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The Effects of Thinning in Commercial Conifer Plantations on Breeding Bird Abundance and Diversity in the North of Scotland

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EXECUTIVE SUMMARY

1. It is predicted that the thinning of dense woodland could influence breeding bird populations especially if that restructuring leads to changes ground vegetation cover and types. This study assesses the influence of thinning practices, which are currently typical within commercial conifer plantations in northern Scotland, on the species richness and abundance of breeding birds.

2. Breeding bird populations were assessed using timed point counts within ten pairs of study sites in the north of Scotland. One of each pair was a conifer plantation that had undergone thinning as part of its ongoing management and was paired by tree species, plantation age, geographical location, aspect and altitude with a reference plantation in which no thinning had been undertaken. Bird abundance, occurrence rates and species richness were compared to assess any effect of thinning.

3. The mean tree density within the thinned sites (11 stems within 5 m radius of survey points, or equivalent to 1408 trees per ha) was 31% less than in the reference sites (16 stems within 5 m radius of survey points, or equivalent to 2055 trees per ha). There were no significant differences in measures of ground cover vegetation or in the occurrence of shrubs within the plantations between treatments, however.

4. Forty-four bird species in total were recorded within study sites: 37 in the thinned plantations and 36 in the unthinned reference sites suggesting no difference in species richness. Initially, the only statistically significant difference in species abundance between treatments was for Bullfinches to be recorded 3.5 times more frequently in the unthinned reference sites. Pheasants were recorded at 3.8 times more count points in the thinned sites but there was no statistically significant difference in their abundance. Both these differences were only marginally significant (P = 0.05 & 0.04 respectively) and both became non-significant after standard Bonferroni correction. Although questionable, we suggest these initial apparent differences should not be totally disregarded.

5. For the more abundant species (Chaffinch, Coal Tit, Goldcrest, Robin, Siskin, Song Thrush and Wren), generalised linear modelling found no significant effect of tree density on their abundance within the range found within the 20 study sites. Tree species and study site both had a greater influence on the abundance of those species than thinning treatment.

6. We conclude that thinning, as currently practiced in commercial conifer plantations in the north of Scotland has minimal effect on breeding bird populations. However, greater degrees of plantation restructuring may benefit some of the species that were encountered rarely during our survey and potentially also others that were not recorded at all.

1. INTRODUCTION

The bird communities of European woodlands can vary markedly with tree species, stand structure and woodland age as major causal factors for that variation (Fuller 1995). Woodland management practices that influence those factors have similarly been shown to influence their associated bird communities (e.g. Fuller 1995, Patterson *et al.* 1995, Donald *et al.* 1998, Fuller *et al.* 1999, Poulsen 2002, Wilson *et al.* 2006). A number of studies demonstrate, or suggest, an influence of tree density on the diversity and abundance of birds, however these are often confounded with other variables such as grazing, tree age and peripheral habitats. An influence of the density of trees, or rather growing stems, on breeding bird assemblages was demonstrated in a specific study within stands of coppiced Small-leaved Lime in Worcestershire (Fuller & Green 1998). In the absence of other variables such as tree species, the highest density of birds were generally in recently coppiced areas and lowest where the canopy was the most dense and corresponding ground vegetation was the least developed. The measured differences were interpreted as an influence of different habitat structures between woodland treatments. In northern Scotland, Crested Tits were found in some conifer plantations (though at considerably lower densities than in stands of native Scots Pine) where their occurrence appeared to be related to the presence and structure of a Heather-dominated field layer (Summers *et al.* 1999) which in turn would be dependent on the canopy structure and density of trees within the plantations with heather likely to be found in the least dense and more open plantations (Ferris *et al.* 2000). These two examples offer some of the strongest evidence for an influence of tree density on bird assemblages or abundance in the absence of other confounding variables.

A number of published studies give further supportive evidence for an influence of tree density on bird communities but these also identify factors such as grazing, tree age and peripheral habitats as additional factors confounding the potential influence of tree density. For example, in Ireland, as well an influence of the growth stage of Sitka Spruce and Ash plantations (and therefore tree size and structure) on breeding bird assemblages, there was a strong influence associated with the development of a shrub layer within or by the plantation and also the proximity to the plantation edge, both associated with higher densities of some generalist woodland species (Wilson *et al.* 2006). In north-east Scotland, within naturally regenerating birch scrub, the diversity of bird species, and also their abundance, tended to increase with development from open to closed scrub and ultimately to mature stands, but bird densities also varied according to whether the birch stands were grazed or not (Fuller *et al.* 1999). Within commercial Sitka spruce plantations in northern Britain, tree age appeared to have the greatest influence on bird communities with little effect of altitude, planting generation or admixture of other conifers being detected (Patterson *et al.* 1995). Amongst the species generally considered as woodland birds, that were thought to be breeding (i.e. those present during surveys in Spring), the majority were most abundant in stands of trees that were 9-25 years old potentially reflecting an influence of woodland structure.

Planting densities within commercial conifer plantations in the UK tend to be relatively high, in the order of about 2000 trees per hectare (Avery & Leslie 1990). The traditional aims have been to suppress competitive ground vegetation through a quick closure of the canopy and also to reduce the proportions of 'juvenile' wood or branches within the final timber crop (Hamilton 1974, Avery & Leslie 1990). Thinning, a practice that removes a proportion of the growing trees in late thicket and older stands, is undertaken in some commercial plantations where the aims include producing individual trees of wider girth or otherwise maximising timber production (Hamilton 1974). However, decreases in timber prices have led to a reduction in thinning in recent years (e.g. Lewis & Manly 2004, Backeus *et al.* 2006). A recent development is the creation of a potential market for thinnings from commercial plantations for woodfuel, a carbon-neutral biomass energy source (McKay 2006). Local woodfuel industries can provide a market for thinnings and thus create incentives for active management of forests. Increased thinning could create a more open woodland structure, potentially stimulate the development of field layer vegetation and ultimately have an influence on the bird communities of the affected woodland stands, similar to those described above (Fuller & Green 1998, Fuller *et al.* 1999, Summers *et al.* 1999, Fuller & Browne 2003). Although thinning to restructure plantations has been advocated as being beneficial to birds (e.g. MacMillan & Marshall 2004), quantitative studies designed specifically to investigate the influence of forestry thinning as applied to commercial plantations in Britain have been lacking. This report describes a study that assessed the influence of thinning practices, which are currently typical within commercial plantations in northern Scotland, on the diversity and abundance of breeding birds.

2. METHODS

2.1 Study Sites

Twenty study sites, all conifer plantations, in the north of Scotland were selected with the help of the relevant forest managers within the catchment of the Moray Firth (Table 2.1, Figure 2.1). Ten sites had undergone thinning as part of ongoing management. Each of these was then paired with another site that had not undergone thinning since initial planting. The latter sites were used as references against which the thinned plantations were compared. Pairing aimed to match other factors that were likely to influence the bird communities, that is tree species, age, altitude, aspect and proportion of the plot boundary that bordered onto non-forested land (e.g. Fuller 1995, Patterson *et al.* 1995, Donald *et al.* 1998, Fuller & Green 1998, Wilson *et al.* 2006) in order that the principal cause of any differences was the practice of thinning, or lack of it. Distances between each of a pair of sites varied from 1.5 to 9.5 km. This aimed for each of a pair to be sufficiently close for any influence of extrinsic factors such as weather to be comparable but also to be adequately distant for their bird populations to be independent.

2.2 Bird Survey

Timed point counts were used to measure bird abundance. Within each study area, 16 count points were spaced at regular intervals of either 100 m or 200 m spacing at intersections of a grid based on the Ordnance Survey's National Grid. Where the size and shape of the study plot permitted, the wider spacing was chosen, however it was also ensured that the same spacing was used for each of a pair of study sites to maximise the comparability of bird data. Eight sites (four pairs) accommodated 16 points at 200 m spacing and the remainder at 100 m. Two survey visits were made in spring and early summer 2006, the first between 14 April and 15 May (the 'early visit') and the second between 16 May and 15 June (the 'late visit'). There was an interval of at least 14 days between early and late visits for each site. Each survey visit started within half an hour of first light and was completed within five hours of starting. During each of the early or late visits, both of a pair of sites was surveyed by the same surveyor to eliminate any observer-based bias, and on consecutive mornings, unless weather conditions prevented this, to eliminate any seasonal differences within paired comparisons. Surveys were not undertaken in persistent or heavy rain or in strong winds (in excess of Beaufort scale force 4). The maximum interval caused by inappropriate weather between surveys of each of a site pair was two days.

Each count point was located using hand held GPS when possible. Where canopy thickness prevented the functioning of the GPS, compass bearings and pacing were used. On arrival at each point, the surveyor waited for a two-minute settling period and then recorded all birds seen or heard, with associated activity codes (CBC activity codes: Bibby *et al.* 2000), for a period of 10-minutes. The density of sampling points, and the duration of sampling at each, aimed to maximise the likelihood of registering birds within the immediate vicinity but also reduce the risk of double counting individuals (Fuller & Langslow 1984, Drapeau *et al.* 1999) and thus violate the assumptions of the point count methodology (Bibby *et al.* 2000). Each registration of a bird was assigned to one of four distance bands from the count point (0-25 m, 25-50 m, 50-100 m and 100 m+) with that assignation being the first distance for which each individual bird was recorded regardless of any subsequent movements. Birds seen or heard only in flight were also recorded separately. In the field care was taken to try and avoid recording individuals more than once, both at each count point and within each study site.

2.3 Habitat Recording

To aid interpretation of any measured differences in bird abundance between thinning treatment, a number of basic habitat variables were recorded at each count point:

a) The diameter at breast height (DBH, to the nearest 5 cm) of the closest four trees to the count point greater than one metre high;
b) The number of trees greater than three metres high within a 5 m radius of the count point;
c) The presence or absence of shrubs (e.g. hawthorn, elder, juniper that is between 1-3 m tall) or

trees of species other than the principal crop species that were considered to have become established naturally within a 10 m radius of the count point;

d) Ground cover – each of the following were assigned to an estimated cover (none, <1/3, 1/3-2/3, >2/3) within a 5 m radius of the count point:
   - Ericaceous dwarf shrubs;
   - Bracken and other ferns;
   - Grasses, sedges or herbs;
   - Brush (tree cuttings or fallen branches);
   - Bryophytes;
   - Needle litter or bare soil.

2.4 Analyses

2.4.1 *Bird data*

Paired t-tests were used to compare species richness, the occurrence rates of each species and their abundance between thinned and their paired reference sites:

a) *Species richness* - a simple comparison of the number of species recorded at each site, combined from the two survey visits. This included all registrations apart from over-flying waders, waterbirds and gulls that were clearly associated with habitats outside of the forested study sites;

b) *Occurrence rates* - a comparison of the number of count points at which each species was recorded combined from the two survey visits. This excluded all registrations of birds in flight only;

c) *Species abundance* – a comparison of the number of registrations for each species combined from the two survey visits. This included only registrations within 100 m of the count points and excluded birds only recorded in flight.

An alternative analysis was undertaken for the most abundant species examining any relationship of the abundance of those species with tree density using each sampling point as the count unit (i.e. 320 points in total). Although strictly this violates the sampling approach of thinned sites paired with unthinned reference sites, it was considered potentially informative to look at the nature of any relationships within the range of tree densities encountered within the study sites. For those species, a generalised linear model considered the relationship between the number of registrations (abundance), the dependent variable, and:

1. 'Tree species' (n = 4, as described in Table 2.1) nested within 'Study Site';
2. Study Site (n = 20);
3. The number of trees within 5 m of the count point (a continuous variable and a measure of tree density).

The models assumed a Poisson error distribution and a log-link function. For each species, the number of registrations was taken as that from either just the early or late visit, whichever had the maximum number of registrations across all sites for that particular species. Registrations from distances greater than 100 m from the count point and flight-only registrations were excluded.

The population densities of birds found in the study sites were estimated using distance sampling analyses (Buckland *et al.* 2001) and the program Distance 5.0 (Thomas *et al.* 2005) for those species that were recorded in sufficient numbers (i.e. more than 40 registrations across all sites in either the early or late survey visits (Buckland *et al.* 2001)). Distance sampling works on the principal that randomly distributed objects (in this instance, birds) become more difficult to detect with increasing distance (in this instance, from the count points). As a result, an increasing proportion of the birds become more difficult to detect in the more distant recording distance bands. The program Distance 5.0 models this decline in detectability with distance (the detection function) in order to include an estimate of undetected individuals in its calculation of density. In our analyses we assign the distance of the mid-point of the relevant distance band (i.e. 12.5 m, 37.5 m and 75 m) that the birds were first recorded in. Birds in the final distance band (> 100 m) were excluded from the analyses, as counts within an unbounded category are difficult to interpret. Truncation of this kind is routinely recommended for accurately estimating density using the distance sampling technique (Buckland *et al.* 2001). Data from birds recorded in flight only were also excluded. The calculated estimates of bird density, and their precision, were used to assess the general typicality of the population densities found in the study sites and also to provide a reference for other, similar studies.

2.4.2 *Habitat data*

Paired t-tests were used to compare the density of trees between thinned and reference sites, both the means and the coefficients of variation of the number of trees within 5m of the count points. Similarly paired t-tests were used to compare the mean tree diameters between thinned and reference sites and the non-parametric equivalent (Kruskall-Wallis test) was used to compare the number of points at which volunteer-seeded shrubs were present.

The proportions of each ground cover type recorded are not independent of each other in that the presence of one of the categories at any one point will exclude the presence of the others. To account for this, the ground cover proportions were transformed to log-ratios, the ratio of each score divided by that of another, the denominator being arbitrarily chosen but of the same ground cover type throughout, and that ratio then log-transformed (Aitchison 1986). To prevent the division by a zero, where the cover by any one vegetation type was scored as such, these were changed to the extremely low value of 0.001 (after Aebischer *et al.* 1993). A paired MANOVA of the log ratios and the Wilk's Lambda (Λ) statistic was used to assess the significance of any difference in ground cover between the thinned and reference study sites. In this analysis, the mid point of the four ground cover categories has been used as appropriate (i.e. 0, 0.17, 0.5 and 0.83, see Section 2.3(d)).

3. RESULTS

3.1 Species Richness

A total of 44 species were recorded within the woodland study plots (Table 3.1.1). Of these, 37 were recorded in thinned study sites and 36 in the reference sites (Table 3.1.2). The mean number of species recorded at the thinned sites was 19.0 (range 13 – 24) and at the reference sites, 19.2 (range 15 – 22) (Table 3.1.2). There was no significant difference in the number of species between treatments ($t_9 = 0.14$, $P = 0.89$).

3.2 Occurrence Rates and Species Abundance

Amongst the 44 species recorded, only one showed a statistically significant difference in the number of points at which they were recorded between treatments; Pheasants were recorded at 3.8 times as many points within the thinned sites than within the reference sites ($P = 0.04$, Table 3.1.1). Of the remaining species for which no significant difference was detected, 19 were recorded at more points in thinned plantations and 17 at more points in the reference, unthinned sites (Table 3.1.1).

Only one species showed a statistically significant difference in abundance (the mean number of registrations within 100 m of each count point) between treatments; Bullfinches were recorded 3.5 times more frequently in the unthinned reference sites than within the thinned sites ($P = 0.05$, Table 3.1.1). Of the remaining species for which no significant was detected, 19 were recorded more frequently in the thinned sites and 11 were recorded more frequently in the unthinned reference sites (Table 3.1.1).

The validity of these two apparent differences should be considered with caution, however. A total of 88 paired comparison tests were made to compare the abundance and occurrence rates of each species (Table 3.1.1). With the convention of accepting differences as significant at the 0.05 level, there is a likelihood that a Type 1 error will be committed in 5% of tests carried out (Quinn & Keough 2002). With 88 such tests, the possibility of the apparently significant results being a result of a Type 1 statistical error is high. Applying a Bonferroni correction, a standard procedure when the running of simultaneous tests has an associated high risk of a Type 1 error (Quinn & Keough 2002), reduced the level to ‘accept’ statistical significance to 0.0006. Following this convention, none of the observed differences would have achieved statistical significance. With the conservative nature of the paired t-tests used, such a level to achieve statistical significance may be argued to be unrealistic, and the two original apparent significant results perhaps should not be discounted. For Bullfinch abundance and Pheasant occurrence rates, the levels of statistical significance (at 0.05 and 0.04 respectively) probably remain marginal, however.

Nine species were recorded sufficiently frequently for reliable use of distance sampling analyses to estimate their population densities across all the study sites combined. In decreasing order mean abundance, these were Goldcrest, Chaffinch, Coal Tit, Siskin, Wren, Wood Pigeon, Robin, Willow Warbler and Song Thrush (Table 3.2.1).

3.3 Relationships between Species Abundance, Tree Density and Tree Species

Seven species were recorded in sufficient numbers for the generalised linear models investigating relationships between species abundance and tree density to successfully converge: Song Thrush, Robin, Wren, Coal Tit, Goldcrest, Siskin and Chaffinch. For the other species, the data were too sparse (a result of relatively low numbers of birds) for any relationships to be successfully modelled and assessed. Of the seven species for which the relationships were successfully modelled, no significant relationships were found between abundance and tree density (Table 3.3.1). Dominant tree species and/or site were found to be of more influence however (Table 3.3.1). There was no consistent relationship between the dominant tree species and bird abundance between the different bird species which showed different rankings in their order of abundance (Table 3.3.2).

Indices of species abundance when plotted against tree density confirm the absence of relationships (Figures 3.3.1-3.3.7), however for Coal Tit (Figure 3.3.2) and, perhaps less obviously for Robin (Figure 3.3.4), there does appear to be a peak of abundance at between 9 and 14 trees within a 5 m radius of the count points within the lower half of the tree densities recorded (i.e. up to about 18 trees within a 5 m radius). Outside of that range and for the other species across the full range of tree densities recorded, there is no real suggestion of any trend or pattern.

3.4 Habitat Variables

The number of standing trees within 5 m of each count point was, on average, 31% less at the thinned sites than at the unthinned reference sites (Table 3.4.1, $t_9 = 2.61$, $P = 0.03$). For the thinned sites, the mean of 11.05 trees within a 5 m radius of the count points is equivalent to 1408 stems per hectare. The equivalent for the reference sites was 2055 stems per hectare. The difference was not consistent across all pairs of sites, however, with both pairs 'B' and 'H' having a higher recorded density of trees in the thinned site than in the unthinned reference site and there being very little difference between treatments in pair 'E' (Table 3.4.1). Tree density was significantly more variable within the thinned plantations (Table 3.4.1) $t_9 = 2.37$, $P = 0.04$). Again, however, the difference was not consistent with the reference sites of pairs 'B' and 'E' having greater coefficients of variation than their paired thinned sites (Table 3.4.1). The greater variation of tree densities within the thinned sites is expected as the thinning of trees tends not to be carried out evenly across a plantation or forest coup.

Compositional analysis of the extent ground cover types found no significant difference between thinning treatments ($\Lambda = 0.36$, $P = 0.55$) (Table 3.4.2). Although not statistically significant, there was a tendency for there to be more grasses, sedges and herbs and ericaceous ground vegetation within the thinned plantations and more brush, needles and bare soil and bryophytes as ground cover within the unthinned sites (Table 3.4.2).

The presence or absence of naturally established shrubs or trees did not differ between thinned or unthinned study sites and, in general, were scarce within the study sites (Table 3.4.3) $Z = 0.41$, $P = 0.69$). The mean tree diameter, a potential measure of tree structure, did not differ between thinned or unthinned study sites (Table 3.4.4, $t_9 = 0.63$, $P = 0.54$).

4. DISCUSSION

Amongst the 44 species recorded, only two statistically significant differences in either abundance or frequency of occurrence between thinned sites and unthinned references were apparent; Bullfinch was apparently more abundant in the reference sites and Pheasants were recorded at more count points in the thinned sites.

The local abundance of Pheasants can be greatly influenced by the releasing of hand-reared birds (Robertson 1993). The occurrence rates of Pheasants at two thinned study sites (Cawdor A and The Bochel) are largely responsible for the statistically significant difference (before Bonferroni correction) between treatments. It is unknown whether greater numbers of Pheasants had been released in the season(s) prior to the survey within the vicinity of these two sites compared to the other study sites, and so any potential influence of plantation management remains uncertain. In any case, the minimal (and non-significant) difference in the abundance of Pheasants measured by the number of registrations, between plantation treatments suggests no influence of treatment. Apart from Pheasant and Bullfinch, for which the differences may only be marginally statistically significant, we did not find any significant difference in the abundances of breeding birds between thinned conifer plantations and their comparable unthinned reference sites. Therefore, we can say with some confidence that thinning as practiced at our study sites had no measurable affect on the abundance of the majority of the more common breeding species encountered (Blackbird, Chaffinch, Crossbill (unspecified), Coal Tit, Goldcrest, Great Spotted Woodpecker, Great Tit, Mistle Thrush, Robin, Siskin, Song Thrush, Treecreeper, Wood Pigeon, Wren and Willow Warbler). The encounter rates for the remaining species were low and so the power of the tests to actually be able to detect significant differences would also be low. As we did not find any difference in the number of species found between plantation treatments, we conclude that thinning within the study areas is similarly likely to have had little influence on breeding populations of those scarcer species.

No significant effect of absolute tree density within the range encountered in the 20 study sites (as opposed to thinning treatment) was detected for the more abundant bird species, although some potential patterns are suggested for Coal Tit, and less convincingly for Robin in the range of 9 – 14 trees within 5 m radii of the count points (Figures 3.3.2 & 3.3.4). Principal tree species within the plantations and/or also site had more of an influence on the abundance on all seven of the species for which data was sufficient to successfully model their relative influences; however, there were differences between these relationships for each bird species, with no principal tree species associated with greater abundances of most of the species (Table 3.3.2).

The near-absence of any measured effect on bird populations could either be a result that thinning as practiced on the study sites (and as is currently typical for conifer plantations in Scotland) does not alter the quality of the habitats for most breeding birds, or that densities are already high and other factors could limit population density rather than any expected improvement through thinning. For the nine species for which sufficient data was collected to calculate reliable density estimates with measures of their precision, only two were within the lower half of the expected range for woodland in the UK (Goldcrest and Wood Pigeon, Table 3.1.2). It is possible that, of the species commonly found in Scottish conifer plantations, those plantations remain good quality habitats regardless of whether they are thinned or not.

This is counter to some expectations whereby thinning might be expected to enhance ground vegetation with a corresponding response by populations of breeding birds (e.g. Fuller & Browne 2003). Amongst species recorded rarely in this study (Capercaillie, Black Grouse, Tree Pipit, Spotted Flycatcher, Redstart, Crested Tit and Lesser Redpoll), all have reported preferences for woodlands that are more open than those surveyed (e.g. Cramp & Simmons 1980, Cramp 1988, Cramp & Perrins 1993, 1998). Furthermore, there are other typical woodland species that were not recorded at all during this study but do occur within the same geographical area as the study sites, for example Green Woodpecker, Blackcap, Garden Warbler, Wood Warbler, Chiffchaff, Tree Pipit, Pied Flycatcher and Long-tailed Tit (Gibbons *et al.*

1993). Again, most of these species have reported preferences for open woodlands and/or more developed field and shrub layers than typically found in conifer plantations (Cramp & Simmons 1980, Cramp 1988, Cramp & Perrins 1993, 1998, Marquiss *et al.* 1997, Summers *et al.* 1999, Calladine 2005, Shaw *et al.* 2006).

The absence of any statistically significant differences in habitat measures (ground cover and presence of shrubs) between treatments, despite a measured difference in tree density, suggests that the tree densities after thinning (with a mean equivalent to *ca.* 1400 stems per hectare) are still too great to permit adequate development of ground vegetation with corresponding changes in bird communities and populations. A greater level of restructuring of conifer plantations may potentially result in enhanced densities of or even colonisation by, some breeding birds. The thinning of some Scots Pine plantations, where the aim was to enhance conditions for Capercaillie have apparently lead to measurable changes in ground vegetation within three years, however post-thinning tree densities of 680 – 1200 stems per hectare (Alice Broome *pers comm.*) are somewhat less than those found in our study. Also, in our study, the differences in tree densities between treatments was not consistent, within two pairs, greater tree densities found in the thinned sites and similar anomalies found in the measures of variation of tree density, where greater variation might be expected in the thinned sites. This may be a result of differences in original planting densities or potentially the thinning only of trees that were likely to be suppressed by their growing neighbours. The practicalities and economics of thinning for commercially managed plantations is beyond the scope of this report, but it should be acknowledged that the conifer plantations as they are currently managed do support respectable densities of some breeding birds, and that tree species and geographical area also have an effect on bird abundances within these. There is scope for further work on the bird communities within commercially managed plantations to identify relationships with a broader suite of plantation types and management regimes in relation to a range of silvicultural outputs.

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Tables

Table 2.1. Descriptive features of the conifer plantation plots surveyed in northern Scotland in 2006.

Pair	Site	Thinned Site					Reference Site						Distance between paired sites (km)
		Grid ref.	Spp	Alt. (m)	Aspect	% boundary open	Site	Grid ref.	Spp	Alt. (m)	Aspect	% boundary open	
A	Achany (A)	NC564017	SS	170	E	20	Achany (B)	NC564035	SS	130	NE	20	2.5
B	Easter Ardross (A)	NH660726	SS	220	NE	30	Easter Ardross (B)	NH648754	SS	220	NE	30	2.5
C	Lairg (A)	NH554988	SP	150	SW	40	Lairg (B)	NC576086	SP	150	SW	30	9.5
D	Abriachan (A)	NH537354	LP/SP	310	NE	50	Abriachan (B)	NH558346	LP/SP	270	SE	50	1.5
E	Cawdor (A)	NH885471	MC	140	NW	20	Cawdor (B)	NH890507	MC	150	NW	30	4
F	Moy (A)	NH783339	SS/SP	330	W	40	Moy (B)	NH769358	SS/SP	300	W	40	2.5
G	Meallmore (A)	NH752364	SP	320	NE	0	Meallmore (B)	NH729369	SP	300	NW	10	2
H	Inshriach (A)	NN832990	SP/LP	300	N	0	Inshriach (B)	NH838012	SP/LP	340	N	0	2
I	Cairn Daimh	NJ164249	MC	340	NW	20	Cnoc Fergan	NJ132224	MC	350	NW	30	3
J	The Bochel	NJ226229	MC	360	SW	75	Lecht	NJ233149	LP/SS	550	N	90	7.5

Notes: 1. The given grid references and altitudes are those of the mid-points of the study areas.
2. Tree species are the dominant ones in each study area (i.e. estimated to comprise 70% or more of the surveyed area): SS – Sitka spruce; SP – Scots pine; LP – Lodgepole Pine; MC – Mixed conifer (where no one, or two species predominated). Where just 2 species comprised 70% or more of the surveyed area together, these are indicated e.g. LP/SP.
3. The aspect is that which is predominant for the whole study area.
4. The '% boundary open' refers to the proportion of the boundary of the study area that adjoins non-forested land.
5. The above descriptions refer to the areas surveyed for birds only, not the entire forest blocks in which they are located.

Table 3.1.1. The bird species recorded at the conifer plantation study sites and their relative occurrence rates and abundances in 2006

Species	**Occurrence rate (mean no. of points per site)**				**Abundance (mean registrations within 100m per site)**			
	Thinned	Unthinned	t-value	*P*	Thinned	Unthinned	t-value	*P*
Blackbird	0.9	1.0	0.29	0.78	0.9	0.9	0.00	1.00
Bullfinch	0.2	0.5	1.96	0.08	0.2	0.7	0.24	0.05
Black Grouse	0	0.2	1.50	0.17	0	0		
Blue Tit	0.2	0.3	0.43	0.69	0.2	0.4	0.69	0.51
Buzzard	0.2	0	1.50	0.17	0.1	0	1.00	0.34
Carrion Crow	0.8	0.9	0.21	0.84	0.7	0.7	0.00	1.00
Collared Dove	0.2	0.2	0.00	1.00	0.3	0.3	0.00	1.00
Chaffinch	15.1	15.0	0.22	0.83	42.4	41.8	0.14	0.89
Crested Tit	0.3	0.1	0.80	0.44	0.3	0.2	0.32	0.76
Cuckoo	1.6	1.1	1.17	0.27	0.4	0.3	0.29	0.78
Capercailie	0.1	0.0	1.00	0.34	0.1	0.0	1.00	0.34
Crossbill spp.	2.8	2.0	0.81	0.44	6.2	3.2	0.73	0.48
Coal Tit	12.3	12.8	0.71	0.50	23.6	26.0	0.95	0.37
Dunnock	0.3	0.2	0.36	0.73	0.4	0.3	0.25	0.81
Goldcrest	11.4	10.8	0.47	0.65	21.6	20.1	0.45	0.67
Goldfinch	0.2	0	1.00	0.34	0.2	0	1.00	0.34
Great spotted Woodpecker	1.4	1.1	0.71	0.50	1.0	0.9	0.26	0.80
Great Tit	0.6	0.6	0.00	1.00	0.6	0.7	0.21	0.84
House Sparrow	0	0.1	1.00	0.34	0	0		
Jay	0	0.1	1.00	0.34	0	1.0	1.00	0.34
Jackdaw	0.1	0.1	0.00	1.00	0.1	0	1.00	0.34
Lesser Redpoll	0.1	0	1.00	0.34	0.1	0	1.00	0.34
Mistle Thrush	1.3	1.4	0.22	0.83	1.3	1.6	0.54	0.60
Meadow Pipit	0.1	0	1.00	0.34	0	0		
Pheasant	1.9	0.5	2.40	0.04	0.3	0.2	1.00	0.34
Robin	8.3	8.7	0.28	0.79	11.2	12.2	0.44	0.67
Redwing	0	0.1	1.00	0.34	0	0.1	1.00	0.34
Raven	0.2	0	1.50	0.17	1.0	0	1.00	0.34
Rook	0.1	0.1	0.00	1.00	0	0		
Redstart	0.1	0	1.00	0.34	0	0		

Siskin	9.0	7.8	0.84	0.43	18.1	13.3	1.23	0.25
Skylark	0.1	0	1.00	0.34	0	0		
Spotted Flycatcher	0.2	0.1	0.56	0.59	0.2	0.1	0.56	0.59
Sparrowhawk	0.2	0.1	0.43	0.68	0.2	0.1	0.43	0.68
Song Thrush	3.8	3.7	0.12	0.90	2.3	2.9	0.82	0.43
Treecreeper	1.3	0.9	0.88	0.40	1.7	1.1	0.73	0.48
Tawny Owl	0	0.1	1.00	0.34	0	0		
Tree Pipit	0.1	0.1	0.00	1.00	0.1	0.1	0.00	1.00
Whinchat	0	0.1	1.00	0.34	0	0		
Whitethroat	0.1	0	1.00	0.34	0.1	0	1.00	0.34
Woodcock	0	0.1	1.00	0.34	0	0		
Wood Pigeon	6.9	9.4	1.71	0.12	11.6	17.8	1.78	0.11
Wren	9.0	11.4	1.39	0.20	15.6	23.3	1.49	0.17
Willow Warbler	3.4	4.4	1.29	0.23	4.3	6.9	1.43	0.19

Note: Both the occurrence rates and relative abundances are the frequency with which each species was recorded (number of count points for occurrence and number of registrations for abundance) from both survey visits combined

Table 3.1.2. The number of species recorded at the study sites, April – June 2006.

Pair	Thinned	Reference
A	20	18
B	13	20
C	16	16
D	13	20
E	24	20
F	20	22
G	23	27
H	18	15
I	21	17
J	22	17
All	37	36

Table 3.2.1. The estimated population densities, using distance sampling analysis, of the most frequently recorded species across all 20 conifer plantations surveyed in 2006. For comparison, some published densities typical for the species in woodlands in the UK are also given.

Species	Density - this study (No. per km^2)		Typical density (No. per km^2)
	Mean	95% CI	
Chaffinch	169	153 – 187	24 – 204[1]
Coal Tit	147	126 – 171	200[1]
Siskin	130	107 – 157	40[1]
Goldcrest	298	273 – 328	800 - 1200[1]
Wren	106	88 – 127	
Wood Pigeon	29	19 – 43	17 – 113[2]
Willow Warbler	17	12 – 24	
Robin	75	60 – 95	
Song Thrush	8	5 – 13	4 - 8[2]

Sources: 1 Gibbons *et al.* 1993
2 Newson *et al.* 2005

Table 3.3.1. The relationships from generalised models between bird abundance and tree density, tree species and site within 20 conifer plantations studied in the north of Scotland in 2006.

	FACTOR					
SPECIES	Tree density		Tree species		Site	
	χ^2	*P*	χ^2	*P*	χ^2	*P*
Chaffinch	1.10	0.29	32.33	<0.001	36.95	0.002
Coal Tit	0.00	0.97	5.19	0.16	28.15	0.03
Goldcrest	0.03	0.87	14.27	0.003	78.18	<0.001
Robin	0.01	0.90	5.78	0.12	33.35	0.01
Siskin	0.93	0.33	31.92	<0.001	49.93	<0.001
Song Thrush	0.82	0.37	11.13	0.01	10.41	0.84
Wren	0.03	0.86	8.38	0.04	58.01	<0.001

Note: The indices of bird abundance used in the models were the number of registrations within 100 m of the count points from either the early or the late survey visits. For each bird species, data from the survey visit with most registrations across all sites were used.

Table 3.3.2. The relative ranking by abundance for bird species in plantations with different dominant tree species.

SPECIES	Ranking in descending order of abundance
Chaffinch	LP > SP > MC > SS
Coal Tit	LP > SS > SP > MC
Goldcrest	MC > LP > SP > SS
Robin	LP > SS > SP > MC
Siskin	SP > LP > MC > SS
Song Thrush	SS > SP > MC > LP
Wren	SS > LP > SP > MC

Notes:

1. These rankings follow from the generalised models reported in Table 4.
2. Tree species are the dominant in each study area (estimated to comprise 70% or more of the surveyed area): SS – Sitka spruce; SP – Scots pine; LP – Lodgepole Pine; MC – Mixed conifer (where no one, or two species predominated).
3. Only bird species for which the generalised models relating bird abundance to tree density, study site and tree species are included.
4. The abundance rankings are derived from the generalised models in (2), above, and include any influences of study site and tree density.

Table 3.4.1. The density, and variation in density, of standing trees in the study areas in 20 studied conifer plantations in the north of Scotland.

	Thinned Site Trees within 5 m		**Reference Site** Trees within 5 m	
Pair	Mean	CV	Mean	CV
A	4.81	0.49	16.19	0.32
B	12.19	0.40	7.94	0.45
C	6.44	0.65	15.38	0.32
D	9.75	0.40	16.88	0.27
E	14.73	0.49	14.56	0.65
F	8.81	0.78	15.25	0.68
G	9.75	0.51	20.63	0.18
H	17.81	0.71	12.19	0.72
I	13.06	0.45	20.81	0.33
J	13.13	0.64	21.63	0.32
Mean	11.05	0.55	16.14	0.42
SE	1.24	0.04	1.33	0.06

Means and Coefficients of Variation (CV) for each site refer to those statistics for the number of trees within 5 m of each of the 16 sampling points at each study site.

Table 3.4.2. Mean and median proportions of ground vegetation cover at the study sites in 2006.

Ground cover type	**Coverage score** Mean (SE)		Median	
	Thinned	Reference	Thinned	Reference
Ericaceous	0.03 (0.001)	0.02 (0.001)	0	0
Herbaceous	0.26 (0.04)	0.21 (0.04)	0.17	0
Brush	0.23 (0.03)	0.25 (0.03)	0.17	0.17
Bryophyte	0.31 (0.04)	0.34 (0.04)	0.17	0.5
Needles/Soil	0.25 (0.03)	0.33 (0.04)	0.17	0.17

Ground cover proportions were the mid-points of the ranges in which they were recorded in the field as follows:

0	None
0.17	<⅓ of ground cover within a 5 m radius of the count point
0.50	⅓ - ⅔ of ground cover within a 5 m radius of the count point
0.83	>⅔ of ground cover within a 5 m radius of the count point

Table 3.4.3. The number of count points where naturally established trees or shrubs were present within a 5 m radius

Pair	**No. of points** **Thinned Site**	**Reference Site**
A	0	0
B	0	1
C	1	0
D	9	0
E	8	7
F	8	0
G	0	0
H	0	1
I	0	2
J	2	2
Mean rank score	**9.95**	**11.05**

Table 3.4.4. The mean diameter at breast height of the four nearest trees to each of the 16 count points in the 20 study sites.

Pair	**Mean DBH (cm)** **Thinned Site**	**Reference Site**
A	21.2	23.1
B	15.7	17.2
C	22.5	18.0
D	36.3	46.4
E	18.0	14.5
F	21.7	19.9
G	37.9	30.6
H	17.0	14.8
I	19.2	17.8
J	20.6	18.5
Mean	**23.0**	**22.1**

Figures

Figure 2.1. Location of study areas in north Scotland. Squares represent thinned sites and triangles represent reference sites.

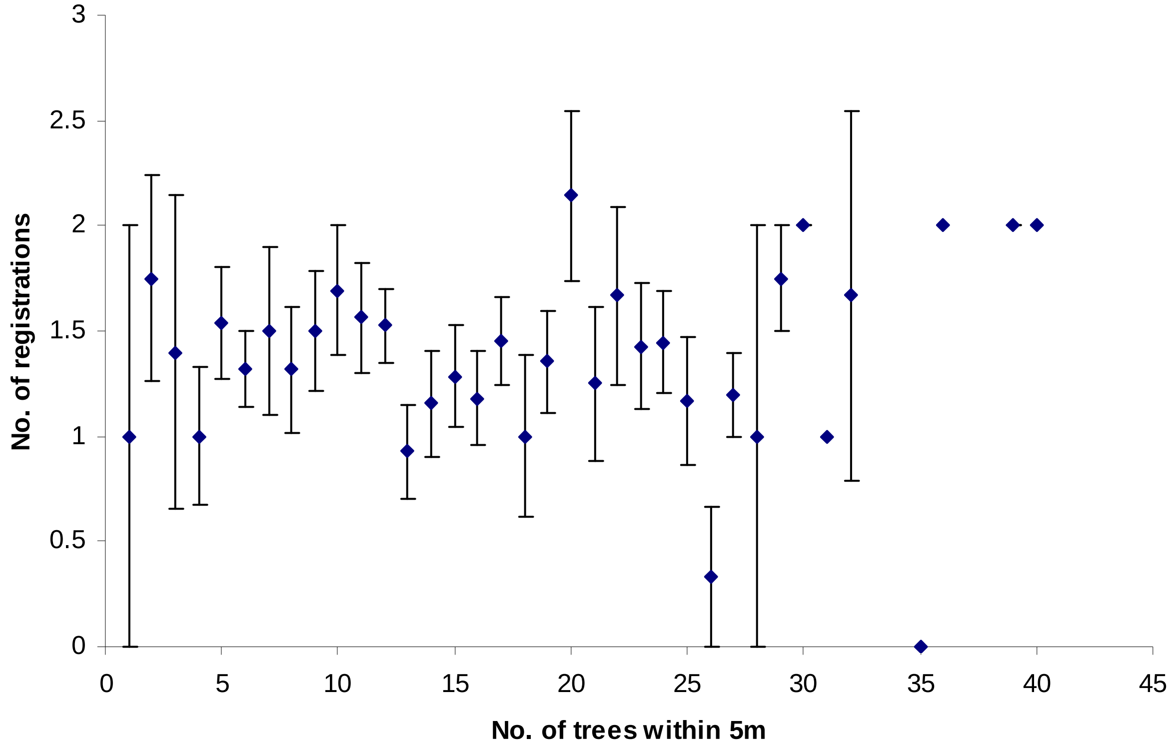

Figure 3.3.1. The variation in indices of Chaffinch population density with tree density found in 20 plantations in the north of Scotland in 2006.

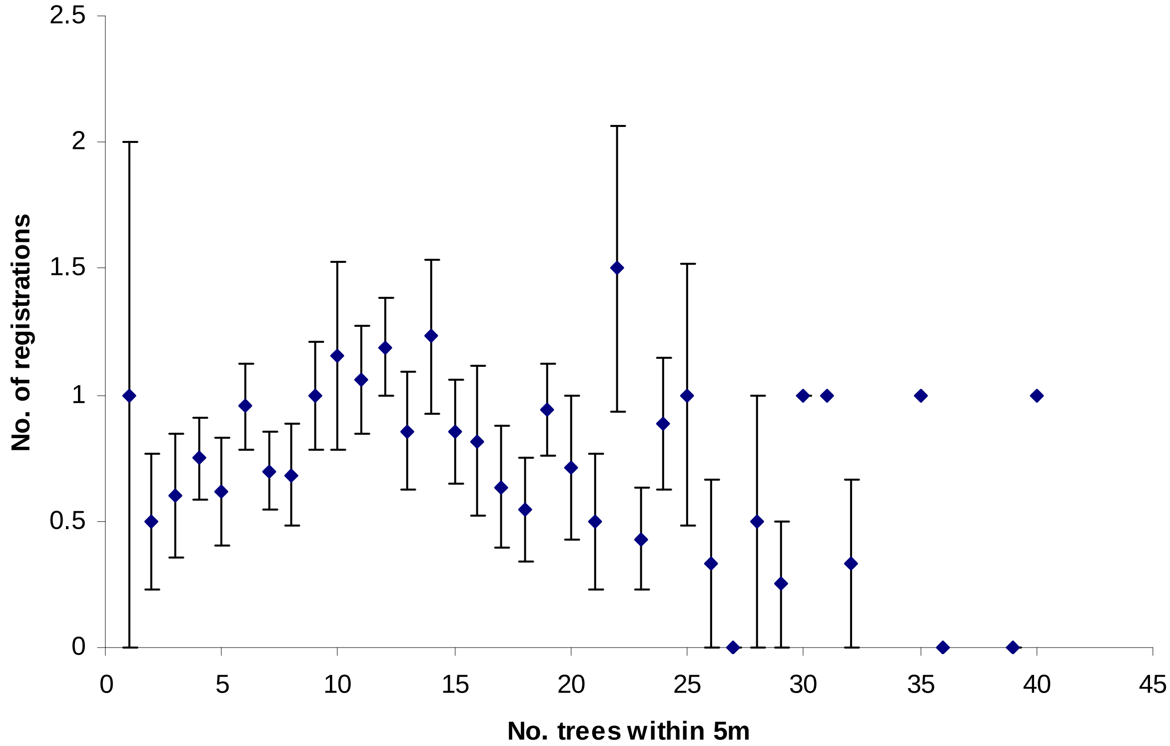

Figure 3.3.2. The variation in indices of Coal Tit population density with tree density found in 20 plantations in the north of Scotland in 2006.

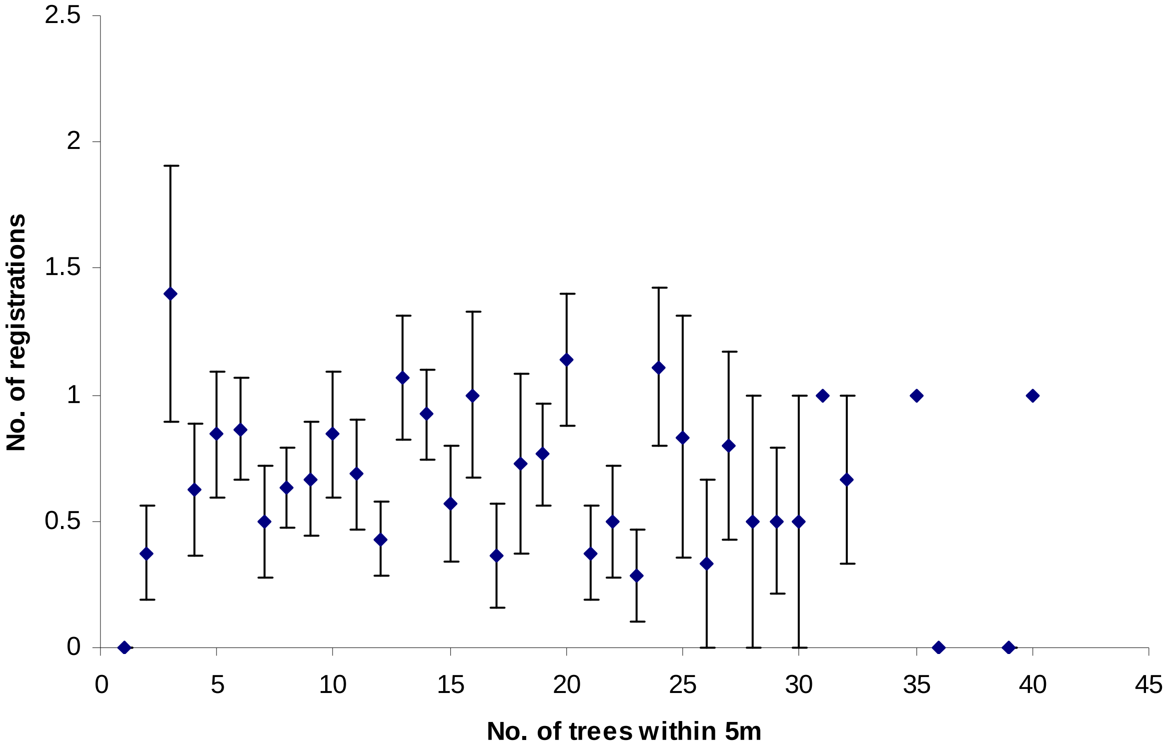

Figure 3.3.3. The variation in indices of Goldcrest population density with tree density found in 20 plantations in the north of Scotland in 2006.

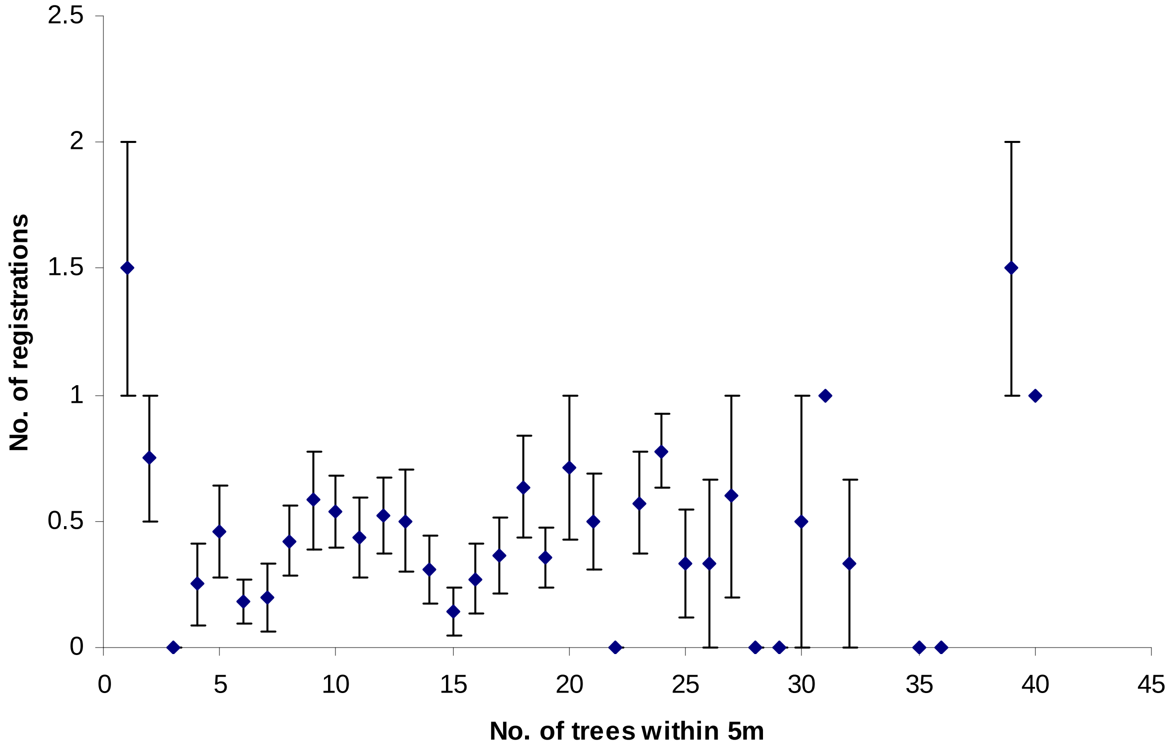

Figure 3.3.4. The variation in indices of Robin population density with tree density found in 20 plantations in the north of Scotland in 2006.

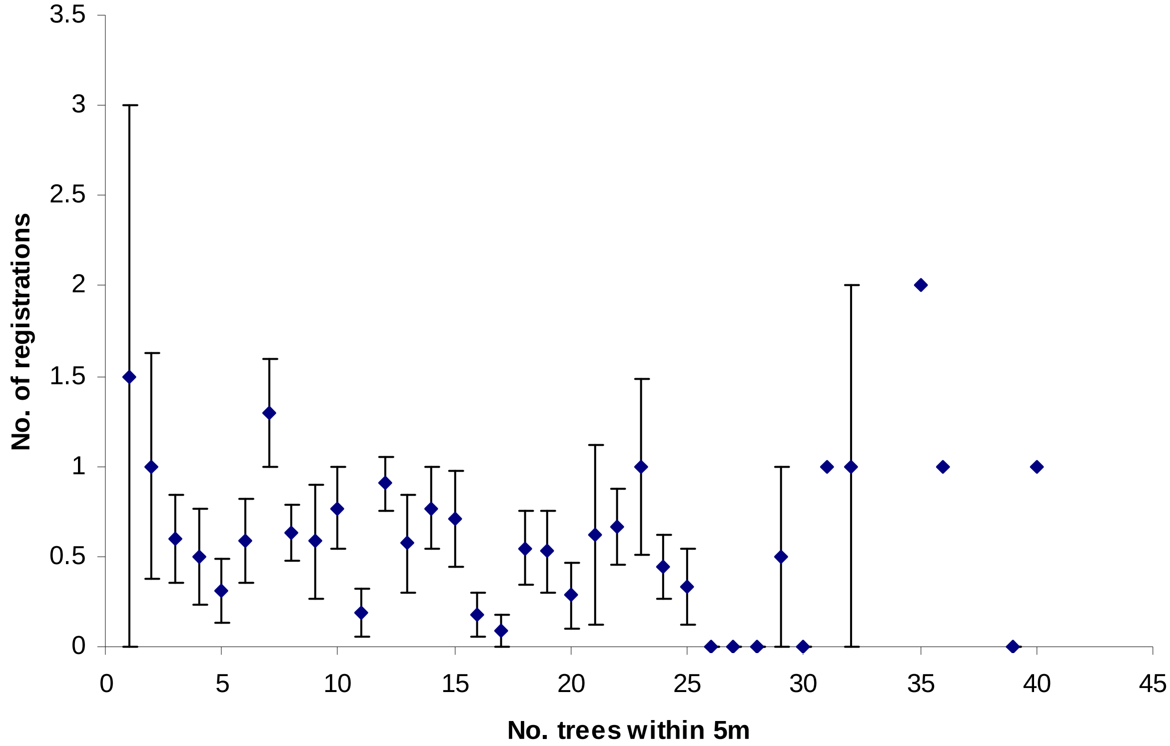

Figure 3.3.5. The variation in indices of Siskin population density with tree density found in 20 plantations in the north of Scotland in 2006.

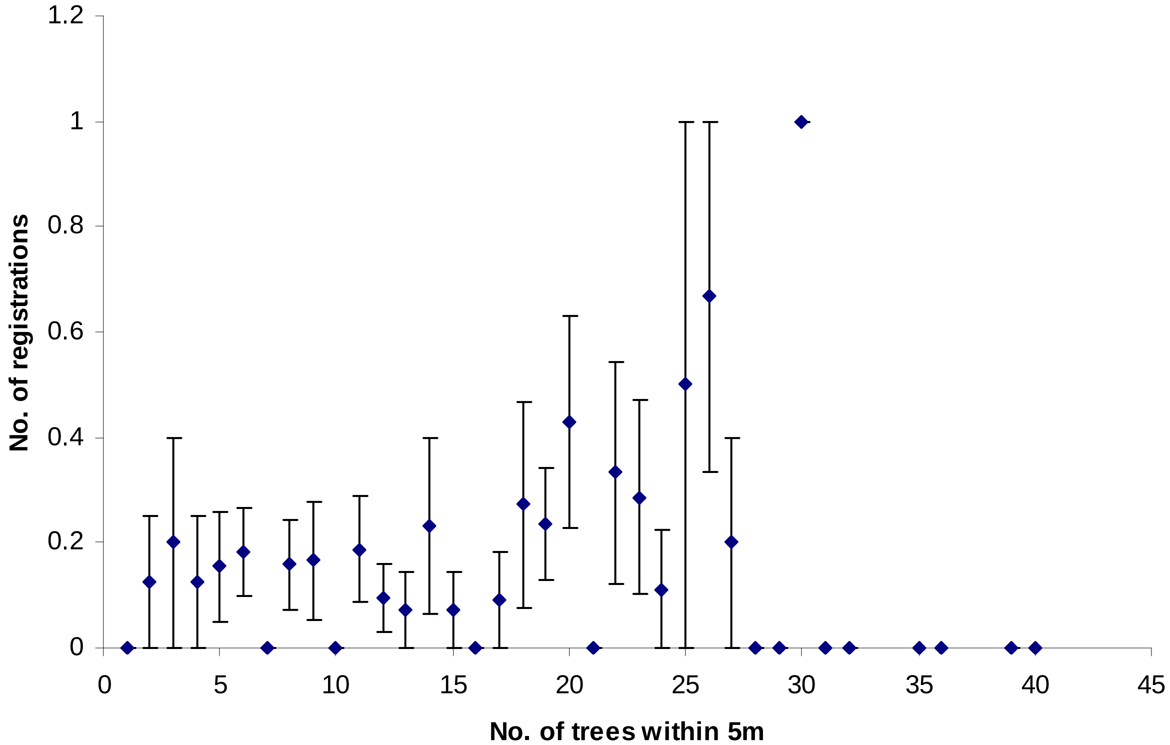

Figure 3.3.6. The variation in indices of Song Thrush population density with tree density found in 20 plantations in the north of Scotland in 2006.

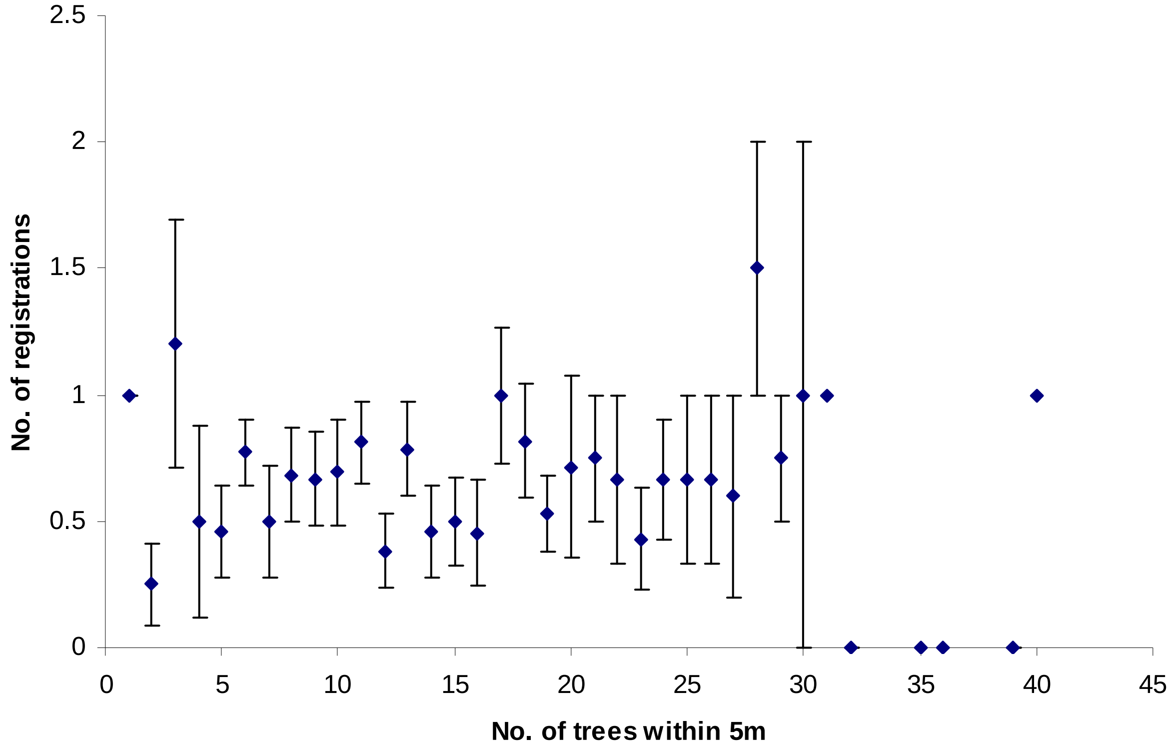

Figure 3.3.7. The variation in indices of Wren population density with tree density found in 20 plantations in the north of Scotland in 2006.