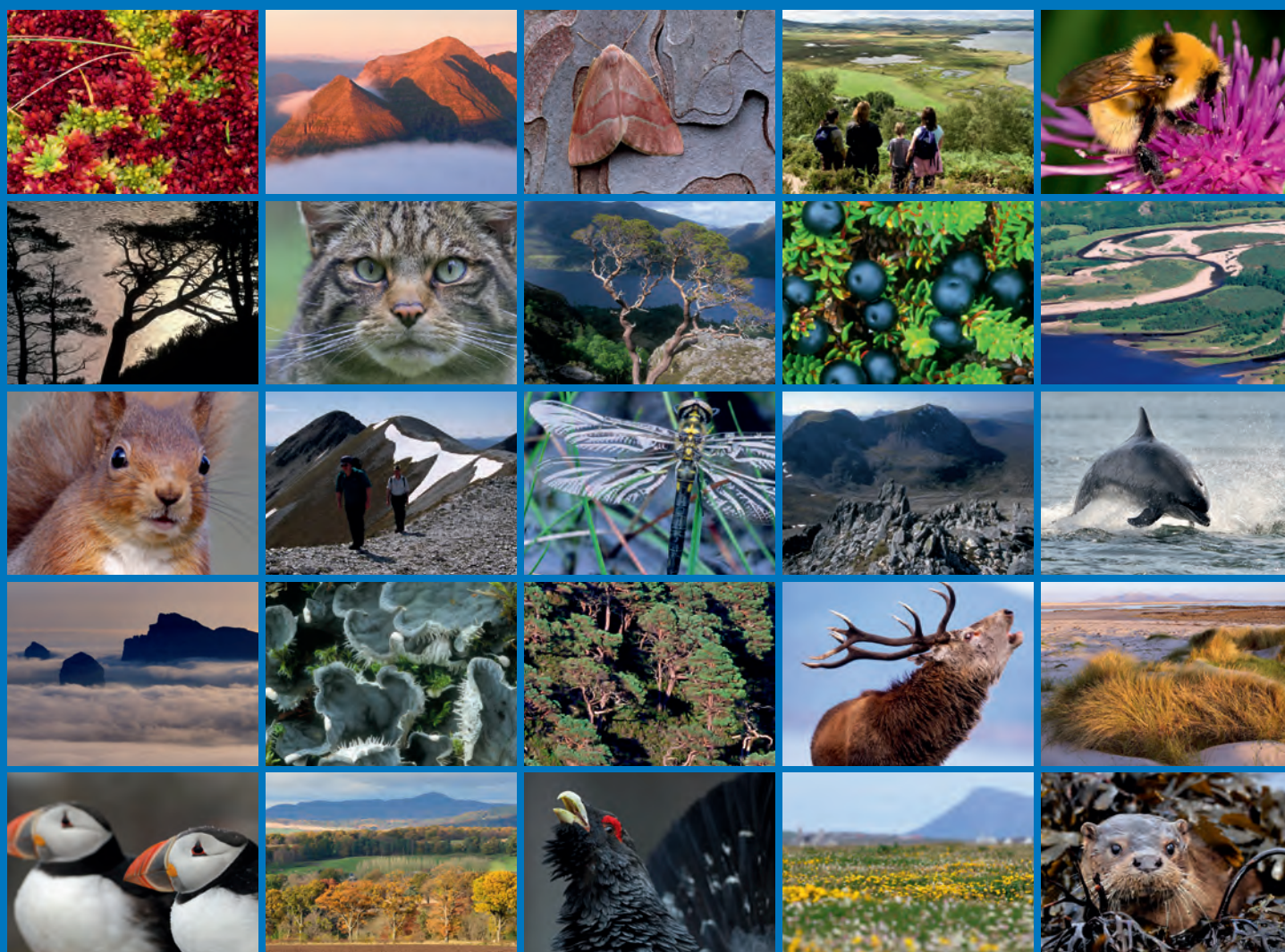


Monitoring of moorland fringe biodiversity: the bird communities of the interface between conifer plantations and moorland in the Galloway Forest Park and their relationships with moorland fringe habitats





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COMMISSIONED REPORT

Commissioned Report No. 456

**Monitoring of moorland fringe biodiversity:
the bird communities of the interface
between conifer plantations and moorland
in the Galloway Forest Park and their
relationships with moorland fringe habitats**

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COMMISSIONED REPORT

Summary

Monitoring of moorland fringe biodiversity: the bird communities of the interface between conifer plantations and moorland in the Galloway Forest Park and their relationships with moorland fringe habitats

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Background

As part of a significant restructuring programme within the Galloway Forest Park, Forest Enterprise Scotland are creating areas of so-called 'moorland fringe' at the interface between conifer plantations and open moorland. These fringe areas aim to establish mosaics of shrubs and open ground forming a transition zone that resembles some natural tree lines.

This report describes a survey of birds in the fringe areas in winter 2008-09 and spring-summer 2009 and describes the relationships with recorded habitat variables. The importance of the bird communities is considered, as are implications for their sustainability in view of the early stages of shrub development encountered at the time of the study and their inevitable development and succession. A review of relevant literature provides additional evidence to interpret the findings of the field study and further guidance towards the management of moorland fringe areas in the long term.

Main findings

- A total of 59 bird species was recorded in the fringe areas and immediately adjacent plantations and moorland, of which 29 are included on current lists of conservation concern, the majority being associated with moorland fringe areas.
- Shrubs (both extent and species composition) were a major influence on the presence and abundance of many bird species with species richness and, in most cases, abundance of individual species positively related to shrub cover (and shrub species diversity and/or the presence of native species) within the ranges found in our study areas. Shrub cover appeared to influence bird communities at different spatial scales between winter and summer, with larger patch-scale influences apparently more important in winter than in the breeding season.
- Relationships between shrub cover in the fringe areas and on bird densities in neighbouring plantations and moorland were apparent. Our data suggest different responses by different species, or even guilds of species, whereby some increase their overall densities and others redistribute themselves. Although further studies would be required to identify mechanisms for these differences, species redistribution could be an initial response to the developing fringe habitats (most of which were <8 years old).

- Other habitat variables with relationships to bird species occurrence and abundance were ground cover (graminoid and ericaceous vegetation and brash) and tree cover. There was considerable variation in the nature of these relationships between species with few common traits across all species and variables.
- Some recommendations for further research, both ecological and applied forestry management are presented.

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EXECUTIVE SUMMARY

1. This report describes a study that quantifies the bird communities which use the interface between commercially managed conifer plantations and open moorland in the Galloway Forest Park, in winter 2008-09 and in summer 2009. In particular, the influence of restructuring the forest edge to include mosaics of shrubs and more open habitats on bird species richness and on species occurrence and abundance are examined. This provides a measure of the benefits to nature conservation of that forest edge restructuring (creating 'moorland fringe' areas) and provides guidance as to its long-term management and sustainability. As far as we are aware, this is the first study to look specifically at the bird communities at the interface between managed conifer plantations and open moorland.
2. A review of relevant literature is presented which includes (i) the influences of forestry on moorland birds, both in terms of direct habitat replacement and effects of proximity, (ii) the bird communities that use conifer plantations, and factors that influence them, and (iii) the bird communities that use scrub and the factors that influence them. The literature provides evidence that conifer plantations can support interesting bird communities that include species that are of particular conservation value and those communities and species will differ through the stages of plantation management. However, plantations can, and have, replaced moorland habitats and their associated bird communities that are also considered to be of conservation value and can also have a negative impact on some breeding waders on adjacent unplanted moorland. There are forest-edge effects whereby increased light penetration and a greater range of available habitats enhance the species richness and population densities of some species at the forest or plantation edges. The development of moorland fringe habitats (shrub mosaics) at the edges of plantations might be expected to enhance those forest edge effects further. Furthermore, the shrub habitats themselves can be expected to support interesting bird communities in their own right. 'Softening' the edges of plantations through the development of fringe habitats might also be expected to have some ameliorating effects on the influence of plantations on some proximate moorland breeding birds, however the evidence for this from the literature is less conclusive. The literature review was used to inform the design of the field study and aid the interpretation of the data collected and its analyses.
3. Birds were surveyed from 240 sampling points in five study areas where moorland fringe areas are being developed within the Galloway Forest Park. The sampling points were selected from 1,020 points, within the moorland fringe areas and neighbouring plantations and open moorland, where the vegetation (type and structure) were recorded. The bird sampling points were selected from these to provide a representative range of habitat variables, especially those that were identified from the literature review to be important determinants of bird distribution and abundance (shrub cover and type, tree cover and type, ground vegetation and brash cover). Timed point counts (10 minutes each) sampled the birds at each point twice in each of the two survey seasons (November 2008 – February 2009 and April – June 2009). The timed counts were used to produce measures of species richness and occurrence rates and indices of abundance for each species.
4. A total of 59 species was recorded in the two seasons, 35 during the winter and 49 in the breeding season. Among them were 11 species that are included on the current red-list of birds of conservation concern (black grouse, hen harrier, herring gull, common cuckoo, European nightjar, sky lark, tree pipit, song thrush, common grasshopper warbler, spotted flycatcher and lesser redpoll) and also 18 amber-listed species (Eurasian teal, red grouse, golden eagle, common kestrel, merlin, Eurasian woodcock,

common snipe, green woodpecker, barn swallow, meadow pipit, hedge accentor, whinchat, wheatear, mistle thrush, common whitethroat, willow warbler, common bullfinch and reed bunting).

5. Generalised linear models and generalised linear mixed models were used to investigate the relationships between measures of species richness and species-specific occurrence rates and indices of abundance with the recorded habitat variables. Analyses were undertaken at two spatial levels (at sub-site or area level and at the sampling-point level) and where the data were sufficient (i.e. individual species were not too rare) to successfully model the relationships.
6. Shrubs (both their extent and species composition) were identified as a major influence on the presence and abundance of many bird species. Species richness and, in most cases, abundance of individual species were positively related to shrub cover within the ranges found in our study areas (0-13% cover at the sub-site level and 0-67% at finer sampling point level). Differences in the statistical significance of the relationships between winter and breeding seasons suggested differences in the spatial scales of their influence on birds between the seasons. In summer, species richness tended to be most strongly influenced by shrub cover at the sampling point level (i.e. the finer level) while in the winter, shrub cover at the sub-site level (i.e. a broader area level) appeared to be more important. Bird species richness and the abundance of most species were also positively related to the number of shrub species that were present. In our study areas, where more than one or two shrub species were present, this was invariably because of the presence of native broad-leaved shrubs (or young trees) as opposed to the non-native coniferous crop species. Therefore, the diversity of shrubs was confounded with the occurrence of native broad-leaved species and so the relative importance of either could not be assessed.
7. Statistically significant relationships of shrub cover in fringe areas with the abundance of some species in neighbouring post-thicket plantations and open moorland indicates that shrub can influence the bird communities in neighbouring habitats. Differences in the responses to shrubs between two apparent guilds of species suggests different mechanisms on bird populations may operate within the newly developing fringe areas (note that most are 8-years old or less); ground feeders and trunk gleaners that feed on molluscs and other large invertebrates (e.g. blackbird and song thrush) tended to be more abundant in plantations next to fringe areas with more shrub cover which suggests an ability to benefit from enhanced conditions in neighbouring habitats. Foliage gleaners that feed on small invertebrates (e.g. winter wren, willow warbler and goldcrest) tended to be less abundant in post-thicket plantations next to fringe areas with more shrub cover, while they were more abundant in that shrub which suggests that those species have responded by redistributing themselves to concentrate within the developing shrub habitats.
8. In addition to shrub cover, other habitat variables that could be modelled to demonstrate a relationship with the bird communities were ground cover (graminoid and ericaceous vegetation as well as brash cover) and tree cover. Within the range of variables present in our study areas and which could be modelled, some were mostly positively related to bird abundance, for example graminoid and ericaceous ground cover. There was, however, considerable variation in the direction of relationships across the full range of habitat variables between the bird species that could be modelled. For example tree cover within the open habitats tended to be positively related to the occurrence of black grouse, tree pipit and lesser redpoll, but was negatively related to the occurrence of red grouse, common cuckoo, song thrush, common grasshopper warbler and willow warbler.

9. In the absence of interventional management, the shrub mosaics of the moorland fringe habitats will naturally succeed into woodland and therefore the biodiversity interests will become different to that found in the present study and could potentially hold fewer species of conservation importance and be counter to other objectives (e.g. landscape) for the fringe areas. To sustain the biodiversity interest and value to nature conservation of the fringe areas, the managers of the Galloway Forest Park will need to consider options for ongoing maintenance which could include grazing, mowing, supplementary planting and the use of slow growing shrubs. Consideration should be given to the benefits of moorland fringe management *per se* as opposed to the benefits that can be delivered through typical rotational management of the forestry crops. Such management, either of fringe areas or of rotational cropping, should consider the spatial requirements of the birds at different seasons and also connectivity with and proximity to similar habitats and open moorland. Some of these issues will require further research to identify optimal management regimes.
10. Recommendations for further ecological research include (i) repeat monitoring at five-year intervals to identify optimum stages of shrub and fringe development for particular species and groups, (ii) autecological studies to elucidate the mechanisms by which species use and distribute themselves within the fringe and neighbouring areas, and (iii) similar studies at sites with a broader suite of moorland birds than were found in the Galloway study areas. There is also scope for further research to identify management procedures to ensure the sustainability of fringe habitats at the interface between moorland and plantations and also how some of the observed conservation benefits could be incorporated into more typical rotational forestry management.

1. BACKGROUND

As part of a significant restructuring programme within the Galloway Forest Park, Forest Enterprise Scotland are creating areas of so-called 'moorland fringe' as a buffer between the hard edge of the conifer plantations and open hill ground. These fringe areas aim to establish mosaics of shrubs and open ground forming a transition zone that is somewhat akin to some natural tree lines. The restructuring of the edges of upland conifer plantations is advocated for the purposes of nature conservation, notably for black grouse (the scientific names of species mentioned in the text are listed in Appendix 1), and although the logical interpretation of the known ecology of the species implies there could be benefits, there are no supportive empirical data (Calladine 2002). Similarly, the restructuring of forest plantation edges might be expected to benefit a range of other species, including tree pipit, song thrush, spotted flycatcher, common bullfinch and reed bunting that are prioritised by the [UK Biodiversity Action Plan](#). However, once again empirical data supporting the benefits of such edge restructuring are currently lacking. Given both the expense (in terms of initial capital costs and profits foregone) of forest edge restructuring, and also the potential benefits to nature conservation, it is appropriate that this research is carried out: (i) to quantify the bird assemblages of restructured Forestry-Moorland fringe areas; (ii) to assess factors that influence those assemblages; (iii) to contribute towards the production of best practice guidance for the creation of the fringe areas; and (iv) to contribute towards the assessment of the sustainability of such fringe areas.

This report comprises:

- a) A review of literature to provide background information (Section 2). This review is used to (i) inform the strategy for the bird surveys, (ii) to aid the interpretation of the bird data and (iii) to further inform best practice guidelines for the future creation of moorland fringe areas;
- b) A description of the selection of study sites and the collection of habitat data within them and how the habitat data are used to inform the final survey design for assessing factors that influence the distribution and abundance of birds associated with 'moorland fringe' habitats, neighbouring plantations and open moorland (Section 3). The limitations of the study areas in identifying factors that may influence bird populations are also considered;
- c) A description of the field methods and results of the bird surveys undertaken during winter 2008-09 and spring/summer 2009, and the analytical methods used to describe relationships between the bird and habitat data (Section 4). Also included are the quantified relationships between bird distribution and abundance (in both summer and winter) and habitat variables that could be identified within the study areas (Section 5);
- d) A discussion (Section 6) which considers the conservation importance of the birds found in the fringe areas and factors that contribute towards an understanding of how birds (as an indicator of broader biodiversity) use the restructured fringe areas and also how that might be sustained in the long term. Some recommendations for further research are also identified.

As far as we are aware, this study in the Galloway Forest Park is the first to look specifically at the bird communities at the interface between moorland and commercially managed forestry plantations.

2. A REVIEW OF LITERATURE

This literature review has informed the planning and collection of data on the breeding and winter bird communities of developing fringe areas, and associated moorland and plantation areas, in the Galloway Forest Park (Sections 3 and 4). It further informs the analyses and interpretation of the relationships between birds and habitat variables (Sections 4 & 5). In combination with the survey results, it is ultimately used in contributing towards the development of best practice guidelines for the future creation and ongoing management of 'fringe areas' at the interface of managed conifer plantations and open moorland in terms of nature conservation interest, as indicated by the bird communities that occupy or otherwise use those fringe areas (Section 6).

The review is presented as four sections:

1. The influence of forestry on moorland birds;
2. Bird communities that inhabit conifer plantations and factors that influence them;
3. Bird communities in scrub and factors that influence them;
4. An overview to identify factors of potential relevance to bird communities of fringe habitats at the interface between conifer plantations and open moorland.

The review is derived from information published in peer-reviewed scientific literature identified using the search engine [Web of Science](#), the references cited within those papers and other standard reference books and grey literature which could be identified and sourced. Reviewed literature included autecological studies of relevant bird species as well as relevant management related studies on bird communities.

Although those habitats and geographic locations most similar to the Galloway study area are accorded preferential 'weighting' in the review, it also draws on studies from around the world. In considering how the findings from other study areas are transferable to Galloway, or more broadly to Britain, it should be recognised that the occurrence of virtually all groups of woodland birds is lower in Britain, and even lower in Ireland, than other temperate areas of mainland Europe. This is mainly a result of both insularity and also an apparent west-east gradient in species richness across the continent (Fuller *et al.* 2007a). Consequently, some species in Britain probably use habitats in different ways to mainland Europe for reasons related to competition, predation and historical adaptation (Fuller *et al.* 2007a). A west-east gradient is also apparent in species richness of woodlands within Britain (Fuller & Browne 2003), therefore the plantations of Galloway could conceivably support particularly restricted bird communities. It follows that some species may not necessarily respond to habitat variables or to management in the same way in western insular Britain as they might do elsewhere in their range. Similarly, local populations could potentially change as a result of broader redistributions in response to wider population change, rather than to local management initiatives (Fuller *et al.* 2007a). For example, the European nightjar exists at the edge of its breeding range in Galloway, where it occupies pre-thicket forestry plantations (Conway *et al.* 2007, Spray 2007). Although the total UK nightjar population increased by 36% between 1992 and 2004, the local population in Dumfries and Galloway declined by 23% (Conway *et al.* 2007). Such a divergence in trends may not necessarily result from reduced availability or quality of habitat in Galloway, and could potentially be a local response to redistribution into higher quality areas within the broader range of the species.

2.1 Forestry and moorland birds

In this section we consider the impact of forestry on moorland birds. Moorland species can be defined as those requiring open areas of semi-natural habitat dominated by dwarf ericaceous shrubs, grasses, sedges or combinations of these, usually in upland areas or where the climate is otherwise sufficiently cool and damp to permit the development of peat

soils. In reviews of the influence of afforestation on birds in the UK (Stroud *et al.* 1987, Avery & Leslie 1990, Petty & Avery 1990), mechanisms by which moorland birds are influenced by planted commercial forests include:

- a) The replacement and fragmentation of moorland;
- b) Increased predation;
- c) Changes in water quality (sediment loads, acidification and physical changes of water courses);
- d) The use of chemicals (e.g. fertiliser and herbicides) within the managed forests.

2.1.1 Forestry replacing moorland

Bird species richness and overall densities of breeding birds are generally greater in plantations and naturally regenerating scrub than on open moorland (e.g. Moss *et al.* 1979, Gillings *et al.* 2000). However, there are a number of species which nest on moorland that are displaced by forestry and are also recognised as of conservation importance. These recognitions include the European Communities Directive on the Conservation of Wild Birds (Eurasian golden plover; Stroud *et al.* 2001) or prioritisations within the UK such as Biodiversity Action Plan Species (red grouse, northern lapwing, Eurasian curlew, sky lark, ring ouzel, twite and reed bunting; Eaton *et al.* 2007). The simplest mechanism by which these species are lost is direct replacement of their preferred habitats (open moorland) with one that is inhospitable to them (enclosed woodland). However, the influence of plantations on the suitability of moorland for breeding birds can also extend beyond the boundary of the planted area. Afforestation and associated changes in drainage can affect the hydrological regimes of adjacent unplanted areas, thereby influencing vegetation structure and composition (Smith & Charman 1988). Changes in the management of remaining moorland areas may also occur. For example, 'islands' of mire or moorland within plantations can often become ungrazed (Smith & Charman 1988). Similarly, small or fragmented areas of moorland outside of a forestry block could also become ungrazed. Alternatively, such fragmented areas of moorland could become more intensively grazed, if graziers choose to redistribute their stock and increase stocking densities on the remaining unplanted ground.

Other aspects of moorland management may alter with changing size or fragmentation of moorland. For example, managers of grouse moors may reduce the intensity of, or cease, heather burning (muirburn) and/or predator control, if that area of moorland becomes too small or fragmented for economically viable grouse shooting. Vegetation composition and structure (and therefore grazing and burning regimes) and predator control can influence the breeding densities and productivity of some moorland birds (e.g. Fuller & Gough 1999, Tharme *et al.* 2001, Calladine *et al.* 2002, Pearce-Higgins & Grant 2006). For example, on moorland in northern England and southern Scotland, red grouse and stonechat were associated predominantly with heather, while Eurasian curlew, common snipe and meadow pipit were associated with more heterogeneous mosaics of vegetation (that included some dwarf shrubs, grasses, sedges and rushes) (Pearce-Higgins & Grant 2006). Sky lark and Eurasian golden plover were associated with short vegetation (short grasses or dwarf shrubs) and whinchats were associated with dense vegetation, notably bracken (Pearce-Higgins & Grant 2006). In Scotland and northern England, moorland actively managed for red grouse shooting has been shown to hold higher densities of breeding gamebirds and waders (such as red grouse, Eurasian golden plover, northern lapwing and Eurasian curlew) than moorland which is not managed for that purpose. However passerines such as meadow pipit, sky lark, whinchat and carrion/hooded crows showed a general trend toward lower breeding densities on managed grouse moors (Tharme *et al.* 2001). Differences in the communities of breeding birds between grouse moors and 'other' moors were considered to result from a combination of rotational heather burning and predator control, the latter having a positive influence on breeding waders and grouse and a negative influence on crows, one of the predators targeted for control. A reduction in grazing intensity around moorland

edges, typically a mosaic of grasses, rushes and heather, has been shown to lead to an increase in the density and breeding success of black grouse in northern England (Calladine *et al.* 2002). However this effect was scale-dependent and where the area in which grazing had been reduced exceeded c.1 km², declines in the recorded summer densities of females were apparent (Calladine *et al.* 2002).

Birds breeding on moorland adjacent to forestry plantations might be predicted to respond to changes in grazing regime, vegetation structure (its spatial extent and heterogeneity) and predator control in a similar manner to those recorded on 'open' moorland. Where 'fringe habitats' are to be established at the interface between moorland and forestry plantations, the effects on moorland bird communities could depend firstly, on whether the fringes are created by extension from the plantations (thereby reducing the area of moorland) or by felling into the plantation (thereby increasing the moorland area); and secondly, on the choice of management implemented in the unplanted areas, including burning (or alternatively swiping or cutting) and grazing.

2.1.2 Edge effects of forestry on moorland birds

In addition to the direct influence of forestry plantations replacing moorland, an edge effect of plantations on adjacent moorland has been reported by some studies. In the Caithness and Sutherland peatlands, the densities of breeding moorland waders (Eurasian curlew, Eurasian golden plover and dunlin) tended to be lower on moorland close to plantations: this was interpreted as largely a result of vegetation differences close to the plantations (Avery 1989a). In the same study area, an experiment was conducted to measure variation in predation rates of chicken eggs at different distances from plantations. Predation was highest closest to plantations but again the results were confounded with differences in vegetation composition with varying distance from plantations (Avery 1989b). These studies did not determine whether vegetation differences close to the plantation were a product of forestry or an artefact of plantation boundaries coinciding with underlying vegetation boundaries. A separate study of dunlin in the same areas suggested that afforestation could have influenced adjacent vegetation, as a result of advances in forestry technology during the 1980s, permitting the ploughing and planting of wetter areas occupied by breeding dunlin (Lavers and Haines-Young 1996). The moorland adjacent to the plantations was considered likely to have supported higher densities of breeding dunlin prior to planting and, therefore, the plantations were suppressing numbers outside of the planted area.

An analysis of 1980s bird survey data in the North Pennines and Sutherland also reported lower densities of breeding waders close to plantations. Sufficient data were only available to detect species-specific trends for Eurasian golden plover and dunlin, however a trend was also apparent for all wader species combined (also including common redshank, Eurasian curlew, northern lapwing, common snipe, common greenshank and common sandpiper) (Stroud *et al.* 1990). For Eurasian golden plover, and all waders combined, reduced densities were apparent within 400 metres of the plantation edge. For dunlin, plantation edge effects were thought to extend over a greater distance, but data were insufficient to formally measure the extent of the 'edge' effect. Unlike Avery (1989a, 1989b), no apparent confounding effect of vegetation type with proximity to plantations was reported (although the authors suggest a low statistical power to detect such differences). It was suggested that predation, or a redistribution of birds to minimise predation risk, was reducing wader breeding densities on moorland close to plantations (Stroud *et al.* 1990). Negative effects of the proximity of plantations for moorland breeding birds were demonstrated for red grouse (based on counts in 2000) and dunlin (based on recorded declines between surveys in 1988 and 2000) were identified in the peatlands of Caithness and Sutherland (Hancock *et al.* 2009). The same study found weaker (not statistically significant at the $P = 0.05$ level) possible relationships for lower abundance of breeding Eurasian golden plovers close to plantations in 2000 and for a decline in dunlin abundance between 1988 and 2000, however

no influences were detected for common greenshank (Hancock *et al.* 2009). Another study in Sutherland also failed to find an influence of the proximity of plantations, in this case new native-type woodland, on breeding common greenshank (Christian & Hancock 2009), however the trees remained small (< 3 m) during that study and so the woodland was perhaps not sufficiently developed for an influence to be exerted. The authors of the latter study also considered that retaining the planting open to grazing animals may have contributed to the lack of apparent change in that vole numbers may not have increased in response to grazing exclusion and therefore predators may not have responded with a responsive increase. Plantations are likely to harbour increased predator densities, as a result of more suitable habitat and reduced levels of predator control, relative to many moorland areas (Section 2.1.1). The extinction of a breeding population of Eurasian golden plovers on moorland in north-east Scotland was thought to have been at least partly attributable to encroachment by forestry and associated increases in predation (Parr 1992).

The proximity of plantations (eucalyptus and oak) were demonstrated to have a negative influence on some (calandra lark and short-toed lark) but not all (little bustard and tawny pipit) steppe birds in agricultural landscapes in Portugal with lower densities occurring closer to the plantations (Reino *et al.* 2009). Although strictly not moorland birds, there are parallels between obligate steppe birds and those obligate open habitat species found on moorland. This latter study was also able to investigate interactions of the edge effects with both the structure of the plantation edge and with the landscape characteristics in general: a less pronounced negative influence on steppe birds was apparent next to 'soft-edged' oak plantations compared to the 'hard' edge of the taller eucalyptus plantations and the abundance of steppe birds tended to increase more readily in otherwise open landscapes compared to within fragmented open habitats (Reino *et al.* 2009). If obligate open moorland species respond to the proximity of plantations in a similar way to steppe birds in Portugal, it could be expected that any effect may be reduced where the plantation edge was 'soft', for example by the incorporation of a 'fringe' and/or where the area of open moorland is relatively extensive and not fragmented.

2.1.3 Other effects of forestry on moorland birds

Afforestation can have an influence on some avian predators that rely on open ground for finding prey or carrion. In northern England and southern Scotland, the abandonment of breeding territories by ravens in the 1970s appeared to be dependent on both the extent of afforestation and also the availability of food (associated with upland sheep farming) in the remaining unplanted areas. Ravens were found to persist in areas where the unplanted ground supported high prey and carrion levels (Marquiss *et al.* 1978). In Wales, both buzzards and ravens persisted in forested landscapes that had retained intensive sheep pastures within a fragmented forested landscape (Newton *et al.* 1982). Golden eagles typically inhabit open country, with a much lower density of trees than commercially managed conifer plantations. The large scale afforestation in Galloway in the 1970s coincided with reduced breeding success in three out of four pairs of golden eagles (Marquiss *et al.* 1985). However, studies in Argyll suggest that the response of individual golden eagle pairs varied: territories with poorer breeding productivity appeared more vulnerable to abandonment following afforestation than those occupied by more productive pairs, while pairs that were less constrained by neighbouring eagle territories could even demonstrate increased productivity following restricted afforestation (Whitfield *et al.* 2007). Therefore, the effect of afforestation on a large territorial raptor, such as the golden eagle, is likely to be influenced by the quality of that territory or occupying pair, the degree to which that territory is constrained by neighbouring pairs or by unsuitable habitat and also the extent and nature of the afforestation (Whitfield *et al.* 2007). Although prey availability for eagles can be high in some partially forested landscapes, breeding densities may be relatively low. However, given suitable conditions such as areas with widely spaced trees and linked large open areas, productivity could potentially be high (McGrady & Petty 2005). These studies

suggest that given sufficient open areas with high prey availability, generalist predators can persist in landscapes that contain a high proportion of commercial forestry. Other than the inability of some specialist moorland species to persist in highly fragmented landscapes highlighted above (Sections 2.1.1 & 2.1.2), there is little additional literature regarding the extent to which species of woodland and open ground can coexist in mixed landscapes (Humphrey *et al.* 2003).

There are also potential impacts of forestry on birds that use the aquatic environment. Interactions between forestry and aquatic ecosystems can lead to increased acidity, aluminium content, dissolved organic carbon and runoff from herbicides and fertilisers (applied in plantations) in water courses. Planting and harvesting forestry can lead to marked increases in sediments in water courses, reducing the habitat quality for bird species that use water bodies for breeding or nursery areas (e.g. Ormerod & Tyler 1989, Fox & Bell 1994). Local conditions, such as geology and atmospheric pollution, can sometimes have a greater impact on aquatic ecology than forestry itself (Giller & O'Halloran 2004). It might therefore prove difficult to predict any influence of the establishment of moorland/plantation fringe areas on aquatic habitats. Such habitats could potentially act as a buffer to reduce sediment and other runoff from forestry and forestry operations, reducing the negative impacts on water courses (e.g. Broadmeadow & Nisbet 2002).

2.2 Bird communities in conifer plantations

Commercially managed conifer plantations have been shown to support a high diversity of birds, and in Britain may support nationally important populations of several scarce or declining species (Fuller & Browne 2003). Among these, mature stands can be important for northern goshawk, western capercaillie, long-eared owl, firecrest, crested tit, and crossbill species. Young stages of growth can be important for hen harrier, black grouse, short-eared owl, European nightjar, wood lark, tree pipit, whinchat, common grasshopper warbler and lesser redpoll (Fuller & Browne 2003). As with woodlands in general, a variety of local habitat factors such as stand structure, tree species and age, foliage height diversity, ground vegetation, shrub layer and adjacent habitats can influence their bird communities. In addition, wider-scale geographical and geological factors and the regional population sizes of relevant bird species can influence the woodland bird communities (e.g. Petty & Avery 1990, Patterson *et al.* 1995, Donald *et al.* 1998, Fuller & Green 1998, Fuller *et al.* 1999, Summers *et al.* 1999, Poulsen 2002, Fuller & Browne 2003, Wilson *et al.* 2006). Of particular relevance to the development of fringe habitats, at the interface between plantations and moorland, are the influences of stand age and woodland edge effects on bird communities.

2.2.1 Plantation age and bird communities

The bird communities of young plantations, up to the thicket-stage, are often comparable with those of scrub (see Section 2.3) and moorland (see Section 2.1), or at least have similarities with them. A suite of breeding birds typical of open ground and/or scrub have been found within pioneer or pre-thicket forestry in Scotland (Moss *et al.* 1979), Wales (Bibby *et al.* 1985), Ireland (Wilson *et al.* 2006) and France (Marion & Frochot 2001). Typical species found in these studies were willow warbler, winter wren, tree pipit, meadow pipit, common whitethroat, common grasshopper warbler, common bullfinch, whinchat, lesser redpoll, linnet, reed bunting and stonechat.

Species such as black grouse, hen harrier and short-eared owl appear to thrive within young pre-thicket plantations. In the Galloway Forest Park, peak breeding densities of short-eared owls were found in young plantations of 3 – 7 years old, but older areas of trees, c.12 years old, were avoided. The smallest occupied coupe of young trees was 62 ha (Shaw 1995). Similarly, conifer plantations generally become unsuitable for black grouse once the canopy

has closed, typically 12 – 20 years after planting (Baines *et al.* 2000, Pearce-Higgins *et al.* 2007). This species appears to occupy only the largest of coupes of young forestry (> ca. 200 ha), or those that are contiguous with other open habitats (Garson & Starling 1990, Haysom 2002). Hen harriers nest and hunt within young conifer plantations (Madders 2000, Redpath *et al.* 2002). Although such areas are generally abandoned following closure of the canopy, in Northern Ireland and Scotland at least, this species has been found nesting within mature conifer plantations, either within small open areas or in the crowns of spruce trees (Scott *et al.* 1993, Sim *et al.* 2007). A study of tree pipits found that breeding densities peaked within restocked conifer plantations when the trees were 1 – 6 years old (Burton 2007).

As plantations mature, species more typical of woodland become predominant. These include common blackbird, common chiffchaff, Eurasian robin, coal tit, goldcrest, song thrush and Eurasian sparrowhawk. In south-west Scotland, overall densities of breeding passerines (all species combined) increased with plantation age: numbers in recently planted (or establishment) plantations, thicket stages and areas >20 years old were 125 – 200, 230 – 290 and 300 – 440 individuals km⁻² respectively (Moss *et al.* 1979). Conversely, species richness may decline in older plantations (Moss *et al.* 1979, Marion & Frochot 2001). However it should be noted that, in these studies, the most mature plantations (i.e. older than the pole-stage with a developed ground under-storey and ground flora) were rare or not surveyed. Such areas could potentially support a number of forest-specialist species (Petty & Avery 1990, Marion & Frochot 2001).

2.2.2 Forest edge effects

Many studies report influences of forest edges on bird communities. A review suggested that birds that are wholly dependent on resources that are found within woodland will tend to avoid forest edges. Those woodland species that are dependent on, or can use, resources found in adjacent habitats will tend to be found near woodland edges where such resources can be exploited (McCollin 1998). The review by McCollin (1998) identified four main factors to explain the use of forest edges by birds:

1. Individualistic resource and patch use: relating to nest sites in woods being close to food resources on the edge or outside of the wood;
2. Biotic interactions: relating to interspecific competition, predation and also brood parasitism (the latter interpretation was largely dominated by Cowbirds in North America);
3. Microclimate modifications and their influence on food supply;
4. Heterogeneity in vegetation structure, providing opportunities for nesting, feeding and song posts and so on.

A study of lowland English woodlands found little evidence of change in the breeding densities of birds at forest edges bordering agricultural land in the 30 years between the late 1960s and the late 1990s. There was also little evidence of a response to potentially increased levels of nest predation from higher corvid densities (Hewson & Fuller 2006). If resources in adjacent agricultural land were of major importance to those birds on the woodland edge, then a marked reduction in woodland bird density, concurrent with changes in farming practices, might have also been apparent as has been recorded for many farmland specialist bird species in the same regions (e.g. Chamberlain *et al.* 2000). For most woodland edge birds in those fragmented woodlands studied within a lowland agricultural landscape, resources outside of the wood and the biotic interaction of predation (within factors 1 and 2 above) may not have been of overriding importance as to why most birds used those woodland edges.

Edge areas between habitats, for example between woodland and open ground, can be more species rich because more species can be favoured than are inhibited (e.g. Paquet *et al.* 2006). A number of studies from outside the UK have shown varying preferences between different guilds of bird species for woodland edges or interiors. In chaco woodland, Argentina, frugivores, terrestrial and arboreal granivores, terrestrial insectivores and long-distant flight insectivores tended to be more abundant at the woodland edge, while bark insectivores and short-flight insectivores typically preferred woodland interiors (De Casenave *et al.* 1998). In North America, long-distance Neotropical migrants tend to dominate forest interiors, while short-distance migrants and resident species prefer forest edges and associated successional vegetation (Germaine *et al.* 1997). Within the comparatively bird species-poor plantations of Galloway (an influence of insularity and latitudinal and longitudinal species gradients: Fuller *et al.* 2007a, Hinsley *et al.* 1998; see introductory section of the literature review), such differentiation between guilds may not necessarily be apparent (but see Section 6.4). In the Forest of Dean (Gloucestershire), however, breeding migrant birds (principally warblers) tended to be more abundant in woodland with an open canopy and well structured ground vegetation (Donald *et al.* 1998). It follows that plantation edges that includes shrubs and ground cover could be especially important for migrant species that might otherwise be scarce or absent within the plantations. In northern England and Scotland, the numbers of birds present within established spruce plantations, even without 'fringe habitats', tended to be highest within 10 m of the edge (Patterson *et al.* 1995). Planting densities within commercial conifer plantations in the UK tend to be relatively high (with a target 2500 trees per hectare). It has been shown that initial planting density impacts on the quality of timber, with the aims of suppressing competitive ground vegetation through a quick closure of the canopy and reducing the proportion of 'juvenile' wood or branches within the final timber crop (Hamilton 1974, Low 1974, Brazier & Mobbs 1993, Worrell & Ross 2004). As a result, ground vegetation and understorey tend to be very sparse in commercially managed plantations, which potentially limits the number of bird species that may be supported (e.g. Calladine *et al.* 2009).

A functional mechanism by which forest edges can influence bird abundance and behaviour, has been shown for coal tits in mountain forests in the Pyrenees (Brotons & Herrando 2003). In winter, greater numbers and larger flock sizes were found along forest edges compared to the interior. This difference was associated with a greater abundance and availability of pine cones on the forest edge. The influence of light penetration into forest edge areas is also suggested to influence bird communities. In central Sweden, the edges of clear-cut areas within old spruce/pine forests showed a high occurrence of tree-gleaning species (e.g. Eurasian robin, song thrush and tits), which were thought to be exploiting higher abundances of invertebrates within 50 m of the cut areas (Hanson 1983). Similarly, within ash-lime woodland in Lincolnshire, overall bird densities were highest within the outer 50 m of thinned woodland, but only within 25 m of the edge where trees were more densely spaced (Fuller & Wittington 1987). Differences in the bird populations in the Lincolnshire woodlands were associated with shrub layers within the wood. These shrub layers were less evident along rides within the woodland, compared to the woodland edge where it bordered open farmland. The narrow rides within the wood were thought to permit less light penetration than the open edge (Fuller & Wittington 1987). In spruce plantations in upland northern England and Scotland, birds tended to be more abundant within 10 m of the plantation edge (Patterson *et al.* 1995), again potentially associated with habitat quality and light penetration into the plantations at their boundaries. In Alberta, Canada, experimental clear-cutting of edges, in boreal mixed forests, failed to find any 'edge effect' on bird abundance within the first two years after cutting. It was suggested that birds were not responding to the edge itself, but could in time respond to habitat changes that develop as a result of the clear-cutting, including those of light penetration into the forest edge (Villard *et al.* 2007). In Vermont, USA, experimental clearing of 0.4 ha patches, within extensive broad-leaved forests, was conducted. No measurable effect of distance from the clear-cut patches on birds within the forest was found. However, some forest-interior specialists were less

abundant within study plots that included clearings than in ones that did not (Germaine & Vessey 1999). The Vermont woodland type could potentially have a well structured shrub layer and ground vegetation, relative to boreal forests and especially upland conifer plantations in Britain. An influence of additional light penetration through a woodland edge may therefore have little measurable effect on existing bird populations in those Vermont woodlands.

Given the general trend of increasing bird abundance and species richness at forest edges, particularly where light penetration into the interior parts of the forest is very restricted, it is perhaps logical that the length, shape and complexity of the forest edge can influence those effects. Studies of natural tree-line situations in Wyoming (Norment 1991) and within mixed conifer-broadleaved woodlands in Wisconsin (Hawrot & Niemi 1996) have both reported positive relationships between bird diversity and / or abundance and increasing length of forest edge within a survey unit.

As expected, forest edges may also be negatively associated with some forest interior species (e.g. Germaine & Vessey 1999). However, gaps within forests do not necessarily preclude interior forest species (e.g. Greenberg & Lanham 2001). When considering the creation of forest-moorland interface habitats in Galloway, the impacts of creating edges on 'forest interior' species is probably somewhat academic, because of the impoverished forest avifauna resulting from plantation type and geographical location.

The presence of forest edges may also influence bird movements within forests. In southern Sweden, the diurnal use of forest edges and the rate of crossing of gaps between forest patches by passerines was thought to be lower in low light conditions, when the risk of predation by pygmy owls was high (Rodriguez *et al.* 2001). It was also considered that forest fragmentation restricted the rate of bird movements between old forest patches, a conclusion that contrasts with the general inference that potential use of such fragmented landscapes by birds could be high. Perceived predation risk is also thought to influence nest site selection by crossbills in Scottish pinewoods (Summers *et al.* 2002), with birds found to settle in areas of preferred tree density. The latter is thought to be a compromise between having sufficient cover to provide shelter and reduce the risk of avian predation, and openness to reduce the risk from arboreal predators such as pine marten (Summers *et al.* 2002). Perceived predation risk is also thought to influence winter foraging use of forest edges by common bullfinch in upland north-east Scotland, when heather seeds are sought (Marquiss 2007). In the presence of Eurasian sparrowhawks, bullfinches tended to remain close to cover (shrubs or woodland edges). Where such cover was not available and alternative food was scarce, predation rates were relatively high (Marquiss 2007).

To summarise edge effects, practical considerations for the development of moorland fringe areas in Galloway (and elsewhere), and for their long-term sustainability in terms of delivering conservation benefit, include:

1. Increasing light penetration into the forestry edge with associated development of ground and shrub layers and an enhanced diversity of foliage height;
2. Providing a diversity of habitats thereby potentially supporting a more species-rich bird community;
3. Providing cover to reduce the risks from predation;
4. Increasing the range and abundance of potential prey available for predators.

Note that 3 and 4 above are potentially contradictory, in that increasing the populations of prey species might rely on reducing the ease with which birds could be preyed. Population densities and breeding success of predators are often positively correlated with the population densities and availability of their prey (e.g. Korpimäki & Nordahl 1991, Redpath & Thirgood 1999, Amar *et al.* 2003, Whitfield *et al.* 2006). It therefore follows that

within habitats at the moorland-forestry interface, prey availability will be important in determining predator levels. However, the sustainability of predator-prey relationships will require that the prey species are sufficiently abundant to tolerate predation levels.

2.3 Bird communities in scrub

The moorland fringe areas of the Galloway Forest Park are likely, or are intended, to include substantial proportions of scrub, either specifically planted or developed through regeneration from locally occurring seed sources. Within the UK there are relatively few specialist scrub bird species. In the eastern Highlands of Scotland, a study of scrub regeneration on moorland reported that most species present within scrub also occurred either on moorland or in more mature woodland. Moorland species such as meadow pipit and Eurasian curlew were considered to be at one extreme of a successional gradient, and woodland species such as common redstart, spotted flycatcher, blue tit and Eurasian treecreeper at the other (Fuller *et al.* 1999). Such upland scrub sites in the eastern Highlands typically support 20 – 30 bird species, and are frequently dominated by at least two of meadow pipit, willow warbler and chaffinch, depending on the successional stage of the scrub (Gillings *et al.* 1998, 2000, Gillings & Fuller 1998). Within the observed successional changes from open moorland through to mixed deciduous woodland, the lowest bird species diversity was found in the open moorland, and the highest in the mixed deciduous woodland. Typical species within the different types and successional stages surveyed were (after Gillings *et al.* 2000):

Open moorland – meadow pipit, red grouse, northern wheatear and twite;

Very early stages of birch regeneration – willow warbler and whinchat;

Moorland with isolated trees – chaffinch, tree pipit, winter wren, common redstart and ring ouzel;

Birch scrub mosaic – meadow pipit, sky lark, tree pipit, willow warbler, chaffinch, long-tailed tit, common cuckoo, winter wren, stonechat, whinchat and common blackbird;

Old birch scrub – willow warbler, chaffinch, tree pipit, Eurasian robin, song thrush, spotted flycatcher and great tit;

Old birch woodland – willow warbler, chaffinch, blue tit, common redstart, Eurasian treecreeper, great-spotted woodpecker, great tit, Eurasian robin and hedge accentor;

Pine scrub mosaic – willow warbler, meadow pipit, chaffinch, winter wren, Eurasian robin, goldcrest, coal tit, Eurasian siskin, lesser redpoll, whinchat and tree pipit;

Juniper scrub mosaic – willow warbler, black grouse, red grouse, northern wheatear, chaffinch, song thrush, winter wren, hedge accentor, ring ouzel, whinchat and goldcrest;

Willow scrub mosaic – willow warbler, meadow pipit, chaffinch, sedge warbler, winter wren, reed bunting, Eurasian curlew, common grasshopper warbler, common linnet, twite and lesser redpoll;

Mixed deciduous woodland – willow warbler, chaffinch, Eurasian robin, blue tit, winter wren, coal tit, spotted flycatcher, wood warbler, common chiffchaff and blackcap.

Similar changes in bird communities have been recorded in developing conifer plantations, where the older establishment and thicket stages resemble scrub, both structurally and in terms of their bird communities (Section 2.2.1). Mature juniper and willow scrub may hold similar bird communities to early birch scrub, which is probably a function of the relatively stunted structure and resemblance to young birch scrub, even when quite mature (Gillings *et*

al. 2000). This suggests that the structure of scrub at the interface between plantations and open moorland is likely to be important in determining the suite of species that may benefit from such habitats. This also has implications for the long-term viability of fringe areas, depending on the target species. There is little information on the use of scrub by wide-ranging species such as raptors (Gillings & Fuller 1998). It might be anticipated that the bird communities of extensive scrub areas might resemble those of extensive areas of young plantations (Section 2.2.1).

Scrubby habitats at the interface between plantations and moorland will generally be relatively restricted and fragmented. This raises the potential issue of connectivity of such areas, and the viability of bird populations that use them (e.g. Bélisle 2005). Scrub is naturally a habitat of transitional change, for example when a restrictive grazing regime is relaxed and the habitats are able to develop towards a 'natural' climax. The animals that predominantly use scrub are therefore likely to possess the dispersal ability to colonise such fragmented habitats, as has been suggested for birds of similarly transient reedbeds (e.g. Baillie *et al.* 2000). However, tree pipits breeding within young restocked plantations in East Anglia occurred at highest densities when those restocked coupes were within the largest forest blocks. This indicates an influence of the total extent of suitable habitat available at a local or regional level on the use of a resource by a species at the site level (Burton 2007).

2.4 Mixed habitats at the plantation – moorland interface

A variety of birds are likely to benefit from the development of moorland fringe habitats at the edges of plantations. These include species inhabiting plantation edges (see Section 2.2.2), scrub (and comparable young plantation, during its successional development), moorland species that tolerate proximate forestry (see Section 2.1.2) and, potentially, some species may benefit from the juxtaposition of woodland, scrub and moorland. The value of the moorland-forestry interface for birds, both for particular species or overall species richness could also vary seasonally. This type of effect has been reported for birds recorded at the interface between reedbeds and forest in central Europe, with this interface being particularly species rich in winter (Vâlcu 2006). As far as we are aware, this study in the Galloway Forest Park is the first to look specifically at the bird communities at the interface between moorland and plantations.

3. STUDY SITES, HABITAT RECORDING AND THE SAMPLING STRATEGY FOR BIRD SURVEYS

3.1 Study sites

Five study areas within the Galloway Forest Park were selected from information provided by Forest Enterprise on the basis of including areas where forest edges have already been felled and moorland fringes are being allowed to develop (1 - 4 below) or where natural regeneration of the moorland – plantation interface had already created comparable fringe areas (5 below) (Figure 1):

1. Loch Skerrow – where felling commenced in 2001;
2. Lamachan – which includes areas that were felled in 2001, 2004 and 2007;
3. Loch Dee – where felling commenced in 2003;
4. Gala Lane – where moorland fringes are being developed in areas affected by extensive fires in 1994 and 2007;
5. Black Craig of Dee – where moorland fringe areas have become established though natural regeneration of trees on moorland.

Inclusion of the Black Craig of Dee as a study site aimed to provide data on the structure and bird communities of more mature fringe areas. A sixth potential site, Laurieston (Figure 1) was excluded as a potential study area because initial examination found that the majority of the apparent or planned moorland fringe area had actually been planted as restock.

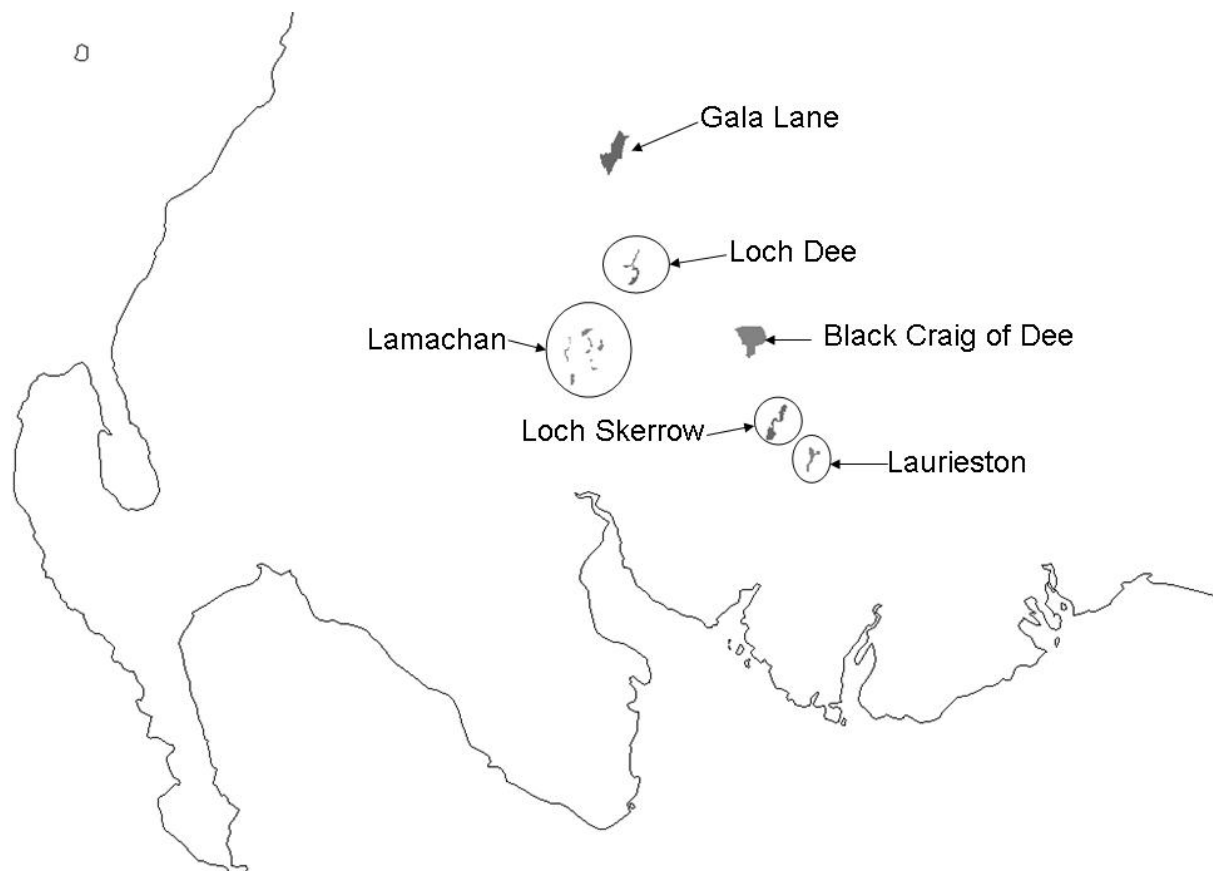


Figure 1. Location of the study sites within the Galloway Forest Park. Note that Laurieston has been excluded as a study area.

3.2 Habitat recording

Systematic habitat recording was undertaken in the five selected study areas in July and August 2008. The principal aims of the habitat recording were: (i) to collect baseline data on the characteristics of fringe areas and adjacent plantation and moorland; (ii) to assess the variation in habitats within the study areas; and (iii) following from these, inform the final sampling strategy for surveying birds so as to maximise the power of the study to identify relationships between habitat variables and bird abundance.

Linear transects were established within the five study areas to include fringe areas and adjacent plantation and moorland to examine the variation in vegetation composition within four main habitat types: (i) pre-thicket plantation (tree height <3m); (ii) post-thicket plantation (≥3m); (iii) fringe; and (iv), moorland. Habitat variables were recorded from 1020 survey points spaced at 50m intervals along the linear transects (Table 1).

Table 1. Summary of habitat survey sampling points within the Galloway Forest Park

Site	Number of points surveyed per habitat				
	Pre-thicket plantation	Post-thicket plantation	Fringe	Moor	Total
Black Craig of Dee	13	39	86	0	138
Loch Dee	20	46	66	59	191
Gala Lane	2	32	104	30	168
Lamachan	48	60	130	102	340
Loch Skerrow	14	56	78	35	183
Total	97	233	464	226	1020

The suite of habitat variables recorded were those that were expected to influence bird abundance following advice from the project's steering group (made up of members of SNH and FE) and additional information found during the review of literature (Section 2). At each sampling point the following variables were recorded:

1. *Soil type (surface layer only)*: Soil type could influence the natural and planted vegetation, its composition, structure and development. Soil types were defined as (i) peat, (ii) gley, (iii) non-gley mineral soils or (iv) modified soils. Modified soils included those that were ploughed so that otherwise peat or gley soils included a high proportion of well drained soils and areas where planting history and associated build up of needle leaf litter strongly influenced the surface layer of soil.
2. *Altitude*: Altitude may affect vegetation composition and micro-climate and hence bird communities. In the field, altitude was determined using hand-held GPS with the value for a number of sampling points being confirmed from contours on 1:25000 scale Ordnance Survey maps.
3. *Ground-level vegetation cover*: The proportion of cover by (i) Grasses, (ii) Herbs, (iii) Ericaceous plants, (iv) Bryophytes, (v) Ferns, (vi) Rushes, (vii) Bare ground and/or leaf/needle litter, (viii) Rosebay willowherb *Epilobium angustifolium*, and (ix) Brash were each estimated into one of four categories (a) None, (b) present but <33% cover, (c) 33-67% cover, and (d) >67% cover, within a 5 m radius of the sampling

point. Ground level vegetation cover will also be a surrogate measure of light penetration into areas with standing trees.

4. *Brash depth*: As well as potentially influencing bird assemblages by creating a habitat with structure in itself, the depth of brash will affect the development of ground vegetation and natural regeneration. Brash depths were categorised as (a) None, (b) <25 cm, (c) 25-50 cm, and (d) >50 cm.
5. *Shrubs and young trees (woody plants between 1-3 m tall)*: As well as assessing their intrinsic importance, the value of these transient habitats will have relevance for the long-term sustainability of fringe areas, and/or indicate management that may be required to ensure that sustainability. The number of shrubs within a 10 m radius of the sampling point and the dominant shrub species were recorded, and the estimated ground cover by shrubs was classed into one of four categories (a) None, (b) <33% cover, (c) 33-67% cover, and (d) >67% cover, within a 5 m radius of the sampling point. In addition to quantifying shrub cover in open habitats (moorland and fringe areas), the presence of shrubs within plantations will provide a further index of light penetration within them.

At alternate sampling points (i.e. at 100 m spacing) the following additional variables were also recorded:

6. *Physical landscape features*: The presence or absence of Streams, Drains, Craggs, Flushes and Dead trees within 50 m of the sampling point.
7. *Age of moorland fringe sites*: The number of years that sites have been left to develop (data from Forestry Commission). In practice, tree and shrub height (see 8 and 9 below) could be used as a surrogate for age, and is likely to be more informative in explaining the influence on bird species richness and abundance.
8. *Details of potential tree seed parents (in fringe and moor areas only)*: (i) Species of the nearest tree; (ii) Distance to the nearest tree, categorised into (a) <10 m, (b) 10-25 m, (c) 26-50 m, (d) 51-100 m, and (e) > 100m; (iii) Height of the nearest tree, categorised into (a) <3 m, (b) 3-10 m, (c) 11-15 m, (d) 16-20 m, and (e) >20 m; and (v) the number of trees within a 25 m radius of the sampling point.
9. *Details of tree composition (in plantations only)*: (i) The number of trees within a 5 m radius of the sampling point categorised into (a) 1-10, (b) 11-20, (c) 21-30, and (d) >30; (ii) the average height of trees within a 5 m radius of the sampling point categorised into (a) 3-10 m, (b) 11-15 m, (c) 16-20 m, and >20 m; (iii) the dominant tree species with a 5 m radius of the sampling point, and (iv) the number of tree species within a 5 m radius of the sampling point.
10. *Herbivore activity*: The presence or absence of herbivore droppings (and species) within 5 m of the sampling points. Evidence of browsing and sightings of herbivores were also recorded.

Another variable that would likely provide a useful measure of the influence of fringe areas would be the nearest distances to the edge of the neighbouring habitat types. For example, for a sampling point within a post-thicket plantation, the nearest distance to the plantation boundary and the habitat that adjoins it (pre-thicket plantation, fringe or moorland) or for moorland, the distance to a plantation or fringe area. In practice this was difficult to determine within our available study areas because ongoing management had created a complex and dynamic mosaic of habitat types. Fringe areas, the principal interest of the study, in the Loch Dee, Lamachan, Black Craig of Dee and Loch Skerrow study areas were

within areas that were actively being felled or were recently felled. As a result, they were within areas that included patches of maturing plantation, felled coupes and areas of recently restocked planting. In addition to the spatial complexities, the recent and ongoing management would have given little time for any effects associated with habitat edges on the bird communities to have developed. At Gala Lane, the fringe areas were being allowed to be developed with areas recently affected by extensive fires. Again, the resulting spatially complex mosaic of unaffected stands of trees, open areas and areas with standing dead (burnt) trees made the identification of realistic habitat boundaries impractical.

3.3 The selection of sampling points for bird surveys

In order to assess the influence of the fringe areas on bird communities, a paired comparison approach was initially proposed for this study, where transects of sampling points including fringe areas were compared with matched “reference” sampling points in comparable areas but where the plantation-moorland interface remained ‘hard’, with no fringe areas either established or in development. During the course of selecting sampling points for surveys, it became apparent that this was not a practical option. This was because a high proportion of the fringe areas were being developed in coupes that had been felled and were being only partially restocked, the remainder being ‘left’ to develop as the fringe area (see also Section 3.2). Because of the often complex and dynamic mosaic of the habitats within the available study areas, there were relatively few sites where there were sufficient extents of post-thicket stage plantation with an integration to open moorland through a developed fringe area and therefore there were very few opportunities to establish paired study sites. Therefore the statistical power to detect any influence of the fringe areas on bird communities through a comparison of matched paired sites would have been very low. As an alternative approach, the sampling was designed to investigate relationships between bird species richness, distribution and abundance at the site level and at the sampling point level (see Section 4.2).

Although there is good evidence that all of the measured habitat variables (Section 3.2) are likely to influence bird use of the interface between plantations and open moorland (Section 2), it is most unlikely that it would be possible to incorporate all of them in subsequent modelling of bird data. Either there would be too many variables for effective modelling, or there would be insufficient variation in some to be able to quantify any influence on bird communities within the Galloway Forest Park study areas. For example, if the vast majority of sampling points included the same proportions or category of a particular habitat variable, its inclusion in a model would not be informative in that there would be very little, or no, statistical power to detect any significant influence of that variable on the bird data. Therefore a subset of the variables likely to be most informative was selected based on their recorded variation within the study areas. Within each of the four main habitat types (post-thicket plantation, pre-thicket plantation, fringe and moorland) selection was based on an assessment of the variation within each variable according to the following criteria:

- a) For those variables with three or more categories (see Section 3.2), only those with $\geq 10\%$ of observations in at least three of the categories were selected;
- b) For those variables with only two categories (presence/absence) only those with $\geq 20\%$ of observations in each category were selected.

In some cases, features were rare within the study areas (e.g. crags), while in others, single attributes were dominant, or actually defined, the sampled habitat (e.g. peat soils on moorland). The following habitat measures exhibited sufficient variation to satisfy the above criteria for their potential inclusion within models to describe the bird communities within the study areas:

In pre-thicket plantation:

- Grass cover
- Bryophyte cover
- Bare/dead litter cover
- Shrub cover
- Number of shrub species present
- Brash cover
- Brash depth
- Stream presence/absence
- Drain presence/absence
- Flush presence/absence
- Number of tree species present
- Tree density

In post-thicket plantation:

- Soil type
- Grass cover
- Bryophyte cover
- Bare/dead litter cover
- Drain presence/absence
- Dead tree presence/absence
- Dominant tree species
- Number of tree species present
- Tree density
- Tree height

In moorland fringe areas:

- Grass cover
- Shrub cover
- Dominant shrub species
- Brash cover
- Brash depth
- Drain presence/absence
- Flush presence/absence
- Dead tree presence/absence
- Age of fringe area
- Nearest tree species
- Distance to nearest tree
- Tree density

Note that “Herbivore dropping type” also fulfilled the criteria for this habitat. However as the presence of herbivore droppings was very low (only 4.5% of survey points) a variable describing the herbivore species was not likely to prove informative and hence would be unsuitable for inclusion.

On moorland:

- Ericaceous plant cover
- Flush presence/absence
- Nearest tree seed species
- Distance to nearest tree
- Height of nearest tree

In practice, models would have to include a selection of these variables only, in order to allow model convergence and also to avoid using highly correlated habitat variables (see Section 4.2.2).

To maintain a high level of independence of bird data, the selected sampling points are at least 100 m distant from each other, in most cases at least 200 m distant, which is compatible with the general distance for reliable detection of the majority of birds within woodland and scrub of up to 50 m (Bibby & Buckland 1987). The field recording protocols also further reduce the possibility of the multiple recording of individual birds (see Section 4.1). Following all the above criteria, a subset of 240 survey points was identified for use in subsequent bird surveys to take place in winter 2008/9 and spring/summer 2009 (Table 2, Appendices 2 & 3). The variation in vegetation composition within these selected points was comparable with that shown across all survey points (Figures 2 – 8), confirming that the areas selected for bird surveys were representative of the fringe areas, and their adjacent plantations and moorland, currently available for study within the Galloway Forest Park.

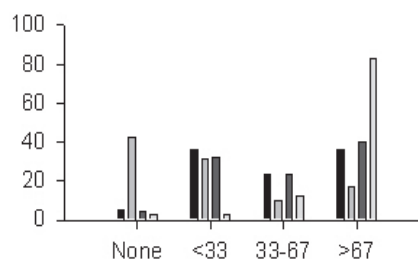
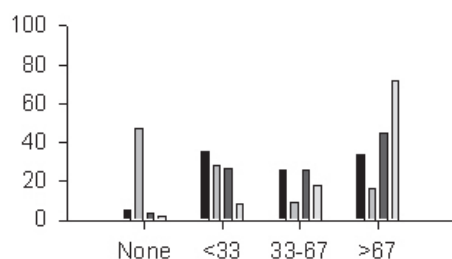
Table 2. Summary of bird survey sampling points within the Galloway Forest Park

Site	Number of points surveyed per habitat				
	Pre-thicket plantation	Post-thicket plantation	Fringe	Moor	Total
Black Craig of Dee	4	13	18	0	35
Loch Dee	11	17	18	10	56
Gala Lane	0	14	18	10	42
Lamachan	16	11	18	10	55
Loch Skerrow	8	16	18	10	52
Total	39	71	90	40	240

Grasses and sedges

a)

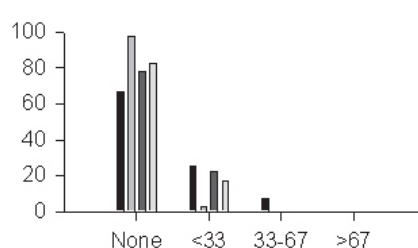
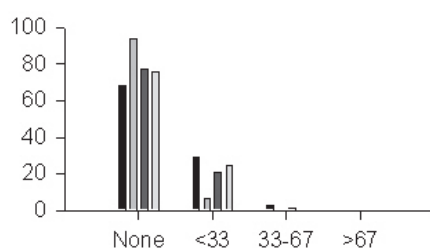
b)



Herbaceous plants

a)

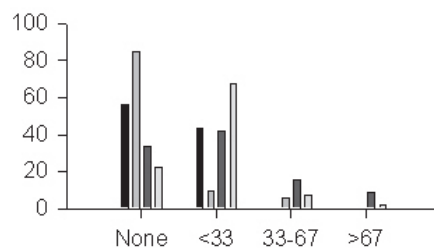
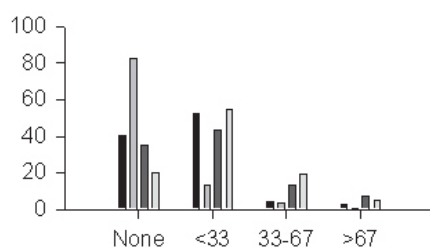
b)



Ericaceous plants

a)

b)



Bryophytes

a)

b)

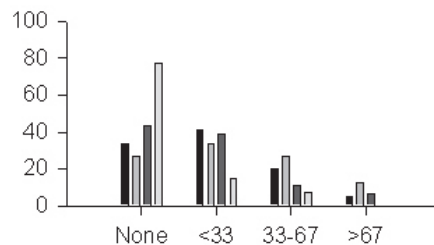
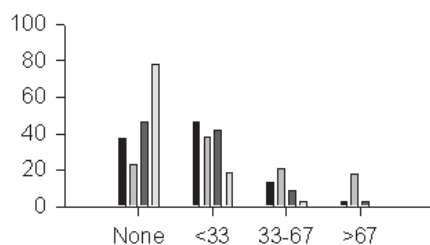
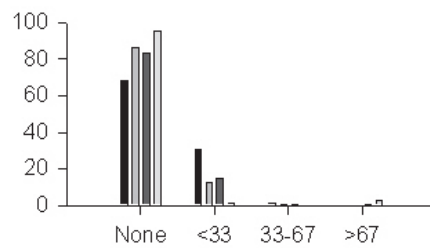


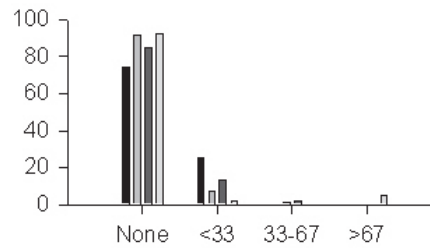
Figure 2. Ground cover composition within 5m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 1020$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland. See key at the bottom of the figure.

Ferns

a)

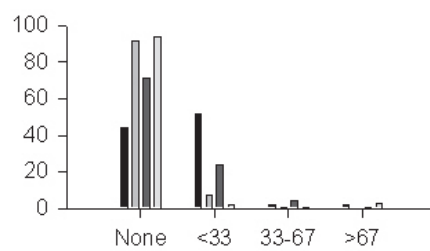


b)

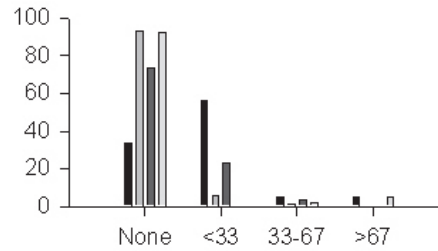


Rushes

a)

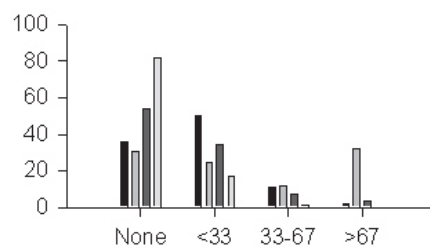


b)

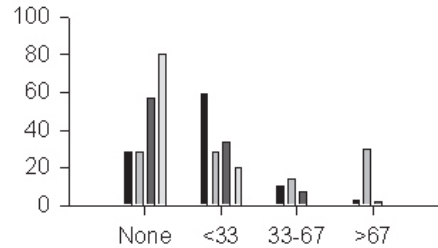


Bare ground and/or dead leaf/needle litter

a)

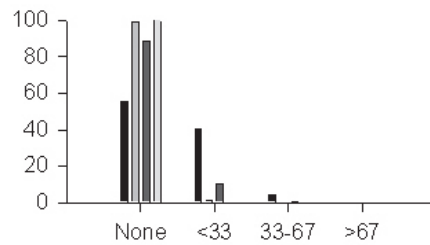


b)



Rosebay willowherb

a)



b)

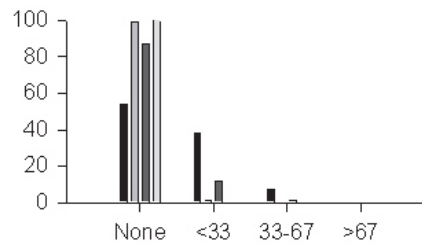
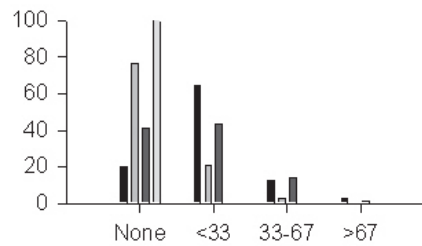
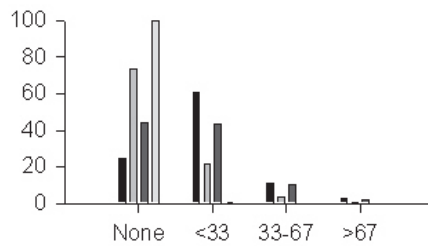


Figure 2 contd. Ground cover composition within 5m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 1020$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland.

Brash cover

a)

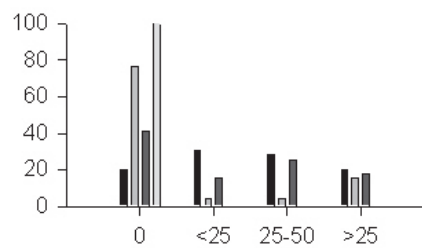
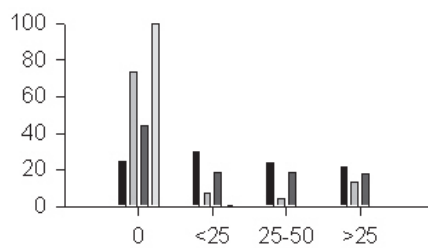
b)



Brash depth

a)

b)



Key

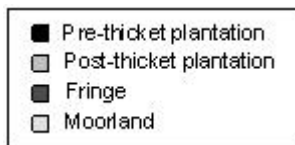


Figure 2 contd. Ground cover composition within 5m radii of sampling points in the Galloway Forest Park, (a) in all sampling points (n = 1020) and (b) sampling points selected for bird surveys (n = 240). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland.

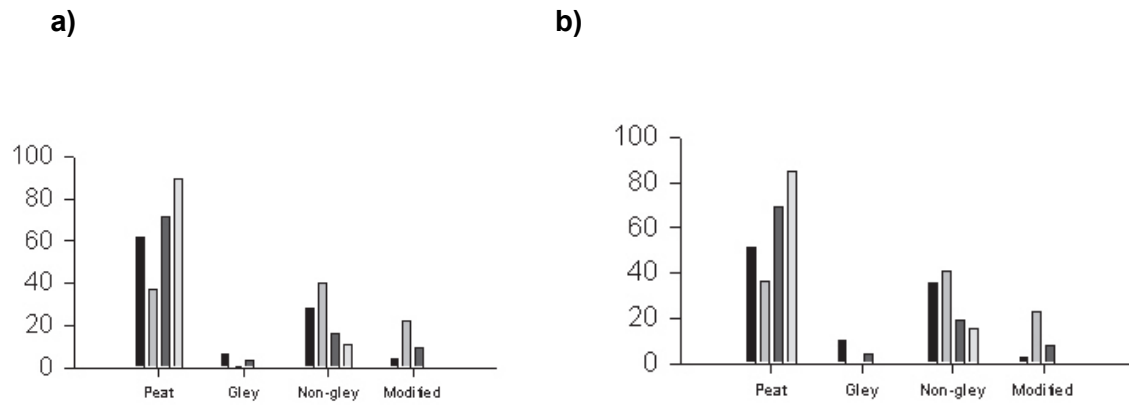
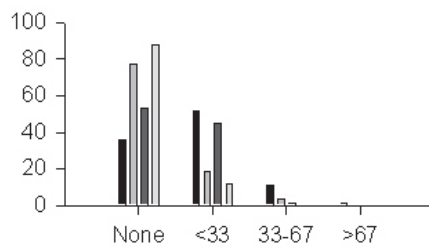


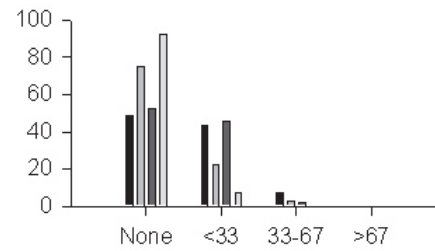
Figure 3. Surface soil types recorded within 5m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 1020$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland. For key, see bottom of Figure 2.

Shrub cover

a)

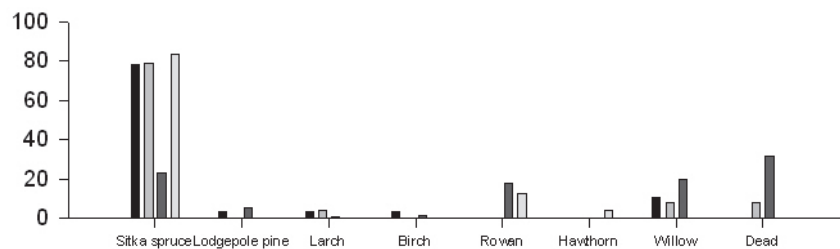


b)

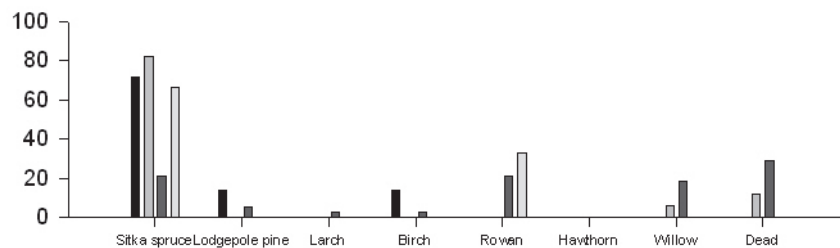


Dominant shrub species

a)

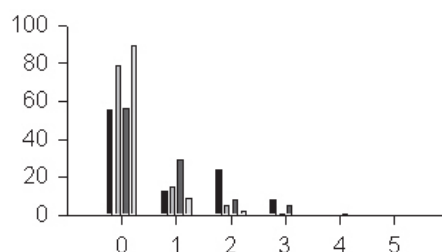


b)



Number of shrub species

a)



b)

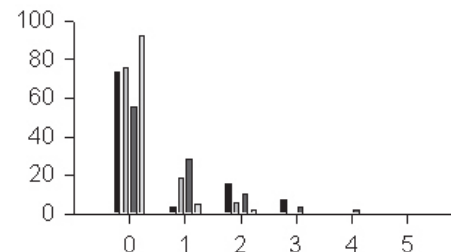
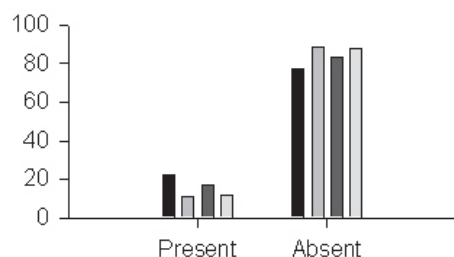
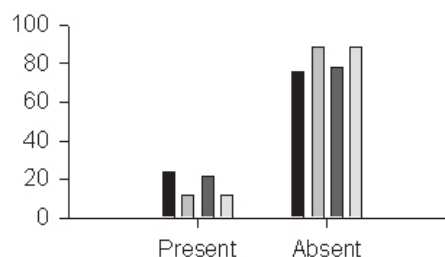


Figure 4. Shrub cover and its composition within 10 m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 1020$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland. For key, see bottom of Figure 2.

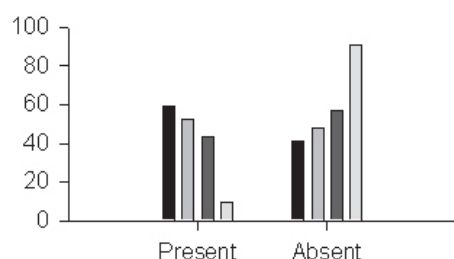
Stream
a)



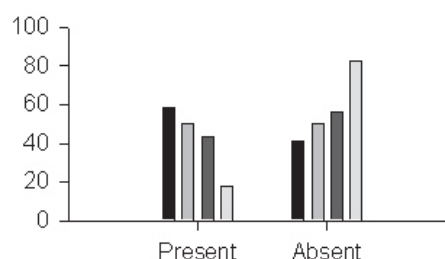
b)



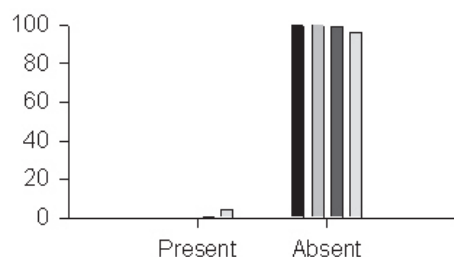
Drains
a)



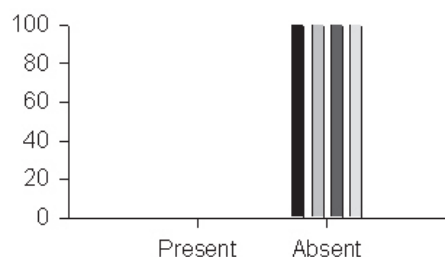
b)



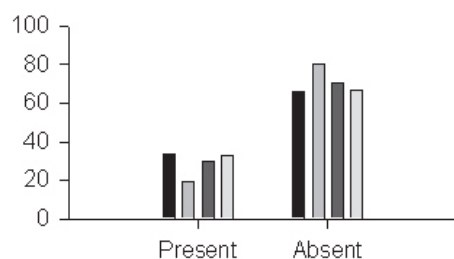
Crags
a)



b)



Flush
a)



b)

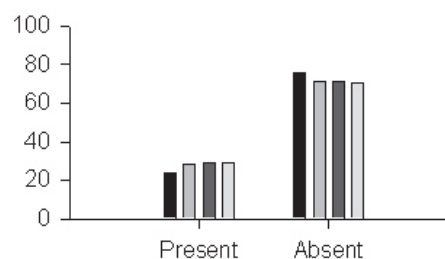


Figure 5. The presence or absence of landscape features within 50 m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 510$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland. For key, see bottom of Figure 2.

Dead tree

a)

b)

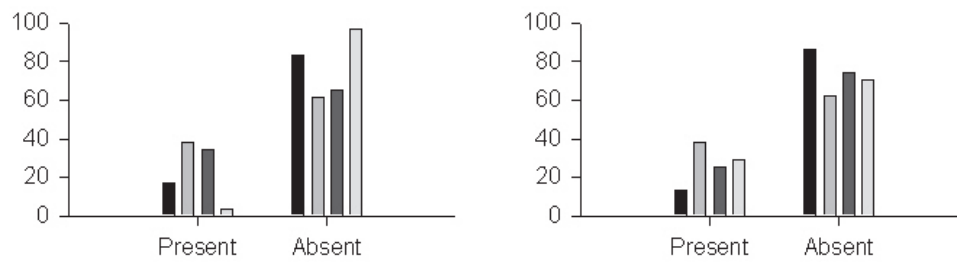
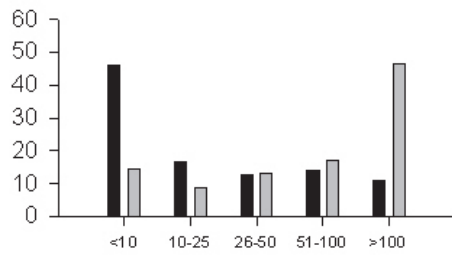


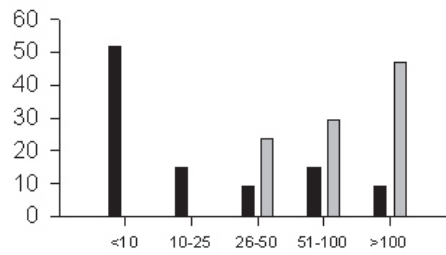
Figure 5 contd. The presence or absence of landscape features within 50 m radii of sampling points in the Galloway Forest Park, (a) in all sampling points ($n = 510$) and (b) sampling points selected for bird surveys ($n = 240$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland.

Distance to nearest tree seed parent

a)

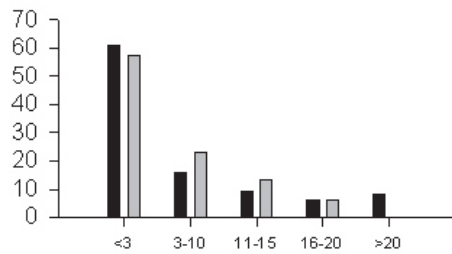


b)

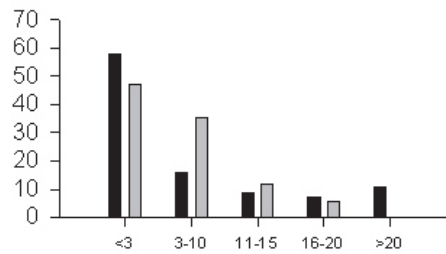


Height of nearest tree seed parent (m)

a)

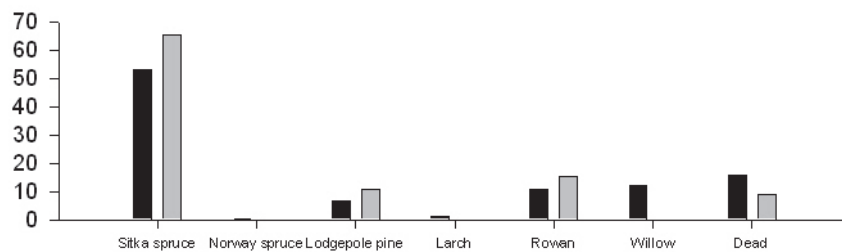


b)



Nearest tree seed parent species

a)



b)

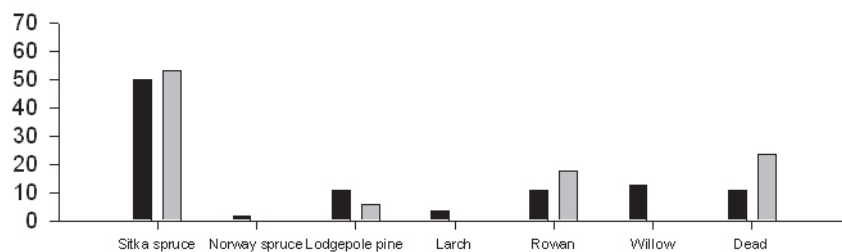
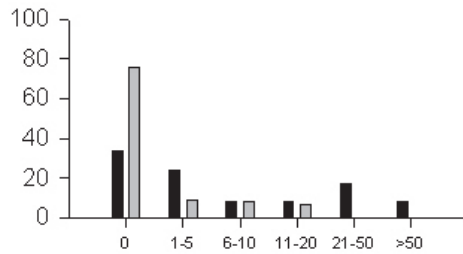


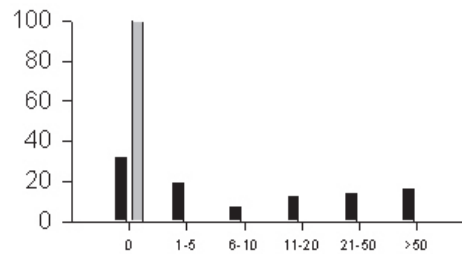
Figure 6. Descriptive variables of regenerating tree cover in Fringe and Moorland habitats in the Galloway Forest Park, (a) in all sampling points ($n = 345$) and (b) sampling points selected for bird surveys ($n = 65$). Note each column, within each category, represents one habitat type, in order from left to right: Fringe; Moorland. For key, see bottom of this Figure.

Number of trees within 25 m

a)

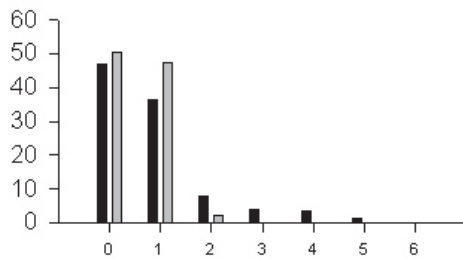


b)

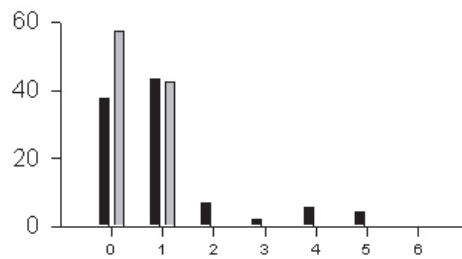


Number of tree species

a)



b)



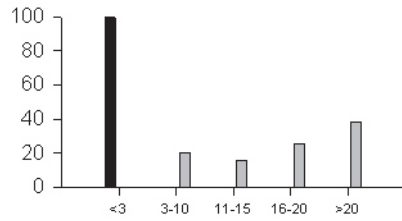
Key



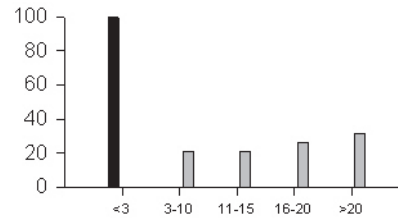
Figure 6 contd. Descriptive variables of regenerating tree cover in Fringe and Moorland habitats in the Galloway Forest Park, (a) in all sampling points ($n = 345$) and (b) sampling points selected for bird surveys ($n = 65$). Note each column, within each category, represents one habitat type, in order from left to right: Fringe; Moorland. For key, see bottom of this Figure.

Tree height

a)

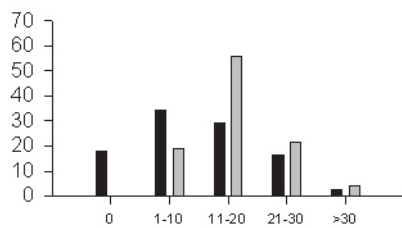


b)

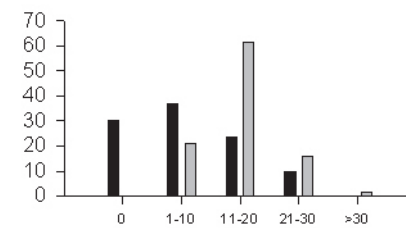


Number of trees within 5 m

a)

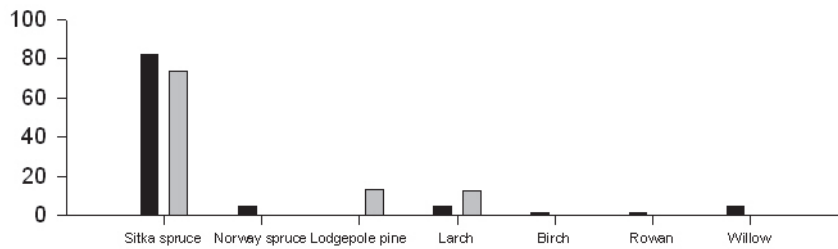


b)



Dominant tree species

a)



b)

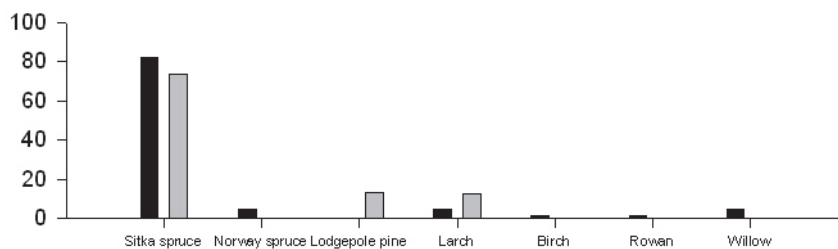
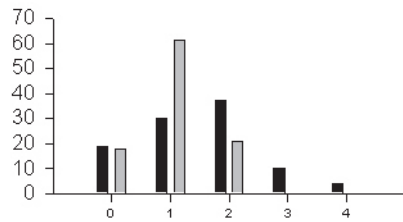


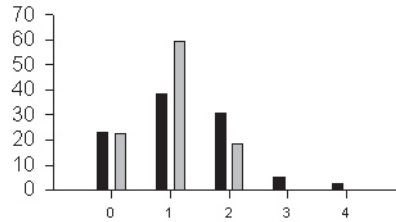
Figure 7. Descriptive variables of tree cover in Plantation habitats in the Galloway Forest Park, (a) in all sampling points ($n = 165$) and (b) sampling points selected for bird surveys ($n = 55$). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation. For key, see bottom of this Figure.

Number of tree species

a)



b)



Key

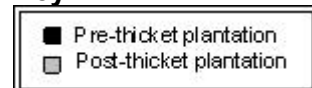
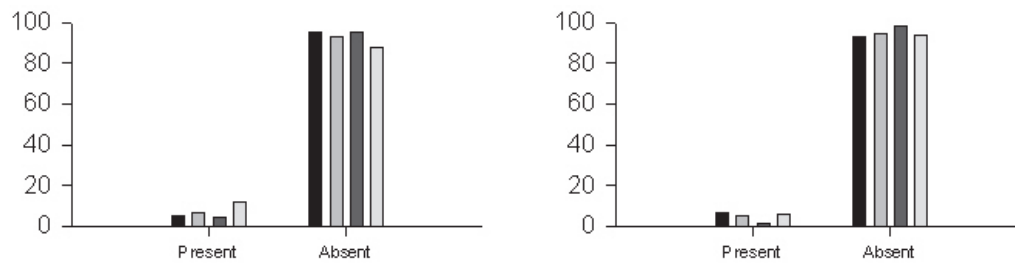


Figure 7 contd. Descriptive variables of tree cover in Plantation habitats in the Galloway Forest Park, (a) in all sampling points (n = 165) and (b) sampling points selected for bird surveys (n = 55). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation. For key, see bottom of this Figure.

Presence/absence of herbivore droppings

a)

b)



Herbivore species (where present)

a)

b)

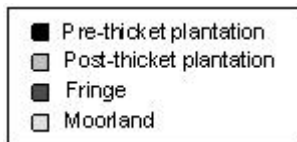
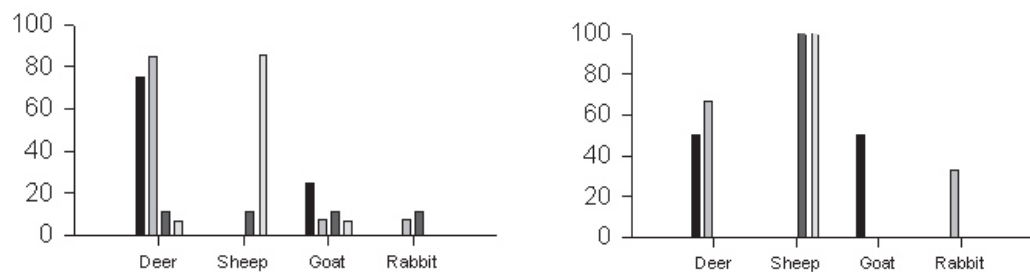


Figure 8. Herbivore activity at of sampling points in the Galloway Forest Park, (a) in all sampling points (n = 510) and (b) sampling points selected for bird surveys (n = 240). Note each column, within each category, represents one habitat type, in order from left to right: Pre-thicket plantation; Post thicket plantation; Fringe; Moorland. For key, see bottom of Figure.

4. BIRD SURVEYS AND ANALYTICAL APPROACHES

4.1 Field surveys of birds

The bird communities of the study areas were sampled in winter (November 2008 – January 2009) and in the breeding season (April – June 2009), with each of the selected sampling points surveyed twice in each season (Table 3). Winter surveys were undertaken throughout daylight hours but avoided the latest hour when bird activity can be low. Breeding season surveys were undertaken in the early mornings when many bird species are most detectable (Skirvin 1981, Reed *et al.* 1985, Calladine *et al.* 1999, Bibby *et al.* 2000, Hoodless *et al.* 2006). For breeding surveys, it was intended to complete most by 09:00 and this was achieved for 72% of the timed point counts. Logistics and weather necessitated that some surveys were undertaken later in the morning, with 88% achieved by 10:00, 99% by 11:00 and the very latest by 11:28. When surveys of breeding birds were undertaken later in the morning, this was only done when the surveyor involved was confident that bird activity remained high, typically when conditions remained cool and dull. Surveys were not undertaken during persistent or heavy rain or when wind speeds exceed Beaufort scale force 4, conditions that are likely to reduce the detection rates of many birds.

Table 3. The dates of bird surveys undertaken in the Galloway Forest Park study sites in 2008 – 09.

Site	WINTER		BREEDING	
	Early	Late	Early	Late
Black Craig of Dee	16, 17 & 26 Nov.	14, 16 & 18 Jan.	25 & 26 Apr.	16 & 20 Jun.
Gala Lane	21 Nov.	21 Jan.	22 & 23 Apr.	26 May
Lamachan	18, 22 & 25 Nov.	17, 19, 20 & 21 Jan.	12 & 13 May	25 & 26 May
Loch Dee	19, 24 & 25 Nov	12 & 14 Jan.	7, 8 & 13 May	26 May
Loch Skerrow	20 & 22 Nov.	13 & 16 Jan.	26, 27 & 28 Apr.	15 Jun.

On arrival at each point, the surveyor waited for a two-minute settling period to minimise any influence of walking to the point on the detection rates of birds, and then recorded all birds seen or heard for a period of 10 minutes. The sampling interval aimed to maximise the likelihood of registering birds within the immediate vicinity but also reduce the risk of counting individuals multiple times (Fuller & Langslow 1984, Drapeau *et al.* 1999), which would violate the assumptions of the point count methodology (Bibby *et al.* 2000).

Birds were recorded in four distance classes: within 10 m of the count point; between 10 and 25 m; between 25 and 50 m; and greater than 50 m from the count point. Each registration was assigned to the distance band in which the individual bird was first recorded regardless of any subsequent movements. Birds seen or heard in flight only were recorded separately. Any birds that arrived into the 10 m distance band during the 10-minute sampling period were also distinguished separately, to further assess any potential bias introduced by the presence of a surveyor in the area. Some species, for example, sky larks and meadow pipits perform display flights over their breeding territories. Where these or other species were observed displaying in flight, they were recorded as if in the terrestrial distance band above which they are displaying.

During the breeding season surveys, juvenile birds (those hatched in the current calendar year) were recorded separately, when they could be reliably aged as such in the field, to ensure that the calculated indices of abundance corresponded to breeding adults as far as is possible, rather than reflecting a contribution made by breeding productivity in the current year.

4.2 Analyses of bird surveys

4.2.1 Indices of abundance and species richness

Measures of species richness and indices of bird abundance are presented for each study site and habitat type. These are presented to (i) describe the bird communities present at the time of this study and thereby also permit spatial and temporal comparisons, and (ii) used, where appropriate, to investigate relationships with the recorded habitat variables. Measures of species richness are simply the number of species recorded within the relevant areas. These include all species that were seen within and flying over the study areas but exclude those species only seen on Loch Skerrow (a freshwater body that was visible from some of the sampling points within the study area of the same name) and were clearly associated with the Loch rather than any habitats relevant to the study. Excluded species from that area were great cormorant, greylag goose, mallard, Eurasian teal, red-breasted merganser, common goldeneye, common sandpiper, herring gull and lesser black-backed gull. Birds seen in flight only are included within the measure of species richness in order to include raptors and other species that hunt or forage over the study areas. Up to four indices of abundance were generated:

i) *Occurrence rates* - the number of points where a given species is recorded (regardless of abundance) divided by the total number of points surveyed. Note that individual birds that are known to have been recorded from more than one survey point will be included for the original point of registration only;

ii) *Abundance index* – the mean number of registrations per survey point. Note that (a) individual birds that are known to have been recorded from more than one survey point will be included for the original point of registration only, and (b) registrations will only be included if judged to be within 50 m of the survey point (the mid-distance between survey points along transects);

iii) *Simple bird density* - a simple summing of all individuals of a species recorded within the 50 m distance band divided by the area sampled within that distance band across the study area;

iv) *Site-level density* - using a simple formula that assumes a known detectability function that is constant for all sites and species and adjusts for decreased detectability in the outer distance bands (Bibby et al. 1985), using only two distance bands. The formula to be used (after Bibby et al. 1985) was:

$$D = \log_e(n/n_2) * n / (m\pi r^2)$$

Where: D = calculated bird density
n = total number of birds detected (in this case, 0 – 100 m)
n₂ = the number outside of the distance band r (in this case 50 – 100m)
m = number of survey points

Because this method involves a single calculation of density (at the study area level), no measure of precision (error limits) is estimated (Bibby et al. 1985). The calculation will also become invalid when there are no registrations for the outer distance band (n₂, above) and

returns a density of zero when there are no registrations for the inner distance band even when there are registrations for the outer band. Deviation of the empirical data from the assumed detection function, and errors associated with zero counts in either distance band, will tend to be greatest when sample sizes are small. Therefore, we expect to be able to present estimates of site-level density, calculated in this way, only when the number of qualifying registrations is 20 or more;

Note that all of the indices of abundance excluded birds seen only in flight. For all indices, including the occurrence rate (i above), any individual birds that were known to have been recorded from more than one sampling point were only included for the point of its original detection. For all winter data, and for the occurrence rates in summer, the indices include data from both early and late survey visits, so a registration of a species from a point on just one visit counts equally as if recorded on both visits in the measures of occurrence rates. Winter abundance indices will effectively be a mean of the two survey visits. Given the greater mobility of birds in winter compared to the breeding season (lesser ties to a breeding territory) and a greater tendency for flocking leading to a more aggregated distribution of birds (more zero-inflated data), we consider that combining data from both survey visits would present a more representative indicator of the winter bird communities and the areas that they use, rather than restricting the data to those from single visits (as is the case with the breeding season data, see below).

For measures of abundance in the breeding season, only data from a single survey visit were incorporated. This was to reduce biases associated with differential arrival times of migrants onto their breeding territories and the presence of juvenile birds. Ideally, juvenile birds should be excluded from the calculations of indices or estimates of abundance of breeding populations in that their presence is a measure of breeding success in a particular year rather than an indicator of population density. Although known juvenile birds were identified during field surveys, in practice the reliable ageing of individuals was frequently not possible. Timed sampling surveys, such as this, rely on the field identification and initial detection of the majority of birds by call and many birds are either not seen or inadequately seen for them to be reliably aged and therefore excluded if they were juvenile. To minimise the risk of including juveniles in the calculated abundance indices, we have taken the pragmatic approach of considering only registrations from the early survey visits for non-migrant species. For these non-migrants, the majority of breeding adults were expected to have been present at the survey sites and most juveniles would not have yet fledged at the time of the early survey visits. By the time of the second survey visits, it is expected that some or many juveniles would have fledged and could have been recorded as not separable from adult individuals. For the remaining species, which were predominantly long-distance migrants or non-passerines we used the maximum counts of the two survey visits summed across all survey points within a site. The arrival dates of the longer distance migrants in the breeding areas varies between species (e.g. Wernham *et al.* 2002) and possibly also between survey sites. Using the maximum counts is likely to give a better representation of breeding density for the species concerned, while the risks associated with the potential inclusion of juvenile birds are likely to be less for migrant species that tend to commence breeding later in the spring than many resident species. For non-passerines, we assume that the field identification of juvenile birds was sufficiently reliable for them to be excluded during field work. Following these criteria, data collected from both the early and late survey visits were used to calculate indices of abundance for barn swallow, blackcap, garden warbler, common whitethroat, chiffchaff and spotted flycatcher. For all other species, only the early survey visits were used for measures of abundance in the breeding season.

4.2.2 Relationships with habitat variables

Analyses to investigate the relationships between species richness and individual species abundance were undertaken at two levels: (i) at the sub-site level; and (ii) at the point level,

with separate analyses undertaken for the winter and breeding seasons. Each study area was divided into two or three sub-sites following logical geographic divisions (see Appendix 3). Analyses at the sub-site level therefore had a sample size of 13 survey units but were able to consider data from all 1020 points where habitat variables were recorded. Analyses at the point level had a sample size of 240 but only incorporated habitat data from those points where birds had been surveyed.

The dependent variables in the models used were one of: (a) Species Richness; (b) Abundance Index (see Section 4.2.1); or (c) the number of points where a species was recorded. In the latter case, the total number of points sampled within each area was also entered into the models as an offset thereby effectively making the Occurrence rate (see Section 4.2.1) the dependent variable. Models with the Abundance index and the Occurrence rate were used to investigate relationships for individual species within either season.

Analyses were undertaken separately for post-thicket plantations and for the remaining three broad habitat types (see Section 3.2) separately. The younger plantations, fringe and moorland areas were combined for analytical purposes because of their similarities in terms of key habitat variables (notably shrubs and trees <3 m high) and in light of the relatively young and so far undeveloped fringe areas (Section 3.1). This enabled a broader range of shrub structures to be included within the models than would have been possible within the fringe areas alone and thereby permitted a more rigorous investigation of the influences of shrub structure and extent on bird communities. The inclusion of other factors (notably the number of shrub species present) within the models permitted the assessment of shrub diversity (as expected within a fringe area) in addition to the influence of shrub presence or extent, which can be established by single species within young plantations (see below). For models investigating the influences on bird communities or abundance within the non-enclosed habitats (i.e. thicket and pre-thicket plantations, fringe and open moorland) at the sub-site level, the following factors, or independent variables, were included:

Brash cover – The proportion of vegetation sampling points within each sub-site where brash was estimated to cover more than 66% of the ground within a 5 m radius. The proportions were arcsine-square-root transformed before inclusion in the models;

Ericaceous cover – The proportion of vegetation sampling points within each sub-site where dwarf shrubs (*Calluna vulgaris*, *Erica* spp. or *Vaccinium myrtillus*) was estimated to cover more than 66% of the ground within a 5 m radius. The proportions were arcsine-square-root transformed before inclusion in the models;

Grass cover – The proportion of vegetation sampling points within each sub-site where grasses were estimated to cover more than 66% of the ground within a 5 m radius. The proportions were arcsine-square-root transformed before inclusion in the models;

Shrub cover – The proportion of vegetation sampling points within each sub-site where shrubs (woody species 1 – 3 m in height) were estimated to cover more than 33% of the ground within a 10 m radius. The proportions were arcsine-square-root transformed before inclusion in the models;

Number of trees – The proportion of vegetation sampling points where there were 5 or more trees (> 3 m high) within a 25 m radius. The proportions were arcsine-square-root transformed before inclusion in the models;

Altitude – The mean altitude of vegetation sampling points within each sub-site;

Brash Depth – The median score of brash depth (0 – 25 cm; 25 – 50 cm; 50+ cm) recorded at the vegetation sampling points within each sub-site;

Number of shrub species – The median number of shrub species (woody species 1 – 3 m in height) recorded within a 10 m radius of each vegetation sampling point.

Number of Tree species – The median number of tree species (woody species > 3 m in height) within a 25 m radius of each vegetation sampling point.

Generalised linear models (Proc Genmod in the statistical package SAS 9.1) were used to examine the influence of the above factors on the dependent variables, assuming a Poisson error distribution and a log-link function.

For models investigating the influences on bird communities or abundance within the non-enclosed habitats (i.e. thicket and pre-thicket plantations, fringe and open moorland) at the point level, the same factors, or independent variables, as above were included but measures of ground cover (brash, ericaceous, grass and shrub) were introduced as class variables, each with four classes (see Section 3.2). Altitude, brash depth and the numbers of shrub and tree species were modelled as continuous variables. Generalised linear mixed models (Proc Glimmix in the statistical package SAS 9.1) were used to examine the influence of these factors on the dependent variables. The sub-site (n = 13) was introduced into the mixed models as a random variable, to account for 'site' effects and the models assumed a Poisson error distribution and a log-link function.

Separate analyses for post-thicket plantations examined the influence of habitat variables within the plantations and also that of shrub cover in nearby areas using generalised linear models (Proc Genmod, SAS 9.1). Either species richness or the number of points within post-thicket plantations where a species was recorded within the post-thicket plantation in each sub-site was the dependent variable. For the number of points where a species was recorded, the number of points within the relevant habitat that were sampled was entered into the models as an offset to effectively make the Occurrence rate the dependent variable. Factors, or independent variables, considered in the model were:

Altitude – the mean altitude of vegetation sampling points within post-thicket plantation within each sub-site;

Tree density – the number of trees within a 5 m radius of the sampling point (0 – 9; 10 – 19; 20 – 29; 30 +);

Tree height – the average height of trees within a 5 m radius of the sampling point (3 – 10 m; 11 – 15 m; 16 – 20 m; > 20 m);

Shrub cover – The proportion of vegetation sampling points (outwith the post-thicket plantation) within each sub-site where shrubs (woody species 1 – 3 m in height) were estimated to cover more than 33% of the ground within a 10 m radius. The proportions were arcsine-square-root transformed before inclusion in the models.

These models aimed to identify any influence of a shrubby fringe on the bird communities within proximate older plantation stands. Only shrub cover was included as a variable for the 'open' habitats as this is the principal feature that is being introduced into the landscape through restructuring of the interface between plantations and open moorland and also proved to be one of the major influences on bird communities within the more open habitats (see Section 5.2).

5. RESULTS

5.1 Species richness and indices of abundance

A total of 59 species were recorded in the two seasons, 35 during the winter bird surveys in 2008-09 and 49 during the breeding bird surveys in 2009 (Tables 4 & 5). An additional nine species (great cormorant, greater Canada goose, greylag goose, mallard, common goldeneye, red-breasted merganser, common sandpiper, mew gull and lesser black-backed gull) were recorded only from the main water body of Loch Skerrow and are therefore excluded from all the following summaries and analyses as they were clearly not associated with the forestry, fringe or moorland areas that were being surveyed. Similarly, registrations of Eurasian teal and herring gull on Loch Skerrow have been excluded but registrations from other areas are included.

Of the four main habitat types, the fringe areas were the most species rich in both winter and breeding seasons (32 and 44 species respectively), in winter this was followed by post-thicket plantations (21 species), thicket and pre-thicket plantations (18 species) and the poorest areas were moorland (15 species) (Tables 6 - 10). In the breeding season, the order was slightly different with the thicket and pre-thicket plantations being the second most species rich (33 species) followed by post-thicket plantation (28 species) and moorland (27 species) (Tables 6 - 13).

For information and also for the purposes of future site monitoring, indices of abundance for each of the five study sites are presented in Appendix 4.

Table 4. Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) in the Galloway Forest Park

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Eurasian teal	0.4			
Willow ptarmigan (red grouse)	6.3	0.10	1.3	1.6*
Black grouse	1.7	0.08	1.1	
Hen harrier	0.8			
Northern goshawk	0.4			
Eurasian sparrowhawk	0.4	0.02	0.3	
Common buzzard	3.3			
Golden eagle	0.4			
Common kestrel	1.3	0.02	0.3	
Common snipe	0.8	0.08	1.1	
Eurasian woodcock	1.3	0.04	0.5	
Common wood pigeon	0.4			
Great spotted woodpecker	5.4	0.04	0.5	
Meadow pipit	6.3	0.38	4.8	7.0*
Bohemian waxwing	0.4			
Winter wren	52.1	4.19	53.3	82.7
Hedge accentor	8.8	0.42	5.3	7.5
European robin	7.5	0.42	5.3	9.3
Stonechat	1.3	0.08	1.1	
Fieldfare	0.4			
Goldcrest	20.0	2.02	25.7	46.5
Long-tailed tit	1.7	0.33	4.2	6.8*
Coal tit	32.1	1.38	17.5	23.5
Blue tit	1.7	0.13	1.6	
Great tit	0.4	0.02	0.3	
Eurasian treecreeper	1.3	0.04	0.5	
Carrion crow	10.4			
Common raven	19.6			
Chaffinch	2.1	0.06	0.8	
European goldfinch	1.3	0.02	0.3	
Eurasian siskin	0.8			
Lesser redpoll	7.1	0.04	0.5	
Common crossbill	0.8	0.02	0.3	
Common bullfinch	4.6	0.17	2.1	2.9*
Reed bunting	6.7	0.15	1.9	2.3*

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 5. Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	2.5	0.04	0.5	
Black grouse	5.0	0.08	1.1	
Common pheasant	1.3			
Grey heron	0.4			
Common buzzard	4.6			
Golden eagle	0.8			
Common kestrel	0.4			
Merlin	0.4	0.04	0.5	
Common snipe	1.3			
Herring gull	0.4			
Common wood pigeon	8.8	0.50	6.4	9.2*
Common cuckoo	25.0	0.04	0.5	
European nightjar	0.4			
Green woodpecker	0.4			
Great spotted woodpecker	2.9	0.04	0.5	
Sky lark	4.6	0.21	2.7	
Barn swallow	1.7			
Tree pipit	11.7	0.42	5.3	7.2*
Meadow pipit	62.9	7.92	100.8	147.1
White/Pied wagtail	0.8			
Winter wren	73.3	7.50	95.5	143.5
Hedge accentor	7.1	0.42	5.3	9.3*
European robin	49.2	4.25	54.1	83.3
Whinchat	1.3	0.08	1.1	
Stonechat	4.2	0.21	2.7	
Northern wheatear	1.3	0.04	0.5	
Common blackbird	17.1	0.38	4.8	5.9*
Song thrush	23.8	0.42	5.3	6.4
Mistle thrush	2.5	0.04	0.5	
Common grasshopper warbler	8.3	0.50	6.4	8.5*
Blackcap	0.4	0.08	1.1	
Garden warbler	3.3	0.21	2.7	
Common whitethroat	8.8	1.00	12.7	17.8
Common chiffchaff	0.4	0.04	0.5	
Willow warbler	66.7	7.58	96.5	137.8
Goldcrest	22.9	1.67	21.2	52.4
Spotted flycatcher	0.8	0.04	0.5	
Coal tit	23.8	1.54	19.6	35.7
Blue tit	0.4	0.04	0.5	
Great tit	1.3	0.04	0.5	
Eurasian jay	0.4			
Carrion crow	8.8	0.04	0.5	
Common raven	5.4			
Chaffinch	73.8	7.50	95.5	136.5
Eurasian siskin	24.2	0.33	4.2	5.6*
Lesser redpoll	15.8	0.75	9.5	13.6*
Common crossbill	6.3			
Reed bunting	2.1	0.04	0.5	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 6. Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) within post-thicket plantations in the Galloway Forest Park

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Eurasian teal	1.4			
Black grouse	1.4	0.07	0.9	
Hen harrier	1.4			
Common buzzard	1.4			
Common kestrel	2.8	0.07	0.9	
Eurasian woodcock	1.4	0.07	0.9	
Great spotted woodpecker	7.0	0.07	0.9	
Winter wren	21.1	1.83	23.3	36.3
Hedge accentor	8.5	0.49	6.3	
European robin	9.9	0.70	9.0	17.1*
Fieldfare	1.4			
Goldcrest	28.2	4.72	60.1	114.7
Coal tit	26.8	2.75	35.0	51.1
Eurasian treecreeper	2.8	0.14	1.8	
Carrion crow	5.6			
Common raven	9.9			
Chaffinch	2.8	0.14	1.8	
Lesser redpoll	1.4			
Common crossbill	1.4	0.07	0.9	
Common bullfinch	4.2	0.14	1.8	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 7. Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) within post-thicket plantations in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Common pheasant	1.4			
Common buzzard	1.4			
Common wood pigeon	15.5	1.55	19.7	28.6*
Common cuckoo	16.9			
Great spotted woodpecker	5.6	0.14	1.8	
Tree pipit	8.5	0.28	3.6	
Meadow pipit	11.3			
Winter wren	35.2	4.51	57.4	89.1
Hedge accentor	8.5	0.56	7.2	
European robin	39.4	9.72	123.7	201.5
Common blackbird	16.9	0.28	3.6	
Song thrush	23.9	0.99	12.6	16.2*
Mistle thrush	2.8	0.14	1.8	
Common grasshopper warbler	2.8	0.14	1.8	
Blackcap	1.4	0.28	3.6	
Garden warbler	1.4	0.14	1.8	
Common whitethroat	1.4	0.28	3.6	
Willow warbler	36.6	8.17	104.0	152.9
Goldcrest	33.8	5.07	64.6	179.4
Coal tit	32.4	4.08	52.0	95.2
Great tit	2.8	0.14	1.8	
Eurasian jay	1.4			
Carrion crow	7.0	0.14	1.8	
Common raven	1.4			
Chaffinch	38.0	13.24	168.5	254.0
Eurasian siskin	25.4	0.28	3.6	
Lesser redpoll	11.3	0.70	9.0	
Common crossbill	9.9			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 8. Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) within pre-thicket and thicket plantations in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Black grouse	2.6	0.13	1.6	
Eurasian sparrowhawk	2.6	0.13	1.6	
Common snipe	2.6	0.13	1.6	
Great spotted woodpecker	7.7			
Meadow pipit	5.1	0.13	1.6	
Winter wren	43.6	6.41	81.6	129.2
Hedge accentor	12.8	0.77	9.8	
European robin	7.7	0.38	4.9	
Stonechat	5.1	0.38	4.9	
Goldcrest	10.3	0.77	9.8	
Coal tit	23.1	0.51	6.5	7.7*
Blue tit	2.6	0.13	1.6	
Carrion crow	20.5			
Common raven	10.3			
Lesser redpoll	10.3			
Common bullfinch	5.1	0.51	6.5	
Reed bunting	10.3	0.51	6.5	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 9. Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) within pre-thicket and thicket plantations in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	5.1			
Black grouse	2.6			
Common buzzard	7.7			
Golden eagle	2.6			
Lesser black-backed gull	2.6			
Common wood pigeon	5.1	0.26	3.3	
Common cuckoo	15.4			
Green woodpecker	2.6			
Sky lark	2.6			
Tree pipit	15.4	0.77	9.8	
Meadow pipit	46.2	11.28	143.6	208.5
White/Pied wagtail	2.6			
Winter wren	51.3	15.13	192.6	291.0
Hedge accentor	5.1			
European robin	15.4	0.77	9.8	
Whinchat	2.6	0.26	3.3	
Stonechat	5.1	0.26	3.3	
Common blackbird	12.8	0.51	6.5	
Song thrush	10.3			
Mistle thrush	2.6			
Common grasshopper warbler	10.3	1.03	13.1	
Garden warbler	10.3	0.77	9.8	
Common whitethroat	7.7	0.26	3.3	
Willow warbler	41.0	7.69	97.9	141.6
Goldcrest	7.7	0.51	6.5	
Spotted flycatcher	2.6	0.26	3.3	
Great tit	2.6			
Carrion crow	12.8			
Common raven	10.3			
Chaffinch	43.6	4.36	55.5	74.3
Eurasian siskin	17.9			
Lesser redpoll	28.2	1.28	16.3	
Common crossbill	2.6			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 10. Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) within fringe habitats in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	8.9	0.17	2.1	
Black grouse	2.2	0.11	1.4	
Northern goshawk	1.1			
Common buzzard	5.6			
Golden eagle	1.1			
Common kestrel	1.1			
Common snipe	1.1	0.17	2.1	
Eurasian woodcock	2.2	0.06	0.7	
Common wood pigeon	1.1			
Great spotted woodpecker	5.6	0.06	0.7	
Meadow pipit	8.9	0.61	7.8	11.3
Bohemian waxwing	1.1			
Winter wren	25.6	6.11	77.8	121.1
Hedge accentor	10.0	0.39	5.0	6.5*
European robin	5.6	0.39	5.0	
Stonechat	1.1	0.06	0.7	
Goldcrest	12.2	1.33	17.0	28.7
Long-tailed tit	3.3	0.67	8.5	14.7*
Coal tit	22.2	1.17	14.9	18.9
Blue tit	3.3	0.28	3.5	
Great tit	1.1	0.06	0.7	
Eurasian treecreeper	1.1			
Carrion crow	8.9			
Common raven	20.0			
Chaffinch	2.2	0.06	0.7	
European goldfinch	2.2	0.06	0.7	
Eurasian siskin	2.2			
Lesser redpoll	8.9	0.11	1.4	
Common crossbill	1.1			
Common bullfinch	5.6	0.11	1.4	
Reed bunting	7.8	0.17	2.1	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 11. Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April - June 2009) within fringe habitats in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	3.3	0.11	1.4	
Black grouse	5.6	0.22	2.8	
Common pheasant	2.2			
Grey heron	1.1			
Common buzzard	6.7			
Golden eagle	1.1			
Merlin	1.1	0.11	1.4	
Common snipe	1.1			
Herring gull	1.1			
Common wood pigeon	5.6			
Common cuckoo	16.7	0.11	1.4	
European nightjar	1.1			
Great spotted woodpecker	3.3			
Sky lark	2.2	0.22	2.8	
Barn swallow	3.3			
Tree pipit	13.3	0.56	7.1	
Meadow pipit	28.9	9.00	114.6	171.9
White/Pied wagtail	1.1			
Winter wren	31.1	9.11	116.0	173.0
Hedge accentor	8.9	0.67	8.5	
European robin	25.6	3.11	39.6	58.7
Whinchat	2.2	0.11	1.4	
Stonechat	5.6	0.44	5.7	
Northern wheatear	1.1			
Common blackbird	11.1	0.56	7.1	
Song thrush	13.3	0.33	4.2	
Mistle thrush	2.2			
Common grasshopper warbler	8.9	0.67	8.5	11.1*
Garden warbler	2.2	0.11	1.4	
Common whitethroat	14.4	2.11	26.9	39.4
Common chiffchaff	1.1	0.11	1.4	
Willow warbler	25.6	10.00	127.3	179.7
Goldcrest	6.7	0.22	2.8	
Spotted flycatcher	1.1			
Coal tit	10.0	0.89	11.3	
Blue tit	1.1	0.11	1.4	
Carrion crow	8.9			
Common raven	5.6			
Chaffinch	30.0	7.22	91.9	129.3
Eurasian siskin	15.6	0.67	8.5	
Lesser redpoll	10.0	0.89	11.3	
Common crossbill	5.6			
Reed bunting	1.1	0.11	1.4	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 12. Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) within moorland in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	17.5	0.25	3.2	
Hen harrier	2.5			
Common buzzard	5			
Meadow pipit	7.5	0.75	9.5	
Winter wren	25	1.88	23.9	34.2
Long-tailed tit	2.5	0.50	6.4	
Coal tit	10	0.25	3.2	
Carrion crow	7.5			
Common raven	17.5			
Chaffinch	2.5			
European goldfinch	2.5			
Lesser redpoll	5			
Common bullfinch	2.5			
Reed bunting	5			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Table 13. Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) within moorland in the Galloway Forest Park.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow ptarmigan (red grouse)	2.5			
Black grouse	10.0			
Common kestrel	2.5			
Common snipe	5.0			
Common wood pigeon	2.5			
Common cuckoo	17.5			
Sky lark	15.0	0.75	9.5	
Barn swallow	2.5			
Meadow pipit	52.5	15.75	200.5	287.9
Winter wren	35.0	1.00	12.7	
European robin	20.0	0.25	3.2	
Whinchat	2.5			
Stonechat	7.5			
Northern wheatear	5.0	0.25	3.2	
Common blackbird	2.5			
Song thrush	2.5			
Common grasshopper warbler	7.5	0.25	3.2	
Garden warbler	2.5			
Common whitethroat	5.0	0.50	6.4	
Willow warbler	32.5	0.50	6.4	
Coal tit	7.5			
Carrion crow	7.5			
Common raven	5.0			
Chaffinch	32.5	0.75	9.5	
Eurasian siskin	15.0			
Lesser redpoll	10.0			
Reed bunting	10.0			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

5.2 Relationships with habitat variables within ‘open’ habitats

5.2.1 Species richness

There was a general increase in species richness associated with increases in shrub cover within the thicket and pre-thicket forestry, fringe and open moorland areas combined (Table 14, Figures 9 & 10). In winter, this relationship was statistically significant at the sub-site level but not at the point level (Appendix 5, Figure 9). Conversely, in the breeding season, the relationship was significant only when modelled at the point level (Appendix 5, Figure 10). Although the absence of a statistically significant relationship does not preclude there actually being an influence, this does suggest that species richness in winter is more greatly influenced by the wider abundance of shrubs within an area (between the ranges of zero and 13% of ground dominated by shrubs as found in our study areas) than by the extent of shrub cover within the immediate vicinity of a particular point. Conversely, in the breeding season it is possible that the immediate abundance of shrub cover was of greater importance in determining the number of species present. Although this study cannot elucidate mechanisms by which apparent relationships operate, this does suggest a difference of scales between seasons. In the breeding season, birds tend to be associated with a territory, and therefore could be most influenced by local vegetation composition within that territory. In winter, birds tend to be more mobile and not attached to a territory, and therefore vegetation composition across a broader area could be of more importance.

Table 14. A summary of the relationships between habitat variables within ‘open’ habitats (thicket and pre-thicket plantations, fringe and moorland combined) and species richness and indices of abundance for individual species.

	SEASON	ANALYTICAL LEVEL	ERICACEOUS COVER	GRASS COVER	SHRUB COVER	ALTITUDE
SPECIES RICHNESS	WINTER	SUB-SITE	+	+++	+++	-
		POINT				---
	SUMMER	SUB-SITE			+++	---
		POINT				

Note: ‘+’ and ‘-’ symbols represent positive and negative relationships respectively. Three symbols (e.g. ‘+++’) denotes a statistically significant relationship ($P < 0.05$) while a single symbol (e.g. ‘-’) denotes a marginally non-significant relationship ($0.05 > P > 0.1$). The species summaries are derived from analyses of both abundance indices and occurrence rates which have been undertaken at both the sub-site and sampling point levels (see Section 4.2.2). There were no contrasting trends between analytical approaches where at least one proved to be statistically significant. Statistical significance in just one of the analytical approaches for a species is sufficient to be included as such in the above table. There were no statistically significant relationships with measures of brash cover, brash depth, tree cover, the number of shrub species or the number of tree species, otherwise only outputs from models that successfully converged are summarised. Full statistical outputs for the models are presented in Appendix 5.

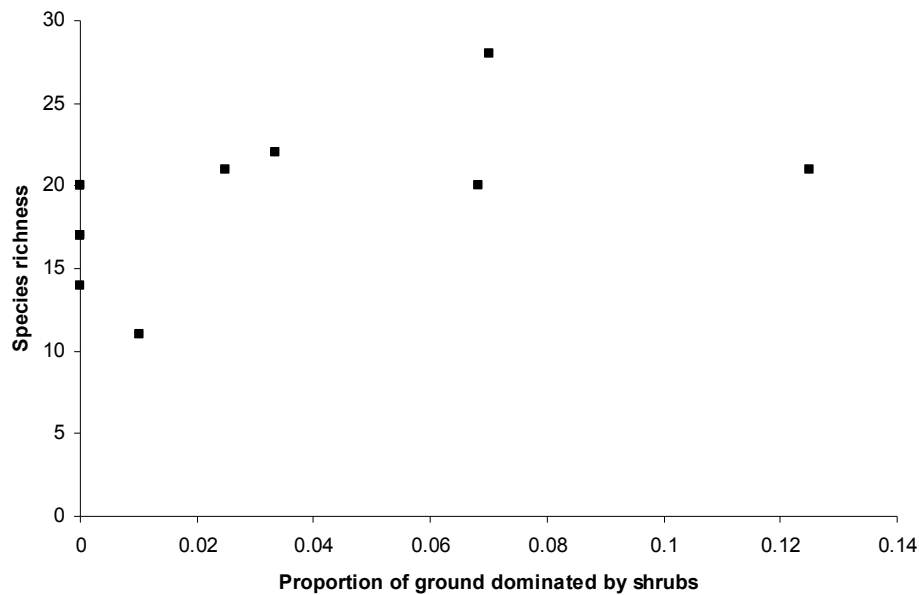


Figure 9. The number of bird species (species richness) recorded during the winter (November 2008 – March 2009) in relation to shrub cover within the thicket and pre-thicket plantations, fringe and open moorland areas combined. The x-axis shows the proportion of vegetation sampling points where shrubs were estimated to cover more than 33% of the ground within a 10 m radius within each of the 13 sub-sites.

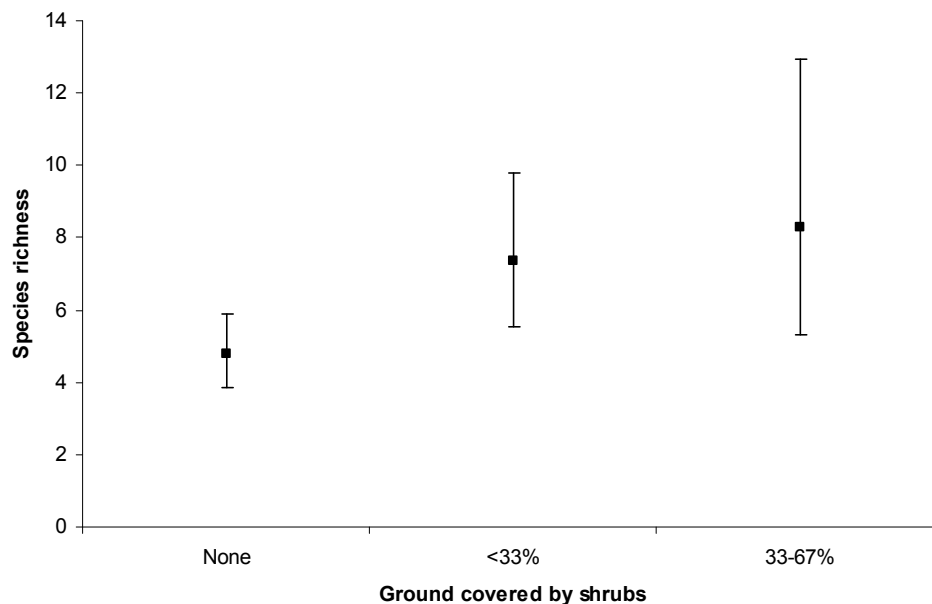


Figure 10. The number of bird species (mean with 95% CI) recorded during the breeding season (April – June 2009) in relation to shrub cover within the thicket and pre-thicket plantations, fringe and open moorland areas combined. The x-axis shows the proportion of ground cover by shrubs within a 10 m radius of the sampling points ($n=240$). Note the means and confidence intervals are back-transformed from the models undertaken at the point level (see Section 4.2.2).

5.2.2 Species-specific relationships

Statistically significant relationships between measured habitat variables and indices of species abundance were identified for 22 species within the thicket and pre-thicket plantations, fringe areas and open moorland combined (8 in winter and 16 in the breeding season; Table 15). No statistically significant relationships were detected for bullfinch and common buzzard, potentially a result of the low power to detect relationships for the rarer species, while for other scarce species the data were too sparse for model convergence.

5.2.2.1 Shrubs

Of the habitat variables considered in the models, statistically significant relationships with the proportional cover by shrubs were apparent for the greatest number of species ($n = 19$; Table 15). Among those species, the majority showed a positive relationship in that they were present more frequently and/or were more abundant in areas with greatest shrub cover, within the ranges found in the Galloway study areas (this includes common cuckoo, tree pipit, meadow pipit, winter wren, hedge accentor, stonechat, blackbird, song thrush, common grasshopper warbler, willow warbler, goldcrest, lesser redpoll and reed bunting). A few (sky lark, European robin, coal tit, chaffinch and Eurasian siskin) showed a negative influence in that they were present less frequently and/or were less abundant in areas with greatest shrub cover. All the statistically significant relationships with shrub cover were at the sub-site level, with data perhaps too sparse for each species to detect relationships or, in many cases, for the models to successfully converge (Table 15, Appendix 5). Among those species with a positive association with scrub cover, their known ecology implies that this should be expected, at least in the early stages of scrub development (see Section 2.3). For sky lark, an obligate open-ground species (e.g. Donald 2004), its negative association with shrubs can also be expected. The apparent negative associations for the remaining four species are probably more complex.

Within the study areas, 'shrubs' occur as either young crop species (thicket and pre-thicket plantations) or within the fringe areas and as isolated stands within moorland. Within the thicket and pre-thicket plantations, the shrubs are dominated by a single species, predominantly sitka spruce, the principal crop species (Figure 4). In the fringe areas, a number of shrub species are found (Figure 4), either regenerating naturally or deliberately planted. An assessment of the influence of the number of shrub species on bird species abundance can be seen as an indication of the influence of shrub composition as opposed to simply shrub structure, as the latter can be provided by the single crop species.

Seven species showed a statistically significant positive relationship with the number of shrub species present (Table 15). All except one species had a similarly positive relationship with shrub cover (Table 15) indicating an influence of shrub species diversity, or arguably the presence of native broad-leaved species (birch, rowan, hawthorn and willow; Figure 4) within the shrub vegetation. European robin showed a negative relationship with the extent of shrub cover but a positive relationship with the number of shrub species that were present (Table 15). Similarly, a marginally non-significant positive relationship with the number of shrub species was suggested for chaffinch, a species that also showed a negative relationship with shrub cover (Table 15). For these two species at least, it appears that the species composition of the shrubs was more important than the extent of shrub cover *per se*.

As well as shrub cover, its extent and its composition, relationships of species abundance with other measured habitat variables were apparent, with all of the variables included within the models influencing the abundance of at least some species, though there were few common relationships between all species across all of the variables that could be modelled (Table 15). For example, among the 13 species with a statistically significant positive

relationship with shrub cover, three species also had a significant positive relationship with tree cover while 8 had a negative relationship (Table 15).

5.2.2.2 Brash

The presence of brash will effectively create structure and cover but it can suppress the development of living vegetation. Among the suite of species for which the influence of brash could be modelled, most were less abundant where brash cover was most extensive, but conversely, brash depth appeared to be associated with higher abundances for the majority (Table 15). For the species that showed a negative relationship with brash cover, most also showed a positive relationship with vegetative ground cover (ericaceous or grass; Section 5.2.2.3), suggesting that reduced vegetation cover was a causal factor. Thicker brash was present where it had been piled up, thereby creating diversity of structure and also clearing a higher proportion of the ground to permit the development of living ground vegetation, both probably benefiting some bird species. However, some species (hedge accentor in winter and meadow pipit, willow warbler and carrion crow in summer) were more abundant where brash cover was most extensive (Table 15), therefore it appears that some species favour those conditions. For meadow pipit, although a statistically significant positive relationship with brash cover was apparent in the breeding season, there was a marginally non-significant ($0.05 < P < 0.10$) negative relationship in the winter (Table 15) suggesting, for that species at least, there could be a different influence of brash cover at different seasons.

5.2.2.3 Ground vegetation

The predominant ground vegetation was either ericaceous or grasses and sedges, and where these were absent ground cover was largely low bryophytes, covered with needle litter (where close to coniferous trees) or was bare peat (where recently disturbed) (Figure 2). Clearly the proportionate cover by each of these variables will not be independent in that cover by one will exclude another. Following the observed distributions of ground cover (Figure 2), we have taken the pragmatic approach of modelling only the relationships of the predominant forb (ericaceous plants) and graminoid (grasses and sedges) cover with bird abundance. For each apparent relationship with ericaceous and/or graminoid ground cover, an opposite relationship could be apparent for those habitat variables that indicate their low occurrence (bryophytes, needle litter and bare peat).

Within the study area, ericaceous and graminoid ground cover within 'open' habitats (i.e. moorland, fringe, thicket and pre-thicket plantations) characterised areas that had the most time for such vegetation to develop following disturbance associated with felling earlier rotation crop trees, subsequent replanting or areas that had never been planted. Among those species for which the influence of ericaceous and grass/sedge cover could be modelled, most were more abundant where ground vegetation cover of those types was most extensive (Table 15). Interestingly this included three species that also demonstrated a positive relationship with brash cover (hedge accentor, meadow pipit and willow warbler; see Section 5.2.2.2). This suggests that for those species, the influence of brash cover is unlikely to be associated with its ability to suppress ground vegetation.

Perhaps surprisingly, three species showed a negative relationship with extent of developed ground vegetation (coal tit in winter and chaffinch and Eurasian siskin in the breeding season; Table 15). All three are arguably species more associated with woodlands and the apparently negative relationships with ground vegetation within more open habitats are difficult to explain.

5.2.2.4 Trees

Within the 'open' habitats, most species for which the relationships could be modelled, showed a negative relationship with both proportion of cover by trees (over 3 m high) and by the number of tree species (Table 15). These included an array of species that could be considered as both specialists of open habitats (e.g. red grouse and common grasshopper warbler) but also of more wooded habitats (e.g. song thrush and goldcrest) as well as habitat generalists (e.g. winter wren). Among those species with a positive relationship were some notable species of conservation concern: black grouse, tree pipit and lesser redpoll (Eaton *et al.* 2009).

5.2.2.5 Altitude

The majority of species-specific relationships that could be modelled and for which an effect was shown to be statistically significant suggested reduced densities with increasing altitude (Table 15). There were some notable exceptions however, with meadow pipit, stonechat, willow warbler and carrion crow all tending to be more abundant at increasing altitudes (within the limits of the study sites) during the breeding season (Table 15). The most extensive areas of open ground tended to be at the higher altitudes as unplanted moorland above the conifer plantations. Such a correlative relationship between extent of open ground and altitude probably explains the positive relationships of the abundance of meadow pipit, stonechat and carrion crow with altitude, as these species have preferences for more open habitats. The possible causes for increasing willow warbler densities (a shrub and woodland species) with altitude are not clear, however.

Table 15. A summary of the relationships between habitat variables within 'open' habitats (thicket and pre-thicket plantations, fringe and moorland combined) and indices of abundance for individual species.

SPECIES	SEASON	ANALYTICAL LEVEL	BRASH COVER	ERICACEOUS COVER	GRASS COVER	SHRUB COVER	TREE COVER	ALTITUDE	BRASH DEPTH	NUMBER OF SHRUB SPP.	NUMBER OF TREE SPP.
RED GROUSE	WINTER	SUB-SITE	---			+	---				
BLACK GROUSE	SUMMER	SUB-SITE	---	+++			+++				
COMMON CUCKOO	SUMMER	SUB-SITE	---	+++	+++	+++	---	---	+++	+++	---
SKY LARK	SUMMER	SUB-SITE		+++		---					
TREE PIPIT	SUMMER	SUB-SITE				+++	+++				---
MEADOW PIPIT	WINTER	SUB-SITE	-				+++		+++		
	SUMMER	SUB-SITE	+++	+++	+++	+++		+++	---	---	
WINTER WREN	WINTER	SUB-SITE POINT			+	+++	---	---	+++	+++	
	SUMMER	SUB-SITE POINT	---	+++	+	+++		---	+++		---
			-		+						
HEDGE ACCENTOR	WINTER	SUB-SITE POINT	+++	+++	+++	+++	---				
	SUMMER	SUB-SITE		-				+	---		
EUROPEAN ROBIN	SUMMER	SUB-SITE POINT	---	+++	---	---	+++	---	+++	+++	---
							+++				
STONECHAT	SUMMER	SUB-SITE	+			+++		+++			
BLACKBIRD	SUMMER	SUB-SITE	---	+++		+++	---		+++	+++	---
SONG THRUSH	SUMMER	SUB-SITE	---	+++	+++	+++	---	---	+++	+++	---
COMMON GRASSHOPPER WARBLER	SUMMER	SUB-SITE				+++	---	---		+	
WILLOW WARBLER	SUMMER	SUB-SITE	+++	+++	+++	+++	---	+++	-	+++	
GOLDCREST	WINTER	SUB-SITE	---		---						
	SUMMER	SUB-SITE	---	+++	+++	+++	---	---			---
COAL TIT	WINTER	SUB-SITE	---	---	---	---		---			
CARRION CROW	SUMMER	SUB-SITE	+++				+++	+++	---		
COMMON RAVEN	WINTER	SUB-SITE			+	-		+			
CHAFFINCH	SUMMER	SUB-SITE POINT	-	---	---	---	---	-		+	+++
EURASIAN SISKIN	SUMMER	SUB-SITE	---	---	---	---	---		+++		+++
LESSER REDPOLL	SUMMER	SUB-SITE			+++	+++	+++	---	+++	+++	---
REED BUNTING	WINTER	SUB-SITE		---		+++					

Note: '+' and '-' symbols represent positive and negative relationships respectively. Three symbols (e.g. '+++') denotes a statistically significant relationship ($P < 0.05$) while a single symbol (e.g. '-') denotes a marginally non-significant relationship ($0.05 > P > 0.1$). The species summaries are derived from analyses of both abundance indices and occurrence rates which have been undertaken at both the sub-site and sampling point levels (see Section 4.2.2). There were no contrasting trends between analytical approaches where at least one proved to be statistically significant. Statistical significance in just one of the analytical approaches for a species is sufficient to be included as such in the above table. Only outputs from models that successfully converged are summarised; other species insufficiently abundant apart from bullfinch and common buzzard for which no statistically significant relationships were apparent. Full statistical outputs for the models are presented in Appendix 5.

5.3 The influence of shrub cover in fringe habitats on bird abundance in adjacent enclosed plantations and open moorland

Only two species were sufficiently numerous within open moorland areas for successful convergence of the models investigating any relationship with shrub cover in neighbouring fringe areas. Both sky lark and meadow pipit tended to be more abundant on moorland adjacent to areas with greater cover of shrubs (Table 16). Within post-thicket plantations, the relationship of neighbouring shrub fringes could be modelled for a greater number of species, however the nature of their relationships was variable between species (Table 17). Four species (blackbird, song thrush, coal tit and chaffinch) tended to be more abundant in plantations that neighboured fringe areas with a greater proportion of shrub cover, within the range found in our study areas. For five species (winter wren, hedge accentor, European robin, willow warbler and goldcrest), that relationship tended to be in the opposite direction with lower abundance in plantations next to fringe areas with the greatest shrub cover (Table 17). Overall, there was a tendency (statistically, marginally non-significant) for species richness in post-thicket plantations to be positively related to shrub cover in neighbouring fringe areas (Table 17).

Table 16. A summary of the relationships between indices of species abundance and species richness and shrub cover within fringe and thicket and pre-thicket plantations and other habitat variables within adjacent areas of open moorland.

SPECIES	SEASON	ADJACENT SHRUB COVER	ALTITUDE
SKY LARK	SUMMER	+++	+++
MEADOW PIPIT	SUMMER	+++	
SPECIES RICHNESS	SUMMER WINTER		

Note: '+' and '-' symbols represent positive and negative relationships respectively. Three symbols (e.g. '+++') denotes a statistically significant relationship ($P < 0.05$) while a single symbol (e.g. '-') denotes a marginally non-significant relationship ($0.05 > P > 0.1$). The species summaries are derived from analyses of both abundance indices and occurrence rates which have been undertaken at the sub-site level (see Section 4.2.2). There were no contrasting trends between analytical approaches where at least one proved to be statistically significant. Statistical significance in just one of the analytical approaches for a species is sufficient to be included as such in the above table. Only outputs from models that successfully converged are summarised. Full statistical outputs for the models are presented in Appendix 6.

Table 17. A summary of the relationships between indices of species abundance and species richness and shrub cover within fringe and thicket and pre-thicket plantations and other habitat variables within adjacent areas of post-thicket plantations.

SPECIES	SEASON	ADJACENT SHRUB COVER	TREE DENSITY	TREE HEIGHT	ALTITUDE
WINTER WREN	<i>SUMMER</i>	---	---		---
	<i>WINTER</i>	---		---	---
HEDGE ACCENTOR	<i>WINTER</i>	-			
EUROPEAN ROBIN	<i>SUMMER</i>				---
	<i>WINTER</i>	---	---	---	---
BLACKBIRD	<i>SUMMER</i>	+++	-	---	
SONG THRUSH	<i>SUMMER</i>	+++	---	---	---
WILLOW WARBLER	<i>SUMMER</i>	---	---	---	---
GOLDCREST	<i>SUMMER</i>	---		+++	---
	<i>WINTER</i>				
COAL TIT	<i>SUMMER</i>	+		+++	
	<i>WINTER</i>	+			---
CHAFFINCH	<i>SUMMER</i>	+++		+++	+++
EURASIAN SISKIN	<i>SUMMER</i>		---	+++	+++
SPECIES RICHNESS	<i>SUMMER</i>	+			
	<i>WINTER</i>				

Note: '+' and '-' symbols represent positive and negative relationships respectively. Three symbols (e.g. '+++') denotes a statistically significant relationship ($P < 0.05$) while a single symbol (e.g. '-') denotes a marginally non-significant relationship ($0.05 > P > 0.1$). The species summaries are derived from analyses of both abundance indices and occurrence rates which have been undertaken at the sub-site level (see Section 4.2.2). There were no contrasting trends between analytical approaches where at least one proved to be statistically significant. Statistical significance in just one of the analytical approaches for a species is sufficient to be included as such in the above table. Only outputs from models that successfully converged are summarised. Full statistical outputs for the models are presented in Appendix 7.

6. DISCUSSION

6.1 Conservation status of birds recorded

The study areas in the Galloway Forest Park supported a diverse assemblage of birds (59 species recorded in the two seasons) with 11 that are included on the current red-list of birds of conservation concern (species that based on their current known status and recent population trends are considered to be of the highest conservation priority in the UK; Eaton *et al.* 2009) and 18 amber-listed species (species with high conservation priorities, though with less threatened status and/or less marked recent population declines than those on the red list; Eaton *et al.* 2009) (Table 18). The importance of scrub at the interface between plantations and open moorland is indicated by the presence of 27 (out of the 29) species which are considered to be of conservation concern in the fringe habitats with 20 recorded in the thicket and pre-thicket plantations (Table 18). The suite of species that was found in the fringe and younger stage plantations was representative of those that might be expected in developing scrub within upland Britain (see section 2.3). Hen harrier was the single species of conservation concern that was not recorded in either of the two habitat types in which shrubs constitute a major component (Table 18).

Table 18. Red and amber-listed species of conservation concern (after Eaton et al. 2009) recorded in each of the four main habitat groups in the Galloway Forest study areas in winter 2008-09 (W) and the breeding season 2009 (S).

SPECIES	POST- THICKET PLANTATIONS	THICKET & PRE- THICKET PLANTATIONS	FRINGE	MOORLAND
RED-LISTED				
Black grouse	W	W, S	W, S	S
Hen harrier	W			W
Herring gull			S	
Common cuckoo	S	S	S	S
European nightjar			S	
Sky lark		S	S	S
Tree pipit	S	S	S	
Song thrush	S	S	S	S
Common grasshopper warbler	S	S	S	S
Spotted flycatcher	S	S	S	
Lesser redpoll	W	W, S	W, S	W, S
AMBER-LISTED				
Eurasian teal			W	
Willow ptarmigan (red grouse)		S	W, S	W, S
Golden eagle		S	W, S	
Common kestrel			W	S
Merlin			S	
Eurasian woodcock			W	
Common snipe		W	W, S	S
Green woodpecker		S		
Barn swallow			S	S
Meadow pipit	S	W, S	W, S	W, S
Hedge accentor	W, S	W, S	W, S	
Whinchat		S	S	S
Wheatear			S	S
Mistle thrush		S	S	
Common whitethroat	S	S	S	S
Willow warbler		S	S	S
Common bullfinch	W	W	W	W
Reed bunting		W	W, S	W, S

6.2 Seasonal use of habitats at the interface between plantation and moorland

As expected, seasonal migrants to Britain were recorded in the appropriate seasons within the Galloway Forest Park study areas in that summer migrants (e.g. tree pipit, warblers and whinchat) were recorded only during the breeding season and winter migrants (e.g. fieldfare and Bohemian waxwing) and species whose populations are augmented by migrants in the winter (e.g. Eurasian woodcock) were only recorded in the winter (Tables 4, 5 & 18). A number of species that are resident within Britain were recorded in greater abundance or only in the breeding season, for example sky lark, European robin and song thrush (Tables 4, 5 & 18). Again, this might be expected in that some species will disperse away from upland areas, such as the Galloway Forest Park in winter and/or be more detectable during the breeding season when they are likely to be singing or displaying. Perhaps less expected was a small number of species that are generally resident in Britain but were recorded in our study areas either only in the winter (long-tailed tit, Eurasian treecreeper, European goldfinch and common bullfinch) or in markedly greater abundance in the winter (reed bunting) (Tables 4 & 5). Long-tailed tit and European goldfinch were recorded in the fringe and open moorland, Eurasian treecreeper in post-thicket plantations and fringe areas, reed bunting in three of the four main habitat types (missing from post-thicket plantations) and common bullfinch in all four habitat types in winter (Tables 6, 8, 10 & 12). These species were presumably dispersing into the study areas specifically for the resources they offer in winter, for example foraging opportunities and cover (e.g. Marquiss 2007 for bullfinch).

The influence of habitat variables on the bird community appeared to operate at different spatial scales between the breeding and winter seasons. In the breeding season, species richness in the 'open' habitats appeared to be influenced by the extent of shrub cover at a finer scale than was apparent in the winter (Section 5.2.1). In the breeding season, birds will tend to be more territorial in that they will be attached to a specific nest site and breeding territory while in winter this may not be the case and birds will range more widely. Therefore management of the interface between plantations and open moorland for conservation purposes should consider these different scales. Relatively small patches of shrubs may be able to support a relatively large number of breeding species; in our study, the greatest species richness in the breeding season was achieved when over 33% of the area within a 10 m radius of a given point was covered by shrubs (Figure 10). In winter, the greatest number of species were recorded when at least 5% of the gross area was dominated by shrubs (Figure 9). The inference from this is that a diversity of breeding birds could be supported by the maintenance of relatively small patches of shrubs, provided they were within the dispersal capabilities of the species concerned (see Section 2.3). In winter, more extensive areas of scrub (or scrub mosaic) habitats would be required to support species. Unfortunately, within the range of species present in both seasons we do not have the power to identify different spatial scales of influence for individual species. Further study would be required to understand the mechanisms between these seasonal differences in the scale of habitat requirements and how they might vary between species (see section 6.6.1).

6.3 The influence of multiple habitat variables on bird abundance

The development of shrubs at the interface between plantations and open moorland is one of the principal objectives of the moorland fringe management in the Galloway Forest Park and its presence was one of the principal habitat influences on bird abundance (Section 5.2.2.1). Where no relationship between abundance and shrub cover (or indeed any other habitat variable) was detected, this does not necessarily mean that there was not one, as for some of the scarcer species, there will be low power to detect such effects. For example, the known ecology of the black grouse suggests that they will use shrubs and therefore a relationship might be expected. Given that the species was scarce in the study area, there would be low power to detect statistically significant relationships and therefore it would be incorrect to assume with certainty that there was no relationship. However, given that positive relationships with both tree and ericaceous cover within the open habitats were apparent, this does imply that within the conditions of the Galloway Forest Park study areas factors other than shrub cover have a greater influence on the abundance of black grouse.

Among the species that demonstrated a positive relationship between their abundance and shrub cover within open habitats, some demonstrated a similarly positive relationship with tree cover (e.g. tree pipit and lesser redpoll), while others demonstrated a negative relationship with tree cover (e.g. common grasshopper warbler and willow warbler) (Table 15). Within the range of habitat variables that could be included in the models examining their influence on bird abundance, some were generally positive for most species, for example vegetative ground cover (ericaceous and/or graminoid) and shrub cover. There was, however, considerable variation in the direction of relationships across the full range of habitat variables between the species that could be modelled (Table 15). Therefore any targeted management of the fringe areas would need to consider carefully the specific conservation objectives, or at the very least ensure that there is sufficient heterogeneity in the vegetative composition and structure to be able to provide conditions that are suitable for a broad range of species. For example among the suite of species that are considered to be of conservation concern (Table 18), the encouragement of tree cover, within the range encountered in the open habitats during our study, might prove beneficial for black grouse, tree pipit and lesser redpoll, but it might also prove detrimental for red grouse, common cuckoo, song thrush, common grasshopper warbler and willow warbler (see Table 15). When interpreting the results of the present study to deliver conservation benefits, it must be remembered that all of the fringe areas are in their earliest stages of development and are within forestry blocks that have been restructured within the past eight years, or in most cases, even more recently (see Section 3.1). Therefore it is essential to consider the possibility that some of the apparent relationships might be a result of a redistribution of birds within the changing habitats (see Section 6.4), rather than by habitat enhancement alone, and also to consider the sustainability of those habitats in the longer term (see Section 6.5).

6.4 Evidence for species redistribution within changing habitats

Four species (blackbird, song thrush, coal tit and chaffinch) tended to be more abundant in post-thicket plantations that neighboured fringe areas with a greater proportion of shrub cover, within the range found in our study area (Section 5.3, Table 17). Two of those species (blackbird and song thrush) also had higher densities associated with greater proportions of shrub cover within more open habitats (Section 5.2.2.1, Table 15). Intuitively, this appears to be a logical outcome whereby birds detected in the older plantations will have been able to use and benefit from the enhanced resources in the fringe areas, or alternatively, there was a surplus of birds overspilling from adjacent high quality habitats. In contrast, both coal tit and chaffinch abundances within post-thicket plantations were negatively related to the proportion of shrub cover within the adjacent open habitats (Section 5.2.2.1, Table 15). Similar in their apparent contradiction were winter wren, willow warbler and goldcrest, which tended to be less abundant in post-thicket plantations where neighbouring open habitats included more shrub cover (Table 17), whereas within those open habitats their abundances demonstrated a positive relationship with shrub cover (Table 15). These relationships are counter to intuition whereby birds that are found at the edges of plantations do not appear to benefit, and even appear to be disadvantaged by what under other circumstances appear to be enhanced conditions for them. Given the early stages of development of most of the fringe areas at the time of the study, it is possible that some birds had redistributed themselves within the available changing habitats but as yet had not had time to respond by increasing their population sizes across all of those available habitats. Winter wren, willow warbler and goldcrest are generally foliage gleaners and feed on small invertebrates while blackbird and song thrush are generally ground feeders and trunk gleaners that specialise on large invertebrates such as molluscs. Differences in habitat occupancy can differ between guilds of species (e.g. De Casenave *et al.* 1998, Germaine & Vessey 1999; see Section 2.2.2) and therefore it is perhaps not unexpected that different guilds would respond differently to changing habitats at the interface between plantations and moorland. In the moorland fringe areas of the Galloway Forest Park, the two thrushes that feed on large invertebrates might exploit the interface between habitats more rapidly and demonstrate that through an increased abundance both within the older plantations and the open habitats that are close to that interface. The species that feed on smaller

invertebrates might initially redistribute and concentrate within more favourable habitats that become available or develop and in the first instance do not necessarily increase their abundance across the range of habitats that they could potentially occupy.

Redistribution of birds within a recently modified environment could possibly explain some of the counterintuitive relationships that were apparent. Notable among these were some of the negative relationships between species abundance and the presence of trees and range of tree species that were present (Section 5.2.2.4). An understanding of how species respond to the natural development of fringe habitats at the interface between plantations and open moorland would contribute to an assessment of the sustainability of management for shrubs in terms of its benefits to nature conservation.

6.5 The sustainable management of moorland fringe areas

Management of the moorland fringe areas in the Galloway Forest Park aims to establish a mosaic of shrubs and open ground to form a transition zone that is akin to a natural tree line (Section 1). All the study areas are below the altitudinal limit of any natural tree line, however, and therefore will not be subject to climatic conditions that prevent tree growth (e.g. Körner 1998). It follows that without intervention, succession is inevitable and the fringe areas will develop into woodland. The present study identifies shrubs as an important component of the fringe habitat that can enhance both bird species richness and the abundance of a broad suite of bird species (Section 5.2.2.1) including some that are considered to be of conservation concern (Section 6.1). Further, the presence of native shrub species is important for the avian communities (Section 5.2.2.1). As the crop species (e.g. Sitka spruce and lodgepole pine) are major components of the shrub community (Figure 4), it follows that without intervention, the shrubs will develop into trees, and it is likely that non-native crop species will form a major, even dominant, component of those trees. Potentially, this would ultimately lead to the development of another 'hard' boundary between the plantations and open moorland. Although the resultant areas of naturally regenerated woodland (albeit including non-native tree species) may contribute to the biodiversity of the plantation-moorland interface, the suite of species involved would be different to those found in the current study. Given that based on evidence from natural tree lines, it is expected that the biodiversity of the fringe areas will be positively related to the lengths of wood and shrub edge (Norment 1991, Hawrot & Niemi 1996; see Section 2.2.2), such hard edges may have a reduced nature conservation/biodiversity value.

This study can only describe the bird communities and their relationships with habitat variables within the range of habitats that were present in the study area. Repeated monitoring would be required to assess how the bird communities change as the vegetation within the fringe areas develop (Section 6.6.1); changes might be expected to be similar to those observed in developing plantations and in regenerating scrub (see Sections 2.2.1 & 2.3). There are, however, sufficient data to demonstrate the conservation benefits of shrub-heath-mire mosaics at the interface of plantations and moorland. Managers of the Galloway Forest Park will have to decide whether those benefits should be maintained and then, what management intervention is required to sustain those benefits. Options to maintain mosaics including shrubs include periodic cutting of trees and shrubs, supplementary planting of some trees and shrubs, grazing and mowing (e.g. Mortimer *et al.* 2000) or the inclusion of slow growing shrub species, for example juniper and some willows, that can retain their low scrub-like structure and associated bird communities (Gillings *et al.* 2000; Section 2.3). For extensive forestry plantations such as the Galloway Forest Park, an important question related to practical management would be to assess the benefits of the specific management of moorland fringe areas for nature conservation over and above the biodiversity that is achieved through typical rotational management of forestry crops.

Principal differences between restocked forestry coupes and specifically managed moorland fringe habitats include the diversity of shrub species that are present, the presence of native shrub species and connectivity with other open habitats. Typical forestry practice is to replant the single crop species which will form the equivalent of a shrub layer, albeit

temporarily, within the replanted coupe. This study shows that either the diversity of shrub species and/or the presence of native species is important to the majority of bird species for which its influence could be modelled (Section 5.2.2.1; Table 15), including species that are considered to be conservation priorities (Section 6.1). Therefore, for restocked plantation coupes to deliver conservation benefits that are comparable to those of fringe areas, they should include a range of shrub species, possibly including native species. The extent of available habitat (within rotational forestry, the coupe size) and functional connectivity to similar and/or open habitats have been shown to be important for black grouse (Calladine *et al.* 2002, Haysom 2002) and tree pipit (Burton 2007) and it is likely that such factors will influence a wider range of species that use moorland fringe habitats and young restocked plantations. Therefore, to maximise the conservation benefits of restocked coupes, their proximity to similar open habitats should be considered within forest management plans. Further, there could be benefits to moorland birds to having 'soft' fringe areas (Section 2.1.2), however in our study areas, there were too few moorland species for this to be fully investigated. The different practicalities of maintaining moorland fringe habitats and maximising the conservation benefits of rotational forestry would need to be considered by forest managers (see Section 6.6.2).

6.6 Recommendations for further research

Recommendations for further research should come under two broad categories: (i) Ecological studies that further our understanding of how birds use the interface between plantations and moorland; and (ii) Management studies or trials that investigate the practicalities and cost-effectiveness of maintaining moorland fringe areas or their equivalent.

6.6.1 Further ecological research

This should aim to further our understanding of how birds use shrubs and other habitats at the interface between plantations and open moorland and how any conservation benefits can be sustained in the long term. Suggestions for further work are:

- i) Repeated surveys at five-year intervals (i.e. the first repeat survey in 2014) using the same survey points and methods as in 2009 to monitor how the bird populations change with the development of vegetation at the moorland fringe. This will identify any optimum stages of development for particular species or groups and therefore provide guidance for management that both maximises and sustains the conservation value of the plantation-moorland interface;
- ii) Autecological studies of how birds use the interface between moorland and plantations and specifically the role of shrubs and other habitats within those interface areas. As well as building on the data collected in 2008 and 2009, methods such as ringing mark-recapture and radio-telemetry would elucidate how species and individuals range within and make use of the available habitats and provide evidence for levels of functional connectivity, or lack of it, between habitat patches and how that may differ between species and seasons. It would also provide empirical evidence of how the birds either redistribute themselves within developing fringe habitats or change their population sizes in response to those changing habitats. Studies of contrasting species would prove most informative, for example song thrush (as a species that has higher densities both within shrubby fringes and their neighbouring post-thicket plantations) and willow warbler (as a species that appears to have redistributed itself in response to changing available habitats). Both these species are sufficiently abundant within the study areas to collect meaningful quantitative data and both are identified as of conservation concern and so any autecological study could have benefits beyond their use of plantations and the moorland fringe;

- iii) Investigate the influence of moorland fringes at sites where there is a broader suite of moorland birds. In particular, study sites should be identified that support populations of breeding waders;

The above could also be included as part of adaptive management studies that assess the practicalities of management of the fringe habitats (see Section 6.6.2),

6.6.2 Applied forestry management

This should aim to identify management procedures that can maximise and sustain the conservation benefits of fringe habitats. Although these are essentially outwith the remit of this report some suggestions for both theoretical and practical trials include:

- i) Assessments of how to maintain the shrub-heath mosaic at the plantation-moorland interface. Interventional treatments could include periodic cutting/mowing and/or the introduction of grazing. Assessments could also include the commercial value of any by-products from fringe area management, for example the cuttings of broad-leaved shrubs and trees and of ericaceous and other dwarf shrub vegetation;
- ii) Assessing the practicalities of including a broader range of shrub species (including native non-crop species) within restocked coupes as an alternative to managing moorland fringe areas. Such an assessment could also include the commercial value of any products as in (i) above;

If any such management trials are initiated, we suggest that these be undertaken as part of carefully designed studies to assess rigorously the impacts or effectiveness of that management. Such studies would need to follow a number of key principals: (a) baseline surveys in advance of any management; (b) the implementation of only one management technique at a time (so that any observed effects are not confounded and impossible to interpret rigorously); (c) careful documentation of the management undertaken; and (d) include comparable monitoring of reference sites where the management is not implemented.

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APPENDIX 1 – SCIENTIFIC NAMES OF BIRDS MENTIONED IN THE REPORT

English name	Scientific name	English name	Scientific name
Greylag Goose	<i>Anser anser</i>	Meadow Pipit	<i>Anthus pratensis</i>
Greater Canada Goose	<i>Branta canadensis</i>	Tawny Pipit	<i>Anthus campestris</i>
Eurasian Teal	<i>Anas crecca</i>	White/Pied Wagtail	<i>Motacilla alba</i>
Mallard	<i>Anas platyrhynchos</i>	Bohemian Waxwing	<i>Bombycilla garrulus</i>
Common Goldeneye	<i>Bucephala clangula</i>	Winter Wren	<i>Troglodytes troglodytes</i>
Red-breasted Merganser	<i>Mergus serrator</i>	Hedge Accentor	<i>Prunella modularis</i>
Willow Ptarmigan (Red Grouse)	<i>Lagopus lagopus scotica</i>	European Robin	<i>Erithacus rubecula</i>
Black Grouse	<i>Tetrao tetrix</i>	Common Redstart	<i>Phoenicurus phoenicurus</i>
Western Capercaillie	<i>Tetrao urogallus</i>	Whinchat	<i>Saxicola rubetra</i>
Common Pheasant	<i>Phasianus colchicus</i>	Stonechat	<i>Saxicola torquatus</i>
Little Bustard	<i>Tetrax tetrax</i>	Northern Wheatear	<i>Oenanthe oenanthe</i>
Great Cormorant	<i>Phalacrocorax carbo</i>	Ring Ouzel	<i>Turdus torquatus</i>
Grey Heron	<i>Ardea cinerea</i>	Common Blackbird	<i>Turdus merula</i>
Hen Harrier	<i>Circus cyaneus</i>	Fieldfare	<i>Turdus pilaris</i>
Northern Goshawk	<i>Accipiter gentilis</i>	Song Thrush	<i>Turdus philomelos</i>
Eurasian Sparrowhawk	<i>Accipiter nisus</i>	Mistle Thrush	<i>Turdus viscivorus</i>
Common Buzzard	<i>Buteo buteo</i>	Common Grasshopper Warbler	<i>Locustella naevia</i>
Golden Eagle	<i>Aquila chrysaetos</i>	Sedge Warbler	<i>Acrocephalus schoenobaenus</i>
Common Kestrel	<i>Falco tinnunculus</i>	Blackcap	<i>Sylvia atricapilla</i>
Merlin	<i>Falco columbarius</i>	Garden Warbler	<i>Sylvia borin</i>
European Golden Plover	<i>Pluvialis apricaria</i>	Common Whitethroat	<i>Sylvia communis</i>
Northern Lapwing	<i>Vanellus vanellus</i>	Common Chiffchaff	<i>Phylloscopus collybita</i>
Dunlin	<i>Calidris alpina</i>	Willow Warbler	<i>Phylloscopus trochilus</i>
Common Snipe	<i>Gallinago gallinago</i>	Goldcrest	<i>Regulus regulus</i>
Eurasian Woodcock	<i>Scolopax rusticola</i>	Firecrest	<i>Regulus ignicapilla</i>
Eurasian Curlew	<i>Numenius arquata</i>	Spotted Flycatcher	<i>Muscicapa striata</i>
Common Redshank	<i>Tringa totanus</i>	Long-tailed Tit	<i>Aegithalos caudatus</i>
Common Greenshank	<i>Tringa nebularia</i>	Crested Tit	<i>Lophophanes cristatus</i>
Common Sandpiper	<i>Actitis hypoleucos</i>	Coal Tit	<i>Periparus ater</i>
Mew Gull	<i>Larus canus</i>	Blue Tit	<i>Cyanistes caeruleus</i>
Lesser Black-backed Gull	<i>Larus fuscus</i>	Great Tit	<i>Parus major</i>
Herring Gull	<i>Larus argentatus</i>	Eurasian Treecreeper	<i>Certhia familiaris</i>
Common Wood Pigeon	<i>Columba palumbus</i>	Eurasian Jay	<i>Garrulus glandarius</i>

Common Cuckoo	<i>Cuculus canorus</i>	Carrion Crow	<i>Corvus corone</i>
Long-eared Owl	<i>Asio otus</i>	Hooded Crow	<i>Corvus cornix</i>
Short-eared Owl	<i>Asio flammeus</i>	Common Raven	<i>Corvus corax</i>
Pygmy Owl	<i>Glaucidium</i>	Chaffinch	<i>Fringilla coelebs</i>
	<i>passerinum</i>		
European Nightjar	<i>Caprimulgus</i>	European Goldfinch	<i>Carduelis carduelis</i>
	<i>europaeus</i>		
Green	<i>Picus viridis</i>	Eurasian Siskin	<i>Carduelis spinus</i>
Woodpecker			
Great Spotted	<i>Dendrocopos</i>	Common Linnet	<i>Carduelis cannabina</i>
Woodpecker	<i>major</i>		
Wood Lark	<i>Lullula arborea</i>	Twite	<i>Carduelis flavirostris</i>
Sky Lark	<i>Alauda arvensis</i>	Lesser Redpoll	<i>Carduelis cabaret</i>
Short-toed Lark	<i>Calandrella</i>	Common Crossbill	<i>Loxia curvirostra</i>
	<i>brachydactyla</i>		
Calandra Lark	<i>Melanocorypha</i>	Common Bullfinch	<i>Pyrrhula pyrrhula</i>
	<i>calandra</i>		
Barn Swallow	<i>Hirundo rustica</i>	Reed Bunting	<i>Emberiza schoeniclus</i>
Tree Pipit	<i>Anthus trivialis</i>		

APPENDIX 2 – LIST OF SAMPLING POINTS FOR BIRDS SURVEYS

Note that the grid references given are those determined using hand-help GPS and therefore their accuracy will be somewhat less than the 12-figure references imply.

a) Gala Lane

Unique ID	Habitat type	Grid reference
galA7	Fringe	NX4629991085
galA12	Fringe	NX4615390883
galA21	Fringe	NX4588590520
galB13	Fringe	NX4617490264
galB19	Fringe	NX4635590503
galB31	Fringe	NX4671490986
galC12	Fringe	NX4669790445
galC15	Fringe	NX4662990310
galC26	Fringe	NX4632189853
galD6	Fringe	NX4730691350
galD9	Fringe	NX4716991410
galE9	Fringe	NX4708791782
galE16	Fringe	NX4741491648
galF12	Fringe	NX4738692045
galF15	Fringe	NX4752291972
galG5	Fringe	NX4758392284
galG11	Fringe	NX4730592411
galG15	Fringe	NX4713792517
galA2	Moor	NX4645391284
galA5	Moor	NX4636291166
galA25	Moor	NX4576090364
galA27	Moor	NX4569890283
galB2	Moor	NX4580889854
galB6	Moor	NX4594190001
galC20	Moor	NX4649690100
galC23	Moor	NX4640989977
galD20	Moor	NX4663591570
galD24	Moor	NX4644791627
galB26	Post-thicket plantation	NX4656490788
galB28	Post-thicket plantation	NX4662190860
galC5	Post-thicket plantation	NX4688990740
galC7	Post-thicket plantation	NX4683090650
galC9	Post-thicket plantation	NX4676790579
galD13	Post-thicket plantation	NX4697891483
galD16	Post-thicket plantation	NX4684191543
galE1	Post-thicket plantation	NX4673191960
galE4	Post-thicket plantation	NX4686091880
galE6	Post-thicket plantation	NX4696591824
galF4	Post-thicket plantation	NX4701292187
galF7	Post-thicket plantation	NX4715192131
galF10	Post-thicket plantation	NX4729092075
galF17	Post-thicket plantation	NX4760591916

b) Loch Dee

Unique ID	Habitat type	Grid reference	Unique ID	Habitat type	Grid reference
deeC9	Fringe	NX4860082127	deeA3	Post-thicket plantation	NX4830082934
deeE9	Fringe	NX4843181904	deeA6	Post-thicket plantation	NX4845082895
deeE13	Fringe	NX4830781742	deeA9	Post-thicket plantation	NX4859682854
deeE18	Fringe	NX4809681623	deeA12	Post-thicket plantation	NX4874482821
deeE21	Fringe	NX4794581597	deeB12	Post-thicket plantation	NX4868082428
deeF27	Fringe	NX4848281342	deeB15	Post-thicket plantation	NX4852782447
deeG1	Fringe	NX4852281514	deeB17	Post-thicket plantation	NX4843082473
deeG5	Fringe	NX4868381391	deeD11	Post-thicket plantation	NX4908281547
deeG8	Fringe	NX4879081283	deeD13	Post-thicket plantation	NX4908581452
deeG11	Fringe	NX4889081175	deeD16	Post-thicket plantation	NX4907681302
deeG14	Fringe	NX4882381039	deeD18	Post-thicket plantation	NX4907281209
deeG18	Fringe	NX4877180841	deeH2	Post-thicket plantation	NX4887880127
deeG22	Fringe	NX4871280649	deeH5	Post-thicket plantation	NX4874880213
deeG26	Fringe	NX4860680478	deeH8	Post-thicket plantation	NX4864080291
deeG30	Fringe	NX4849680310	deeH18	Post-thicket plantation	NX4815480476
deeG32	Fringe	NX4842780227	deeH20	Post-thicket plantation	NX4805380533
deeH13	Fringe	NX4837980366	deeH23	Post-thicket plantation	NX4794380614
deeH16	Fringe	NX4824180431	deeC1	Pre-thicket plantation	NX4824982317
deeA16	Moor	NX4893182751	deeC3	Pre-thicket plantation	NX4833882271
deeA20	Moor	NX4912382690	deeC5	Pre-thicket plantation	NX4842782228
deeB9	Moor	NX4882582388	deeC7	Pre-thicket plantation	NX4851082172
deeC13	Moor	NX4879682070	deeF12	Pre-thicket plantation	NX4781481137
deeD5	Moor	NX4909181850	deeF14	Pre-thicket plantation	NX4791781121
deeE3	Moor	NX4871181836	deeF16	Pre-thicket plantation	NX4801981103
deeF3	Moor	NX4736281132	deeF18	Pre-thicket plantation	NX4811481100
deeF6	Moor	NX4751781147	deeF20	Pre-thicket plantation	NX4821781113
deeF9	Moor	NX4766281140	deeF22	Pre-thicket plantation	NX4830181171
deeF32	Moor	NX4866781513	deeF24	Pre-thicket plantation	NX4837981231

c) Black Craig of Dee

Unique ID	Habitat type	Grid reference
blaA13	Fringe	NX5740476495
blaA17	Fringe	NX5758776414
blaA22	Fringe	NX5783176360
blaB5	Fringe	NX5794576435
blaB8	Fringe	NX5808876379
blaB13	Fringe	NX5834376380
blaB18	Fringe	NX5859776412
blaC15	Fringe	NX5890476455
blaD7	Fringe	NX5911876164
blaD10	Fringe	NX5923376262
blaD13	Fringe	NX5935376355
blaE13	Fringe	NX5800274784
blaE16	Fringe	NX5814674830
blaE19	Fringe	NX5828474890
blaF7	Fringe	NX5836974541
blaF11	Fringe	NX5819674436
blaF15	Fringe	NX5802074338
blaF17	Fringe	NX5793174291
blaA2	Post-thicket plantation	NX5690576731
blaA6	Post-thicket plantation	NX5708076638
blaA8	Post-thicket plantation	NX5717476599
blaA11	Post-thicket plantation	NX5731576549
blaC5	Post-thicket plantation	NX5933076706
blaC8	Post-thicket plantation	NX5919976638
blaC11	Post-thicket plantation	NX5908176548
blaD16	Post-thicket plantation	NX5947176453
blaD20	Post-thicket plantation	NX5963776564
blaD23	Post-thicket plantation	NX5977476639
blaE11	Post-thicket plantation	NX5791074743
blaF22	Post-thicket plantation	NX5771274175
blaF25	Post-thicket plantation	NX5757974109
blaE1	Pre-thicket plantation	NX5747174501
blaE4	Pre-thicket plantation	NX5760374575
blaE7	Pre-thicket plantation	NX5772774660
blaF19	Pre-thicket plantation	NX5784074247

d) Lamachan

Unique ID	Habitat type	Grid reference	Unique ID	Habitat type	Grid reference
lamA13	Fringe	NX4309072427	lamA3	Post-thicket plantation	NX4283872466
lamA25	Fringe	NX4338672397	lamB21	Post-thicket plantation	NX4285572222
lamB12	Fringe	NX4331372226	lamB24	Post-thicket plantation	NX4271472242
lamB18	Fringe	NX4301372221	lamC6	Post-thicket plantation	NX4280372050
lamC9	Fringe	NX4295072050	lamJ14	Post-thicket plantation	NX4440274363
lamC16	Fringe	NX4330072050	lamK3	Post-thicket plantation	NX4344975750
lamE8	Fringe	NX4473275595	lamO18	Post-thicket plantation	NX4300874676
lamF4	Fringe	NX4481575432	lamO22	Post-thicket plantation	NX4320174705
lamH3	Fringe	NX4494175191	lamP18	Post-thicket plantation	NX4309574223
lamI15	Fringe	NX4477674812	lamQ2	Post-thicket plantation	NX4355174034
lamJ11	Fringe	NX4455374377	lamQ6	Post-thicket plantation	NX4337073970
lamL2	Fringe	NX4321975348	lamE10	Pre-thicket plantation	NX4464675544
lamL6	Fringe	NX4311075178	lamE15	Pre-thicket plantation	NX4443075421
lamM5	Fringe	NX4269574297	lamG3	Pre-thicket plantation	NX4444675160
lamN5	Fringe	NX4289873933	lamG8	Pre-thicket plantation	NX4468675238
lamO14	Fringe	NX4283174585	lamG11	Pre-thicket plantation	NX4482375269
lamP11	Fringe	NX4277974070	lamI22	Pre-thicket plantation	NX4448574734
lamQ16	Fringe	NX4292773720	lamK5	Pre-thicket plantation	NX4336475694
lamA35	Moor	NX4363272345	lamK7	Pre-thicket plantation	NX4329075627
lamB10	Moor	NX4341672224	lamK9	Pre-thicket plantation	NX4321575559
lamC26	Moor	NX4380072050	lamL9	Pre-thicket plantation	NX4304475045
lamI1	Moor	NX4534075024	lamP13	Pre-thicket plantation	NX4287374111
lamI7	Moor	NX4504974953	lamP15	Pre-thicket plantation	NX4296274152
lamJ4	Moor	NX4490274412	lamQ8	Pre-thicket plantation	NX4327273931
lamK14	Moor	NX4304875372	lamQ10	Pre-thicket plantation	NX4318673879

lamO6	Moor	NX4250674491	lamQ12	Pre-thicket plantation	NX4310273818
lamP5	Moor	NX4250673942	lamQ14	Pre-thicket plantation	NX4301973759
lamQ18	Moor	NX4282673693			

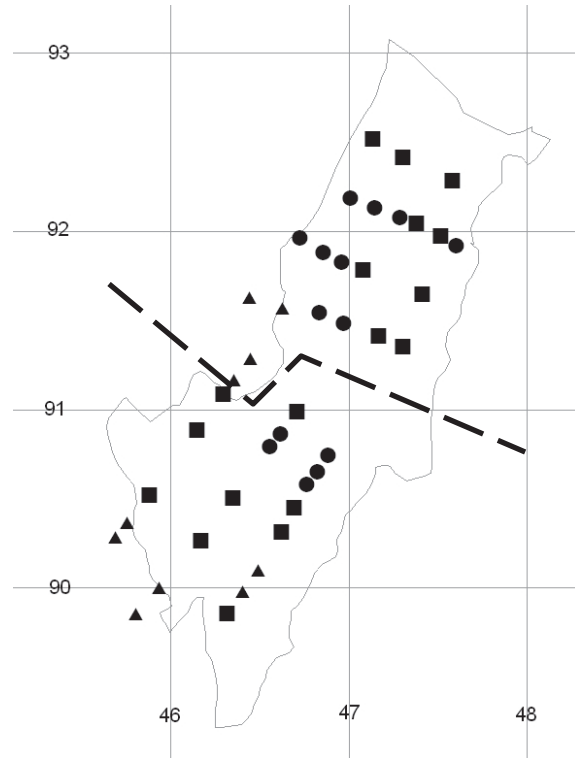
e) Loch Skerrow

Unique ID	Habitat type	Grid reference	Unique ID	Habitat type	Grid reference
strA3	Fringe	NX6014768612	strH13	Moor	NX6038967027
strA7	Fringe	NX6015368403	strH16	Moor	NX6024067057
strA11	Fringe	NX6022068200	strB3	Post-thicket plantation	NX6012468140
strC13	Fringe	NX6098869596	strB6	Post-thicket plantation	NX5998068184
strD12	Fringe	NX6094869181	strB9	Post-thicket plantation	NX5985468251
strD15	Fringe	NX6079769192	strC9	Post-thicket plantation	NX6079269578
strE6	Fringe	NX6037768764	strE12	Post-thicket plantation	NX6007768718
strE10	Fringe	NX6017968735	strE14	Post-thicket plantation	NX5997468704
strF10	Fringe	NX5984668009	strE17	Post-thicket plantation	NX5983068680
strF15	Fringe	NX6006667889	strE20	Post-thicket plantation	NX5967668660
strG1	Fringe	NX5997967347	strF6	Post-thicket plantation	NX5966568087
strG5	Fringe	NX6017967333	strF8	Post-thicket plantation	NX5975968045
strH19	Fringe	NX6009567087	strH26	Post-thicket plantation	NX5975067156
strH21	Fringe	NX5999567107	strH29	Post-thicket plantation	NX5959867180
strH24	Fringe	NX5984767138	strH32	Post-thicket plantation	NX5945667220
strJ10	Fringe	NX5971867528	strJ1	Post-thicket plantation	NX5928567400
strJ15	Fringe	NX5996167587	strJ5	Post-thicket plantation	NX5948467468
strJ19	Fringe	NX6015867629	strJ8	Post-thicket plantation	NX5963067505
strD1	Moor	NX6148969076	strC1	Pre-thicket plantation	NX6039069528
strD4	Moor	NX6134169107	strC3	Pre-thicket plantation	NX6049169540
strD6	Moor	NX6124669132	strC5	Pre-thicket plantation	NX6058969554
strG10	Moor	NX6042867314	strC7	Pre-thicket plantation	NX6068769563
strG13	Moor	NX6057867302	strC11	Pre-thicket plantation	NX6088769593
strG16	Moor	NX6072867289	strD18	Pre-thicket plantation	NX6064969216
strH6	Moor	NX6073466957	strD20	Pre-thicket plantation	NX6054969227
strH9	Moor	NX6058466986	strD23	Pre-thicket plantation	NX6040569254

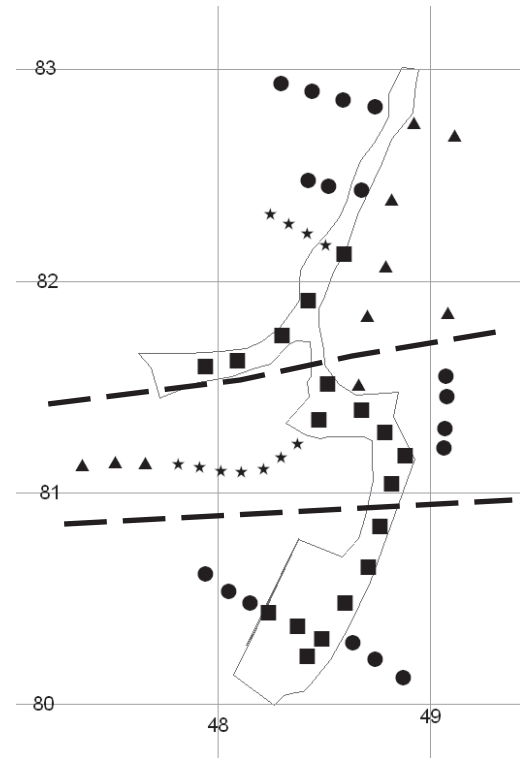
APPENDIX 3 – MAPS OF SAMPLING POINTS FOR BIRD SURVEYS

Squares represent points in fringe areas. Triangles represent points in open moorland. Stars represent points in pre-thicket plantations. Circles represent points in post-thicket plantations. The grid and associated numbers represents the 1-km grid lines Ordnance Survey's national grid and the shape outline represents the approximate boundaries of the areas managed for moorland fringe as indicated by maps provided by the Forestry Commission. The dashed lines show boundaries of sub-sites that were used in analyses to investigate the relationships between habitat variables and species abundance.

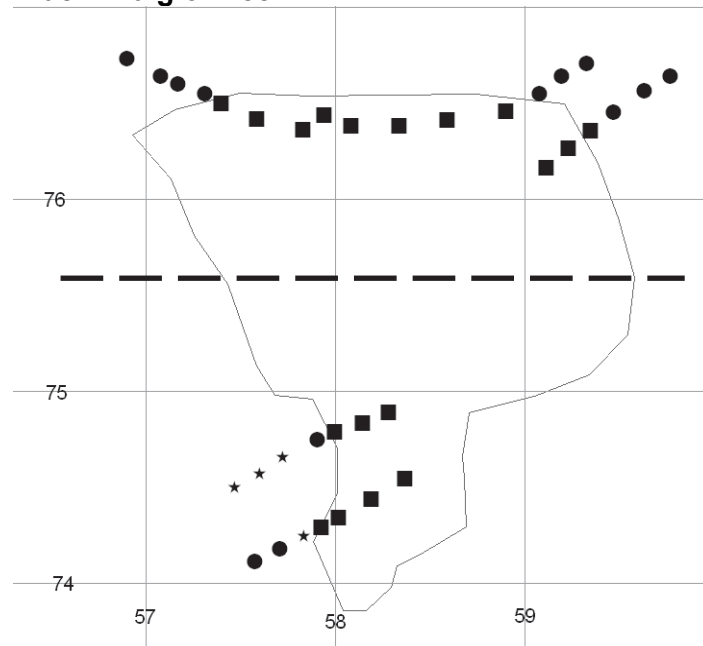
Gala Lane



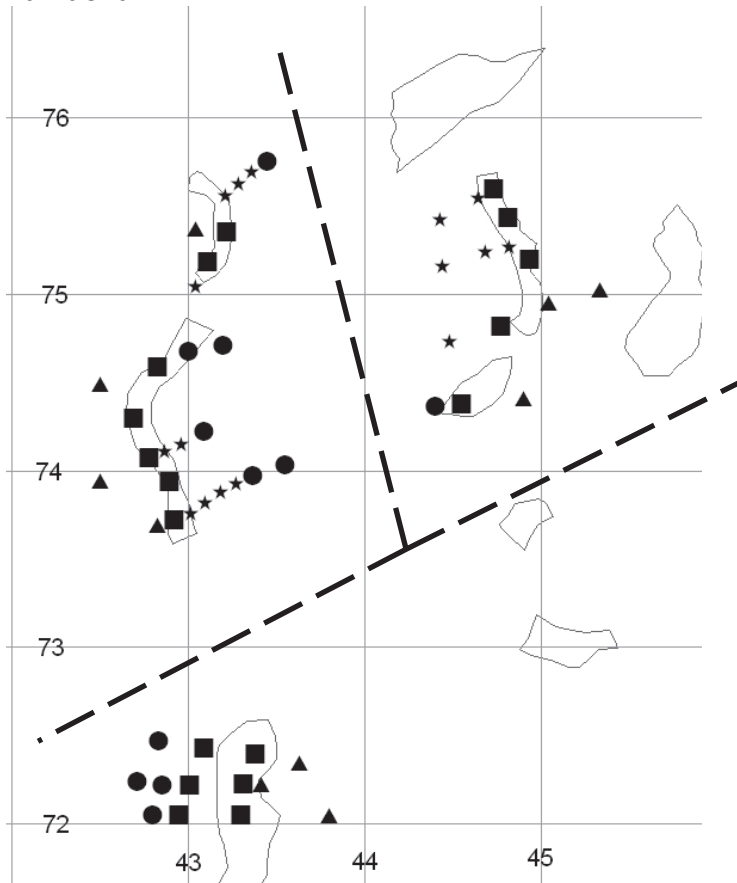
Loch Dee



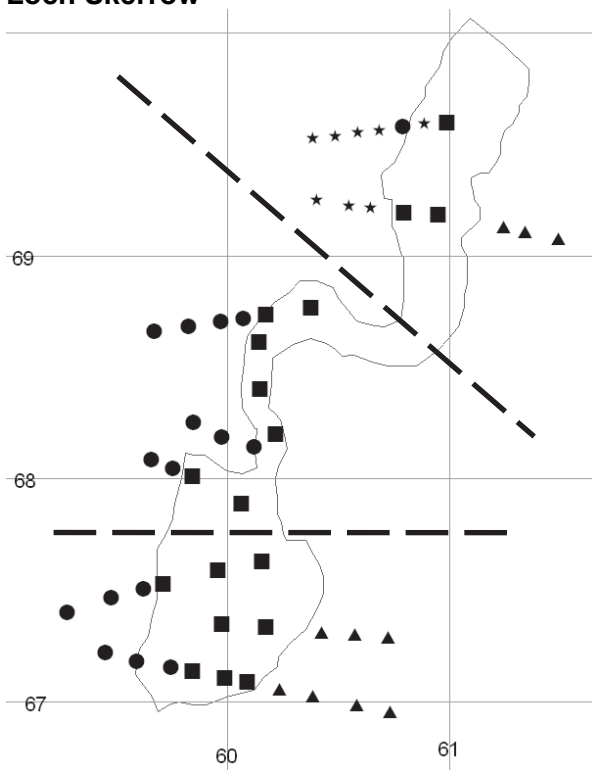
Black Craig of Dee



Lamachan



Loch Skerrow



APPENDIX 4 – OCCURRENCE RATES AND INDICES OF ABUNDANCE FOR EACH SPECIES RECORDED AT THE FIVE MAIN STUDY SITES WITHIN THE GALLOWAY FOREST PARK

Appendix 4a - Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) from Black Craig of Dee.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan	17.1	0.43	5.5	
(Red Grouse)				
Black Grouse	2.9	0.14	1.8	
Common Buzzard	5.7			
Great Spotted Woodpecker	5.7			
Meadow Pipit	8.6	0.43	5.5	
Winter Wren	54.3	3.43	43.6	63.9
Hedge Accentor	2.9			
European Robin	5.7	0.29	3.6	
Fieldfare	2.9			
Goldcrest	22.9	1.71	21.8	40.3*
Long-tailed Tit	2.9	0.57	7.3	
Coal Tit	28.6	0.57	7.3	
Blue Tit	2.9	0.14	1.8	
Carrion Crow	11.4			
Common Raven	22.9			
Common Crossbill	2.9	0.14	1.8	
Common Bullfinch	5.7	0.29	3.6	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4b - Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) from Black Craig of Dee.

Species		Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan		11.4	0.29	3.6	
(Red Grouse)					
Black Grouse		11.4	0.57	7.3	
Common Pheasant		2.9			
Common Buzzard		2.9			
Merlin		2.9	0.29	3.6	
Herring Gull		2.9			
Common Wood Pigeon		11.4	0.57	7.3	
Common Cuckoo		20.0			
Green Woodpecker		2.9			
Great Spotted Woodpecker		5.7	0.29	3.6	
Tree Pipit		20.0	1.71	7.3	
Meadow Pipit		60.0	24.86	87.3	156.0
Winter Wren		80.0	17.14	120.0	177.5
Hedge Accentor		20.0	2.00	18.2	
European Robin		54.3	9.71	76.4	127.6
Whinchat		2.9	0.29	3.6	
Stonechat		2.9	0.29	3.6	
Northern Wheatear		2.9	0.29		
Common Blackbird		11.4	0.86		
Song Thrush		42.9	1.71	18.2	
Mistle Thrush		11.4			
Common Grasshopper Warbler		14.3	1.14	10.9	
Blackcap		2.9	0.57	7.3	
Garden Warbler		14.3	1.14	14.5	
Willow Warbler		85.7	19.43	174.6	243.2
Goldcrest		34.3	7.43	50.9	147.8*
Coal Tit		31.4	7.14	32.7	
Great Tit		2.9	0.29		
Carrion Crow		20.0	0.29	3.6	
Common Raven		11.4			
Chaffinch		71.4	19.71	69.1	104.8
Eurasian Siskin		31.4	2.00		
Lesser Redpoll		14.3	0.86		
Common Crossbill		2.9			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4c - Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) from Gala Lane.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Eurasian Teal	2.4			
Hen Harrier	2.4			
Northern Goshawk	2.4			
Common Buzzard	7.1			
Eurasian Woodcock	2.4			
Great Spotted Woodpecker	7.1	0.12	1.5	
Meadow Pipit	2.4	0.12	1.5	
Bohemian Waxwing	2.4			
Winter Wren	40.5	2.74	34.9	51.2
Hedge Accentor	4.8	0.24	3.0	
European Robin	14.3	0.71	9.1	
Stonechat	2.4	0.12	1.5	
Goldcrest	21.4	2.86	36.4	101.1
Coal Tit	57.1	4.05	51.5	72.4
Blue Tit	7.1	0.60	7.6	
Great Tit	2.4	0.12	1.5	
Eurasian Treecreeper	2.4	0.12	1.5	
Carrion Crow	9.5			
Common Raven	28.6			
Chaffinch	2.4	0.12	1.5	
European Goldfinch	2.4			
Common Bullfinch	2.4	0.12	1.5	
Reed Bunting	4.8	0.12	1.5	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4d - Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) from Gala Lane.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Black Grouse	7.1			
Common Buzzard	9.5			
Common Snipe	7.1			
Common Cuckoo	26.2			
Sky lark	2.4			
Tree Pipit	14.3	1.67		
Meadow Pipit	78.6	23.33	175.8	267.9
Winter Wren	54.8	4.52	42.4	62.2*
Hedge Accentor	2.4	0.48	6.1	
European Robin	78.6	11.67	94.0	138.3
Whinchat	2.4			
Northern Wheatear	4.8	0.24	3.0	
Common Blackbird	31.0	2.38	12.1	
Song Thrush	28.6	0.48	3.0	3.2*
Mistle Thrush	2.4			
Common	2.4			
Grasshopper Warbler				
Willow Warbler	95.2	16.90	118.2	164.8
Goldcrest	14.3	1.90	6.1	
Coal Tit	26.2	3.81	15.2	
Great Tit	2.4	0.24	3.0	
Carrion Crow	4.8			
Common Raven	7.1			
Chaffinch	95.2	24.05	133.4	193.6
Eurasian Siskin	11.9	0.71		
Lesser Redpoll	9.5	0.24	3.0	
Reed Bunting	2.4	0.24	3.0	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4e - Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) from Lamachan.

Species		Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan		7.3			
(Red Grouse)					
Black Grouse		5.5	0.27	3.5	
Common Buzzard		3.6			
Common Kestrel		5.5	0.09	1.2	
Common Snipe		3.6	0.36	4.6	
Great Spotted Woodpecker		1.8			
Meadow Pipit		12.7	0.64	8.1	
Winter Wren		54.5	4.09	52.1	83.4
Hedge Accentor		16.4	0.82	10.4	15.9*
European Robin		7.3	0.45	5.8	
Stonechat		3.6	0.27	3.5	
Goldcrest		5.5	0.45	5.8	
Coal Tit		9.1	0.36	4.6	
Carrion Crow		14.5			
Common Raven		20.0			
European Goldfinch		3.6	0.09	1.2	
Lesser Redpoll		23.6	0.18	2.3	
Common Bullfinch		5.5	0.18	2.3	
Reed Bunting		3.6	0.09	1.2	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4f - Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) from Lamachan.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan (Red Grouse)	1.8			
Black Grouse	5.5			
Common Pheasant	3.6			
Common Buzzard	1.8			
Common Kestrel	1.8			
Common Wood Pigeon	3.6	0.18	2.3	
Common Cuckoo	27.3			
Sky lark	14.5	1.64	11.6	
Barn Swallow	1.8			
Tree Pipit	10.9	1.09	9.3	
Meadow Pipit	81.8	20.36	152.8	214.0
White/Pied Wagtail	1.8	0.18		
Winter Wren	89.1	21.82	122.7	172.3
Hedge Accentor	7.3	0.73		
European Robin	27.3	3.64	30.1	46.9*
Whinchat	1.8	0.18	2.3	
Stonechat	9.1	0.73	6.9	
Common Blackbird	18.2	1.09	6.9	
Song Thrush	18.2	0.91	2.3	
Common Grasshopper Warbler	1.8			
Common Whitethroat	3.6	0.18	2.3	
Willow Warbler	67.3	17.45	71.8	101.8
Goldcrest	1.8	0.36	2.3	
Coal Tit	1.8	0.36	4.6	
Eurasian Jay	1.8	0.18		
Carrion Crow	10.9			
Common Raven	5.5			
Chaffinch	47.3	8.00	67.1	93.1
Eurasian Siskin	10.9	1.45	13.9	18.6*
Lesser Redpoll	23.6	1.82	20.8	29.7*
Common Crossbill	1.8			

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4g - Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) from Loch Dee.

Species		Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan	(Red Grouse)	8.9	0.18	2.3	
Golden Eagle		1.8			
Meadow Pipit		3.6	0.27	3.4	
Winter Wren		37.5	2.68	34.1	61.3
Hedge Accentor		1.8	0.09	1.1	
European Robin		1.8	0.18	2.3	
Goldcrest		17.9	1.61	20.5	36.2*
Coal Tit		32.1	0.89	11.4	14.9*
Carrion Crow		3.6			
Common Raven		17.9			
Eurasian Siskin		3.6			
Lesser Redpoll		3.6			
Reed Bunting		3.6	0.09	1.1	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4f - Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) from Loch Dee.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Willow Ptarmigan (Red Grouse)	1.8			
Common Buzzard	7.1			
Golden Eagle	1.8			
Common Wood Pigeon	1.8			
Common Cuckoo	8.9			
Sky lark	1.8			
Tree Pipit	3.6	0.36	2.3	
Meadow Pipit	51.8	11.61	75.0	107.1
Winter Wren	60.7	12.50	72.7	113.0
Hedge Accentor	1.8	0.18		
European Robin	46.4	6.43	40.9	60.1
Stonechat	3.6	0.18	2.3	
Common Blackbird	7.1	0.54	4.5	
Song Thrush	7.1	0.36	2.3	
Common Grasshopper Warbler	3.6	0.36	4.5	
Common Chiffchaff	1.8	0.18	2.3	
Willow Warbler	35.7	3.04	29.6	39.7*
Goldcrest	35.7	4.82	13.6	
Spotted Flycatcher	1.8	0.18	2.3	
Coal Tit	23.2	3.39	13.6	
Great Tit	1.8	0.18		
Common Raven	5.4			
Chaffinch	85.7	17.14	127.3	173.2
Eurasian Siskin	35.7	0.71		
Lesser Redpoll	3.6			
Common Crossbill	7.1	0.18		

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4h - Occurrence rates and indices of abundance of birds recorded during winter surveys (November 2008 – January 2009) from Loch Skerrow.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Hen Harrier	1.9			
Eurasian Sparrowhawk	1.9	0.10	1.2	
Common Buzzard	1.9			
Eurasian Woodcock	3.8	0.19	2.4	
Common Wood Pigeon	1.9			
Great Spotted Woodpecker	13.5	0.10	1.2	
Meadow Pipit	3.8	0.38	4.9	
Winter Wren	73.1	7.60	96.7	147.4
Hedge Accentor	15.4	0.77	9.8	13.6*
European Robin	9.6	0.48	6.1	
Goldcrest	34.6	3.65	46.5	75.6
Long-tailed Tit	5.8	1.15	14.7	25.5*
Coal Tit	38.5	1.35	17.1	21.4
Eurasian Treecreeper	3.8	0.10	1.2	
Carrion Crow	13.5			
Common Raven	11.5			
Chaffinch	7.7	0.19	2.4	
Lesser Redpoll	3.8			
Common Crossbill	1.9			
Common Bullfinch	9.6	0.29	3.7	
Reed Bunting	19.2	0.38	4.9	

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

Appendix 4f - Occurrence rates and indices of abundance of birds recorded during breeding season surveys (April – June 2009) from Loch Skerrow.

Species	Occurrence rate ¹	Abundance index ²	Simple bird density ³	Site level density ⁴
Black Grouse	3.8			
Grey Heron	1.9			
Common Buzzard	1.9			
Golden Eagle	1.9			
Common Wood Pigeon	26.9	1.73	22.0	33.6*
Common Cuckoo	42.3	0.19	2.4	2.8*
European Nightjar	1.9			
Great Spotted Woodpecker	9.6	0.96		
Sky lark	1.9			
Barn Swallow	5.8			
Tree Pipit	13.5	0.77	7.3	
Meadow Pipit	44.2	4.42	22.0	28.8*
White/Pied Wagtail	1.9			
Winter Wren	80.8	14.42	117.5	198.4
Hedge Accentor	7.7	0.77	7.3	
European Robin	48.1	7.88	46.5	75.6
Stonechat	3.8	0.58		
Common Blackbird	19.2	0.96		
Song Thrush	30.8	0.77	4.9	
Mistle Thrush	1.9	0.19	2.4	
Common Grasshopper Warbler	21.2	1.54	17.1	22.1*
Garden Warbler	5.8	0.19	2.4	
Common Whitethroat	36.5	4.62	56.3	79.7
Willow Warbler	63.5	12.69	124.9	193.7
Goldcrest	30.8	7.50	41.6	127.4*
Spotted Flycatcher	1.9			
Coal Tit	40.4	6.73	36.7	64.4*
Blue Tit	1.9	0.19	2.4	
Carrion Crow	11.5			
Chaffinch	73.1	23.85	78.3	125.1
Eurasian Siskin	30.8	2.31	4.9	
Lesser Redpoll	26.9	1.54	19.6	28.0
Common Crossbill	17.3	1.15		
Reed Bunting	7.7	0.38		

¹ The percentage of points from which the species was recorded.

² The mean number of individuals recorded within 50 m of ten survey points.

³ A summing of all individuals of a species recorded within 50 m of a count point divided by the area sampled within that distance band.

⁴ Estimated density of birds assuming a common detection function. An asterisk denotes species for which the number of qualifying registrations is between 10 – 19 inclusive, otherwise estimates are only given for species where the number of qualifying registrations is 20 or more.

APPENDIX 5 – STATISTICAL OUTPUTS FOR MODELS INVESTIGATING THE RELATIONSHIPS BETWEEN HABITAT VARIABLES AND SPECIES RICHNESS AND SPECIES-SPECIFIC ABUNDANCE INDICES WITHIN ‘OPEN HABITATS’ (I.E. THICKET AND PRE-THICKET PLANTATIONS, FRINGE AND OPEN MOORLAND).

Appendix 5.1. The statistical output from the model that investigated the relationship between species richness and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-2.53025	2.92886	0.746329	0.387641
Ericaceous cover	1	1.746106	1.053923	2.744877	0.097567
Grass cover	1	1.806728	0.857288	4.441523	0.035075
Shrub cover	1	3.255111	1.397248	5.427314	0.019824
Tree cover	1	-0.20656	0.610553	0.114456	0.735127
Altitude	1	-0.00212	0.001916	1.218962	0.269564
Brash depth	1	1.147809	0.699723	2.690835	0.100927
Number of shrub species	1	0.428716	0.417055	1.056703	0.303968
Number of Tree species	1	-1.36856	1.031054	1.761834	0.184396

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.744139	0.388338
Ericaceous cover	1	2.796107	0.094493
Grass cover	1	4.570013	0.032536
Shrub cover	1	5.684279	0.017118
Tree cover	1	0.114658	0.734902
Altitude	1	1.21213	0.270911
Brash depth	1	2.700427	0.100321
Number of shrub species	1	1.043146	0.307091
Number of Tree species	1	1.726022	0.18892

Appendix 5.2. The statistical output from the model that investigated the relationship between species richness and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	1.338505	2.401986	0.310527	0.577357
Ericaceous cover	1	0.531857	0.787869	0.455704	0.499639
Grass cover	1	0.887672	0.670667	1.751826	0.185647
Shrub cover	1	0.169032	1.028377	0.027017	0.869441
Tree cover	1	-0.63214	0.512794	1.519618	0.217677
Altitude	1	-0.0003	0.001575	0.036275	0.848948
Brash depth	1	-0.11035	0.552897	0.039832	0.841809
Number of shrub species	1	-0.17212	0.326978	0.27711	0.598602
Number of Tree species	1	1.047702	0.853832	1.505672	0.219801

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.312087	0.576402
Ericaceous cover	1	0.458354	0.498394
Grass cover	1	1.765694	0.183916
Shrub cover	1	0.02706	0.869339
Tree cover	1	1.537465	0.214996
Altitude	1	0.036241	0.849018
Brash depth	1	0.039861	0.841753
Number of shrub species	1	0.279818	0.59682
Number of Tree species	1	1.54741	0.213518

Appendix 5.3. The statistical output from the model that investigated the relationship between species richness and habitat variables within open habitats in winter at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	0.138936	0.564343	122	0.246192	0.805948
Brash cover	1	0.202725	0.546775	122	0.370765	0.711456
Brash cover	2	0.223388	0.543001	122	0.411396	0.681504
Brash cover	3	0				
Ericaceous cover	0	0.559831	0.334264	122	1.674817	0.096532
Ericaceous cover	1	0.476832	0.332474	122	1.434193	0.154075
Ericaceous cover	2	0.352141	0.370334	122	0.950873	0.343549
Ericaceous cover	3	0				
Grass cover	0	0.32019	0.286205	122	1.118743	0.265448
Grass cover	1	0.176829	0.179323	122	0.986088	0.326042
Grass cover	2	0.018557	0.174857	122	0.106129	0.915654
Grass cover	3	0				
Shrub cover	0	0.158656	0.409637	122	0.38731	0.699202
Shrub cover	1	0.463952	0.364632	122	1.272385	0.205656
Shrub cover	2	0				
Altitude		-0.00292	0.000982	122	-2.97541	0.003528
Brash depth	0	0				
Brash depth	1	0.245656	0.224309	122	1.095169	0.2756
Brash depth	2	0.136874	0.205443	122	0.666237	0.506517
Brash depth	3	0				
Number of shrub spp		-0.03529	0.134934	122	-0.26154	0.794121
Number of tree spp		-0.0411	0.062724	122	-0.65531	0.5135

Likelihood ratio statistics for Type 3 analysis:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	122	0.085143	0.918436
Ericaceous cover	3	122	1.048595	0.373703
Grass cover	3	122	0.582712	0.627458

Shrub cover	2	122	1.43795 8	0.241407
Altitude	1	122	8.85308 3	0.003528
Brash depth	2	122	0.59983 5	0.550513
Number of shrub spp	1	122	0.06840 1	0.794121
Number of tree spp	1	122	0.42943 5	0.5135

Appendix 5.4. The statistical output from the model that investigated the relationship between species richness and habitat variables within open habitats in the breeding season at the sampling point level.

Analysis of parameter estimates

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-0.13049	0.33943	122	-0.38443	0.701329
Brash cover	1	0.014711	0.331889	122	0.044325	0.964718
Brash cover	2	-0.13152	0.334426	122	-0.39327	0.694807
Brash cover	3	0				
Ericaceous cover	0	0.296057	0.202141	122	1.464603	0.145601
Ericaceous cover	1	0.25747	0.200512	122	1.284065	0.201552
Ericaceous cover	2	0.397088	0.220772	122	1.798629	0.07455
Ericaceous cover	3	0				
Grass cover	0	0.121533	0.185883	122	0.653815	0.514461
Grass cover	1	0.039381	0.114749	122	0.343191	0.732045
Grass cover	2	-0.12505	0.111985	122	-1.11665	0.26634
Grass cover	3	0				
Shrub cover	0	-0.48381	0.221839	122	-2.18092	0.031107
Shrub cover	1	-0.14081	0.189198	122	-0.74426	0.458151
Shrub cover	2	0				
Altitude	0	-0.00185	0.000605	122	-3.06371	0.002691
Brash depth	0	0				
Brash depth	1	0.025389	0.142323	122	0.178392	0.858711
Brash depth	2	-0.0533	0.128048	122	-0.41628	0.677934
Brash depth	3	0				
Number of shrub spp.		-0.08555	0.083961	122	-1.01893	0.310253
Number of tree spp.		0.024128	0.038837	122	0.62125	0.535594

Likelihood ratio statistics for Type 3 analysis:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	122	0.560066	0.572633
Ericaceous cover	3	122	1.169151	0.324403
Grass cover	3	122	0.733239	0.534116
Shrub cover	2	122	3.282318	0.040882
Altitude	1	122	9.386315	0.002691
Brash depth	2	122	0.207053	0.813262
Number of shrub spp	1	122	1.038215	0.310253
Number of tree spp	1	122	0.385952	0.535594

Appendix 5.5. The statistical output from the model that investigated the relationship between the occurrence rate of winter wren and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-0.60138	1.213488	0.245602	0.620189
Ericaceous cover	1	0.540133	0.459476	1.381899	0.239778
Grass cover	1	-0.18667	0.405102	0.212335	0.644944
Shrub cover	1	2.365379	0.588626	16.14817	5.86E-05
Tree cover	1	-0.57115	0.262124	4.747766	0.029336
Altitude	1	-0.00285	0.000832	11.74819	0.000609
Brash depth	1	0.452887	0.298146	2.30739	0.12876
Number of shrub species	1	0.677375	0.179992	14.16294	0.000168
Number of Tree species	1	-1.01506	0.421895	5.788653	0.01613

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.245281	0.620417
Ericaceous cover	1	1.390811	0.238268
Grass cover	1	0.212538	0.644785
Shrub cover	1	16.66036	4.47E-05
Tree cover	1	4.76681	0.029014
Altitude	1	11.72043	0.000618
Brash depth	1	2.310992	0.128462
Number of shrub species	1	14.00713	0.000182
Number of Tree species	1	5.687049	0.017091

Appendix 5.6. The statistical output from the model that investigated the relationship between the abundance index of winter wren and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-2.07252	2.761846	0.563119	0.453006
Ericaceous cover	1	0.815828	1.129945	0.521293	0.470291
Grass cover	1	1.363675	0.893441	2.329646	0.126931
Shrub cover	1	4.279721	1.558271	7.543012	0.006024
Tree cover	1	-0.14427	0.61333	0.055331	0.814034
Altitude	1	-0.00514	0.001827	7.909689	0.004917
Brash depth	1	1.579577	0.705158	5.017745	0.025089
Number of shrub species	1	0.351935	0.466023	0.570308	0.450137
Number of Tree species	1	-1.17766	1.04044	1.281171	0.257681

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.559461	0.454477
Ericaceous cover	1	0.51875	0.471375
Grass cover	1	2.360478	0.124444
Shrub cover	1	8.611483	0.003341
Tree cover	1	0.05539	0.813937
Altitude	1	7.95281	0.004801
Brash depth	1	5.176404	0.022896
Number of shrub species	1	0.564438	0.452478
Number of Tree species	1	1.265599	0.260594

Appendix 5.7. The statistical output from the model that investigated the relationship between the abundance index of winter wren and habitat variables within open habitats in winter at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-	0.59175	191	-	0.144979
		0.86602			1.46348	
Brash cover	1	-0.5861	0.57085	191	-	0.305857
			5		1.02671	
Brash cover	2	-	0.56758	191	-	0.80074
		0.14345	9		0.25274	
Brash cover	3	0				
Ericaceous cover	0	-	0.39027	191	-	0.272822
		0.42921	5		1.09976	
Ericaceous cover	1	-	0.38705	191	-	0.288823
		0.41169	3		1.06367	
Ericaceous cover	2	-	0.40597	191	-	0.693685
		0.16014			0.39446	
Ericaceous cover	3	0				
Grass cover	0	-	0.30172	191	-	0.015947
		0.73372			2.43179	
Grass cover	1	-	0.21487	191	-	0.161151
		0.30226	3		1.40667	
Grass cover	2	-0.0009	0.21919	191	-0.0041	0.996731
			4			
Grass cover	3	0				
Shrub cover	0	-	0.39426	191	-	0.024414
		0.89441	3		2.26855	
Shrub cover	1	-	0.33435	191	-1.7835	0.076093
		0.59633	8			
Shrub cover	2	0				
Altitude		-	0.00114	191	-	1.32E-06
		0.00573	7		4.99614	
Brash depth	0					
Brash depth	1	0.40447	0.27873	191	1.45110	0.148391
		6	7		5	
Brash depth	2	0.31888	0.25799	191	1.23601	0.21797
		1			9	
Brash depth	3	0				
Number of shrub spp.		-	0.15546	191	-	0.464001
		0.11407	1		0.73375	
Number of tree spp.		0.20593	0.09180	191	2.24311	0.026039
			6		1	

Likelihood ratio statistics for Type 3 analyses:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	191	2.11837	0.123043
			8	
Ericaceous cover	3	191	0.59097	0.621625
			8	
Grass cover	3	191	2.40253	0.068981

			6	
Shrub cover	2	191	2.59361	0.07738
			9	
Altitude	1	191	24.9614	1.32E-06
Brash depth	2	191	1.12664	0.326263
			6	
Number of shrub spp	1	191	0.53839	0.464001
Number of tree spp	1	191	5.03154	0.026039
			6	

Appendix 5.8. The statistical output from the model that investigated the relationship between the occurrence rate of coal tit and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-6.87156	2.853598	5.798622	0.016039
Ericaceous cover	1	-1.51311	0.756933	3.995998	0.045608
Grass cover	1	-2.01896	0.660892	9.332443	0.002251
Shrub cover	1	-2.83092	1.121547	6.371172	0.011599
Tree cover	1	0.243197	0.586671	0.171842	0.67848
Altitude	1	-0.00813	0.002414	11.34374	0.000757
Brash depth	1	0.361071	0.610063	0.350296	0.553946
Number of shrub spp	1	0.384073	0.259676	2.187582	0.139128
Number of tree spp	1	-1.86609	1.156611	2.603107	0.106654

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	5.884186	0.015277
Ericaceous cover	1	3.916845	0.047805
Grass cover	1	9.56728	0.001981
Shrub cover	1	6.339035	0.011811
Tree cover	1	0.170772	0.679427
Altitude	1	12.38452	0.000433
Brash depth	1	0.35275	0.552561
Number of shrub spp	1	2.200031	0.138008
Number of tree spp	1	2.633791	0.104612

Appendix 5.9. The statistical output from the model that investigated the relationship between the occurrence rate of raven and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	2.078005	2.364557	0.772313	0.379502
Ericaceous cover	1	-0.1029	0.72318	0.020244	0.886858
Grass cover	1	0.996011	0.570473	3.04831	0.080821
Shrub cover	1	-1.71329	0.97919	3.061456	0.08017
Tree cover	1	-0.76239	0.469903	2.632302	0.10471
Altitude	1	0.003089	0.001663	3.450001	0.063252
Brash depth	1	-0.30603	0.532055	0.330843	0.565163
Number of shrub spp	1	0.34788	0.267427	1.692188	0.193313
Number of tree spp	1	1.014207	0.78102	1.686277	0.194092

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.774363	0.378871
Ericaceous cover	1	0.02023	0.886897
Grass cover	1	3.08679	0.07893
Shrub cover	1	3.054731	0.080502
Tree cover	1	2.683494	0.101393
Altitude	1	3.500031	0.061368
Brash depth	1	0.331384	0.564845
Number of shrub spp	1	1.677533	0.195253
Number of tree spp	1	1.727359	0.188749

Appendix 5.10. The statistical output from the model that investigated the relationship between the occurrence rate of hedge accentor and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	52.61202	14.00897	14.1045	0.000173
Ericaceous cover	1	14.82845	4.516874	10.77744	0.001027
Grass cover	1	17.67981	6.174653	8.198421	0.004193
Shrub cover	1	36.38898	10.60225	11.77995	0.000599
Tree cover	1	-21.0977	6.108544	11.92875	0.000553

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	16.46313	4.96E-05
Ericaceous cover	1	13.24891	0.000273
Grass cover	1	9.12168	0.002526
Shrub cover	1	14.03284	0.00018
Tree cover	1	13.6679	0.000218

Appendix 5.11. The statistical output from the model that investigated the relationship between the abundance index of hedge accentor and habitat variables within open habitats in winter at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-	1.44440	191	-	0.094758
		2.42538	7		1.67915	
Brash cover	1	-0.1876	1.32453	191	-	0.887515
			4		0.14164	
Brash cover	2	0.37960	1.27038	191	0.29881	0.76541
		5	8			
Brash cover	3	0				
Ericaceous cover	0	-	1.75790	191	-	0.281532
		1.89843	4		1.07994	
Ericaceous cover	1	-	1.78432	191	-	0.172258
		2.44473			1.37012	
Ericaceous cover	2	-	1.78863	191	-	0.357723
		1.64902	9		0.92194	
Ericaceous cover	3	0				
Grass cover	0	-	0.92117	191	-	0.807481
		0.22478	8		0.24402	
Grass cover	1	-	0.64154	191	-	0.928086
		0.05798	2		0.09037	
Grass cover	2	-	0.87809	191	-	0.173423
		1.19981	1		1.36639	
Grass cover	3	0				
Shrub cover	0	-	1.90209	191	-	0.061949
		3.57153	4		1.87768	
Shrub cover	1	-	1.15821	191	-1.7022	0.090345
		1.97151	6			
Shrub cover	2	0				
Tree Score		0.01770	0.18013	191	0.09827	0.921814
		3	6		9	
Altitude		-	0.00472	191	-	0.425427
		0.00378	8		0.79875	
Brash depth	0	0				
Brash depth	1	0.08548	0.77807	191	0.10986	0.912633
		3	6		4	
Brash depth	2	-	0.64633	191	-1.1212	0.263611
		0.72467	9			
Brash depth	3	0				
Number of shrub spp		-	1.51137	191	-	0.266783
		1.68331	8		1.11376	
Number of tree spp		-	0.41775	191	-	0.17862
		0.56395			1.34998	

Likelihood ratio statistics for Type 3 analyses:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	191	0.458484	0.632935
Ericaceous cover	3	191	0.834057	0.476664
Grass cover	3	191	0.777138	0.508063

Shrub cover	2	191	2.271444	0.105943
Tree score	1	191	0.009659	0.921814
Altitude	1	191	0.638003	0.425427
Brash depth	2	191	0.906343	0.405729
Number of shrub spp	1	191	1.240455	0.266783
Number of tree spp	1	191	1.822446	0.17862

Appendix 5.12. The statistical output from the model that investigated the relationship between the occurrence rate of red grouse and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-5.01999	2.122985	5.591298	0.01805
Ericaceous cover	1	-0.74065	0.774105	0.915423	0.33868
Grass cover	1	-1.15549	1.883963	0.376175	0.539658
Shrub cover	1	6.372628	3.332585	3.656576	0.055848
Tree cover	1	-5.23373	2.551715	4.206863	0.040261

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	5.533108	0.01866
Ericaceous cover	1	0.934816	0.333615
Grass cover	1	0.385947	0.534437
Shrub cover	1	3.622007	0.05702
Tree cover	1	4.135571	0.041991

Appendix 5.13. The statistical output from the model that investigated the relationship between the occurrence rate of reed bunting and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-0.86529	1.343532	0.414788	0.519549
Ericaceous cover	1	-6.12381	3.053386	4.022344	0.044901
Grass cover	1	0.523684	1.326552	0.155844	0.693012
Shrub cover	1	8.331717	1.840072	20.50215	5.96E-06
Tree cover	1	0.808976	0.676916	1.428242	0.232052

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.417306	0.518284
Ericaceous cover	1	4.090254	0.043131
Grass cover	1	0.156653	0.692257
Shrub cover	1	22.87956	1.72E-06
Tree cover	1	1.490505	0.222138

Appendix 5.14. The statistical output from the model that investigated the relationship between the occurrence rate of goldcrest and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-4.71513	2.230084	4.470379	0.034487
Ericaceous cover	1	2.01176	2.149443	0.875992	0.349302
Grass cover	1	-2.71362	0.949088	8.174958	0.004247
Shrub cover	1	-1.50199	1.15077	1.703566	0.191822
Tree cover	1	0.438836	0.648556	0.457835	0.498638

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	4.387549	0.036202
Ericaceous cover	1	0.871747	0.350472
Grass cover	1	8.708042	0.003168
Shrub cover	1	1.764244	0.184096
Tree cover	1	0.451231	0.501751

Appendix 5.15. The statistical output from the model that investigated the relationship between the occurrence rate of meadow pipit and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-10.7226	6.352207	2.849366	0.09141
Ericaceous cover	1	0.787424	1.294003	0.370294	0.542844
Grass cover	1	-9.09156	2.295101	15.69181	7.45E-05
Shrub cover	1	-6.29739	2.708968	5.403972	0.020091
Tree cover	1	8.012475	2.13705	14.05737	0.000177
Altitude	1	0.001064	0.002207	0.232323	0.629807
Brash depth	1	2.475623	1.229826	4.05211	0.044116

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	2.930644	0.086913
Ericaceous cover	1	0.371734	0.542061
Grass cover	1	15.43862	8.52E-05
Shrub cover	1	5.488475	0.019142
Tree cover	1	15.8439	6.88E-05
Altitude	1	0.234096	0.628503
Brash depth	1	4.280508	0.038552

Appendix 5.16. The statistical output from the model that investigated the relationship between the abundance index of meadow pipit and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-1.95773	15.52943	0.015893	0.89968
Ericaceous cover	1	1.906379	2.717762	0.492035	0.483021
Grass cover	1	-0.78804	5.966828	0.017443	0.894929
Shrub cover	1	2.929865	6.726972	0.189695	0.663171
Tree cover	1	-0.3839	4.745493	0.006545	0.935522
Altitude	1	-0.00322	0.00464	0.482931	0.487098
Brash depth	1	2.273911	2.649817	0.736402	0.390816

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.015663	0.900404
Ericaceous cover	1	0.494452	0.481948
Grass cover	1	0.017162	0.895771
Shrub cover	1	0.192119	0.661159
Tree cover	1	0.006549	0.935502
Altitude	1	0.489379	0.484205
Brash depth	1	0.736912	0.390652

Appendix 5.17. The statistical output from the model that investigated the relationship between the occurrence rate of lesser redpoll and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-14.3543	9.48121	2.292107	0.130033
Ericaceous cover	1	9.494366	2.479726	14.65969	0.000129
Grass cover	1	-8.17537	3.580536	5.213373	0.022414
Shrub cover	1	-21.3519	8.263278	6.676821	0.009767
Tree cover	1	3.591786	4.003851	0.804758	0.369675

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	2.230151	0.135341
Ericaceous cover	1	15.7883	7.08E-05
Grass cover	1	5.121674	0.023629
Shrub cover	1	6.937559	0.00844
Tree cover	1	0.801539	0.370634

Appendix 5.18. The statistical output from the model that investigated the relationship between the occurrence rate of bullfinch and habitat variables within open habitats in winter at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-1.75734	2.476021	0.503736	0.477863
Ericaceous cover	1	1.096458	4.710009	0.054193	0.815922
Grass cover	1	-1.90226	1.93625	0.965195	0.325882
Shrub cover	1	2.328748	1.519101	2.350022	0.125281
Tree cover	1	-0.34286	0.892853	0.147459	0.700976

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	0.514514	0.473191
Ericaceous cover	1	0.054039	0.816179
Grass cover	1	0.984531	0.321083
Shrub cover	1	2.521003	0.112339
Tree cover	1	0.146119	0.702272

Appendix 5.19. The statistical output from the model that investigated the relationship between the occurrence rate of chaffinch and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-2.86179	1.495757	3.660602	0.055714
Ericaceous cover	1	-0.47328	0.416737	1.28977	0.25609
Grass cover	1	-0.29278	0.35771	0.669901	0.413086
Shrub cover	1	-3.84801	0.579501	44.09235	3.13E-11
Tree cover	1	-1.47165	0.307298	22.93452	1.68E-06
Altitude	1	-0.00194	0.001112	3.034175	0.081528
Brash depth	1	0.053297	0.320921	0.027581	0.868098
Number of shrub spp	1	-0.22816	0.156879	2.115244	0.145839
Number of tree spp	1	1.935212	0.513043	14.2282	0.000162

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	3.66333	0.055622
Ericaceous cover	1	1.283718	0.257209
Grass cover	1	0.669109	0.413362
Shrub cover	1	44.3595	2.73E-11
Tree cover	1	24.60858	7.02E-07
Altitude	1	3.080801	0.079222
Brash depth	1	0.027588	0.86808

Number of shrub spp	1	2.12534	0.144881
Number of tree spp	1	15.03868	0.000105

Appendix 5.20. The statistical output from the model that investigated the relationship between the abundance indices of chaffinch and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	10.46504	4.348118	5.792677	0.016093
Ericaceous cover	1	-4.1973	1.249378	11.28635	0.000781
Grass cover	1	2.09078	0.892851	5.483507	0.019197
Shrub cover	1	-5.18763	1.819228	8.131371	0.004351
Tree cover	1	-2.77285	0.986012	7.9084	0.004921
Altitude	1	0.01084	0.003418	10.05816	0.001517
Brash depth	1	-1.87992	0.882981	4.532909	0.033249
Number of shrub spp	1	0.552869	0.391542	1.993824	0.157942
Number of tree spp	1	4.87643	1.539803	10.02937	0.001541

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Brash cover	1	2.083442	0.148904
Ericaceous cover	1	1.98133	0.15925
Grass cover	1	0.783958	0.375933
Shrub cover	1	4.021253	0.04493
Tree cover	1	21.57771	3.4E-06
Altitude	1	0.73228	0.392145
Brash depth	1	2.367031	0.123923
Number of shrub spp	1	2.953491	0.085692
Number of tree spp	1	4.06108	0.043882

Appendix 5.21. The statistical output from the model that investigated the relationship between the abundance indices of chaffinch and habitat variables within open habitats in the breeding season at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-0.62779	0.768843	191	-0.81654	0.415206
Brash cover	1	-0.09687	0.768564	191	-0.12604	0.899832
Brash cover	2	-0.15773	0.792041	191	-0.19914	0.842363
Brash cover	3	0				
Ericaceous cover	0	1.220896	0.713741	191	1.710559	0.088786
Ericaceous cover	1	0.71501	0.716862	191	0.997416	0.319824
Ericaceous cover	2	0.862277	0.754459	191	1.142908	0.254507
Ericaceous cover	3	0				
Grass cover	0	0.612967	0.248453	191	2.467131	0.014501
Grass cover	1	0.211846	0.229965	191	0.921211	0.358102
Grass cover	2	-0.46884	0.292781	191	-1.60133	0.110956
Grass cover	3	0				
Shrub cover	0	0.107904	0.646548	191	0.166893	0.867631
Shrub cover	1	0.336022	0.577374	191	0.581983	0.561264
Shrub cover	2	0				
Tree cover	0	-0.25009	0.197677	191	-1.26514	0.207364
Tree cover	4	0				
Altitude		-0.00194	0.001954	191	-0.99513	0.320934
Brash depth	0	0				
Brash depth	1	-0.14902	0.298869	191	-0.49862	0.61862
Brash depth	2	-0.36535	0.285466	191	-1.27984	0.202155
Brash depth	3	0				
Number of shrub spp		0.130539	0.244982	191	0.532853	0.594755
Number of tree spp		-0.09538	0.116159	191	-0.82116	0.41258

Likelihood ratio statistics for Type 3 analyses:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	191	0.033551	0.967011
Ericaceous cover	3	191	2.660237	0.049463
Grass cover	3	191	4.482701	0.004573
Shrub cover	2	191	0.31177	0.732522
Tree cover	1	191	1.600568	0.207364
Altitude	1	191	0.990277	0.320934
Brash depth	2	191	0.818993	0.442418
Number of shrub spp	1	191	0.283932	0.594755
Number of tree spp	1	191	0.6743	0.41258

Appendix 5.22. The statistical output from the model that investigated the relationship between the occurrence rate of winter wren and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-3.21987	0.969649	11.02677	0.000898
Ericaceous cover	1	1.599781	0.340154	22.11919	2.56E-06
Grass cover	1	-0.25203	0.292476	0.742561	0.388842
Shrub cover	1	1.222603	0.437555	7.807396	0.005203
Tree cover	1	-0.0775	0.200485	0.149432	0.699079
Altitude	1	-0.00238	0.000659	13.06014	0.000302
Brash depth	1	0.835909	0.229758	13.23663	0.000275
Number of shrub spp	1	0.224802	0.144684	2.41412	0.120246
Number of tree spp	1	-1.08842	0.314481	11.9785	0.000538

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	11.04564	0.000889
Ericaceous cover	1	22.58021	2.02E-06
Grass cover	1	0.742709	0.388795
Shrub cover	1	7.89058	0.004969
Tree cover	1	0.149385	0.699124
Altitude	1	12.9764	0.000315
Brash depth	1	13.28041	0.000268
Number of shrub spp	1	2.382314	0.122716
Number of tree spp	1	11.80225	0.000592

Appendix 5.23. The statistical output from the model that investigated the relationship between the abundance indices of winter wren and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-0.40923	2.511492	0.02655	0.870564
Ericaceous cover	1	1.559965	0.907325	2.955997	0.08556
Grass cover	1	0.277104	0.794127	0.12176	0.727133
Shrub cover	1	2.742743	1.16572	5.53582	0.018631
Tree cover	1	-0.81244	0.527858	2.368901	0.123774
Altitude	1	-0.00032	0.00162	0.040173	0.841143
Brash depth	1	0.750223	0.599943	1.563728	0.21112
Number of shrub spp	1	0.439563	0.392881	1.251755	0.263217
Number of tree spp	1	-0.60937	0.831053	0.53766	0.463404

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.026548	0.87057
Ericaceous cover	1	3.008151	0.082847

Grass cover	1	0.121696	0.727202
Shrub cover	1	5.711918	0.01685
Tree cover	1	2.365767	0.124023
Altitude	1	0.040085	0.841314
Brash depth	1	1.567878	0.210515
Number of shrub spp	1	1.217121	0.269926
Number of tree spp	1	0.532447	0.46558

Appendix 5.24. The statistical output from the model that investigated the relationship between the abundance indices of winter wren and habitat variables within open habitats in the breeding season at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-0.39475	0.77285	191	-0.51078	0.610098
Brash cover	1	0.210076	0.763538	191	0.275135	0.78351
Brash cover	2	0.268948	0.767901	191	0.350238	0.726546
Brash cover	3	0				
Ericaceous cover	0	-0.07488	0.4033	191	-0.18567	0.8529
Ericaceous cover	1	0.048067	0.394659	191	0.121793	0.903191
Ericaceous cover	2	-0.18865	0.421988	191	-0.44706	0.655338
Ericaceous cover	3	0				
Grass cover	0	0.003108	0.302927	191	0.010261	0.991824
Grass cover	1	0.407751	0.232186	191	1.756141	0.080667
Grass cover	2	-0.24941	0.277	191	-0.90041	0.369036
Grass cover	3	0				
Shrub cover	0	-0.48724	0.453028	191	-1.07552	0.283497
Shrub cover	1	-0.25336	0.391785	191	-0.64667	0.518622
Shrub cover	2	0				
Tree cover	0	-0.05797	0.228766	191	-0.25341	0.800222
Tree cover	4	0				
Altitude		-0.00046	0.001355	191	-0.33681	0.736633
Brash depth	0	0				
Brash depth	1	0.35835	0.296692	191	1.207816	0.228611
Brash depth	2	0.265342	0.280441	191	0.94616	0.345263
Brash depth	3	0				
Number of shrub spp		0.217608	0.171555	191	1.268441	0.206184
Number of tree spp		0.03627	0.082063	191	0.441974	0.659008

Likelihood ratio statistics for Type 3 analysis:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	191	0.074194	0.928518
Ericaceous cover	3	191	0.249113	0.8619
Grass cover	3	191	2.28678	0.08004
Shrub cover	2	191	0.593009	0.553676
Tree cover	1	191	0.064218	0.800222
Altitude	1	191	0.113439	0.736633
Brash depth	2	191	0.765522	0.466513
Number of shrub spp	1	191	1.608942	0.206184
Number of tree spp	1	191	0.195341	0.659008

Appendix 5.25. The statistical output from the model that investigated the relationship between the occurrence rate of willow warbler and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	2.078322	1.126164	3.405828	0.064966
Ericaceous cover	1	1.555079	0.384141	16.38788	5.16E-05
Grass cover	1	2.196104	0.313441	49.09023	2.44E-12
Shrub cover	1	0.986907	0.496412	3.95246	0.046803
Tree cover	1	-0.65652	0.236352	7.715732	0.005474
Altitude	1	0.001404	0.000747	3.534696	0.060097
Brash depth	1	-0.23782	0.266847	0.794257	0.372816
Number of shrub spp	1	0.870244	0.134145	42.08566	8.74E-11
Number of tree spp	1	-0.49353	0.404481	1.488766	0.222408

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	3.421022	0.064371
Ericaceous cover	1	16.87704	3.99E-05
Grass cover	1	50.96927	9.38E-13
Shrub cover	1	3.988415	0.045814
Tree cover	1	7.762106	0.005335
Altitude	1	3.558361	0.059246
Brash depth	1	0.795506	0.37244
Number of shrub spp	1	42.56843	6.83E-11
Number of tree spp	1	1.475689	0.22445

Appendix 5.26. The statistical output from the model that investigated the relationship between the abundance indices of willow warbler and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	8.299311	3.08701	7.22783	0.007178
Ericaceous cover	1	1.908444	1.009364	3.574896	0.058659
Grass cover	1	4.437569	0.848298	27.36488	1.68E-07
Shrub cover	1	1.99024	1.311515	2.302843	0.129137
Tree cover	1	-1.77641	0.674752	6.931016	0.008471
Altitude	1	0.003795	0.00174	4.754747	0.029218
Brash depth	1	-1.3598	0.710506	3.662832	0.055639
Number of shrub spp	1	0.883787	0.339543	6.774917	0.009245
Number of tree spp	1	1.407866	1.275889	1.21758	0.269836

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	7.837557	0.005117
Ericaceous cover	1	3.773083	0.052084
Grass cover	1	31.15405	2.38E-08

Shrub cover	1	2.369287	0.123744
Tree cover	1	7.350516	0.006704
Altitude	1	4.956474	0.025993
Brash depth	1	3.788966	0.051592
Number of shrub spp	1	7.071393	0.007832
Number of tree spp	1	1.25836	0.261962

Appendix 5.27. The statistical output from the model that investigated the relationship between the occurrence rate of meadow pipit and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	2.446963	1.167541	4.392491	0.036098
Ericaceous cover	1	0.726656	0.369221	3.873342	0.049059
Grass cover	1	1.983606	0.326898	36.82014	1.3E-09
Shrub cover	1	2.475951	0.521577	22.5345	2.06E-06
Tree cover	1	-0.36456	0.229173	2.530577	0.111659
Altitude	1	0.001862	0.000795	5.483135	0.019201
Brash depth	1	-0.40815	0.263081	2.406889	0.120802
Number of shrub spp	1	0.230256	0.145105	2.518032	0.112551
Number of tree spp	1	-1.10103	0.349838	9.905239	0.001648

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	4.412719	0.035672
Ericaceous cover	1	3.893007	0.048488
Grass cover	1	39.22709	3.77E-10
Shrub cover	1	23.22987	1.44E-06
Tree cover	1	2.536866	0.111215
Altitude	1	5.56032	0.018372
Brash depth	1	2.413516	0.120292
Number of shrub spp	1	2.489774	0.114588
Number of tree spp	1	9.753689	0.00179

Appendix 5.28. The statistical output from the model that investigated the relationship between the abundance indices of meadow pipit and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	22.1709	4.142035	28.65097	8.67E-08
Ericaceous cover	1	-0.25804	0.927234	0.077443	0.780793
Grass cover	1	6.224711	1.230707	25.58169	4.24E-07
Shrub cover	1	-2.76801	1.912176	2.095461	0.147737
Tree cover	1	-0.93006	0.706351	1.733715	0.187937
Altitude	1	0.015461	0.002541	37.02127	1.17E-09
Brash depth	1	-3.51544	0.790297	19.78692	8.66E-06
Number of shrub spp	1	-1.61423	0.514593	9.840122	0.001707
Number of tree spp	1	4.303376	0.844612	25.95995	3.49E-07

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	44.09564	3.13E-11
Ericaceous cover	1	0.077122	0.781236
Grass cover	1	61.83552	3.73E-15

Shrub cover	1	1.906713	0.167329
Tree cover	1	1.807121	0.178854
Altitude	1	48.25014	3.75E-12
Brash depth	1	26.38531	2.8E-07
Number of shrub spp	1	13.78088	0.000205
Number of tree spp	1	29.93069	4.48E-08

Appendix 5.29. The statistical output from the model that investigated the relationship between the occurrence rate of robin and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-9.09636	1.840853	24.41728	7.76E-07
Ericaceous cover	1	0.610981	0.427441	2.043158	0.152892
Grass cover	1	-0.97703	0.358483	7.428148	0.006421
Shrub cover	1	-2.3396	0.617655	14.34802	0.000152
Tree cover	1	-0.38485	0.29753	1.673117	0.195842
Altitude	1	-0.00683	0.00111	37.8696	7.56E-10
Brash depth	1	1.278619	0.374394	11.66338	0.000637
Number of shrub spp	1	0.60015	0.157037	14.60557	0.000133
Number of tree spp	1	-1.40312	0.443176	10.02384	0.001545

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	24.40437	7.81E-07
Ericaceous cover	1	2.067671	0.150451
Grass cover	1	7.44034	0.006378
Shrub cover	1	14.26056	0.000159
Tree cover	1	1.699263	0.192384
Altitude	1	41.79455	1.01E-10
Brash depth	1	11.97407	0.000539
Number of shrub spp	1	14.78057	0.000121
Number of tree spp	1	9.937831	0.001619

Appendix 5.30. The statistical output from the model that investigated the relationship between the abundance indices of robin and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	3.28162	7.23753	0.205587	0.650248
Ericaceous cover	1	2.809698	1.226734	5.245881	0.021999
Grass cover	1	4.062153	1.421921	8.161343	0.004279
Shrub cover	1	-1.49555	1.873232	0.637413	0.424649
Tree cover	1	-1.79621	1.022172	3.087914	0.078876
Altitude	1	-0.00176	0.004517	0.151187	0.697403
Brash depth	1	0.294258	1.161476	0.064185	0.799999
Number of shrub spp	1	0.48864	0.448205	1.188567	0.275619
Number of tree spp	1	0.736281	1.596132	0.212789	0.64459

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.20944	0.647207
Ericaceous cover	1	5.653171	0.017424
Grass cover	1	9.855704	0.001693

Shrub cover	1	0.648805	0.42054
Tree cover	1	3.516275	0.060769
Altitude	1	0.152787	0.695886
Brash depth	1	0.06446	0.799581
Number of shrub spp	1	1.190495	0.27523
Number of tree spp	1	0.216036	0.642077

Appendix 5.31. The statistical output from the model that investigated the relationship between the abundance indices of robin and habitat variables within open habitats in the breeding season at the sampling point level.

Analysis of parameter estimates:

Effect	Score	Estimate	Standard Error	DF	t-value	Probability
Brash cover	0	-0.62459	1.077848	191	-0.57948	0.562949
Brash cover	1	-0.76393	1.082694	191	-0.70558	0.481307
Brash cover	2	-1.06061	1.140765	191	-0.92974	0.35368
Brash cover	3	0				
Ericaceous cover	0	1.191029	1.128015	191	1.055863	0.292365
Ericaceous cover	1	1.497117	1.122994	191	1.333148	0.184071
Ericaceous cover	2	1.079543	1.150982	191	0.937931	0.349464
Ericaceous cover	3	0				
Grass cover	0	0.749541	0.339568	191	2.207336	0.028482
Grass cover	1	0.260397	0.312825	191	0.832404	0.40622
Grass cover	2	-0.48813	0.399152	191	-1.22291	0.222871
Grass cover	3	0				
Shrub cover	0	-1.38626	0.96192	191	-1.44114	0.151183
Shrub cover	1	0.238032	0.781976	191	0.304399	0.761155
Shrub cover	2	0				
Tree cover	0	-1.06759	0.275838	191	-3.87034	0.000149
Tree cover	4	0				
Altitude		0.002622	0.002109	191	1.243111	0.215351
Brash depth	0	0				
Brash depth	1	0.722368	0.463193	191	1.559539	0.120524
Brash depth	2	0.332479	0.437716	191	0.759575	0.448445
Brash depth	3	0				
Number of shrub spp		-0.81627	0.439643	191	-1.85666	0.0649
Number of tree spp		-0.15287	0.152053	191	-1.00537	0.315992

Likelihood ratio statistics for Type 3 analysis:

Effect	NumDF	DenDF	F Value	Probability
Brash cover	2	191	0.47052	0.6254
Ericaceous cover	3	191	0.932556	0.426037
Grass cover	3	191	3.011855	0.031334
Shrub cover	2	191	4.273743	0.015285
Tree cover	1	191	14.97953	0.000149
Altitude	1	191	1.545325	0.215351
Brash depth	2	191	1.219371	0.297705
Number of shrub spp	1	191	3.447174	0.0649
Number of tree spp	1	191	1.010764	0.315992

Appendix 5.32. The statistical output from the model that investigated the relationship between the occurrence rate of common cuckoo and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-5.7432	1.929585	8.858919	0.002917
Ericaceous cover	1	4.027043	0.757447	28.26622	1.06E-07
Grass cover	1	2.968452	0.606771	23.93371	9.97E-07
Shrub cover	1	4.236123	0.928094	20.83307	5.01E-06
Tree cover	1	-1.38967	0.397664	12.21205	0.000475
Altitude	1	-0.00294	0.001161	6.408357	0.011358
Brash depth	1	2.432068	0.480486	25.62066	4.16E-07
Number of shrub spp	1	2.019576	0.259889	60.38706	7.79E-15
Number of tree spp	1	-2.47999	0.743074	11.13871	0.000845

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	8.757387	0.003084
Ericaceous cover	1	31.63693	1.86E-08
Grass cover	1	26.02173	3.38E-07
Shrub cover	1	22.13688	2.54E-06
Tree cover	1	12.56215	0.000394
Altitude	1	6.409825	0.011349
Brash depth	1	25.95687	3.49E-07
Number of shrub spp	1	65.68155	5.3E-16
Number of tree spp	1	10.70484	0.001069

Appendix 5.33. The statistical output from the model that investigated the relationship between the abundance indices of common cuckoo and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-4.61262	14.75119	0.097778	0.754512
Ericaceous cover	1	3.604353	3.908253	0.850529	0.356403
Grass cover	1	5.232428	5.567845	0.883145	0.347342
Shrub cover	1	3.682503	6.989204	0.277607	0.598274
Tree cover	1	-0.69174	5.412957	0.016331	0.898312
Altitude	1	-0.00155	0.010464	0.022031	0.882005
Brash depth	1	2.438035	2.185329	1.244647	0.264577
Number of shrub spp	1	1.745301	5.806441	0.090348	0.763735
Number of tree spp	1	-2.35058	3.554543	0.437304	0.508427

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.097266	0.755136
Ericaceous cover	1	0.912148	0.339545

Grass cover	1	0.970944	0.324445
Shrub cover	1	0.301261	0.583093
Tree cover	1	0.016414	0.898056
Altitude	1	0.022041	0.881979
Brash depth	1	1.264689	0.260765
Number of shrub spp	1	0.092272	0.761308
Number of tree spp	1	0.478972	0.488888

Appendix 5.34. The statistical output from the model that investigated the relationship between the occurrence rate of Eurasian siskin and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-22.4837	2.393152	88.26645	5.72E-21
Ericaceous cover	1	-2.5163	1.144224	4.836188	0.027868
Grass cover	1	-3.49691	0.845616	17.10104	3.54E-05
Shrub cover	1	-3.58441	1.44585	6.145951	0.013171
Tree cover	1	-10.1733	2.878017	12.49506	0.000408
Altitude	1	0.010489	0.005546	3.576294	0.05861
Brash depth	1	1.893352	0.564959	11.23128	0.000804
Number of shrub spp	1	-0.2577	0.295989	0.75801	0.383952
Number of tree spp	1	10.18263	3.741557	7.406539	0.006499

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	98.00938	4.16E-23
Ericaceous cover	1	4.874412	0.027258
Grass cover	1	16.88977	3.96E-05
Shrub cover	1	6.27329	0.012257
Tree cover	1	12.95642	0.000319
Altitude	1	3.566011	0.058974
Brash depth	1	11.75098	0.000608
Number of shrub spp	1	0.749566	0.386614
Number of tree spp	1	7.58568	0.005883

Appendix 5.35. The statistical output from the model that investigated the relationship between the occurrence rate of song thrush and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-11.5996	2.490902	21.6855	3.21E-06
Ericaceous cover	1	4.697138	0.803369	34.18507	5.01E-09
Grass cover	1	1.445504	0.66286	4.755489	0.029205
Shrub cover	1	2.87245	1.037225	7.669368	0.005617
Tree cover	1	-1.74462	0.45636	14.61452	0.000132
Altitude	1	-0.00463	0.001391	11.06071	0.000882
Brash depth	1	2.403746	0.565748	18.05221	2.15E-05
Number of shrub spp	1	2.09585	0.277809	56.91494	4.55E-14
Number of tree spp	1	-3.28772	0.829196	15.72079	7.34E-05

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	23.55116	1.22E-06
Ericaceous cover	1	38.79497	4.71E-10

Grass cover	1	4.838491	0.027831
Shrub cover	1	7.990195	0.004703
Tree cover	1	14.67197	0.000128
Altitude	1	11.47904	0.000704
Brash depth	1	19.0587	1.27E-05
Number of shrub spp	1	64.58688	9.24E-16
Number of tree spp	1	15.3611	8.88E-05

Appendix 5.36. The statistical output from the model that investigated the relationship between the abundance indices of song thrush and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-2.23057	13.25707	0.02831	0.866383
Ericaceous cover	1	5.334912	4.92446	1.173647	0.278653
Grass cover	1	2.979762	3.401794	0.767268	0.381063
Shrub cover	1	3.197503	6.158775	0.269546	0.603636
Tree cover	1	2.882825	12.38911	0.054145	0.816002
Altitude	1	-0.00849	0.023982	0.125302	0.723354
Brash depth	1	1.841985	2.463232	0.559193	0.454586
Number of shrub spp	1	1.935469	1.136596	2.899747	0.088593
Number of tree spp	1	-7.86053	16.14171	0.23714	0.626279

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.028033	0.867032
Ericaceous cover	1	1.225999	0.268187
Grass cover	1	0.74711	0.387393
Shrub cover	1	0.26209	0.608688
Tree cover	1	0.053623	0.816875
Altitude	1	0.125938	0.722681
Brash depth	1	0.57134	0.449727
Number of shrub spp	1	3.130821	0.076825
Number of tree spp	1	0.233487	0.62895

Appendix 5.37. The statistical output from the model that investigated the relationship between the occurrence rate of goldcrest and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-5.7432	1.929585	8.858919	0.002917
Ericaceous cover	1	4.027043	0.757447	28.26622	1.06E-07
Grass cover	1	2.968452	0.606771	23.93371	9.97E-07
Shrub cover	1	4.236123	0.928094	20.83307	5.01E-06
Tree cover	1	-1.38967	0.397664	12.21205	0.000475
Altitude	1	-0.00294	0.001161	6.408357	0.011358
Brash depth	1	2.432068	0.480486	25.62066	4.16E-07
Number of shrub spp	1	2.019576	0.259889	60.38706	7.79E-15
Number of tree spp	1	-2.47999	0.743074	11.13871	0.000845

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	44.17762	3E-11
Ericaceous cover	1	34.97899	3.33E-09

Grass cover	1	60.87712	6.08E-15
Shrub cover	1	15.84467	6.88E-05
Tree cover	1	37.25344	1.04E-09
Altitude	1	40.94106	1.57E-10
Brash depth	1	44.66643	2.34E-11
Number of shrub spp	1	0.452625	0.501091
Number of tree spp	1	38.84034	4.6E-10

Appendix 5.38. The statistical output from the model that investigated the relationship between the abundance indices of goldcrest and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-5.65959	13.71411	0.170308	0.679838
Ericaceous cover	1	4.75819	11.9951	0.157353	0.691605
Grass cover	1	-6.711	12.72178	0.278278	0.597832
Shrub cover	1	0.129747	7.787158	0.000278	0.986707
Tree cover	1	11.8025	39.98834	0.087113	0.76788
Altitude	1	-0.03005	0.093747	0.102732	0.748575
Brash depth	1	0.880419	4.463905	0.0389	0.843647
Number of shrub spp	1	-0.63721	1.300173	0.240195	0.624065
Number of tree spp	1	-13.8852	51.53176	0.072603	0.787584

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	0.1696	0.680468
Ericaceous cover	1	0.158569	0.690477
Grass cover	1	0.289573	0.590494
Shrub cover	1	0.000278	0.986699
Tree cover	1	0.088093	0.766616
Altitude	1	0.104257	0.74678
Brash depth	1	0.039286	0.842883
Number of shrub spp	1	0.245096	0.620549
Number of tree spp	1	0.073398	0.786453

Appendix 5.39 The statistical output from the model that investigated the relationship between the occurrence rate of blackbird and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-9.97999	4.040081	6.102106	0.013502
Ericaceous cover	1	2.035434	1.067002	3.63901	0.05644
Grass cover	1	0.993933	1.199731	0.686351	0.407408
Shrub cover	1	3.060008	1.483256	4.256111	0.039109
Tree cover	1	-1.60911	0.663074	5.889065	0.015235
Altitude	1	-0.00017	0.002762	0.003945	0.949915
Brash depth	1	2.65262	0.644735	16.92727	3.88E-05
Number of shrub spp	1	2.960719	0.39208	57.02223	4.31E-14
Number of tree spp	1	-3.67069	0.899094	16.66804	4.45E-05

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	6.69027	0.009694
Ericaceous cover	1	3.908828	0.048033

Grass cover	1	0.682447	0.408746
Shrub cover	1	4.447328	0.034956
Tree cover	1	6.224478	0.0126
Altitude	1	0.003947	0.949903
Brash depth	1	18.18857	2E-05
Number of shrub spp	1	73.87817	8.31E-18
Number of tree spp	1	15.50235	8.24E-05

Appendix 5.40. The statistical output from the model that investigated the relationship between the occurrence rate of lesser redpoll and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-7.56346	5.101115	2.198419	0.138152
Ericaceous cover	1	-1.76404	1.817759	0.941774	0.331822
Grass cover	1	3.849845	1.246691	9.536055	0.002015
Shrub cover	1	16.71621	6.029167	7.687079	0.005562
Tree cover	1	2.458698	0.74382	10.92635	0.000948
Altitude	1	-0.00375	0.001849	4.112346	0.042571
Brash depth	1	4.454608	2.110714	4.454103	0.034818
Number of shrub spp	1	2.410849	1.246754	3.739201	0.05315
Number of tree spp	1	-6.94471	2.679985	6.714968	0.009561

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	2.285425	0.130594
Ericaceous cover	1	0.940021	0.332272
Grass cover	1	11.89091	0.000564
Shrub cover	1	8.740032	0.003113
Tree cover	1	11.35541	0.000752
Altitude	1	4.279552	0.038574
Brash depth	1	4.862961	0.027439
Number of shrub spp	1	4.110367	0.042621
Number of tree spp	1	7.460194	0.006308

Appendix 5.41. The statistical output from the model that investigated the relationship between the abundance indices of lesser redpoll and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-24.539	21.03713	1.360632	0.243428
Ericaceous cover	1	3.601689	6.812344	0.279524	0.597013
Grass cover	1	10.35345	5.611392	3.404309	0.065026
Shrub cover	1	30.72267	27.7561	1.225183	0.268346
Tree cover	1	2.258263	2.680014	0.710027	0.399435
Altitude	1	-0.01561	0.006919	5.087057	0.024105
Brash depth	1	11.98979	9.211713	1.694112	0.19306
Number of shrub spp	1	5.182446	5.521027	0.881109	0.347898
Number of tree spp	1	-14.4539	11.78146	1.505127	0.219884

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	1.591352	0.207133
Ericaceous cover	1	0.285435	0.593161

Grass cover	1	6.196696	0.012799
Shrub cover	1	1.449686	0.228578
Tree cover	1	0.728203	0.393466
Altitude	1	7.486097	0.006218
Brash depth	1	2.155333	0.142076
Number of shrub spp	1	1.045806	0.306475
Number of tree spp	1	1.857569	0.172906

Appendix 5.42. The statistical output from the model that investigated the relationship between the occurrence rate of carrion crow and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	5.209627	2.409414	4.675096	0.030603
Ericaceous cover	1	-0.85277	1.167528	0.533488	0.465144
Grass cover	1	2.570184	1.703558	2.276222	0.131372
Shrub cover	1	-0.58734	1.416511	0.171927	0.678405
Tree cover	1	2.831839	1.046724	7.319357	0.006822
Altitude	1	0.004595	0.001947	5.56823	0.018289
Brash depth	1	-2.36469	0.544405	18.86703	1.4E-05
Number of shrub spp	1	-0.60271	0.484105	1.550008	0.213134

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	4.740263	0.029465
Ericaceous cover	1	0.521843	0.470057
Grass cover	1	2.520042	0.112408
Shrub cover	1	0.173838	0.676723
Tree cover	1	7.517454	0.00611
Altitude	1	6.031921	0.014049
Brash depth	1	21.13895	4.27E-06
Number of shrub spp	1	1.57651	0.209264

Appendix 5.43. The statistical output from the model that investigated the relationship between the occurrence rate of common grasshopper warbler and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Ericaceous cover	1	-0.58834	1.100617	0.285751	0.592957
Grass cover	1	-0.06501	1.029524	0.003988	0.949649
Shrub cover	1	3.217974	1.034434	9.677416	0.001865
Tree cover	1	-2.84855	0.999359	8.12465	0.004367
Altitude	1	-0.00504	0.001601	9.892315	0.00166
Brash depth	1	-0.25527	0.479398	0.283529	0.594397
Number of shrub spp	1	0.952088	0.588478	2.617543	0.105688

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Ericaceous cover	1	0.283236	0.594588
Grass cover	1	0.003998	0.949584
Shrub cover	1	8.566699	0.003424

Tree cover	1	8.403009	0.003746
Altitude	1	9.296222	0.002296
Brash depth	1	0.289378	0.590619
Number of shrub spp	1	2.713356	0.099511

Appendix 5.44. The statistical output from the model that investigated the relationship between the occurrence rate of hedge accentor and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	13.0161	9.010961	2.086507	0.148606
Ericaceous cover	1	-4.03828	2.104047	3.683673	0.054948
Grass cover	1	3.040036	5.251946	0.335056	0.562697
Shrub cover	1	2.362773	6.151797	0.147516	0.70092
Tree cover	1	-4.4906	3.652464	1.511602	0.218895
Altitude	1	0.0131	0.006685	3.840367	0.050033
Brash depth	1	-2.80432	1.135459	6.09974	0.01352
Number of shrub spp	1	6.291518	4.555159	1.907672	0.167222
Number of tree spp	1	-2.64491	3.302815	0.641289	0.423244

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	2.067551	0.150463
Ericaceous cover	1	3.80681	0.051045
Grass cover	1	0.330103	0.565598
Shrub cover	1	0.146988	0.70143
Tree cover	1	1.498825	0.220852
Altitude	1	3.74999	0.052808
Brash depth	1	6.511744	0.010716
Number of shrub spp	1	1.862601	0.172325
Number of tree spp	1	0.633657	0.426017

Appendix 5.45. The statistical output from the model that investigated the relationship between the occurrence rate of sky lark and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Ericaceous cover	1	20.11191	6.45647	9.70323	0.001839
Shrub cover	1	-20.9446	6.750739	9.625873	0.001919
Altitude	1	-0.00794	0.005376	2.180385	0.139779
Number of shrub spp	1	-1.18516	1.602945	0.546662	0.459685

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Ericaceous cover	1	10.48431	0.001204
Shrub cover	1	9.841797	0.001706
Altitude	1	2.286315	0.13052
Number of shrub spp	1	0.560144	0.454202

Appendix 5.46. The statistical output from the model that investigated the relationship between the occurrence rate of stonechat and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	13.12996	7.481551	3.079949	0.079263
Ericaceous cover	1	-23.3921	13.78213	2.880747	0.089644
Shrub cover	1	10.22914	4.729543	4.677784	0.030555
Tree cover	1	-14.2152	8.270328	2.954349	0.085647
Altitude	1	0.053425	0.029019	3.38941	0.065616
Number of shrub spp	1	35.78762	20.65613	3.001704	0.083177
Number of tree spp	1	-15.8568	8.892164	3.179905	0.074549

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	3.546579	0.059668
Ericaceous cover	1	3.290085	0.069699
Shrub cover	1	5.847764	0.015597
Tree cover	1	3.454882	0.063065
Altitude	1	3.908275	0.048049
Number of shrub spp	1	3.469526	0.062509
Number of tree spp	1	3.733077	0.053345

Appendix 5.47. The statistical output from the model that investigated the relationship between the occurrence rate of black grouse and habitat variables within open habitats in the breeding season at the sub-site level.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Brash cover	1	-7.06194	2.052596	11.83701	0.000581
Ericaceous cover	1	2.002662	0.702995	8.115427	0.004389
Shrub cover	1	1.38999	1.185731	1.374202	0.241091
Tree cover	1	4.193988	1.727642	5.893141	0.0152
Altitude	1	0.002088	0.002698	0.599107	0.438919
Number of shrub spp	1	1.72228	1.025458	2.820792	0.09305
Number of tree spp	1	-4.46253	1.535121	8.450417	0.00365

Likelihood ratio statistics for Type 3 analysis:

Source	DF	Chi Squared	Probability
Brash cover	1	12.36352	0.000438
Ericaceous cover	1	8.179793	0.004236
Shrub cover	1	1.36478	0.242711
Tree cover	1	6.616534	0.010104
Altitude	1	0.60327	0.437333

Number of shrub			
spp	1	3.008221	0.082843
Number of tree spp	1	9.861613	0.001688

APPENDIX 6 – STATISTICAL OUTPUTS FOR MODELS INVESTIGATING THE RELATIONSHIPS BETWEEN SHRUB COVER IN ADJACENT FRINGE AREAS AND HABITAT VARIABLES WITHIN OPEN MOORLAND AND SPECIES-SPECIFIC ABUNDANCE INDICES.

Appendix 6.1 The statistical output from the model that investigated the relationship between the occurrence rate of meadow pipit in the breeding season on open moorland and shrub cover within adjacent fringe habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	5.038833	1.668269	9.122795	0.002524
Altitude	1	0.002188	0.002203	0.986853	0.320513
Number of shrub spp	1	-0.6333	0.818041	0.599332	0.438833

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	6.823943	0.008994
Altitude	1	0.964757	0.325991
Number of shrub spp	1	0.570704	0.449979

Appendix 6.2 The statistical output from the model that investigated the relationship between the occurrence rate of sky lark in the breeding season on open moorland and shrub cover within adjacent fringe habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	6.324042	2.651149	5.690118	0.017061
Altitude	1	0.019553	0.010237	3.648123	0.056132
Number of shrub spp	1	-2.98136	1.269676	5.513715	0.018868

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	5.89352	0.015197
Altitude	1	4.092359	0.043077
Number of shrub spp	1	7.460267	0.006308

APPENDIX 7 – STATISTICAL OUTPUTS FOR MODELS INVESTIGATING THE RELATIONSHIPS BETWEEN SHRUB COVER IN ADJACENT FRINGE AREAS, HABITAT VARIABLES WITHIN POST-THICKET PLANTATIONS AND SPECIES RICHNESS AND SPECIES-SPECIFIC ABUNDANCE INDICES.

Appendix 7.1 The statistical output from the model that investigated the relationship between species richness in winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.628644	0.33901	3.438619	0.063689
Altitude	1	0.001315	0.00215	0.374069	0.540794
Plantation tree density	1	0.176427	0.27198	0.420783	0.516547
Plantation tree height	1	0.119818	0.200533	0.357006	0.550174

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	3.306057	0.069025
Altitude	1	0.383674	0.535643
Plantation tree density	1	0.422597	0.515644
Plantation tree height	1	0.356683	0.550354

Appendix 7.2 The statistical output from the model that investigated the relationship between species richness in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.145396	0.267844	0.294671	0.587242
Altitude	1	0.001088	0.001529	0.505876	0.47693
Plantation tree density	1	0.013125	0.190162	0.004764	0.944975
Plantation tree height	1	0.065944	0.140423	0.220532	0.638635

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	0.290877	0.589659
Altitude	1	0.51672	0.472244
Plantation tree density	1	0.004765	0.944967
Plantation tree height	1	0.220477	0.638676

Appendix 7.3 The statistical output from the model that investigated the relationship between the occurrence rate of coal tit in the winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.213497	0.126739	2.837658	0.092078
Altitude	1	-0.00335	0.000854	15.35514	8.91E-05
Number of tree spp	1	-0.51139	0.162749	9.87335	0.001677
Plantation tree density	1	-0.05889	0.120066	0.240581	0.623787
Plantation tree height	1	0.060052	0.081679	0.540551	0.462205

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	2.780586	0.095413
Altitude	1	14.3818	0.000149
Number of tree spp	1	9.883877	0.001667
Plantation tree density	1	0.239406	0.624635
Plantation tree height	1	0.543138	0.461135

Appendix 7.4 The statistical output from the model that investigated the relationship between the occurrence rate of winter wren in the winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	-0.66645	0.204782	10.59126	0.001136
Altitude	1	-0.00724	0.000881	67.608	1.99E-16
Number of tree spp	1	0.172108	0.180973	0.904428	0.341597
Plantation tree density	1	-0.5196	0.160113	10.53154	0.001174
Plantation tree height	1	-0.67218	0.126542	28.21585	1.09E-07

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	11.0962	0.000865
Altitude	1	62.0848	3.29E-15
Number of tree spp	1	0.906376	0.341078
Plantation tree density	1	10.2719	0.001351
Plantation tree height	1	30.20398	3.89E-08

Appendix 7.5 The statistical output from the model that investigated the relationship between the occurrence rate of hedge accentor in the winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	-0.68975	0.394082	3.063482	0.08007
Altitude	1	0.001957	0.009529	0.042194	0.837251
Plantation tree density	1	0.566676	0.911695	0.386341	0.534229
Plantation tree height	1	0.011008	0.833222	0.000175	0.989459

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	3.160475	0.075441
Altitude	1	0.042101	0.837427
Plantation tree density	1	0.389793	0.532408
Plantation tree height	1	0.000175	0.98946

Appendix 7.6 The statistical output from the model that investigated the relationship between the occurrence rate of goldcrest in the winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.120631	0.145412	0.688211	0.406773
Altitude	1	-0.00251	0.001089	5.318561	0.021099
Plantation tree density	1	-0.18107	0.11604	2.434915	0.11866
Plantation tree height	1	-0.00528	0.092402	0.003262	0.954453

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	0.681561	0.40905
Altitude	1	5.303216	0.021286
Plantation tree density	1	2.432054	0.118877
Plantation tree height	1	0.003263	0.954451

Appendix 7.7 The statistical output from the model that investigated the relationship between the occurrence rate of robin in the winter within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	3.56538	1.016918	12.29247	0.000455
Altitude	1	0.04963	0.013695	13.13076	0.00029
Plantation tree density	1	3.66193	1.105402	10.97439	0.000924
Plantation tree height	1	1.19732	0.431979	7.682354	0.005576

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	11.30128	0.000775
Altitude	1	12.61907	0.000382
Plantation tree density	1	10.71879	0.001061
Plantation tree height	1	8.355606	0.003845

Appendix 7.8 The statistical output from the model that investigated the relationship between the occurrence rate of chaffinch in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.318601	0.107384	8.802661	0.003008
Altitude	1	0.00301	0.000786	14.66808	0.000128
Plantation tree density	1	0.062356	0.070594	0.780213	0.377076
Plantation tree height	1	0.148402	0.055657	7.109595	0.007667

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	8.689923	0.0032
Altitude	1	15.23319	9.5E-05
Plantation tree density	1	0.781984	0.376535
Plantation tree height	1	7.101617	0.007701

Appendix 7.9 The statistical output from the model that investigated the relationship between the occurrence rate of Eurasian siskin in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
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Adjacent shrub cover	1	-0.15242	0.168485	0.81837	0.365657
Altitude	1	0.003147	0.001116	7.953289	0.0048
Plantation tree density	1	-0.47722	0.110859	18.53104	1.67E-05
Plantation tree height	1	0.334756	0.101542	10.8684	0.000978

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	0.825984	0.363436
Altitude	1	8.277238	0.004015
Plantation tree density	1	19.24234	1.15E-05
Plantation tree height	1	11.61754	0.000653

Appendix 7.10 The statistical output from the model that investigated the relationship between the occurrence rate of coal tit in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.221539	0.125758	3.103352	0.078131
Altitude	1	-0.0015	0.000973	2.362864	0.124254
Plantation tree density	1	0.020591	0.11028	0.034864	0.851881
Plantation tree height	1	0.365174	0.090443	16.30232	5.4E-05

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	3.055226	0.080478
Altitude	1	2.354783	0.124899
Plantation tree density	1	0.03486	0.85189
Plantation tree height	1	17.57382	2.76E-05

Appendix 7.11 The statistical output from the model that investigated the relationship between the occurrence rate of goldcrest in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	-0.34603	0.127569	7.357598	0.006678
Altitude	1	-0.00403	0.000891	20.49703	5.97E-06
Plantation tree density	1	-0.10414	0.101227	1.058339	0.303594
Plantation tree height	1	0.268801	0.084469	10.12674	0.001461

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	7.638569	0.005713
Altitude	1	20.51699	5.91E-06
Plantation tree density	1	1.059218	0.303394
Plantation tree height	1	10.72705	0.001056

Appendix 7.12 The statistical output from the model that investigated the relationship between the occurrence rate of willow warbler in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.28918	0.126613	5.216343	0.022376
Altitude	1	0.00239	0.000605	15.61012	7.78E-05
Plantation tree density	1	0.35129	0.07612	21.29749	3.93E-06
Plantation tree height	1	-0.5318	0.062763	71.79498	2.39E-17

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	5.367251	0.020518
Altitude	1	15.1141	0.000101
Plantation tree density	1	21.22495	4.08E-06
Plantation tree height	1	77.98896	1.04E-18

Appendix 7.13 The statistical output from the model that investigated the relationship between the occurrence rate of song thrush in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.476442	0.144995	10.7973	0.001016
Altitude	1	-0.00444	0.001117	15.7867	7.09E-05
Plantation tree density	1	-0.40023	0.096325	17.2638	3.25E-05
Plantation tree height	1	-0.60092	0.10037	35.84497	2.14E-09

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	10.56636	0.001152
Altitude	1	15.7784	7.12E-05
Plantation tree density	1	17.05532	3.63E-05
Plantation tree height	1	40.42844	2.04E-10

Appendix 7.14 The statistical output from the model that investigated the relationship between the occurrence rate of blackbird in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.64301	0.280397	5.258831	0.021836
Altitude	1	0.00158	0.002503	0.398305	0.527966
Plantation tree density	1	-	0.241441	2.840687	0.091905
Plantation tree height	1	-	0.148905	14.40102	0.000148

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	5.181737	0.022825
Altitude	1	0.398615	0.527805
Plantation tree density	1	2.918052	0.087594
Plantation tree height	1	17.99562	2.21E-05

Appendix 7.15 The statistical output from the model that investigated the relationship between the occurrence rate of European robin in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.044654	0.10988	0.165149	0.684459
Altitude	1	-0.00206	0.000808	6.513684	0.010705
Plantation tree density	1	-0.08337	0.082314	1.02593	0.311117
Plantation tree height	1	-0.07833	0.059731	1.719496	0.189758

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	0.164542	0.685009
Altitude	1	6.480656	0.010905
Plantation tree density	1	1.022809	0.311854
Plantation tree height	1	1.726322	0.188881

Appendix 7.16 The statistical output from the model that investigated the relationship between the occurrence rate of winter wren in the breeding season within post-thicket plantations, habitat variables within those plantations and shrub cover within adjacent open habitats.

Analysis of parameter estimates:

Parameter	DF	Estimate	Standard Error	Chi Squared	Probability
Adjacent shrub cover	1	0.47696	0.132864	12.88709	0.000331
Altitude	1	0.00494	0.000586	70.85993	3.84E-17
Plantation tree density	1	0.47651	0.080836	34.74807	3.75E-09
Plantation tree height	1	0.48989	0.067175	53.18429	3.04E-13

Likelihood ratio statistics for Type 3 analyses:

Source	DF	Chi Squared	Probability
Adjacent shrub cover	1	13.54902	0.000232
Altitude	1	67.36476	2.26E-16
Plantation tree density	1	34.48818	4.29E-09
Plantation tree height	1	56.59201	5.36E-14

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