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[Alder, DC](#) and [Fuller, RJ](#) and [Marsden, SJ](#) (2018) *Implications of transformation to irregular silviculture for woodland birds: A stand wise comparison in an English broadleaf woodland*. *Forest Ecology and Management*, 422. pp. 69-78. ISSN 0378-1127

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Publisher: Elsevier

DOI: <https://doi.org/10.1016/j.foreco.2018.04.004>

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1 Implications of transformation to irregular silviculture for woodland birds: a stand
2 wise comparison in an English broadleaf woodland

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11

12 **Summary**

13 Woodland birds in Britain have undergone significant long term declines since the
14 late 1960s, associated in particular with changes in woodland structure in general,
15 and loss of early successional vegetation. Irregular, continuous canopy broadleaf
16 management is a form of selective logging, very recently adopted in UK that produces
17 woodlands with open canopies and substantial mid- and understorey growth. We
18 examined spring and late winter bird densities, estimated using distance sampling, at
19 310 points in irregular, transitional (that being managed towards irregular), limited
20 intervention, and coppice stands within a large working broad-leaf woodland in
21 lowland southern Britain. Almost all understorey and canopy vegetation measures
22 differed significantly across stand types. Ten of 20 species had highest spring
23 abundance in irregular woodland, five in coppice, three in transitional, and just two in
24 limited intervention. In winter, 5-6 species preferred each of limited intervention,
25 irregular and transitional, while no species preferred coppice. Densities differed little

26 across seasons except in Paridae where abundances increased in late winter during
27 which limited intervention stands were used more by this group. Birds generally
28 occupied similar niche positions and had similar niche breadths across seasons.
29 Compared to under-managed woodlands, irregular silviculture in UK's broadleaf
30 woodlands is likely to enhance habitat quality for woodland birds, including several
31 species of conservation concern e.g. marsh tit *Poecile palustris* which was twice as
32 abundant in irregular stands as in any other stand type.

33 Keywords: Continuous cover forestry, Semi-natural woodland, Irregular silviculture,
34 Stand management, Understorey characteristics, Woodland bird communities.

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39 **1. Introduction**

40 Within the European forestry sector there is growing support for continuous cover
41 forestry (CCF). These systems embrace a diversity of approaches but all seek to
42 retain a continuous woodland cover, as opposed to large scale clear-felling (Mason *et al.*
43 *1999*, Mason 2007). CCF systems, sometimes referred to as ‘irregular forestry’, are
44 often advocated on the basis of having economic, ecosystem service and ecological
45 advantages (Susse *et al.* 2011, Löhmus *et al.* 2016, Pukkala *et al.* 2016). They form
46 one strand of silvicultural alternatives to even-aged forestry which also include
47 ‘ecological forestry’ or ‘close-to-nature forestry’ (Seymour & Hunter 1999, Bürgi
48 2015, Puettmann *et al.* 2015). All of these systems emphasise avoidance of clear-
49 cutting, the use of mixtures of tree species, natural regeneration and small-scale
50 structural variability (Puettmann *et al.* 2015). Improved understanding of the
51 responses of biodiversity to a shift towards CCF from other systems such as clear-
52 cutting and rotational coppicing (Harmer & Howe 2003) have become increasingly
53 important to forest managers (Puettmann *et al.* 2015, Quine *et al.* 2007). Using an
54 ‘irregular’ selective felling system, canopy opening is patchy and can resemble
55 natural woodland processes, with canopy gaps leading to localised seedling
56 regeneration, while developing a continuum of tree and shrub ages from young
57 thicket stage to mature trees in each stand (Susse *et al.* 2011). This structure is
58 expected to create a different range of ecological resources to those present within
59 clear-felling and coppice systems with consequent shifts in the composition of bird
60 communities (Quine *et al.* 2007, Fuller *et al.* 2012). In Europe there have been few
61 comparisons of bird communities in stands managed under CCF with those in stands
62 managed under other regimes, though more data are available for North America
63 (see for example Forsman *et al.* 2010). In beech dominated woodlands in the Belgian

64 Ardenne, bird abundances were higher in uneven stands compared with even-aged
65 (du Bus de Warnaffe and Deconchat, 2008). However, the effects of stand
66 composition (conifer vs broadleaf) was more explicitly demonstrated where
67 management for uneven-aged conifer did not enhance bird diversity. Understorey
68 development from conifer stands undergoing CCF management, important to several
69 species of conservation concern, has highlighted the value of this management type in
70 the UK (Calladine *et al.* 2015).

71 There is a more specific question concerning the wider adoption of new irregular
72 forestry – can it assist in the recovery of declining woodland biodiversity? In the case
73 of birds, several species of woodland birds in Britain have undergone striking
74 contractions of range and decreases in abundance in recent decades. The species
75 affected vary in taxonomy and ecology, though a disproportionately high number of
76 long-distance migrants have declined (Hewson *et al.* 2007, Hewson & Noble 2009,
77 Fuller *et al.* 2013). There are several potential causes of these declines, one of which
78 is reduction in habitat quality as a result of progressive shifts in woodland
79 management that occurred during the 20th century (Fuller *et al.* 2007). Towards the
80 end of that century much woodland had become heavily shaded, with associated
81 reduction of understorey complexity, partly as a result of the demise of coppicing and
82 partly due to canopy-closure in plantations within afforestation and existing
83 broadleaf woodland (Hopkins & Kirby 2007, Mason 2007). Concurrently, numbers of
84 deer also increased in Britain with similar consequences for woodland structure as
85 lack of management (Gill & Fuller 2007). These factors have led to interest in new
86 regimes for woodland management that reflect both biodiversity concerns and which
87 adapt to changes in woodland product demand (Fuller 2013).

88 Britain lacks most of the specialist species dependent on late forest successional
89 stages that can be found, for example, in eastern Europe and Fennoscandia where the
90 conservation priority focuses mainly on retaining old forest stands (Wesołowski
91 2005, Roberge *et al.* 2008). In Britain, however, the restoration of some form of
92 woodland management including CCF Forestry, to unmanaged woods is widely
93 regarded as potentially beneficial for conservation (Fuller *et al.* 2007). This reflects
94 the fact that most unmanaged woodland does not consist of ‘near natural’ stands but
95 is woodland that had formerly been harvested especially by a long tradition of
96 coppicing (Buckley & Mills 2015), and currently exists in a neglected often
97 structurally homogenous condition (Peterken & Mountford 2017, Mason 2007).
98 Therefore, woodland management, which we define here as sustainable harvesting of
99 standing timber of varying age classes, may enhance habitat quality for a range of
100 scarce and declining vertebrate and invertebrate species associated with early
101 successional habitats; many of these species are ones that have been adapted to a
102 very long history of human exploitation of British woodlands (Fuller 2013, Hinsley *et*
103 *al.* 2015). However, not all species may benefit from reintroducing coppicing, an
104 example being marsh tit *Poecile palustris* (Broughton & Hinsley 2015) and
105 invertebrates that depend on features such as standing deadwood (Sterling &
106 Hambler 1988).

107 The results presented here provide, as far as we are aware, the first assessment of the
108 responses of birds to CCF within temperate broadleaved stands in Europe. Our aim
109 was to compare bird abundance and relevant vegetation attributes across four stand
110 types in a large ancient semi-natural woodland: coppice; limited intervention
111 (formerly managed, now neglected); irregular high forest; and transitional high
112 forest. The latter consisted of stands undergoing initial management towards

113 irregular. Having examined differences in habitat structure between these four
114 broadleaf management types, we then compare bird densities both in spring and
115 winter across stand types, and identify contrasts in habitat use across species and
116 seasons.

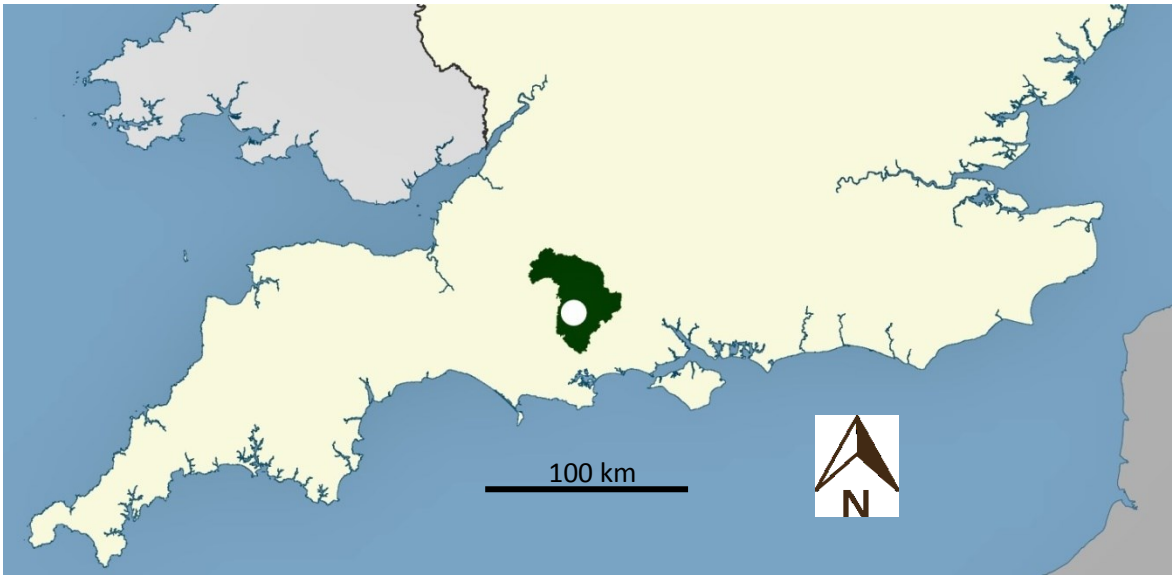
117 **2. Methods**

118

119 *2.1 Location and general description*

120

121 The study was conducted on 442 ha broadleaf woodland and statutorily protected
122 Site of Special Scientific Interest (SSSI) spread across nine contiguous blocks on the
123 Rushmore Estate, in southern England (110-190 m a.s.l; 395724.26 E, 117963.15 N;
124 Figure 1). The principal National Vegetation Classifications (NVC) are W8 (ash-field
125 maple) associated with base-rich soils with some W10 (oak-birch) on slightly acidic
126 soils, that fall within the broad category of lowland mixed deciduous woodlands on
127 fertile soil with several sub-categories around the former (Rodwell *et al.* 1991, B.
128 Edwards *pers. comm.* 2017). The dominant tree and shrub species are ash *Fraxinus*
129 *excelsior*, pedunculate oak *Quercus robur*, field maple *Acer campestre*, silver birch
130 *Betula pendula*, downy birch *Betula pubescens*, hazel *Corylus avellana*, spindle
131 *Euonymus europaeus*, hawthorn *Crataegus monogyna*, willow *Salix cinerea*, goat
132 willow *Salix caprea*, dogwood *Cornus sanguinea* and blackthorn *Prunus spinosa*. There
133 is scattered mature and veteran whitebeam *Sorbus aria*, and more locally distributed
134 beech *Fagus sylvatica* and sycamore *Acer pseudoplatanus*. There are a significant
135 number of veteran trees particularly of oak, ash and field maple along with
136 whitebeam and 19th Century beech plantings (Poore 2016).

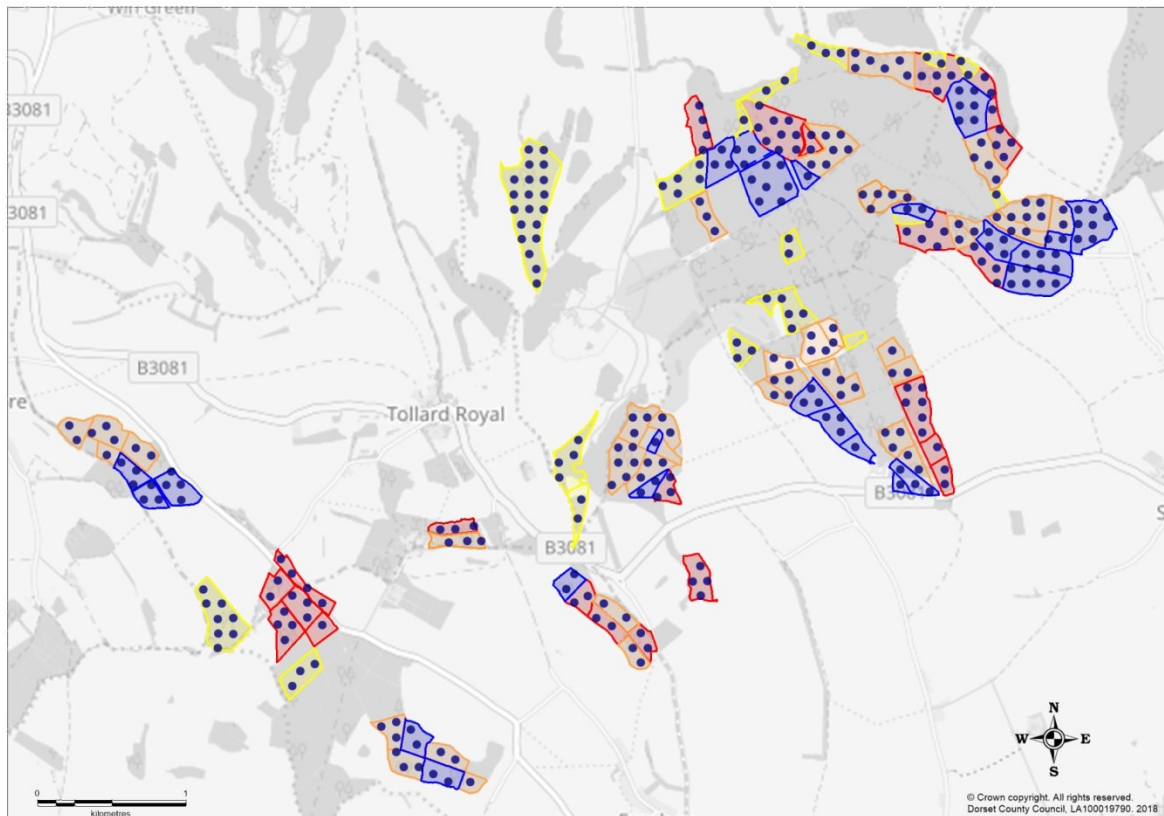


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139 **Fig. 1.** Location of Cranborne Chase and study area, Dorset-Wiltshire border, southern England, UK.

140



141

142 **Fig. 2.** Sampling points within stand types; orange – coppice, blue – transitional high forest, yellow -
 143 limited intervention, and red – irregular high forest.

144

145 *2.2 Descriptions of Stand types*

146

147 The following broadleaf stand management types and prescriptions are described (A.
 148 Poore pers. comm. 2017; see Table 1 and Figure 2).

149 ‘Limited intervention’ stands were those with a closed canopy, high tree density, and
 150 limited understorey due to a long period (>30 years) without formal silvicultural
 151 intervention. Some of the limited intervention stands have developed from open
 152 canopy high forest and have higher understorey densities.

153 'Coppice stands' have few canopy trees (<10% canopy cover) and include both simple
154 coppice and coppice with standards with up to 25% cover of standard trees. Coppice
155 cycle lengths vary depending on uses with hazel dominated, (covering c.15 ha), cut
156 every 8-12 years for hurdle fencing, thatching materials and bean poles. Birch
157 coppice managed on two rotations of pure birch (c.19 ha) cut at 3-4 years for horse
158 jumps or revetment faggots and the remaining 50 ha hazel-birch mix on 25-30 year
159 cycles for wood fuel. (There was a broad representation of growth stages with a mean
160 age of coppice during the study of 9.4 years (SD \pm 6.7) with 0-5 years (n = 25), 6-9
161 years (n = 37), 10-15 (n = 21), years and 15-30 years (n = 18)). At each cutting the
162 entire panel between 0.5-1.5 ha of underwood is removed leading to even-aged
163 regrowth (Harmer & Howe 2003).

164

165 'Irregular High Forest stands' (continuous cover forestry) have been transformed
166 from unmanaged coppice or even-aged stands to a selective irregular management
167 for at least 30 years. This involves selective removal of harvestable trees, and of
168 weaker growing specimens along with cutting of the understorey to increase light
169 levels reaching the woodland floor. The aim is to increase incremental growth of
170 retained trees to enhance their silvicultural and economic value, promote natural
171 regeneration of trees and shrubs and establish a range of tree age classes. Selection
172 of the trees best adapted to site conditions (phenotypes) is a key objective (Susse *et*
173 *al* 2011). Stands with 'moderate stocking' have stand basal areas (> 7.5 cm dbh) in
174 the range 17-24 m² ha⁻¹ whilst those classified as 'low stocking' are in the range 10-16
175 m² ha⁻¹. Understorey stocking varies with past management and the effects of deer,
176 and can be dense in places yet patchily distributed.

177 'Transitional High Forest' stands are intermediate between coppice and irregular
 178 High Forest and are developing towards irregular from former coppice or even-aged
 179 high forest. Transitional stands have undergone initial interventions within the
 180 previous 10-20 years but are yet to develop the range of irregular stand elements i.e.
 181 mixed age and height classes of trees and saplings but often with a developed
 182 understorey. They are variable with regard to both canopy and understorey density.
 183 However, they broadly separate into two categories depending on whether large
 184 trees or pole-stage trees form the canopy (Poore 2016).

185

Woodland type	Stand Type	Area (ha)	% Broadleaf Wood	Number of Sample plots
Semi-Natural Broadleaved Woodland	Irregular High Forest	137.1	31	73
	Transitional High Forest	97.4	22	75
	Limited intervention	102	23	61
	Coppice	106.1*	24	101
Total		442.6	100	310

186 * Area in active rotation currently 85 ha.

187 **Table 1**

188 Areas of semi-natural broadleaved woodland stand types within the Rushmore Estate and number of
 189 sample plots where habitat structural measures and bird community data were collected.

190

191



192

193 **Fig. 3.** Examples of stand types used in study shown clockwise from top left; limited intervention,
194 coppice, transitional and irregular.

195

196 *2.3 Data Collection*

197

198 A plot-based stratified sampling approach was used (Bibby et al 1998, Kent 2012) for
199 310 plots derived from grid coordinates generated in MapInfo (Pitney Bowes Ltd
200 2014) representative of the four stand types. Plots were a minimum distance of 100
201 m apart to minimise duplication in counts of birds (Table 1). To reduce the influence
202 of proximate habitats, plots were located a minimum distance of 30 m from stand
203 edges (Bibby *et al.* 2000). Each plot consisted of a 30 m diameter circle (0.07 ha) with
204 five subplots of 3 m diameter within each (four located at the cardinal points at 10 m

205 radii (see Hansen & Hounihan 1995) and one at 2 m off-centre along a random
206 compass bearing.

207 Within 30 m plots, the following habitat measurements were made: number of trees
208 >50 cm dbh, number of woody stems (coppice and individual trees) of dbh 7.5-≤17.5
209 cm and 17.5-≤50 cm dbh, and the five trees with the largest dbh. These five were
210 identified to species and mean dbh also calculated. At each 3 m subplot, the number
211 of saplings and coppice stems <3 cm, and >3-7.5 cm dbh were counted if >0.5 m tall.
212 Percentage canopy openness was measured with a spherical convex mirror
213 densiometer (Lemmon 1956). Basal area ($\text{m}^2 \text{ha}^{-1}$) was measured at each plot centre
214 using the relascope principle (Bitterlich 1984) with each tree >7.5 cm dbh counted in
215 a 360° sweep at each sample point centre. A minimum number of ten trees are
216 required to give precision (Bitterlich 1984). The relascope application MOTI was
217 used (Rosset *et al.* 2014), calibrated for the basal area factor and camera in a
218 Samsung Galaxy S2 smart-phone. To calculate understorey density, a percentage
219 score of obscuration to the nearest 5% was estimated at each cardinal point using a
220 50 x 30 cm chequer board with 10 x 10 cm squares (Fuller & Henderson 1992).
221 Scores were taken at 0.5 m and 2.0 m above ground to assess variation at different
222 levels. Dead trees and dead branches (snags) over 20 cm diameter were counted at
223 each plot (Charman *et al.* 2010). Percentage means were calculated at each plot for
224 bramble *Rubus fruticosus* cover and area of bare ground.

225 Bird occurrence and abundance was recorded using 5 minute point counts (Bibby *et*
226 *al.* 2000) at the 310 survey plots across three visit periods: early spring (28 April to
227 16 May 2014), late spring (21 May to 13 June 2014) and late winter (10 February to
228 12 March 2015). Counts started one hour after sunrise and completed by 09h30 for

229 the spring visits, and 11h00 for winter visits. Counts took place during fine weather
230 avoiding periods of persistent rain and wind (Bibby *et al.* 1998). The distance to each
231 bird or group on first encounter was measured using a laser rangefinder and
232 distances were estimated to singing/calling birds obscured by vegetation. Birds
233 beyond 50 m of the plot centre were ignored, as were birds flying into or over the
234 plot. Birds flying away were only recorded if they were believed to be 'within' the
235 plot, and the distance to their original position could be measured (Buckland 2006).
236 All fieldwork was carried out by DA.

237

238 *2.4 Data analyses*

239

240 Given the spatial arrangement of woodland stands (Figure 2), it is reasonable to
241 expect some non-independence of sampled survey plots because they are nested
242 within 53 stands. These stands have their own ecological signature, arising both from
243 their geography and its effect on soil, isolation etc, but also through their history of
244 management. The issue of pseudoreplication has received much attention from
245 ecologists and statisticians (e.g. Hulbert 1984), with a great deal of debate as to how
246 important the issue is, and how to best address it (Oksanen 2001; Davies & Gray
247 2015).

248 In an attempt to overcome the effect of non-independence in the across stand type
249 habitat analysis, we "partialled out" the unwanted effect of stand number (the
250 random effect; Davies & Gray 2015). Differences in individual habitat measures were
251 tested across stand type (the Fixed effect) using a generalised linear mixed model in
252 package 'lme4' with Stand number (1-35) as a random factor. The significance of the

253 fixed effect and random effect were calculated using the ANOVA in 'lmerTest', along
254 with Tukey's post hoc pairwise comparisons across stand types.

255 In the bird density analysis, we did not consider stand number as a factor for two
256 reasons. First, points were spaced 100 m apart and positioned in stands which
257 themselves were often just 100-300 m long/wide and usually less than a few
258 hundred metres from each other (Figure 2). Second, numbers of survey points per
259 stand were fairly even (mean = 5.7 ± 3.9 SD) with only five of the 53 stands having
260 more than ten survey points. Any issue in pseudoreplication in the Distance analysis
261 due to two visits to each survey point in the Summer are accounted for in the analysis
262 by lumping data from the two visits to each point under 'effort=2'.

263 To compare across stand types, density estimates (individuals km⁻²), coefficients of
264 variation (% SE) and 95% confidence limits were produced in DISTANCE version 6,
265 (Thomas *et al.* 2010). Data were truncated removing the furthest 5% of bird records
266 to minimise the influence of outliers in the model. Data were entered as groups with
267 'exact' distances to encounters, with encounters of flying birds removed. Detection
268 functions for spring and winter were very different, reflecting both the profound
269 changes in visual detectability caused by leaf-fall in the largely deciduous woodland,
270 and changes in vocalisation patterns between breeding and non-breeding seasons.
271 While covariates (see below) can be added to alter parameters in the detection
272 function to account for variation in vegetation coverage across plots but within
273 season, we thought it safer to conduct separate seasonal analyses as the actual family
274 of detection model (e.g. Uniform, Half-normal) was likely to differ between spring and
275 winter. The Multiple Covariate Distance Sampling (MCDS) engine was used with
276 understorey density included as a covariate likely to influence detection probability

277 (Marques *et al.* 2007). Density estimates for each species in each stand type were
278 compared using ANOVA (seasons analysed separately) and significant differences
279 between pairs of stand types identified with Tukey's range tests.

280 Principal components analysis (PCA) was used to condense the habitat variables onto
281 two component axes/factors (Jolliffe 2002) and centroids for stand type and each
282 bird species plotted on these axes. The differences between mean 'niche positions'
283 (coordinates of plots at which each bird species was recorded) on factors 1 and 2 in
284 spring and winter were tested using Wilcoxon matched pairs tests. Niche widths of
285 species on the two factor axes were calculated as the standard deviations of Factor 1
286 and 2 scores for 'positive' plots for each species. We then examined any widening or
287 narrowing of habitat associations between seasons (Lloyd & Marsden 2008).

288

289 **3. Results**

290

291 *3.1 Habitat differences between stand types*

292

293 Fifteen of the 17 vegetation habitat variables differed significantly across stand types
294 (Table 2). Only dbh of largest tree did not differ significantly between stands.

295 Understorey densities were highest in coppice and irregular with coppice having
296 markedly higher density at 2.0 m. Bramble cover was highest in irregular while the
297 area of bare-ground was significant in limited intervention. Basal areas were lowest

298 in both irregular and coppice compared to limited intervention and transitional
 299 stands. Canopy openness was much greater in irregular plots than in other stands.

Habitat Variable	Coppice (n 101)		Irregular (n 73)		Limited (n 61)		Transition (n 75)		Random	Fixed
Basal Area	18.0	(11-22) L	18.0	(15-22) L	29.0	(24-33) T	22.0	(18-27) L	0.001	< 0.001
Canopy Openness	10.4	(8-19)	21.3	(14-29) L	9.9	(8-14) I	10.9	(8-21)	0.001	0.06
Mean dbh	36.0	(24-49) I	50.6	(44-56) C	42.8	(34-53)	39.4	(34- 50)	0.001	0.001
Largest dbh	61.0	(46-79)	71.0	(58-82)	67.0	(52-83)	62.0	(51-70)	0.02	0.07
No. Oak	1.0	(0-2)	1.0	(0-2)	0.0	(0- 0)	1.0	(0-2)	0.001	0.10
No. Ash	1.0	(0-2) I L	3.0	(2-4) C	2.0	(1-3) C	2.0	(1-4)	0.001	0.002
No. deadwood snags	8.0	(4-12)	13.0	(7-17)	8.0	(6-12)	8.0	(6-16)	0.001	0.07
Logs (m) per plot	0.0	(0-4) L	0.0	(0-4)	3.0	(0-8) C	1.0	(0-4)	0.001	0.02
Understorey density 0.5m	48.0	(25-85) L T	56.0	(19-75) L T	7.0	(3-22) C I	20.0	(11-36) I C	0.001	<0.001
Understorey density 2m	52.5	(30-76) I L T	23.8	(8-39) C	13.8	(5-28) C	17.5	(9-28) C	0.001	<0.001
No. stems ≤3 cm dbh	9.2	(5-18) I L T	2.8	(1-7) C	0.6	(0-2) C	5.4	(2-10) C	0.001	<0.001
No. stems 3-7.5 cm dbh	3.2	(1-7) I L	0.2	(0-1) C	0.8	(1-2) C	2.2	(0-4)	0.001	<0.001
No. trees 7.5-17.5 cm dbh	9.0	(1-39) L	9.0	(1-21) L	69.0	(43-88) C I T	21.0	(7-59) L	0.001	<0.001
No. trees 17.5-50 cm dbh	2.0	(0-4) L T	5.0	(2-7) L	11.0	(5-16) I C	7.0	(3-12) C	0.001	<0.001
No. trees ≥50cm dbh	1.0	(0-2)	2.0	(1-3) C T L	2.0	(1-3)	1.0	(1-2)	0.001	0.10
Bramble % cover	2.8	(0-19) I	30.0	(5-56) C T L	0.0	(0-4) I	0.0	0-7 I	0.001	<0.001
Bare ground %	8.4	(0-29) I	1.4	(0-12) L	26.0	(13-59) I	12.6	(6-35)	0.001	0.008

300

301 **Table 2**

302 Median values of habitat variables measured across the four stand types; lower and upper
 303 quartiles in parenthesis and results of ANOVA tests for random effects (stand number) and fixed
 304 effects (stand type) Pairwise comparisons using Tukey's *post-hoc* test, for stands; C - coppice, I -
 305 Irregular, L - Limited intervention and T - Transitional; those in bold are highly significant P <
 306 0.005.

307

308

309 *3.2 Bird densities across stand types and season*

310

311 Across the 310 points, we accumulated 4,994 bird records of 38 species. We
 312 calculated density estimates for 16 resident species and four spring migrants (Table
 313 3). Three from the 20 species went unrecorded in limited intervention stands, and
 314 two of the species were spring migrants (willow warbler *Phylloscopus trochilus* and
 315 garden warbler *Sylvia borin*). Six and five species had density estimates > 100
 316 individuals km⁻² in at least one stand type in spring and winter respectively. Blue tit
 317 *Cyanistes caeruleus* and wren *Troglodytes troglodytes* had estimates > 100 individuals
 318 km⁻² in all stand types in spring, and blue tit and great tit *Parus major* in all stand
 319 types in Winter.

320

321

	Spring				Winter			
	Coppice	Irregular	Limited intervention	Transitional	Coppice	Irregular	Limited Intervention	Transitional
Woodpigeon <i>Columba palumbus</i>	60.1 ± 10 49-73(86) > I	32.4 ± 17 23-45(33)	74.2 ± 12 59-94(62) > I	66.0 ± 11 53-82(71) > I	17.0 ± 35 9-33(12)	20.0 ± 33 10-39(10)	38.1 ± 22 25-59(16)	47.2 ± 21 31-71(25) > C
Great spotted woodpecker <i>Dendrocopos major</i>	10.4 ± 27 6-18(15)	12.7 ± 31 7-23(13)	7.1 ± 47 3-17(6)	9.2 ± 34 5-18(10)	5.4 ± 50 2-14(4)	19.0 ± 34 10-36(10)	22.8 ± 30 13-41(10)	16.2 ± 36 8-33(9)
Goldcrest <i>Regulus regulus</i>	25.9 ± 27 15-44(16)	27.2 ± 29 16-48 (12)	27.7 ± 32 15-51(10)	60.1 ± 19 42-87(28) > C I	48.8 ± 28 28-84(15)	68.8 ± 30 38-124(15)	93.3 ± 27 55-159(17)	47.9 ± 30 27-86(11)
Blue tit <i>Cyanistes caeruleus</i>	124.7 ± 12 99-158(66)	135.1 ± 13 115-175(51)	129.4 ± 15 96-174(40)	120.5 ± 14 92-158(48)	173.3 ± 10 142-211(74)	244.5 ± 9 206-290(74) > C	197.7 ± 13 153-255(50)	200.5 ± 11 161-249(64)
Great tit <i>Parus major</i>	92.4 ± 22 61-141(27)	115.2 ± 24 72-184(24)	128.9 ± 24 81-206(22)	86.4 ± 25 53-141(19)	155.9 ± 19 107-228(29)	182.1 ± 20 123-269(24)	236.0 ± 19 163-343(26)	194.2 ± 22 126-299(27)
Coal tit <i>Periparus ater</i>	22.5 ± 24 14-36(21)	27.0 ± 24 17-44(18)	9.2 ± 45 4-22(5)	17.1 ± 30 10-30(12)	17.3 ± 43 8-39(7)	59.3 ± 25 36-96(17)	62.6 ± 26 37-105(15)	66.1 ± 24 41-105(20) > C
Marsh tit <i>Poecile palustris</i>	65.1 ± 21 43-99(29)	122.8 ± 19 86-176(39) > C L T	53.8 ± 27 32-91(14)	34.9 ± 29 20-63(12)	63.1 ± 22 41-96(21)	76.4 ± 24 48-122(18)	86.3 ± 27 51-146(17)	68.4 ± 23 43-108(17)
Long-tailed Tit <i>Aegithilos caudatus</i>	66.0 ± 36 33-130(13) > L	56.5 ± 46 24-133(8) > L	0 0	33.5 ± 50 13-86(5) > L	77.7 ± 37 39-157(10)	65.7 ± 45 28-153(6)	78.7 ± 44 34-182(6)	41.6 ± 53 15-112(4)
Chiffchaff <i>Phylloscopus collybita</i>	98.4 ± 11 80-122(82)	82.5 ± 14 63-108(49)	34.9 ± 23 23-55(17)	35.0 ± 21 23-52(22)				

	>> L T	> L T							
Willow warbler	19.3 ± 62 7-64(10)	5.4 ± 89 1-25(2)	0	3.0 ± 113 0.5-16(1)					
<i>Phylloscopus trochilus</i>	> L	> L		> L					
Blackcap	101.1 ± 12	120.2 ± 13	50.4 ± 21	49.3 ± 19					
<i>Sylvia atricapilla</i>	81-127(79) >L T	94-154(67) >>L T	33-77(23)	34-71(29)					
Garden warbler	30.3 ± 20 21-45(38)	18.9 ± 28 11-33(17)	0	7.4 ± 38 4-15(7)					
<i>Sylvia borin</i>	> L T	> L		> L					
Nuthatch	24.4 ± 32	31.4 ± 35	27.9 ± 37	29.7 ± 33	20.8 ± 23	29.4 ± 24	37.3 ± 21	29.6 ± 23	
<i>Sitta europaea</i>	9-32(16)	16-61(16)	14-57(17)	16-56(17)	13-33(16)	18-47(16)	25-56(17)	19-47(17)	
Treecreeper	9.4 ± 32	30.2 ± 21	25.6 ± 25	21.1 ± 24	20.4 ± 31	48.9 ± 22	34.4 ± 33	24.6 ± 32	
<i>Certhia familiaris</i>	5-18(10)	20-46(23) > C	16-41(16)	13-34(17)	11-37(10)	31-76(17)	18-66(10)	13-46(9)	
Wren	108.6 ± 8	221.6 ± 6	148.0 ± 8	180.1 ± 8	77.9 ± 15	163.5 ± 13	88.7 ± 19	106.6 ± 18	
<i>Troglodytes troglodytes</i>	92-128(121)	195-252(176) >> C L	126-172(96)	154-211(151) >> C	58-105(43)	126-212(64) >> C > L	62-128(29)	74-153(44)	
Blackbird	56.2 ± 10	53.6 ± 12	46.9 ± 14	63.2 ± 11	60.1 ± 16	82.4 ± 19	31.0 ± 28	49.2 ± 21	
<i>Turdus merula</i>	46-68(78)	43-68(53)	36-62(38)	51-79(66)	44- 83(36)	56-121(35) > L	18-54(11)	33-74(22)	
Song thrush	29.2 ± 15	24.0 ± 19	11.0 ± 36	24.6 ± 18	24.3 ± 24	21.7 ± 27	19.5 ± 31	27.4 ± 23	
<i>Turdus philomelos</i>	22-39(41) > L	17-35(24)	6-22(9)	17-35(26)	15- 39(19)	13-37(12)	11-36(9)	18-43(16)	
Robin	134.0 ± 9	87.9 ± 13	132.6 ± 12	150.3 ± 10	80.9 ± 13	76.1 ± 15	96.1 ± 14	104.2 ± 11	
<i>Erithacus rubecula</i>	112-161(109)	68-114(51)	106-167(61)	125-182(92) > I	62-105(54)	56-103(36)	73-127(38)	83-131(52)	
Dunnock	51.8 ± 20	61.9 ± 22	20.9 ± 40	26.3 ± 29	67.3 ± 23	107.6 ± 20	15.1 ± 50	57.0 ± 27	
<i>Prunella modularis</i>	35-77(34)	40-96(29)	10-45(8)	15-46(13)	43-105(30)	72-160(34) > L	6-39(4)	34-97(19)	
Chaffinch	16.1 ± 20	29.8 ± 17	25.3 ± 22	19.7 ± 21	26.7 ± 23	25.2 ± 24	23.7 ± 31	35.8 ± 22	
<i>Fringilla coelebs</i>	11-24(25)	22-41(34)	17-39(23)	13-30(23)	17-42(21)	16-41(14)	13-43(11)	23-55(21)	

322

323 Table 3

324 Density estimates (individuals km⁻² ± CV), 95% confidence intervals and numbers of encounters for
325 resident and spring migrant woodland birds by season and stand type. Also shown are results of
326 Tukey's Range Test pairwise comparisons of density across stand types, where > indicates pairs differ
327 at P<0.05 and >> P<0.005. Direction of sign denotes which density estimate is larger. C = coppice; I =
328 irregular; L = limited intervention; T = transitional.

329

330 The mean variation in densities across stand types in spring (the percentage

331 difference between pairs of stand wise densities) was 31.2% ± 23.0 (SD; n = 96). For

332 winter, variation was $29.8\% \pm 20.8$ ($n = 96$), these figures not differing significantly
333 ($W = 4640$, $p = 0.94$). There were significant differences in across-stand densities for
334 twelve species in spring and six in winter (Table 3). Ten species had highest spring
335 density estimates in Irregular stands, with seven of these being significantly higher
336 than in Low intervention stands, and three being significantly higher than in both
337 transitional and coppice. Marsh tit *Poecile palustris* and all four summer warblers had
338 significantly higher densities in irregular over limited intervention. Coppice had five
339 species with highest spring densities, and these included three of the four migrant
340 warblers. All five species occurred in densities within coppice that were significantly
341 higher than in limited intervention, transitional, or both. There were far fewer
342 significant differences in densities across stand types in winter. Irregular stands had
343 higher densities of four species than coppice, limited intervention, or both, while
344 transitional was significant compared to coppice for two species.

345

346 *3.3 Habitat gradients and bird niche positions from ordination*

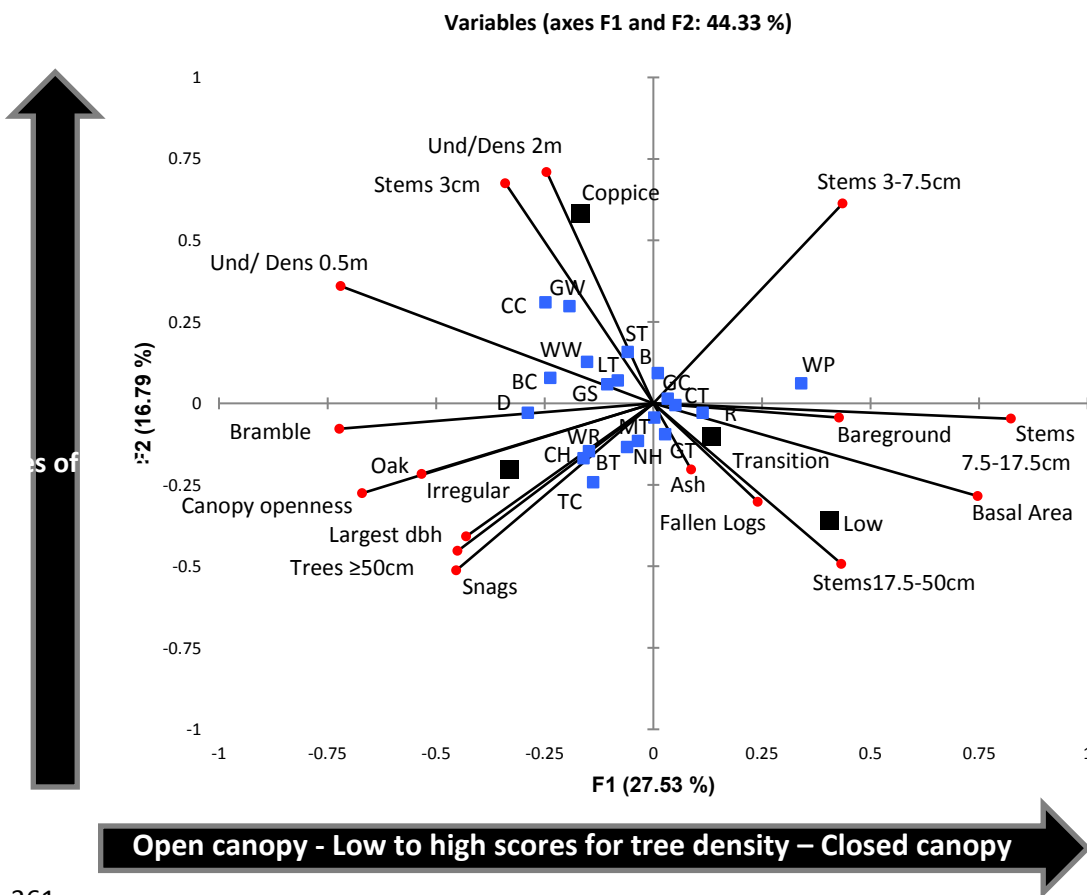
347

348 PCA identified two woodland structural gradients which accounted for 44.3% of the
349 variance within 15 original habitat variables (Figure 3). Factor axis 1 represented a
350 gradient from open canopy mainly oak woodland with scattered large trees (>50 cm
351 dbh) associated with irregular stands to more closed woodland with relatively high
352 tree and stem density aligned closely to limited intervention stands. These denser
353 woodlands were composed of small saplings and shoots (3-7 cm dbh), small to
354 medium (7-17.5 cm dbh), and larger (17.5-50 cm) trees. Factor 2 was associated
355 with greater understorey density at both 0.5m and 2.0m height and had high density

356 of stems (<3 cm dbh) associated with coppice stands. These variables are negatively
 357 correlated with high scores for medium-large diameter sized trees within limited
 358 intervention stands.

359

360

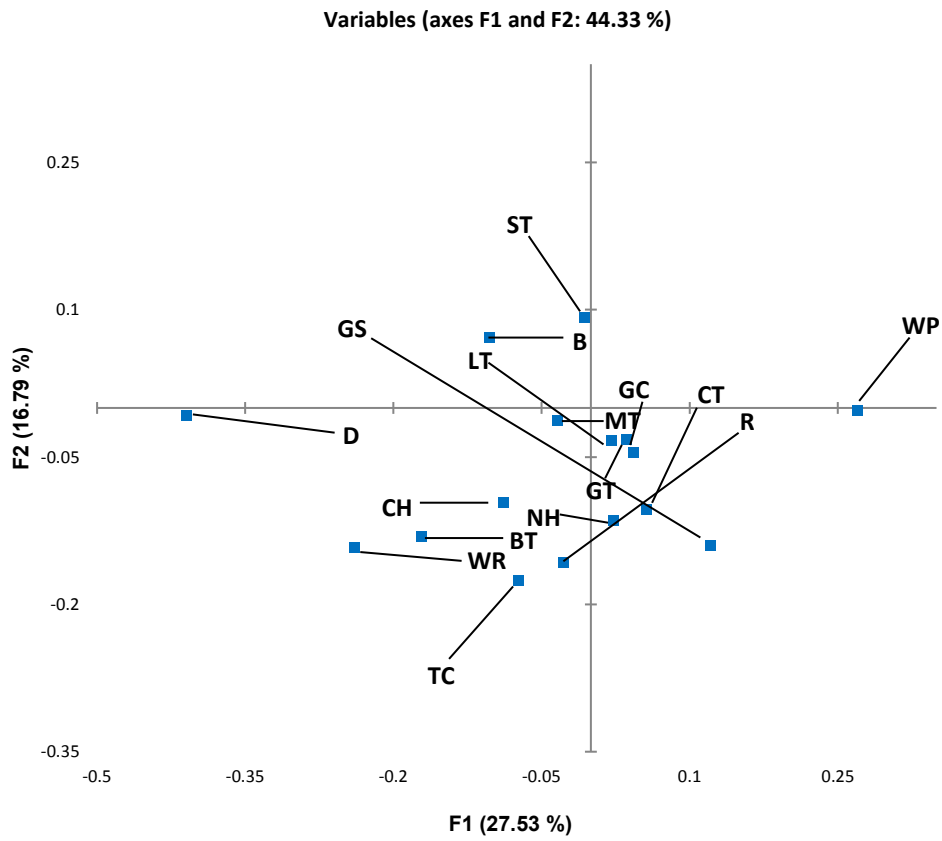


361

362 **Fig. 4.** Ordination of sample plots on PCA Factors 1 and 2 with vectors showing contribution of
 363 individual habitat variables. Ordinations show mean positions of stand management types and bird
 364 species during the spring. B – blackbird, BC – blackcap, BT – blue tit, CH – chaffinch, CC, chiffchaff, CT –
 365 coal tit, D – dunnoek, GC – goldcrest, GS –great spotted woodpecker, GT – great tit, GW – garden
 366 warbler, LT – long-tailed tit, MT – marsh tit, NH – nuthatch, R – robin, ST – song thrush, TC –
 367 treecreeper, WP – woodpigeon, WR – wren, WW – willow warbler.

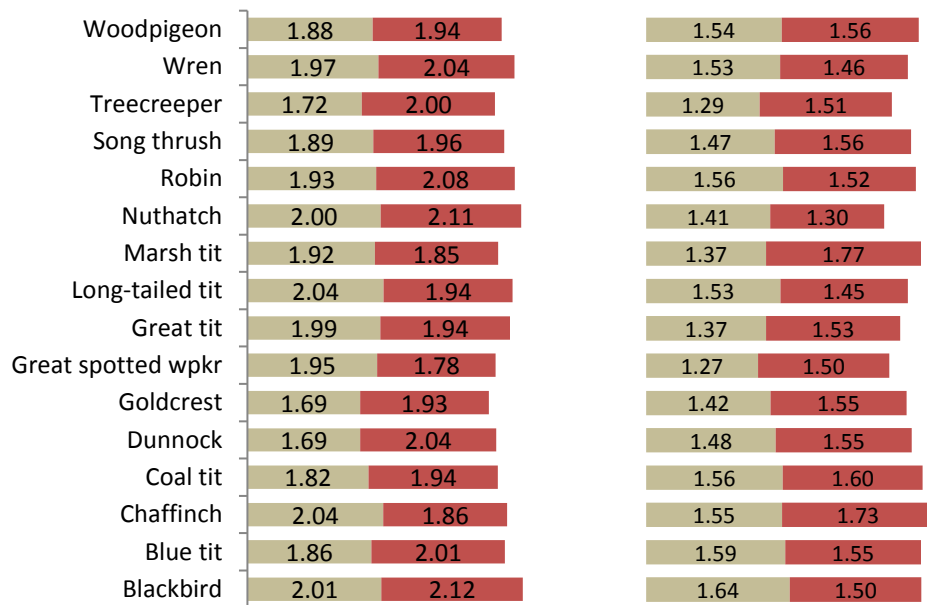
368

369 The majority of bird species were associated with either coppice-like plots (dense
370 understorey; top-left quadrant of Figure 4) or irregular-type plots (open canopy;
371 bottom-left quadrant). Garden warbler and willow warbler were particularly
372 associated with coppice, and treecreeper *Certhia familiaris*, blue tit and chaffinch
373 with irregular-type stands. Woodpigeon *Columba palumbus* was the only species
374 strongly associated with dense plots characteristic of limited intervention
375 management. There was no systematic pattern of seasonal niche position shifts
376 across species (Figure 3a; F1: $V = 64$, $p = 0.85$, $n = 16$; F2: $V = 51$, $p = 0.40$, $n = 16$).
377 Five species 'shifted' to increasingly open woodland in winter - notably dunnock,
378 already associated with open woodland, and wren associated with dense
379 understorey. Great spotted woodpecker *Dendrocopos major* showed the greatest
380 niche position shift, being associated with open woodland and dense understorey in
381 spring and closed canopy plots (limited intervention) in winter. There was no
382 significant increase or decrease in niche breadths between spring and winter (F1: $V =$
383 35 , $p = 0.10$, $n = 16$ F2: $V = 38$, $p = 0.13$, $n = 16$) (Figure 3b).



384

385 a.



386 b.

387 **Fig. 4.** Spring and winter niche characteristics for resident woodland birds. a. niche position shifts
388 from spring (letter codes; see Fig.4.) to Winter – (blue points); b. niche breadth changes from Spring to
389 Winter on Factor 1 and Factor 2 scores left and right respectively.

390

391

392 **4. Discussion**

393 *4.1 Differences between stand types*

394

395 There were clear differences between stand types in both bird communities and
396 woodland structure. Unlike other stand types, irregular management was
397 characterised by more open woodland with larger trees and an uneven mix of ages.
398 Spring bird densities were highest or second highest in irregular for 15 of the 20
399 species examined. In contrast, limited intervention had the lowest or second lowest
400 spring densities for 14 of 20 species, with notably low abundances for species, such
401 as the warblers, that require complex understorey structures. There were generally
402 low numbers of warblers in transitional stands suggesting the understorey was
403 insufficiently developed. As expected from previous studies in the UK, three of four
404 summer migrant warbler species had highest densities in coppice (e.g. Fuller &
405 Henderson 1992, MacColl *et al.* 2014) but all had second highest densities in irregular
406 stands with blackcap *Sylvia atricapilla* more abundant. In winter, for all species, the
407 highest abundances occurred in irregular, transitional and limited intervention
408 stands, although there were fewer differences in bird abundances between stand
409 types than in spring.

410 Previous European studies of birds in CCF stands have generated mixed findings
411 although importantly these are not in pure broadleaf woodlands as in our study.
412 Working in spruce plantations in upland Britain, Calladine *et al.* (2015) found that
413 most 'mature forest' bird species reached higher abundance in CCF than in rotational
414 clear-fells. However, in Belgium, du Bus de Warnaffe and Deconchat (2008) reported
415 that in beech and conifer forests, no clear differences in bird communities were
416 evident between CCF and clear-cut systems. In North America, a meta-analysis by
417 Forsman *et al.* (2010) found that silviculture creation of small gaps did not result in
418 clear negative impacts on bird communities relative to unlogged forest.

419

420 *4.2 Seasonal differences*

421

422 There were fewer differences between bird densities across stand types in winter
423 than in spring, presumably because resource use patterns differ in the former and
424 latter (Fuller *et al.* 2012). In winter, many species, especially titmice, Paridae,
425 nuthatch *Sitta europaea* and treecreeper become increasingly mobile, gleaning insect
426 larvae from bark and buds in stands with higher tree density (Fuller 1995). In our
427 study, this group of birds associated least with coppice in winter. Previous studies
428 have shown these resident species associated with a broader range of woodland
429 habitats in winter (Bilke 1984). Although we did not look at demographic variation in
430 our study it is known that several species differ in their seasonal responses to
431 understorey age, coppice especially, depending on whether they are adult or
432 juveniles (MacCol *et al.* 2014). Four species (blue tit, blackbird *Turdus merula*, wren
433 and dunnoek *Prunella modularis*) had significantly higher winter densities in

434 irregular than in limited intervention stands. For those species associated with
435 foraging close to the woodland floor, it seems likely that the denser understorey of
436 irregular stands provides increased protection from predation risk and thermal
437 variation (Holt *et al.* 2014). Although we found no statistically significant niche shifts
438 from spring to winter for resident species, there were a few notable changes in
439 habitat/niche use. Wren and dunnoek were both significantly more abundant in
440 irregular stands during the breeding season, and this association strengthened
441 during the winter, presumably as they sought increased protection in the denser
442 shrub-layer. Bramble *Rubus fruticosus* cover was significantly higher in irregular
443 stands and contributed to the understorey density values at 0.5 m above ground
444 which was strongly associated with this stand type. Winter marsh tit densities were
445 highest in limited intervention, although its density in irregular stands were only a
446 little lower, perhaps reflecting a widening of home range and differential use of
447 habitats between the breeding and winter periods (Broughton *et al.* 2014). This is
448 likely to be true of several species although there was little evidence of systematic
449 movement of niches. Great spotted woodpecker was associated with open woodland
450 during spring (see Calladine *et al.* 2015) and moved into stands with a greater
451 abundance of fallen deadwood, closed canopy and higher basal area in winter.

452

453 *4.3 Implications for woodland bird conservation*

454

455 We are unaware of any similar research in lowland broadleaved woodland in Britain
456 or Europe where stands have undergone a transformation to an irregular high-forest
457 management system, a type of CCF. Taken overall, the findings suggest that irregular

458 forestry can provide suitable woodland habitats for a high proportion of bird species
459 in lowland British woodland, especially in spring, and that for some species it may
460 even provide preferred habitats. In combination with previous studies referred to
461 above, our research suggests that CCF is likely to be either beneficial or neutral in
462 terms of its effects on bird communities. However, two important caveats should be
463 acknowledged. Firstly, the effects may be context dependent according to region,
464 forest type and the exact stand types being compared. Secondly, some early
465 successional bird species may prefer either coppice or young clear-fells which can
466 provide larger areas of young-growth than are found with CCF (Calladine *et al.* 2015).
467 For example, in our study we found tree pipit *Anthus trivialis* exclusively in recent
468 clear-fell gaps outside of the stand types under question.

469 The value of coppicing to early successional birds and other species associated with
470 dense understorey is well documented (Fuller & Warren 1991, Fuller 1992, Maccoll *et*
471 *al.* 2014) while it has a strong cultural association with many ancient semi-natural
472 woods such as those found in Cranborne Chase (Rackham 1990, A. Poore pers. comm.
473 2017). Other than government grant-funding targeted at sites of high nature
474 conservation value, woodfuel produce is likely to be the main economic driver
475 sustaining coppice management (Fuller 2013, Buckley & Mills 2015). However,
476 irregular stand management as a more widely economically viable system appears to
477 provide resources for most woodland birds associated with both understorey and old
478 growth here in southern England. Furthermore, proponents of CCF point out the
479 multiple benefits it can offer in terms of meeting sustainability measures (Bürge
480 2015).

481 No single silvicultural system can provide the preferred habitat of all woodland birds.
482 In practice, therefore, a conservation strategy that embraces a dynamic range of
483 management interventions is desirable to enhance habitat heterogeneity and
484 complexity at varying spatial and temporal scales (Fuller *et al.* 2007, 2012). Irregular
485 CCF forestry clearly has the potential to play an important role in developing this
486 heterogeneity. However, there is a question about whether it can meet the
487 requirements of all early successional species. In this respect, further work is needed
488 to assess how varying gap sizes within different variants of CCF affect biodiversity
489 (Puettmann *et al.* 2015).

490 Finally, the results of this study support the notion that in a British context,
491 management of neglected woodland benefits the numbers of many woodland bird
492 species. Both the irregular stands and the coppiced stands held higher densities of
493 breeding birds than the limited intervention stands, typical of much neglected
494 woodland in lowland Britain. Restoration of such stands to a structurally more
495 complex state through opening up the canopy to stimulate the understorey would be
496 beneficial and, if conducted on a sufficiently large scale, could potentially assist in the
497 recovery of some woodland bird populations at a regional level. In this context, it is
498 notable that the spring abundance of marsh tit in irregular stands was approximately
499 twice that in the other stand types. Broughton and Hinsley (2015) cautioned that
500 large scale management by coppicing could be detrimental to habitat quality for this
501 species, but it appears that irregular stand management may benefit it, though more
502 research is needed to draw firm conclusions. An integrated approach to forest
503 management which incorporates stand-level targets to attain biodiversity attributes
504 e.g. deadwood, as shown by Susse *et al.*(2012) is an exciting option; particularly if it

505 can be adapted to include measures that provide important functional resources used
506 by woodland birds in the UK including those associated with understorey.

507

508 **Acknowledgements**

509

510 Andy Poore (Consultant Forest Manager) provided background information on stand
511 management and suitable locations for the study. Ian Burt (Rushmore Estate) and
512 Rhiannon Rogers, Jon Corkill (Dorset Environmental Records Centre) helped with
513 fieldwork and GIS support. For access to the woodlands we are grateful to the
514 Trustees of the Rushmore Estate and particularly support from the managing agents
515 Philip Gready and Ruth Mason, along with Andy Taylor, Robert Taylor and Don
516 Taylor for their practical assistance. We are particularly grateful to Dr Annabel King
517 for the recommendation and assistance given during the planning stages. The
518 fieldwork was funded by the Golden Bottle Trust, Henry Hoare Charitable Trust and
519 Forestry Commission (England). The study formed part of a multi-taxon study of the
520 effects of transformation of broadleaf woodland overseen by Dr Phil Sterling (Dorset
521 County Council) and Andy Poore. There are no declarations of conflicts of interests.

522

523

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527 **References**

- 528 Bibby, C. J., Marsden, S., & Jones, M., 1998. Bird surveys. Expedition Advisory Centre.
529
- 530 Bibby, C.J., Burgess, N.D., Hill, D.A., Mustoe, S.H., 2000. Bird census techniques. Second
531 ed. Academic Press, UK.
532
- 533 Bilcke, G., 1984. Seasonal changes in habitat use of resident passerines. *Ardea*, 72(1),
534 pp.95-99.
535
- 536 Bitterlich, W., 1984. The relascope idea. Relative measurements in forestry.
537 Commonwealth Agricultural Bureaux.
538
- 539 Broughton, R., & Hinsley, S. 2015. The ecology and conservation of the Marsh Tit in
540 Britain. *British Birds*, 108(1), 12-28.
541
- 542 Broughton, R. K., Bellamy, P. E., Hill, R. A., & Hinsley, S. A., 2014. Winter habitat
543 selection by Marsh Tits *Poecile palustris* in a British woodland. *Bird Study*, 61(3),
544 404-412.
545
- 546 Buckland, S. T., 2006. Point-transect surveys for songbirds: robust methodologies.
547 *The Auk*, 123(2), 345-357.
548
- 549 Buckley, P., & Mills, J., 2015. The Flora and Fauna of Coppice Woods: Winners and
550 Losers of Active Management or Neglect? *Europe's Changing Woods and Forests:*
551 *From Wildwood to Managed Landscapes*, CABI, Wallingford, UK 129-139.

552

553 Bürgi, M., 2015 Close-to-nature forestry. In: Kirby, K., Watkins, C. (Eds.),
554 Europe's Changing Woods and Forests: From Wildwood to Managed Landscapes.
555 CABI, Wallingford, UK, pp. 107–115

556

557 Calladine, J., Bray, J., Broome, A., & Fuller, R. J., 2015. Comparison of breeding bird
558 assemblages in conifer plantations managed by continuous cover forestry and
559 clearfelling. *Forest Ecology and Management*, 344, 20-29.

560

561 Charman, E. C., Smith, K. W., Gruar, D. J., Dodd, S., & Grice, P. V., 2010. Characteristics of
562 woods used recently and historically by Lesser Spotted Woodpeckers *Dendrocopos*
563 minor in England. *Ibis*, 152(3), 543-555.

564

565 Davies, G.M. & Gray, A. 2015. Don't let spurious accusations of pseudoreplication limit
566 our ability to learn from natural experiments (and other messy kinds of ecological
567 monitoring). *Ecology & Evolution* 5: 5295–5304.

568

569 du Bus de Warnaffe, G. & Deconchat, M., 2008 Impact of four silvicultural systems on
570 birds in the Belgian Ardenne: implications for biodiversity in plantation forests.
571 *Biodiversity and Conservation*, 17, 1041-1055.

572

573 Forsman, J. T., Reunanen, P., Jokimaki, J. & Monkkonen, M., 2010. The effects of small-
574 scale disturbance on forest birds: a meta-analysis. *Canadian Journal of Forest*
575 *Research*, 40, 1833-1842.

576

577 Fowler, J., & Cohen, L., 1996. Statistics for Ornithologists (BTO Guide 22) Thetford,
578 Norfolk. 150pp.
579

580 Fuller, R.J., 1992. Effects of coppice management on woodland breeding birds. In
581 Ecology and Management of Coppice Woodlands. G.P. Buckley (ed.). Chapman & Hall,
582 London, 169-192.
583

584 Fuller, R. J., 2013. Searching for biodiversity gains through woodfuel and forest
585 management. *Journal of Applied Ecology* 50(6): 1295-1300.
586

587 Fuller, R.J., Gillings, S., Lauder, A.W. & Crowe, O., 2013. Pattern and change in the
588 British and Irish avifaunas over a 40 year period. In *Bird Atlas 2007-11: The Breeding
589 and Wintering Birds of Britain and Ireland* (D.E. Balmer, S. Gillings, B.J. Caffrey, R.L.
590 Swann, I.S. Downie & R.J. Fuller), pp 115-146. BTO Books, Thetford.
591

592 Fuller, R. J., & Henderson, A. C. B., 1992. Distribution of breeding songbirds in
593 Bradfield Woods, Suffolk, in relation to vegetation and coppice management. *Bird
594 Study*, 39(2), 73-88.
595

596 Fuller, R. J., 1995. *Bird life of woodland and forest*. Cambridge University Press,
597 Cambridge.
598

599 Fuller, R. J., Smith, K. W., Grice, P. V., Currie, F. A. & Quine, C. P., 2007. Habitat change
600 and woodland birds in Britain: implications for management and future research.
601 *Ibis*, 149 (Suppl.): 261-268.

602

603 Fuller, R. J., Smith, K. W., & Hinsley, S. A., 2012. Temperate western European
604 woodland as a dynamic environment for birds: a resource-based view. In *Birds and*
605 *Habitat: Relationships in Changing Landscapes*, (ed. R.J. Fuller). Cambridge:
606 Cambridge University Press, pp. 352-380.

607

608 Fuller, R.J. & Warren, M.S., 1991. Conservation management in ancient and modern
609 woodlands: responses of fauna to edges and rotations. In Spellerberg, I.F., Goldsmith,
610 F.B. & Morris, M.G. (eds.). *The Scientific Management of Temperate Communities for*
611 *Conservation*. Pp. 445-471. British Ecological Society 31st Symposium. Blackwell,
612 Oxford.

613

614 Gill, R.M.A. & Fuller, R.J., 2007. The effects of deer browsing on woodland structure and
615 songbirds in lowland Britain. *Ibis*, 149 (Suppl.2), 119-127.

616

617 Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments.
618 *Ecol. Monogr.* 54: 187–211.

619

620 Hansen, A.J., and Hounihan, P., 1995. Canopy retention and avian diversity in the
621 Oregon Cascades. In *Biodiversity in managed landscapes: theory and practice*. Edited
622 by R. Szaro and D.W. Johnston. Oxford University Press, London, U.K. pp. 401–421.

623

624 Harmer, R. and Howe, J., 2003. *The silviculture and management of coppice*
625 *woodlands*. Forestry Commission, Edinburgh, UK.

626

627 Hewson, C.M., Amar, A., Lindsell, J.A., Thewlis, R.M., Butler, S., Smith, K. & Fuller, R.J.,
628 2007. Recent changes in bird populations in British broadleaved woodland. *Ibis*, 149
629 (Suppl.2),14-28.

630

631 Hewson, C. M. & Noble, D. G., 2009. Population trends of breeding birds in British
632 woodlands over a 32-year period: relationships with food, habitat use and migratory
633 behaviour. *Ibis*, 151, 464-486.

634

635 Hinsley, S. A., Fuller, R. J., & Ferns, P. N., 2015. The Changing Fortunes of Woodland
636 Birds in Temperate Europe. In: Kirby, K., Watkins, C. (Eds.), *Europe's Changing Woods
637 and Forests: From Wildwood to Managed Landscapes*, 154. CABI Publishing, London,
638 pp. 154–172.

639

640 Holt, C. A., Fuller, R. J., & Dolman, P. M., 2014. Exclusion of deer affects responses of
641 birds to woodland regeneration in winter and summer. *Ibis*, 156(1), 116-131.

642

643 Hopkins, J. J., & Kirby, K. J., 2007. Ecological change in British broadleaved woodland
644 since 1947. *Ibis*, 149(s2), 29-40.

645

646 Jolliffe, I., 2002. *Principal component analysis*. John Wiley & Sons, Ltd.

647

648 Kent, M., 2012. *Vegetation description and data analysis: a practical approach*. Wiley-
649 Blackwell.

650

651 Lemmon, P. E., 1956. A spherical densiometer for estimating forest overstory
652 density. *Forest Science*, 2(4), 314-320.
653

654 Lloyd, H., & Marsden, S. J., 2008. Bird community variation across *Polylepis*
655 woodland fragments and matrix habitats: implications for biodiversity conservation
656 within a high Andean landscape. *Biodiversity and conservation*, 17(11), 2645-2660.
657

658 Lõhmus, A., Nellis, R., Pullerits, M., & Leivits, M., 2016. The potential for long-term
659 sustainability in seminatural forestry: a broad perspective based on woodpecker
660 populations. *Environmental management*, 57(3), 558-571.
661

662 MacColl, A. D., Feu, C. R., & Wain, S. P., 2014. Significant effects of season and bird age
663 on use of coppice woodland by songbirds. *Ibis*, 156(3), 561-575.
664

665 Marques, T. A., Thomas, L., Fancy, S. G., & Buckland, S. T., 2007. Improving estimates
666 of bird density using multiple-covariate distance sampling. *The Auk*, 124(4), 1229-
667 1243.
668

669 Mason, W. L., 2007. Changes in the management of British forests between 1945 and
670 2000 and possible future trends. *Ibis*, 149 (s2), 41-52.
671

672 Mason, W., Kerr, G. & Simpson, J., 1999. What is continuous cover forestry? Forestry
673 Commission Edinburgh.
674

675 Oksanen, L. 2001. Logic of experiments in ecology: is pseudoreplication a
676 pseudoissue? *Oikos* 94: 27–38 .
677

678 Peterken, G., & Mountford, E., 2017. *Woodland Development: A Long-term Study of*
679 *Lady Park Wood*. CABI.
680

681 Pitney Bowes Inc., 2013. *Mapinfo professional user guide 12*. Pitney Bowes Software
682 Inc
683

684 Poore, A., 2016. *Rushmore Estate Woods; management plan 2016-2026*. Estate
685 Office, Tollard Royal, Wiltshire.
686

687 Pukkala, T., Laiho, O. & Lähde, E., 2016. Continuous cover management reduces wind
688 damage. *Forest Ecology and Management*, 372, 120-127.
689

690 Puettmann, K.J., Wilson, S.M., Baker, S.C., Donoso, P.J., Drössler, L., Amente, G., Harvey,
691 B.D., Knoke, T., Lu, Y., Nocentini, S. and Putz, F.E., 2015. Silvicultural alternatives to
692 conventional even-aged forest management-what limits global adoption?. *Forest*
693 *Ecosystems*, 2(1), p.8.
694

695 Quine, C. P., Fuller, R. J., Smith, K. W., & Grice, P. V. 2007. Stand management: a threat
696 or opportunity for birds in British woodland? *Ibis*, 149(s2), 161-174.
697

698 Rackham, O., 1990. *Trees and woodland in the British landscape (No. Ed. 2)*. JM Dent
699 & Sons Ltd.

700

701 Roberge, J-M., Angelstam, P. & Villard, M-A., 2008. Specialised woodpeckers and
702 naturalness in hemiboreal forests – deriving quantitative targets for conservation
703 planning. *Biological Conservation*, 141, 997-1012.

704

705 Rodwell, J. S., Pigott, C. D., Ratcliffe, D. A., Malloch, A. J. C., Birks, H. J. B., Proctor, M. C.
706 F., & Wilkins, P., 1991. *British plant communities. Volume I. Woodlands and scrub.*

707

708 Rosset C, Brand R, Weber D, Gollut C, Wuillemin E, Caillard I, Schmocker A, Fiedler U.,
709 2014. MOTI L'inventaire forestier simplifié par le smartphone. Haute école des
710 sciences agronomiques, forestières et alimentaires HAFL, Zollikofen, Suisse. Rapport
711 final. March 2014. 110 pp

712

713 Seymour, R. S. & Hunter, M. L., 1999. Principles of ecological forestry. Maintaining
714 biodiversity in forest ecosystems (ed. M.L.Hunter), pp. 22-61. Cambridge University
715 Press, Cambridge.

716

717 Sterling, P. H., & Hambler, C. 1988. Coppicing for conservation: do hazel communities
718 benefit. *Woodland Conservation and Research in the Clay Veil of Oxfordshire and*
719 *Buckinghamshire*, 69-80.

720

721 Susse, R, Allegrini, C., Bruciamacchie, M, and Burrus, R., 2011. Management of
722 Irregular Forests: developing the full potential of the forest. Association Futaie
723 Irreguliere. English translation P.Morgan 144pp.

724

725 Thomas, L., S.T. Buckland, E.A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R.B.

726 Bishop, T. A. Marques, and K. P. Burnham., 2010. Distance software: design and

727 analysis of distance sampling surveys for estimating population size. *Journal of*

728 *Applied Ecology* 47: 5-14.

729

730 Wesołowski, T., 2005. Virtual conservation: how the European Union is turning a

731 blind eye to its vanishing primeval forests. *Conservation Biology*, 19, 1349-1358.