Woodland characteristics associated with the presence of Willow Tits *Poecile montanus* in a fragmented population

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Short title: Woodland characteristics and Willow Tit presence

Summary

This study presents evidence that Willow Tits in a declining UK population were more likely to have persisted in woodlands that were further away from a major road, and in which Great Spotted Woodpeckers were not detected. No difference was found in woodland area, herb layer height, canopy cover, or maximum and mean vegetation height between woodlands where Willow Tits were present and those where they were not. Further investigation is required to see whether these relationships occur on a national scale, and if so, how they might be factored into conservation management plans for this species.

Introduction

Woodland bird species in the UK have suffered major declines since the early 1970s, decreasing in abundance on average by around 35% during this period (DEFRA 2025). Some have undergone particularly marked declines, such as Lesser Spotted Woodpecker *Dryobates minor*, Nightingale *Luscinia megarhynchos*, Hawfinch *Coccothraustes coccothraustes*, and Marsh Tit *Poecile palustris* (Massimino *et al*, 2024). Habitat loss, degradation, and fragmentation have been cited as possible causes of decline for these birds (Bellamy *et al* 1996, Villard *et al* 1999, Brotons & Herrando 2001, Aune *et al* 2005, Dolman *et al* 2007, Benítez-López *et al* 2010, Lawson *et al* 2018), yet conclusive evidence of this is currently lacking. Increasing proximity to human populations may also be contributing to changes in bird communities through habitat modification and provisioning of resources, resulting in direct or indirect impacts on productivity and mortality, and changing competitive advantage (Shutt & Lees 2021, Shutt *et al* 2021, Broughton *et al* 2022). Construction of roads is one common type of anthropogenic habitat alteration which has been shown to have wide-ranging impacts on bird species, for example through noise and chemical pollution (Herrera-Montes *et al* 2011, Ortega 2012, Kekkonen 2017), presenting physical barriers to movement (Kociolek *et al* 2011, Ceia-Hasse *et al* 2018) and direct mortality (Jack *et al* 2015, Wiącek *et al* 2015). Further research is needed to better understand the specific drivers of decline in woodland birds, including the potential impact of roads, if conservation strategies are to be implemented.

One woodland bird of major conservation concern is the Willow Tit *Poecile montanus*, Britain's fastest declining resident bird species (Burns *et al* 2020). Its abundance fell by 96% between 1967 and 2021 (Massimino *et al* 2024), placing it on the UK Birds of Conservation Concern Red List (Stanbury *et al* 2021). The Willow Tit is a bird of extensive mixed forest in boreal and alpine regions across much of its range, which extends throughout most of the Western Palearctic and into Northern Asia (Cramp & Perrins 1993, Broughton 2024). However, studies over recent decades indicate the UK subspecies of the Willow Tit (*P. m. kleinschmidti*) is more likely to inhabit early successional woodland habitats, wet woodland, and scrub (Cramp & Perrins 1993, Lewis *et al* 2009b, Broughton 2024). The exact causes of the decline of the Willow Tit are poorly understood, but many factors are thought to contribute, including fragmentation of habitat (Broughton *et al* 2013, Broughton 2024), nest site competition with more dominant generalist species such as Blue Tit and Great Tit (Lewis *et al* 2009a, Parry and Broughton, 2018), as well as climate change and habitat alteration driven by human activity (Vanhinsbergh *et al* 2003, Lewis *et al* 2007). Nest predation by Great Spotted Woodpecker may also play a role (Lewis *et al* 2007, Parry & Broughton 2018), with this species undergoing a 399% increase in abundance during the same period as the Willow Tit's 96% decline (Massimino *et al*, 2024).

Here, we present the results of a small-scale study of a declining Willow Tit population in which we investigate how the continued presence of birds relates to the following woodland characteristics: proximity to a major road, woodland area, herb layer height, canopy cover, maximum and mean vegetation height, and presence of Great Spotted Woodpecker. Our aim was to add to the existing evidence base of this species' requirements and inform conservation. However, with sample sizes being small, the results should be interpreted with caution.

Methods

The study was conducted between 21 July and 25 August 2021 around Barnsley, South Yorkshire (53°33'13"N 1°28'57"W), in and around the former Dearne Valley Green Heart Nature Improvement Area (Natural England 2014), an area of around 1700 ha. The woodlands in this area vary in size and composition, ranging from 8 to 53 ha, and include early successional, wet, coniferous, and mixed woodlands. We surveyed fifteen woodlands where Willow Tits had been recorded in the preceding three years as part of targeted breeding surveys conducted by volunteers (Figure 1).

Playback surveys were conducted to determine whether Willow Tits were still present at each site. Use of playback surveys is a well-established method of determining the presence of this species (e.g. Mönkkönen *et al* 1996, Lewis *et al* 2009a, Broughton *et al* 2020, Morris 2021). We used a recording taken from the Rare Breeding Bird Panel National Willow Tit Survey Methods (RBBP 2020), consisting of a two-minute recording of song and calls. Surveys took place between 0600 h and 1000 h over two visits during the survey period, all in good weather conditions with a wind speed lower than 10mph. The recording was played at intervals of 100 m along a randomly selected transect that intersected the entire woodland from one end to the other (max. 1.5 km, min. 0.6 km in length). A response by a Willow Tit to the recording in the form of song, calls, or movement towards the source of the recording revealed presence in a site. A lack of any of these responses was recorded as absence. Due to time constraints, playback surveys were conducted outside of the optimal period for detecting Willow Tits, so we compared the results of our surveys with those from a report using the same methodology in the same population earlier in the year, from February to April (Carr, 2021). In total, we detected the same presence or absence of Willow Tits at ten of the twelve woodlands surveyed in both studies. Our failure to detect Willow Tits at two sites could be due to the timing of our surveys and indicate that there may have still been Willow Tits present at these sites, or alternatively it may reflect a true loss of the birds, which cannot be ruled out given the rapid rate of decline and subsequent extinction of the species in the Dearne Valley following the conclusion of our study (Carr et al, 2024). We also surveyed three sites that were not included in the report but were surveyed in previous years. ArcGIS Pro (version 2.8.1) was used to calculate road proximity, defined as the nearest point of a woodland to any major highway (a motorway, A-road, or B-road). ArcGIS Pro was also used to calculate woodland area. Herb layer height was recorded using a tape measure, and canopy cover using an iPhone SE (Apple Ltd.) to photograph the canopy at 2 m from ground level and estimate percentage. Both measurements were taken at each 100 m transect interval and then averaged for each woodland location. LiDAR data from the National LiDAR Programme 2021 at a resolution of 1 m (Environment Agency, 2025) were used to calculate the maximum and mean vegetation heights of the woodlands as an indicator of the maturity of the woodland sites using ArcGIS Pro (version 2.8.1). Finally, we collected evidence of the presence of Great Spotted Woodpecker by identifying active territories at each site, which included nesting holes, calling and visual identification of the bird.

All statistical analyses were conducted using Microsoft Excel (2017) and SPSS (IBM statistics, version 26). The data collected were not normally distributed, thus a Mann-Whiney U test was used to statistically compare road proximity and habitat characteristics between sites where Willow Tits were present and those where they were not. The difference in presence of Great Spotted Woodpeckers was analysed using a Fisher's Exact Test.

Results and Discussion

Woodlands occupied by Willow Tits were, on average, 295.2m further away from roads than those where the species was absent, a significant difference (Mann-Whitney U Test, U=10, P<0.05, N=15, Figure 2a). This is supported by previous work showing greater proximity to roads has significant negative impacts on the abundance and diversity of bird species within woodland patches, as well as dispersal and mortality (Brotons & Herrando 2001, Bélisle & St Clair 2002, Wiącek *et al* 2015). Sensitivity to anthropogenic infrastructure and related detrimental effects may not be exclusive to highways and may include other forms of development, including housing.

There was no significant difference in woodland area (U=25, P=0.814, N=15, Figure 2b), herb layer height (U=15, P=0.289, N=15, Figure 2c), canopy cover (U=16, P=0.195, N=15, Figure 2d), maximum vegetation height (U=24, P=0.776, N=15, Figure 2e), or mean vegetation height (U=37, P=0.272, N=15, Figure 2f) between those woodlands where Willow Tits were present and those where they were not. Whilst the direction of the relationships were as expected, according to the results of similar studies (Lewis *et al* 2007, Lewis *et al* 2009a), the power to detect changes was low due to the small sample size. Willow Tits have been observed to have relatively large territory sizes (Broughton *et al* 2020), and as the sample size in our study was relatively small, caution should be applied when interpreting an absence of this effect. Current conservation efforts generally focus on improving habitat for Willow Tit through practices such as coppicing and removing vegetation (Pinder and Carr 2021, Broughton 2024), yet have had little success in preserving Willow Tit populations in Britain (Carr *et al* 2024, Broughton 2024). This suggests that habitat management is unlikely to be a limiting factor in their decline. Therefore, expanding interconnectedness of existing habitat patches and protecting the remaining strongholds from development should be a conservation priority.

Great Spotted Woodpeckers were significantly more likely to be observed at sites where Willow Tits were absent, compared to sites where they were present (Fisher's Exact Test, Z=5.402, P<0.05. However, this result should be treated with caution as Great Spotted Woodpeckers are common in Britain, and their absence from some sites may reflect a lower detection probability outside the breeding season rather than a true absence. Nonetheless, the abundance of Great Spotted Woodpeckers has increased steeply in the same period that the Willow Tit has declined (Massimino *et al* 2024), and our results may indicate an effect of the relative abundance of woodpeckers if not presence or absence. Some studies show no significant relationship between predator and competitor population increases and Willow Tit declines (Siriwardena 2004, Lewis *et al* 2007), whereas others indicate that competition and predation can have a pervasive impact on Willow Tit populations (Ludescher 1973, Parry and Broughton 2018). Therefore, there is an urgent need for further work monitoring landscape-scale impacts of predation and nest-site competition throughout the remaining range of the Willow Tit in Britain.

The increasingly precarious conservation status of the Willow Tit in Britain means that any novel data on this topic are valuable, particularly those which help to improve understanding of the causes of this species' steep national decline. Unfortunately, we were unable to conduct playback surveys during the breeding season of Willow Tits (February to March) when they are known to be effective. Therefore, it is possible that birds may still have been present at some of the sites where they were recorded as absent, as they had been identified using optimally timed surveys at all sites in the preceding three years. This, in addition to the small sample sizes, means that clear inferences from this study are limited, but the results may suggest that habitat patches further away from urban infrastructure somehow buffer persisting Willow Tit populations to pervasive anthropogenic effects. Unfortunately, the Dearne Valley Willow Tit population became extinct in the years following the study (Carr *et al* 2024). Consequently, more data are urgently needed to inform conservation actions for Willow Tits going forward to prevent similar losses elsewhere.

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Legends to Figures

Figure 1. Locations of the woodlands where playback surveys were completed in the former Dearne Valley NIA, Barnsley, South Yorkshire. Red points indicate individual woodland patches.

Figure 2. Mean values of a) road proximity, b) woodland area, c) herb layer height, d) canopy cover, e) maximum vegetation height, and f) mean vegetation height between woodland sites where Willow Tits were present and those where they were absent. Error bars represent standard error.

264 **Figures**

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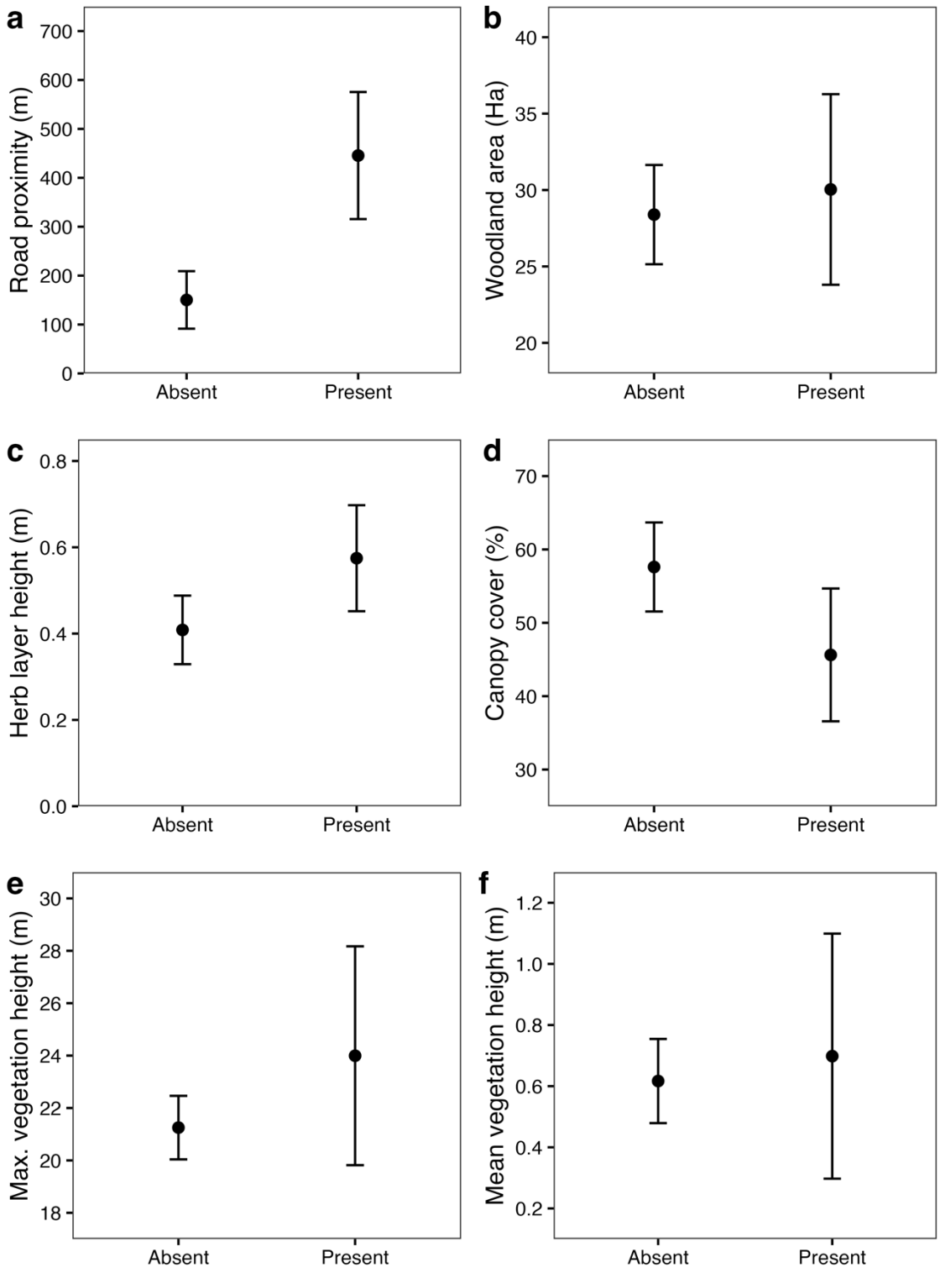
a
Road proximity (m)
0
100
200
300
400
500
600
700
Absent
Present
b
Woodland area (Ha)
20
25
30
35
40
Absent
Present
c
Herb layer height (m)
0.0
0.2
0.4
0.6
0.8
Absent
Present
d
Canopy cover (%)
30
40
50
60
70
Absent
Present
e
Max. vegetation height (m)
18
20
22
24
26
28
30
Absent
Present
f
Mean vegetation height (m)
0.2
0.4
0.6
0.8
1.0
1.2
Absent
Present
Willow Tit occupancy

266