

# Are bird density, species richness and community structure similar between native woodlands and non-native plantations in an area with a generalist bird fauna?

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**Abstract** This study compared the bird assemblages of native semi-natural woodlands and non-native Sitka spruce (*Picea sitchensis*) plantations in Ireland to identify what vegetation variables most influenced birds and to identify management targets in plantations to maximise future bird conservation. Point counts were conducted in 10 Oak (*Quercus* spp.) and 10 Ash (*Fraxinus excelsior*) native woodlands and in five Mid-rotation (20–30 years old) and five Mature (30–50 years old) Sitka spruce plantations. Ordination was used to characterise woodland types according to their constituent bird species. Total bird density (calculated using *Distance* software) and species richness were assessed for the different woodland types. Oak and Ash woodland bird assemblages were separated from Mid-rotation and Mature plantations by the ordination. There was no difference in total bird density between any of the woodland types. Oak woodlands had significantly higher species richness than either Mid-rotation or Mature Sitka spruce plantations. Ash had higher species richness than Mature Sitka spruce plantations. Understorey vegetation was negatively associated with total bird density, which also varied with survey year. Understorey vegetation was positively associated with species richness. Reasons for the relationships between vegetation and bird assemblages are discussed. Management should seek to increase shrub and understorey vegetation in the Mid-rotation phase to improve the contribution of plantations to bird conservation.

**Keywords** Bird communities · Exotic plantations · Forest management · Ireland · Native woodlands · Vegetation structure

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## Introduction

Plantation forests provide potential habitat for birds that utilise woodland habitat, and native woodlands—those occurring naturally in a region—offer a reference point against which to compare the bird assemblages of non-native plantations. While direct comparisons between plantations and more natural woodlands are not always appropriate (Brockerhoff et al. 2008), such comparisons are useful in identifying facets of the woodlands that differ between the woodland types. Because management affects the utility of plantations to birds (Lantschner et al. 2008; Luck and Korodaj 2008; but see Calladine et al. 2009), such comparative studies may therefore provide useful information on aspects of plantations that can be improved with a view to sustainable forest management and biodiversity conservation.

Bird assemblages can differ between native woodlands and non-native plantations (Donald et al. 1998; Sax 2002) and plantations may host fewer species at lower densities than native woodlands (Marsden et al. 2001; Lindenmayer et al. 2002; Barlow et al. 2007b; Farwig et al. 2008). However, non-native plantations may also, in certain situations, possess similar bird species richness to native woodlands (Sax 2002; Magura et al. 2008). Because specialist woodland bird species are more likely to be absent from plantations than generalists (Zurita et al. 2006; Paritsis and Aizen 2008), Ireland offers an excellent opportunity to test whether patterns of bird assemblages in plantations are more similar to native woodlands in regions lacking a specialist woodland bird fauna than in regions that have a specialist woodland bird fauna.

Ireland has experienced one of the highest afforestation rates in the EU in recent times (FAO 2007). Non-native plantations cover approximately 10% of land area, of which Sitka spruce (*Picea sitchensis*) monocultures account for over 50%. Only 15% of plantations are composed of native broadleaf species, with Oak (*Quercus* spp.) and Ash (*Fraxinus excelsior*) accounting for a third of this figure (Forest Service 2007). The extensive native broadleaved woodland that colonised Ireland following the end of the last ice-age (Mitchell 2006) has gradually been reduced by man to the current level of 1% of land area (Cross 1998) and non-native plantations are now therefore the most prevalent woodland habitat. Much of Ireland's native woodland cover contains either Oak or Ash as the dominant canopy tree species. In Britain, Oak supports more invertebrate species than Ash (Birks 1980; Kennedy and Southwood 1984) and, as a result, food availability for breeding birds may differ between these woodland types, which may in turn influence bird assemblages.

The increasing coverage of plantation forests in Europe (FAO 2007), coupled with a documented decline in woodland bird species throughout the continent (Fuller et al. 2005; Gregory et al. 2007; Hewson et al. 2007), means that efforts are required to evaluate the bird assemblages of plantations and, if necessary, improve their utility to a wider range of bird species. Although many of Europe's woodland specialist birds are absent from Ireland, information on how birds utilise plantations in Ireland and which species, if any, are absent from plantations is relevant on a European scale.

The study aimed to evaluate the bird assemblages of Sitka spruce plantations approaching commercial maturity by comparing them with those of native Oak and Ash woodlands, and to make research-based recommendations for future management of plantations. In particular three questions are addressed:

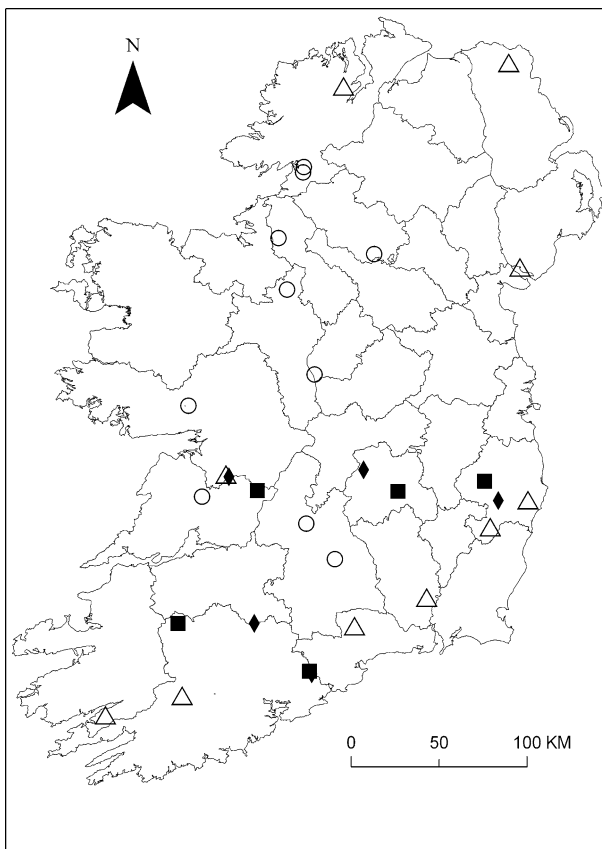
1. Are there differences in the bird assemblages of unmanaged Oak and Ash native woodlands?

2. What differences exist in the bird assemblages of native Oak and Ash woodlands and non-native managed plantation forests?
3. What vegetation and structural variables are most important in explaining the observed patterns in bird assemblages?

## Methods

### Site selection

Bird assemblages were surveyed at 30 forests throughout Ireland: 10 Sitka spruce plantations, 10 Oak dominated native woodlands (Oak) and 10 native woodlands with a high proportion of Ash in the canopy (Ash) (Fig. 1). The native woodlands correspond to the WN1 and WN2 classification of Irish woodland habitat (Fossitt 2000). ArcGIS and local maps were used to identify study sites. Ten second-rotation Sitka spruce plantations in two age classes (five in each age class) were selected: Mid-rotation (20–30 years) and commercially mature (Mature, 30–50 years). Sitka spruce was the primary crop tree in all



**Fig. 1** Distribution of Oak (*open triangle*) and Ash (*open circle*) native woodlands and Mid-rotation (*filled square*) and Mature (*filled diamond*) Sitka spruce plantations surveyed in this study

plantations. The Oak and Ash woodlands were selected on the basis of their presence on 1840s Ordnance Survey maps, the oldest available for the Republic of Ireland, or, in the case of woodlands in Northern Ireland, on a database of ancient and long-established woodland (The Woodland Trust 2007). This was in order to minimise potential differences in bird assemblages as a result of differences in woodland age. However, due to a lack of suitable sites, we included two woodlands that were not present on the 1840s maps or the database. Following analysis we found that these woodlands did not differ significantly from the others and so results are presented for all woodlands. The native woodlands all currently receive little or no management intervention. All fieldwork was carried out during the breeding seasons of 2007 and 2008.

### Point counts

Point counts (Bibby et al. 2000) were used to survey birds at all study sites. Where possible, six points were located in each site to standardise survey effort, but one Ash woodland was too small to accommodate six points and received five. Species accumulation curves were constructed for each forest type using EstimateS (Colwell 2006) and data were checked to ensure that this unequal sampling effort did not bias species richness estimation.

Points were randomly placed a minimum of 100 m apart in edge and interior habitat in each study site, and were located in the field using a Garmin GPS 76. Counts were conducted on calm days (wind speeds under Beaufort scale 4) without persistent or heavy rain. Each point was surveyed twice: early in the breeding season (April–May) and later (May–June). Because this study was part of a larger project, there were a large number of sites to be surveyed and counts therefore took place in the morning (0800–1200) and afternoon (1400–1800). Each forest received one morning and one afternoon visit. This approach has previously been successfully used to study Irish birds (Wilson et al. 2006). Counts lasted for 10 min, and all birds seen or heard within 50 m of the observer were recorded and their distances noted. Distances were typically estimated, but a range finder was used when possible.

### Bird assemblages

Individuals detected in flight were excluded from analysis, as were individuals of the Corvidae (with the exception of Jay, *Garrulus glandarius*) Hirundinidae and Motacillidae as their presence at a study site could not be assumed to indicate a breeding association.

Bird assemblages were analysed in terms of community composition as determined by Non-metric Multidimensional Scaling (NMS) ordination, species richness, and total population density (number of individuals per hectare). Species richness was calculated as the cumulative number of species recorded in each site between the early and late visits.

### Density estimation and data analysis

*Distance* (Thomas et al. 2006) was used to convert bird observations to species densities. Because detectability may differ between species (Allredge et al. 2007) each bird species was allocated to one of four species detection groups (Table 1) and these groups analysed separately in *Distance*. Allocation depended on the method of detection, the distribution of detections in five distance bands (0–10, 11–20, 21–30, 31–40, and 41–50) and knowledge

**Table 1** Species recorded in Mid-rotation and Mature Sitka spruce plantations and in Oak and Ash native woodlands, their population densities (No. ha<sup>-1</sup> ± SE) and the number of forests (Forests present) in which each species was detected. The detection group (DG) to which each species was allocated is also indicated

Species	DG	Scientific name	Mid-rotation Forests present (max = 5)	Mature Forests present (max = 5)	Oak Forests present (max = 5)	Ash Forests present (max = 10)	Forests present (max = 10)			
Blackbird	1	<i>Turdus merula</i>	1.17 (0.30)	5	0.40 (0.10)	5	2.52 (0.62)	10	2.10 (0.14)	10
Blackcap	1	<i>Sylvia atricapilla</i>	0.89 (0.39)	4	0.32 (0.19)	3	0.96 (0.36)	8	1.20 (0.17)	10
Blue Tit	4	<i>Cyanistes caeruleus</i>	0.36 (0.36)	1	0.48 (0.48)	1	6.61 (1.28)	10	5.55 (1.27)	10
Bullfinch	2	<i>Pyrrhula pyrrhula</i>	0	0	0	0	0.40 (0.27)	2	0.54 (0.33)	3
Chaffinch	3	<i>Fringilla coelebs</i>	2.61 (0.67)	5	4.51 (0.92)	5	4.25 (0.60)	10	3.93 (0.75)	10
Chiffchaff	1	<i>Phylloscopus collybita</i>	0.50 (0.14)	4	0.05 (0.05)	1	0.58 (0.12)	9	0.38 (0.13)	6
Coal Tit	4	<i>Periparus ater</i>	18.64 (2.96)	5	15.44 (3.18)	5	6.56 (1.44)	10	7.00 (0.89)	10
Cuckoo	1	<i>Cuculus canorus</i>	0.12 (0.12)	1	0	0	0.06 (0.06)	1	0.03 (0.03)	1
Duncock	2	<i>Prunella modularis</i>	0.95 (0.28)	4	0	0	0.16 (0.11)	2	0	0
Garden Warbler	1	<i>Sylvia borin</i>	0	0	0	0	0.03 (0.03)	1	0	0
Golderest	4	<i>Regulus regulus</i>	24.72 (3.15)	5	20.30 (3.81)	5	7.39 (0.62)	10	7.14 (0.78)	10
Great Tit	3	<i>Parus major</i>	0.05 (0.05)	1	0.33 (0.17)	3	1.06 (0.26)	9	2.18 (0.45)	10
Jay	2	<i>Garrulus glandarius</i>	0.26 (0.16)	2	0.54 (0.26)	3	0.70 (0.28)	6	0.86 (0.38)	6
Long-tailed Tit	4	<i>Aegithalos caudatus</i>	1.05 (0.68)	2	0	0	2.22 (0.89)	4	2.14 (0.74)	8
Mistle Thrush	1	<i>Turdus viscivorus</i>	0.06 (0.06)	1	0.15 (0.10)	2	0.15 (0.05)	5	0.39 (0.17)	6
Pheasant	1	<i>Phasianus colchicus</i>	0	0	0	0	0.09 (0.06)	2	0.18 (0.15)	2
Robin	2	<i>Erithacus rubecula</i>	7.26 (0.74)	5	4.64 (1.25)	5	9.38 (0.60)	10	7.74 (0.82)	10
Siskin	3	<i>Carduelis spinus</i>	0.05 (0.05)	1	0	0	0.08 (0.05)	2	0	0
Song Thrush	1	<i>Turdus philomelos</i>	0.42 (0.21)	3	0.21 (0.21)	1	0.84 (0.17)	8	0.54 (0.06)	10
Sparrowhawk	2	<i>Accipiter nisus</i>	0	0	0	0	0.25 (0.13)	3	0	0
Spotted Flycatcher	2	<i>Muscicapa striata</i>	0	0	0	0	0.24 (0.17)	2	0.26 (0.18)	2
Stock dove	1	<i>Columba oenas</i>	0	0	0	0	0.03 (0.03)	1	0	0
Treecreeper	2	<i>Certhia familiaris</i>	0	0	0.35 (0.14)	3	1.66 (0.43)	9	2.10 (0.56)	9

Table 1 continued

Species	DG	Scientific name	Mid-rotation	Forests present (max = 5)	Mature	Forests present (max = 5)	Oak	Forests present (max = 10)	Ash	Forests present (max = 10)
Whitethroat	2	<i>Sylvia communis</i>	0.13 (0.13)	1	0.27 (0.27)	1	0.07 (0.07)	1	0	0
Willow Warbler	1	<i>Phylloscopus trochilus</i>	0.22 (0.22)	2	0.11 (0.07)	2	0.55 (0.32)	4	0.26 (0.08)	6
Woodpigeon	1	<i>Columba palumbus</i>	0.06 (0.06)	1	0.50 (0.21)	4	0.61 (0.11)	10	1.22 (0.20)	9
Wren	1	<i>Troglodytes troglodytes</i>	2.64 (0.91)	5	2.63 (0.79)	5	2.93 (0.48)	10	3.06 (0.35)	10
Mean density			63.23 (7.15)		51.23 (5.43)		50.36 (3.62)		48.79 (3.40)	

of a species' ecology. Therefore, species with broadly similar detectability were analysed together. To minimise the potential influence of habitat structure on the detection function, we also analysed native woodlands and plantations separately in *Distance*.

Akaike's Information Criteria (AIC) was used to select between four models for fitting of the detection function in *Distance*: Uniform + Cosine, Uniform + Polynomial, Half normal + Hermite and Hazard-rate + Cosine (Buckland et al. 2001). Population densities of all species for both the early and late counts were calculated for each site and the reported density of a species was the maximum of these two values.

### Habitat variables and model building

Vegetation variables were estimated visually in a 30 m radius at each point. Variables measured were: canopy cover and height; understorey cover and height (a layer of woody vegetation below the canopy >2 m tall); shrub cover (woody vegetation <2 m tall) and field cover (herbaceous vegetation). The mean of the recorded variables from each point was used as the site score. We also included mean tree diameter at breast height (DBH), mean tree basal area and mean number of stems collected in three 10 × 10 metre plots in each forest. Year of survey was included in the models to test whether any significant relationships were due to inter-year differences, as were latitude and longitude to ensure that geographical differences were not driving observed patterns. The length of rides and the area of open space in the study sites were calculated from aerial photographs. In the case of rides, because the resolution was coarse and therefore length was unlikely to be calculated precisely, we added ride as a factor (present or absent in a study site) in models.

### Data analysis

NMS using species' densities was carried out in PC-ORD (McCune and Mefford 2006) on the 'slow and thorough' setting, and used to investigate species composition in the different woodlands. NMS was undertaken using Sørensen distance measure and random starting coordinates with six axes. Dimensionality was reduced by one at each cycle. Initial step length towards minimum stress was 0.2. The stability criterion was 0, with 10 iterations to evaluate stability. A Monte Carlo test was carried out using 250 runs.

Indicator species analysis (Dufrene and Legendre 1997) was also carried out in PC-ORD to illustrate those species whose presence characterised each age class. Indicator values were derived from both the abundance and frequency of occurrence of a species in each woodland type to produce an indicator value. This value was tested for statistical significance using a Monte Carlo test. Only species with an indicator value of  $\geq 20\%$  and with  $P < 0.05$  were considered.

ANOVA and Tukey HSD post hoc test were used to test for differences in bird density between the site types. Kruskal–Wallis with Dunn's post hoc test was used to test for differences in species richness between sites.

Before modelling, data were checked for normality, colinearity and outliers using Brodgar (Highland Statistics LTD 2007). Data transformations (log, cube root and fourth root) were applied where appropriate to reduce the effect of outliers and normalise the data. General Linear Modelling (GLM) assuming a Poisson distribution (or, in the event of overdispersion, a quasi-Poisson distribution) was used to investigate relationships between species richness and the habitat variables, and between density and the habitat variables. Backwards and forwards selection was used to select starting models which were identified using minimum Akaike's Information Criteria (AIC). The least significant

explanatory variables were then dropped until all explanatory variables were significantly associated with the response variable. All analyses were carried out in Brodgar (Highland Statistics LTD 2007).

## Results

### Ordination and indicator species analysis

Having excluded species detected in flight and those groups that were not of interest, 27 species were included in the analysis. Twenty species were recorded in Mid-rotation and 17 in Mature Sitka spruce plantations. Twenty-one species were recorded in Ash woodlands and all 27 in Oak woodlands (Table 1).

The ordination represents a gradient from high canopy cover and simple understorey and ground vegetation structure in the Sitka spruce plantations, through to Oak and Ash woodlands which had higher shrub, field and understorey cover. Mid-rotation and Mature Sitka spruce plantations separated clearly from Oak and Ash woodlands along both Axis 1 (31% of variation) and Axis 2 (58% of variation). However, Oak and Ash woodlands did not separate from each other along either axis, nor did Mid-rotation and Mature plantations. Indicator species for Mid-rotation were Coal Tit (32%), Dunnock (68%), Goldcrest (34%) and Robin (25%). Indicators for Mature were Coal Tit (39%) and Goldcrest (42%). Indicator species were the same for Oak and Ash woodlands and included Blue Tit (Oak 51%, Ash 43%), Great Tit (Oak 26%, Ash 60%), Robin (Oak 32%, Ash 27%), Treecreeper (Oak 36%, Ash 46%) and Woodpigeon (Oak 25%, Ash 46%) (Fig. 2).

### Bird density and species richness

We found no significant difference in total bird density between the woodland types ( $F_{3,26} = 1.21$ ,  $P > 0.05$ ). However, species richness was significantly different between woodlands ( $H_c = 84.18$ , D.F. = 3,  $P < 0.01$ ), with Oak woodlands having significantly higher species richness than Mid-rotation ( $Q = 2.70$ ,  $P < 0.05$ ) and Mature ( $Q = 3.25$ ,  $P < 0.01$ ) Sitka spruce plantations and Ash woodlands having significantly higher species richness than Mature Sitka spruce plantations ( $Q = 3.12$ ,  $P < 0.05$ ). Species richness did not differ significantly between the other site types.

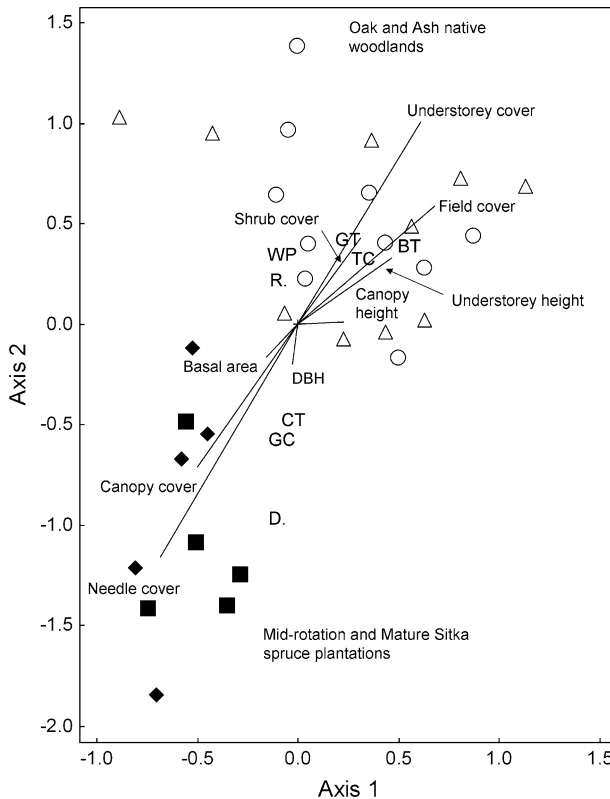
Year of study was positively related to total bird density ( $t = 2.36$ ,  $P = 0.03$ ) while understorey cover was negatively related to total bird density ( $t = -2.53$ ,  $P = 0.02$ ), although the explained deviance of the model was relatively low (24%). In contrast, understorey cover was associated with increasing species richness in a GLM with 55% of the deviance explained ( $Z = 2.93$ ,  $P < 0.01$ ).

## Discussion

### Oak and Ash woodlands

We found little difference in the bird assemblages of Oak and Ash woodlands. Both woodland types had similar indicator species, species richness and bird density. Hence the





**Fig. 2** NMS biplot of species densities in Mid-rotation (*filled square*) and Mature (*filled diamond*) Sitka spruce plantations, and in Oak (*open triangle*) and Ash (*open circle*) native woodlands. Main vegetation and structural gradients are shown with lines. Axis 1,  $r^2 = 0.31$ , Axis 2,  $r^2 = 0.58$ , cumulative  $r^2 = 0.90$ . Indicator species with an indicator value of 20% or more with  $P < 0.05$  are marked on the plot. BT = Blue tit; CT = Coal tit; D. = Dunnock; GC = Goldcrest; GT = Great tit; R. = Robin; TC = Treecreeper; WP = Wood Pigeon. Rough site groups are also indicated on the plot. Final stress for the 2-dimensional solution = 13.57

two major native woodland types in Ireland provide similar habitat for birds and vegetation structure, rather than the dominant tree species, is likely the important factor driving between-site differences in species richness as suggested by the relationships between the response and explanatory variables. The fact that Oak hosts more invertebrate species than Ash (Kennedy and Southwood 1984) may be less important to breeding birds than total invertebrate biomass on the tree. Further research is required to clarify whether this is indeed the case.

### Native and plantation woodlands

The clear separation of Oak and Ash native woodlands from Sitka spruce plantations via ordination illustrates distinct structuring of the bird assemblages of native and plantations woodlands. This provides support for the idea that plantations are complementary habitats (Donald et al. 1998; Barlow et al. 2007a). The difference in species richness suggests that the carrying capacity of plantations is lower than that of native woodlands for most bird

species. That much of the generalist terrestrial bird fauna that characterises Ireland is present at low densities in plantations is an important finding and suggests that differences between plantations and native woodlands will be more pronounced in areas with a specialised woodland bird fauna.

A small number of species (primarily Coal Tit and Goldcrest) present at high densities dominate the bird fauna of plantations. Similar patterns of low diversity and dominance of a few species in coniferous plantations have been reported previously (Bibby et al. 1989; Fuller and Browne 2003), but not in as pronounced a way as reported in this study where Coal Tit and Goldcrest accounted for approximately 60% of the total bird density in plantations.

Other species common to plantations, such as Chaffinch and Robin, achieved similar densities in native woodlands whereas densities of Coal Tit and Goldcrest were much lower in native woodlands than in plantations. Both Coal Tit and Goldcrest are largely arboreal and small-bodied and Goldcrests feed on very small invertebrates of the orders Hemiptera and Collembola (Fuller 1995; Snow and Perrins 1998) which are abundant in Sitka spruce plantations (Straw et al. 2006). Besides also feeding on invertebrates, Coal Tits utilise spruce seeds taken from cones (Snow and Perrins 1998). Such diet preferences may render plantations more suitable for these small bodied species, rather than larger species which may not utilise the smallest prey items. This may help to explain the high population densities of Coal Tit and Goldcrest present in plantations.

Several species recorded in this study have been identified as occurring in Irish Sitka spruce plantations but being closely associated with non-crop broadleaved elements (Wilson et al. 2010). Each of these species (Blackcap, Blue Tit, Bullfinch, Chiffchaff, Great Tit, Long-tailed Tit, Treecreeper and Willow Warbler) was recorded at its highest density in either Oak or Ash woodlands, in some cases being several times as abundant as in plantations. Garden Warbler and Spotted Flycatcher can be added to this list of species that prefer broadleaved vegetation (Snow and Perrins 1998). The occurrence of broadleaf associated species may be one way in which the quality of plantations can be evaluated (Bibby et al. 1989), and by this measure plantations are currently lower quality habitat for birds than native woodlands. This offers a solid method by which the effectiveness of future plantation management can be evaluated in terms of its success in bird conservation.

Two species of conservation concern were detected in this study, the Spotted Flycatcher and the Stock Dove. Both are on the Amber list of birds of conservation concern in Ireland and the Spotted Flycatcher is also a Species of European Concern (Lynas et al. 2007). The Spotted Flycatcher was found in both Oak and Ash woodlands but not in Sitka spruce plantations, while the Stock Dove was found in only one Oak woodland. The Spotted Flycatcher requires open areas and perches for foraging so the typically uniform nature of Sitka spruce plantation canopies may be less suitable. In the case of Stock Dove, native woodlands probably offer tree hollows for nesting (Snow and Perrins 1998).

#### Vegetation structure and bird assemblages

Bird species richness is associated with vegetation structure (Cherkaoui et al. 2009; Nikolov 2009), and changes in the structural diversity of woodland is one possible contributing factor to observed declines in British woodland bird populations (Fuller et al. 2007; Gill and Fuller 2007; Hopkins and Kirby 2007). Our finding, that species richness was significantly related to understorey cover, emphasises the importance of woodland vegetation structure to birds.

Canopy cover is negatively associated with understorey vegetation in plantation forests (Smith et al. 2008), which suggests that measures to reduce canopy cover and allow more light penetration could benefit bird diversity through the promotion of heterogeneous vegetation layers (Ding et al. 2008) which, in turn, provide nesting and foraging opportunities for a wide range of bird species (Quine et al. 2007). Mature coniferous plantations may have low structural diversity in the field and shrub layers (Ferris et al. 2000) and so may represent a lower quality habitat for birds than unmanaged, structurally heterogeneous native woodlands.

The negative association between understorey cover and total bird density initially appears paradoxical when viewed in light of the positive influence of understorey vegetation on species richness. However, understorey vegetation tended to be sparse in Sitka spruce plantations (the maximum value was 8%) yet total bird density was slightly higher than in Oak and Ash native woodlands where understorey vegetation was abundant (maximum value 67%). The model thus negatively associated understorey vegetation with bird density.

Blue Tit, Great Tit and Treecreeper, indicator species identified for Oak and Ash woodlands, are all associated with structural aspects of woodlands. Blue Tit and Great Tit are hole nesting species (Fuller 1995) and it is likely that populations of cavity nesting species are limited in plantations as a result of short rotation times and a lack of old, cavity rich trees (Newton 1994). Treecreepers do not require holes but utilise loose bark and fissures (Fuller 1995), which are also likely to be more common on older trees. The herbivorous diet of Wood pigeons means that native woodlands, with more shrub and understorey vegetation, likely provide higher quality foraging opportunities, hence the identification of this species as an indicator of native woodlands. The occurrence of Robin as an indicator for both native woodlands and Mid-rotation plantations reflects this species' ability to utilise a wide range of habitats (Fennessy and Kelly 2006). Dunnock, common in the pre-thicket and thicket age classes (5–15 years) of plantations (Wilson et al. 2006), was also an indicator of Mid-rotation Sitka spruce plantations. This was surprising as it is a species more associated with scrub (Fuller 1995). It may be that the species manages to persist from early age classes into the Mid-rotation age class, but the oldest plantations become unsuitable, hence the species absence from the Mature stage of the plantation forest cycle.

The Oak and Ash woodlands that were used in this study are all considerably older than any of the plantations. Commercially over-mature (90–150 years) stands of conifers in Great Britain are utilised by birds that are associated with broadleaves (Bibby et al. 1989; Donald et al. 1998). Were Irish plantations allowed to mature to a similar age as native woodlands, bird assemblages of Sitka spruce plantations may eventually come to resemble those of native woodlands as structural diversity increases. Currently, some plantations are being left to mature beyond commercial felling age to provide seed for stock and for recreation purposes, and it would be interesting to survey the bird assemblages of such plantations in the future to test whether they closer resemble those of native woodlands. However, current typical forestry practice involves clearfelling and replanting, and over-mature stands are therefore only likely to occur in areas that are inaccessible or no longer economically viable to harvest.

#### Year of study

We found a positive association between study year and total bird density. Because this study was part of a wider project that also investigated other woodland types, it was not possible to survey all study sites during the same breeding season. Differences between

years were not consistent, although the woodlands with the lowest densities tended to be those surveyed in 2007 and those with the highest in 2008. Year on year differences may be due to high structural complexity in some of the 2008 native woodlands which included some long-established woodland. The winter of 2007 was also unusually mild (Met Éireann 2010) which may have reduced over-winter bird mortality and resulted in higher bird density in 2008.

### Management to benefit bird conservation

A striking feature of these results is the similarity of the bird assemblages of the Mid-rotation and Mature Sitka spruce age classes. Species richness is low in comparison to native woodlands by the time plantations are 20 years old and remains low until felling, which may be 20–30 years later. The Mid-rotation age class therefore provides a management target to increase the utility of plantations to birds.

We have demonstrated the importance of structural components of woodlands, particularly understorey cover, on bird species richness. Thus, management to promote these features and therefore increase the carrying capacity of plantations will likely increase the utility of plantations for bird conservation. Because few woodland specialist species occur in Ireland, and because many of the species in the study occurred in both native and plantation woodlands, there is potential for plantations to host a large proportion of Ireland's terrestrial bird fauna. To achieve this in the relatively short lifetime of a plantation, stands entering the Mid-rotation age class should be targeted for thinning in wide lines or patches to allow light penetration and encourage the establishment of pioneer species such as Birch (*Betula* spp.) and Bramble (*Rubus fruticosus*) and epiphytes such as Ivy (*Hedera helix*). This would mirror more closely the structure of native woodlands and provide both nesting and foraging opportunities for birds, including species of conservation concern such as the Spotted Flycatcher. Alternatively, implementation of forestry practices such as selection systems, where varying numbers of trees are removed at any one time, or the planting of polycultures, may improve structural diversity in plantations (Kerr 1999). The effectiveness of management may then be judged by the population densities of bird species associated with broadleaved vegetation.

Allowing some individual trees or stands of trees to remain and senesce following harvesting may increase nest site availability for cavity nesting species in the long term. The excavation of nest holes by the Great Spotted Woodpecker (*Dendrocopos major*) which appears to be re-colonising Ireland (Coombes 2009) may also increase cavities in such trees in the long term. In the short term, the provision of nest boxes which both Blue Tit and Great Tit are known to readily use (Fuller 1995; Mänd et al. 2009), would likely increase the utility of plantations to cavity nesting species.

### Conclusions

We have demonstrated that the bird assemblages of native woodlands and those of older Sitka spruce plantations are distinct, even in a country with a highly generalised bird fauna. The differences are most likely due to differences in vegetation structure between the woodland types. However, because of the generalist bird fauna typical of Ireland, it is likely that relatively small measures (e.g. carrying out thinning in the Mid-rotation phase) could improve the utility of plantations to birds, and allow more broadleaf-associated species to achieve higher population densities.

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