Swift	*Apus apus*	SI
Tawny Owl	*Strix aluco*	TO
Treecreeper	*Certhia familiaris*	TC
Tree Pipit	*Anthus trivialis*	TP
Wheatear	*Oenanthe oenanthe*	W.
Whinchat	*Saxicola rubetra*	WC
Whitethroat	*Sylvia communis*	WH
Willow Warbler	*Phylloscopus trochilus*	WW
Wood Pigeon	*Columba palumbus*	WP
Wood Warbler	*Phylloscopus sibilatrix*	WO
Wren	*Troglodytes troglodytes*	WR
Yellowhammer	*Emberiza citrinella*	Y.