University of Brighton

BY394 Ecology Project
Final Report
2017 - 2018

Impacts of livestock grazing on winter woodland bird diversity

By

Guy Border

In part fulfilment of requirements for the degree of

BSc (Hons) Biological Sciences

Abstract

An increasing interest in the use of conservation grazing as a tool to restore wood pasture environments poses possible implications for winter woodland bird diversity, due to the known ability of livestock grazing to alter woodland vegetation structure. In order to gain a clearer understanding of the impact this management technique has upon woodland birds during this season, this study compares the bird species richness, abundance of dense understory foragers (Robin *Erithacus rubecula*, Dunnock *Prunella modularis*, Wren *Troglodytes troglodytes* and Blackbird *Turdus merula*), and percentage cover of understory vegetation in two livestock-grazed and two un-grazed Sussex woodlands during the winter of 2017/18. No significant difference is found between either three of these variables in grazed and un-grazed woodland, attributed in part to the grazing pressure on the grazed woodlands being too low to significantly alter their understories. This demonstrates the potential for small numbers of livestock to be introduced into woodlands without significantly altering bird communities or vegetation structure. Elements of this study's data collection methods are then critiqued and recommendations to future repeat studies are discussed, namely to survey woodlands with a range of grazing pressures and grazing histories, enabling an assessment of bird and vegetation-related variables under varying grazing levels.

Introduction

Vegetation structure is considered to be the primary factor determining habitat suitability for temperate woodland birds, with tree species composition regarded as playing a lesser role (Hewson et al., 2011). Greater heterogeneity in vegetation height has been associated with increased species richness of some woodland bird guilds in the United States, by allowing for more niche specialisation (Huang et al., 2014). Diaz (2006) also found structural characteristics of the shrub layer, such as cover or height, to be important determinants of bird abundance and species richness in Iberian woodlands during spring, meanwhile winter bird density has been shown to be positively associated with understory shrubs here too (Carrascal and Diaz, 2006). Furthermore, shrub cover has been positively associated with the occurrence and densities of three wintering woodland bird species in Ohio (Doherty and Grubb, 2000). It is believed that the benefits a well-developed understory can provide to woodland birds during winter include thermal cover, protection from predators, and fruit at a time when other foods can be scarce (Doherty and Grubb, 2000; Carrascal and Diaz, 2006; Carrascal, Villen-Perez and Seoane, 2012; Hardy, Vreeland and Tietje, 2013).

Given then that woody understory vegetation abundance responds negatively to grazing by domestic cattle in temperate regions (Bernes et al., 2018), with reductions in the cover of bramble (*Rubus fruticosus*) exceeding 50% in some cases (McEvoy, Flexen and McAdam, 2006; Uytvanck and Hoffmann, 2009), the fact that there is increasing interest in the use of conservation grazing as a tool for restoring wood pasture environments (Armstrong et al., 2003; Uytvanck and Hoffmann, 2009; Woodland Trust, 2012), in response to the growing awareness of large herbivores' role in shaping European climax communities (Vera, 2000), poses possible implications for winter bird diversity in areas where this management strategy is employed.

In Australia, where more than 70% of land is grazed by livestock (Martin and Possingham, 2005), high levels of grazing resulted in a woodland bird assemblage dominated by generalist species that are increasing in abundance nationally, meanwhile richness of understory-dependent bird species characteristic of woodlands with no or low levels of grazing was reduced (Martin and Possingham, 2005; Martin and McIntyre, 2007). However, the grazing of domestic cattle in Australian forests is almost synonymous with frequent burning, a practise known to reduce the shrub layer more than grazing alone (Tasker and Bradstock, 2006). Therefore, these results could be more exaggerated than those from woodland grazing schemes elsewhere. In the UK, livestock grazing in the Forest of Dean was found to be generally detrimental to the value of woodland regarding winter bird communities (Hill et al., 1991; Donald et al., 1997), with un-grazed areas containing greater bird species richness, particularly of granivores (Donald et al., 1997). However, the grazing here was carried out by domestic sheep (Donald et al., 1997) who, as well as being non-native to the UK, are also known to be more selective grazers than cattle and inflict more structural damage to woodlands (Hill et al., 1991).

There seems to be then a lack of UK or European-based studies investigating the effect of native livestock grazing upon woodland bird diversity during winter, which can then be used to aid the discussion regarding this woodland management approach. The aim of this study is to address this gap, by comparing the following features of un-grazed woodland with that of woodlands grazed by domestic cattle and horses: total bird species richness, abundance of birds favouring a dense understory for foraging in winter (referred to as 'dense understory foragers'), and percentage cover of understory vegetation. In addition, the relationship between dense understory foragers and percentage cover of understory vegetation is measured. Un-grazed woodland was predicted to have a higher bird species richness (Donald et al., 1997) and a higher abundance of dense understory foragers (Martin and Possingham, 2005; Martin and McIntyre, 2007), whilst grazed woodland was predicted to have a lower percentage cover of understory vegetation (McEvoy, Flexen and McAdam, 2006; Uytvanck and Hoffmann, 2009).

Methods

Study area

Four different areas of woodland were used in this study; two of which are grazed by livestock and two are not. Friston Forest in East Sussex was the location of one area of grazed and one of un-grazed woodland. This forest was planted gradually in sections during the first half of the twentieth century, having originally been an area of chalk grassland (Forestry Commission, 1951). At 850 hectares, it is now the largest newly planted forest in the southeast of England (Forestry Commission, 2017). The main species grown here was Beech (*Fagus sylvatica*) as it was considered to be the most appropriate for the area's limestone soil, however coniferous species were also planted to provide shelter belts (Forestry Commission, 1951). In 2008, a small herd of 6 British White cattle were introduced into an 80-hectare enclosure at the northern end of the forest as part of a conservation grazing project (Sussex Wildlife Trust, 2017). These were then replaced with 4 English Longhorn cattle in 2013 (Sussex Wildlife Trust, 2013), who were joined by 11 Konik ponies the following year (Sussex Wildlife Trust, 2014). These livestock are shared with other Sussex Wildlife Trust reserves and so are not all present within Friston forest all year round. This enclosure forms the grazed woodland area, whilst the remaining forest that surrounds the enclosure on all but its northern side forms the un-grazed area, but only extending to approximately 400 metres south of the grazing enclosure in order to ensure these two areas are of a similar size (Figure 1). Both sections of the forest receive some grazing from wild Roe Deer (*Capreolus capreolus*).

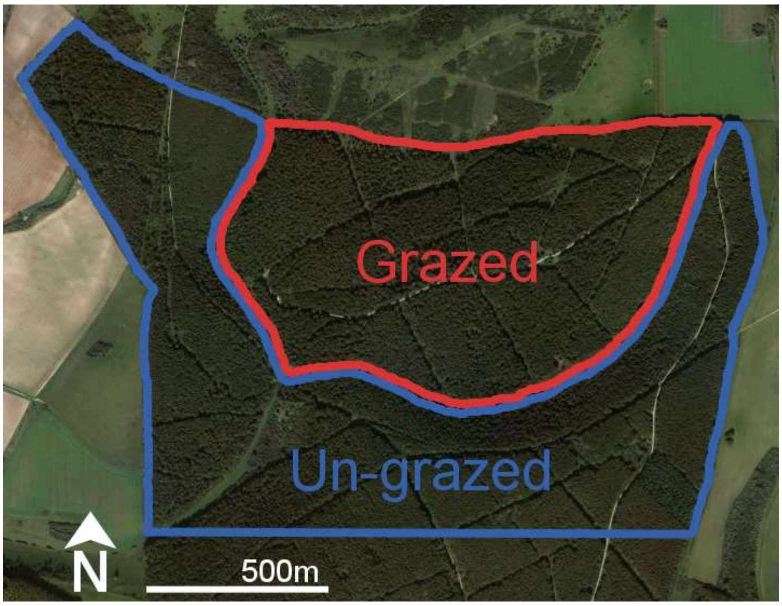

Figure 1: Map of Friston forest showing the grazed and un-grazed area of woodland being studied.

The second area of grazed woodland used in this study lies within an approximately 240-hectare section of Knepp estate, West Sussex. Knepp estate is a pioneering rewilding project where once intensive arable land has been converted into a dynamic landscape managed by several species of free roaming herbivore (Knepp, 2017a). The project began in 2001, after decades of unprofitable farming had made it clear that a different management strategy was required (Knepp, 2017b). Woodland makes up roughly a third of this part of the estate, and is broken up into several parcels ranging from approximately 3 to 15 hectares, comprising a mix of deciduous and coniferous species. The remaining land consists of pasture dotted with mature trees and some hedgerows. Grazing in this section is carried out by a large herd of approximately 100 English Longhorn cattle who are present all year round, as well as wild Roe Deer. Whilst this herd is much larger than at Friston forest, the space they occupy is around three times the size of the Friston forest grazing enclosure and anecdotal observations suggest that they do most of their feeding within the pastureland. As a result, the grazing pressure on the woodland within Knepp estate and Friston forest may not be too dissimilar.

The second area of un-grazed woodland used in this study forms part of the Bakers Farm estate, which borders Knepp estate's western boundary. The permitted study area extends to just over 30 hectares, and consists largely of Silver Birch (*Betula pendula*) plantation with sections of other deciduous species. Whilst this woodland is not grazed by livestock, it is presumed that wild Roe Deer are likely to occur here. As with the two study sites within Friston forest, the close proximity of the woodlands at Bakers farm and Knepp estates (approximately 1.7km) helps to ensures they are not spatially independent.

Vegetation sampling

For each study site (Friston forest grazing enclosure, Friston forest un-grazed area, Knepp estate and Bakers farm estate), 5 quadrats measuring 50m by 50m (Sutherland, 2006) were randomly selected using number generation from a north-aligned grid with cells of the same size overlaid onto a map of each location (Figure 2). Quadrats were selected only from grid cells that fitted entirely within wooded areas on these maps. Each quadrat also had to be at least 200m apart due to the fact that bird point counts would be carried out from the centre of each quadrat (Sutherland, 2006).

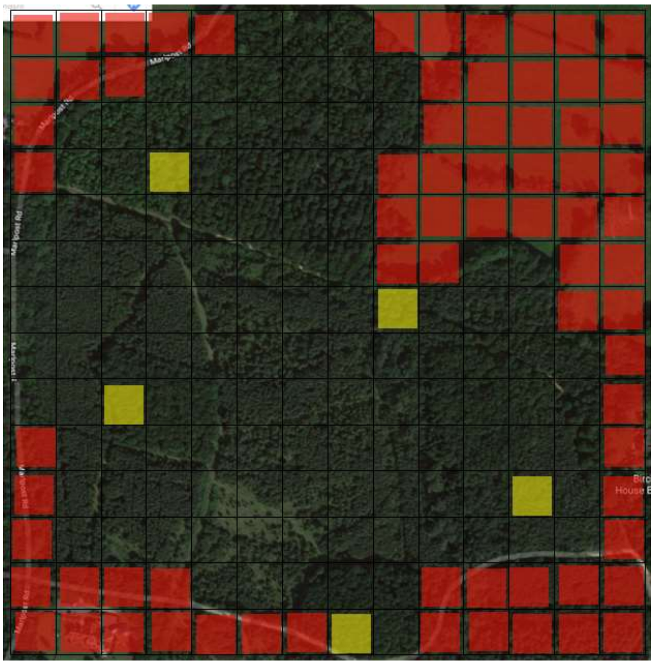

Figure 2: Map of Bakers farm estate showing the overlaid grid. Cells coloured in red are either not entirely wooded or lie at least partially outside the permitted study area, and therefore are excluded from selection. Cells coloured in yellow were selected for surveying using random number generation.

Within each 50m by 50m quadrat, the species of every tree with a diameter at breast height (DBH) greater than 4cm (Forestry Commission, 2016) was recorded to give a measure of species abundance. These surveys were carried out during July/August whilst the trees still had their leaves, in order to aid identification. Inside each 50m by 50m quadrat, three 5m by 5m quadrats (Sutherland, 2006) were positioned using random number generation between 1 and 50 to create coordinates. The percentage cover of understory vegetation in these smaller quadrats was then measured using the Braun-Blanquet scale (0=<1% cover, 1=1-5% cover, 2=6-25% cover, 3=26-50% cover, 4=51-75% cover, 5=76-100% cover). This meant that each larger (50m by 50m) quadrat had three values for understory vegetation cover, which would be averaged during data analysis. Understory vegetation was defined as being all woody scrub with a DBH less than 4cm, such as young trees, bramble (*Rubus fruticosus*) and gorse (*Ulex*). These surveys were conducted during January/February.

Bird sampling

Each of the four locations was surveyed on a separate morning in dry and still conditions, beginning at around 8-8:30am and finishing between 10:30-11am. Ten-minute point counts were conducted from the centre of each 50m by 50m quadrat, meaning each woodland received five point counts. The position was approached slowly, ideally wearing neutrally-coloured clothes, and an adjustment period of 5 minutes was given before counting commenced. The species abundance of every bird seen or heard up to a cut-off distance of 30 metres from the observer (Sutherland, 2006) was recorded, with any birds flying above the canopy being excluded. Each point count was repeated once in order to obtain a set of temporal replicates and account for any seasonal variation in bird activity. The first set of point counts were conducted during December and the repeat set in late January/February.

Data analysis

For each 50m by 50m quadrat, bird survey results from the initial and repeat point counts were combined by taking the maximum count for each species, giving species abundance and richness. The species classified as dense understory foragers were Robin (*Erithacus rubecula*) (Holt, Fuller and Dolman, 2013; Johnstone, 2008), Dunnock (*Prunella modularis*) (Fuller et al., 2005), Wren (*Troglodytes troglodytes*) (Holt, Fuller and Dolman, 2013) and Blackbird (*Turdus merula*) (Post and Gotmark, 2006; Holt, Fuller and Dolman, 2013; Khanaposhtani et al., 2012), and their abundances were also grouped into a separate table giving one value of dense understory forager abundance for each 50m by 50m quadrat. Marsh tit (*Poecile palustris*) abundance has been found to be positively related to vegetation cover within the shrub layer, however particularly at a height of 2-4m (Hinsley et al., 2007). Therefore, the classification of understory vegetation used by this study, being any woody scrub with a DBH less than 4cm, would likely not incorporate this 2-4m vegetation layer and as such it would be wrong to include Marsh tit within this guild of birds. It should also be mentioned here this study's evidence for including the Wren within this group came from Holt, Fuller and Dolman (2013), who in fact categorised this species as a shrub layer, rather than a ground/basal shrub layer, forager. However, as Holt, Fuller and Dolman (2013) defined the shrub layer as the vegetation stratum between 0.5-1.5m, this was deemed low enough to correspond to this study's classification of understory vegetation.

The mean of each 50m by 50m quadrats' three Braun-Blanquet scale scores for understory vegetation cover was calculated (to 1 decimal place). This was in order to create one value per quadrat to be used in a simple linear regression test against abundance of dense understory foragers, and also to rid the data of zeros for a 1-tailed Mann-Whitney U-test comparing understory vegetation cover in grazed and un-grazed woodlands. The use of a non-parametric test here, and in the following two cases, was due to having small sample sizes. A 1-tailed Mann-Whitney U-test was also used for the comparison of bird species richness in grazed and un-grazed woodland, and the abundance of dense understory foragers in grazed and un-grazed woodland. The confidence level for all statistical tests carried out in this study was 95% (α=0.05). Shannon Indexes of bird diversity were also calculated for each 50m by 50m quadrat.

Results

A total of 17 bird species were recorded across all four locations, with Knepp estate and the un-grazed area of Friston forest scoring the joint highest richness of 12 species (Table 1). Grazed woodland's mean Shannon Index for bird diversity was highest at 1.31 (Standard Deviation=0.41), compared to un-grazed woodland's 1.22 (Standard Deviation=0.60), and of the four locations Knepp estate had the highest mean Shannon Index for bird diversity at 1.53 (Standard Deviation=0.32).

Table 1: The total abundances of bird species recorded across all four locations.

Bird species	Knepp estate	Friston forest (grazed)	Friston forest (un-grazed)	Bakers farm
Blackbird (*Turdus merula*)	3	2	7	3
Blue tit (*Cyanistes caeruleus*)	11	3	5	3
Chaffinch (*Fringilla coelebs*)	-	1	6	-
Coal tit (*Periparus ater*)	2	-	1	1

Dunnock (*Prunella modularis*)	1	1	2	-
Goldcrest (*Regulus regulus*)	1	1	3	1
Great spotted woodpecker (*Dendrocopos major*)	-	-	-	1
Great tit (*Parus major*)	2	3	2	-
Long tailed tit (*Aegithalos caudatus*)	13	3	3	5
Marsh tit (*Poecile palustris*)	-	-	-	1
Nuthatch (*Sitta europaea*)	3	-	-	-
Redwing (*Turdus iliacus*)	-	-	2	-
Robin (*Erithacus rubecula*)	9	2	6	4
Sparrowhawk (*Accipiter nisus*)	1	-	-	-
Treecreeper (*Certhia familiaris*)	1	-	-	-
Woodcock (*Scolopax rusticola*)	-	1	1	-
Wren (*Troglodytes troglodytes*)	3	1	1	2

The population median of bird species richness in un-grazed woodland was not found to be significantly greater than that in grazed woodland (W value=102.5, p value=0.59) (Figure 3a). In addition, the population median of dense understory forager abundance in un-grazed woodland was not found to be significantly greater than that in grazed woodland (W value=111.5, p value=0.323) (Figure 3b), and only 8.7% of the variation in this abundance could be explained by the regression in understory vegetation cover (F value=1.72, p value=0.207, DF=1) (Figure 4), therefore no significant linear relationship was found. Despite this however, the two highest abundances of dense understory foragers (6 and 5) were recorded in quadrats with the maximum mean Braun-Blanquet scale score of 5, meanwhile the lowest recorded mean Braun-Blanquet scale score of 0.7 corresponded to a zero abundance of dense understory foragers (Figure 4). This goes a small way to demonstrating a possible trend between these two variables.

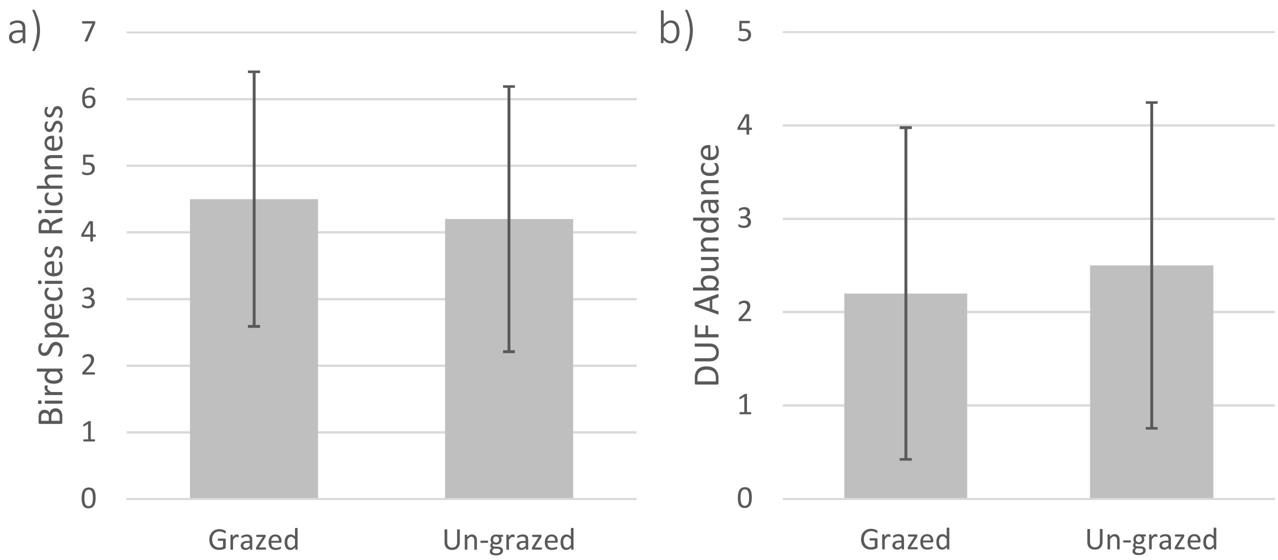

Figure 3: a) The mean bird species richness recorded at survey sites (50m by 50m quadrats) within grazed and un-grazed woodland with standard deviation bars. b) The mean abundance of dense understory foragers (DUF) recorded at survey sites within grazed and un-grazed woodland with standard deviation bars.

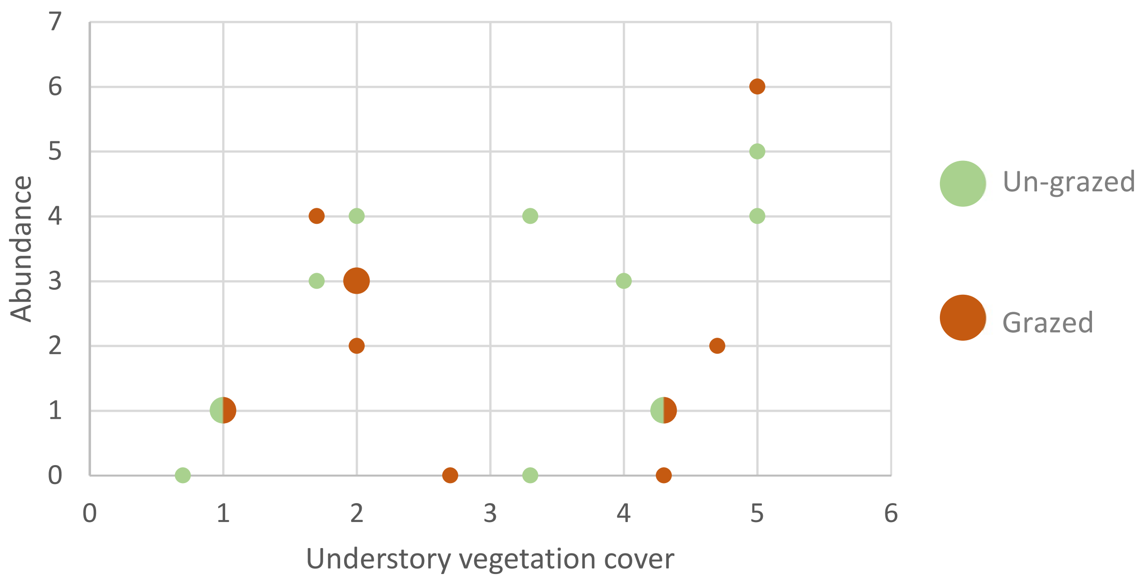

Figure 4: A scatter plot of the mean Braun-Blanquet scale score of understory vegetation cover for each 50m by 50m quadrat against the abundance of dense understory foragers for that quadrat. The larger markers denote a double occurrence of that particular score.

The population median of understory vegetation cover in grazed woodland was not found to be significantly lower than that in un-grazed woodland (W value=105.5, p value=0.53). The mean Braun-Blanquet scale scores for the four individual woodlands were as follows: Knepp estate=2.3, Friston forest grazing enclosure=3.6, Friston forest un-grazed area=2.5, Bakers farm estate=3.5. In terms of trees, a total of 22 species were recorded across all four locations, with Knepp estate scoring the highest richness of 17 species (Table 2). Tree density was lowest at Friston forest, with mean values of 35 trees per 2500m^2 for the grazing enclosure and 58 trees per 2500m^2 for the un-grazed area. Knepp estate had the highest mean density at 214 trees per 2500m^2, largely a result of this location's abundant Hazel (*Corylus avellana*) coppice and Silver Birch (*Betula pendula*) plantation, with Bakers farm also averaging highly at 155 trees per 2500m^2.

Table 2: The total abundances of tree species recorded across all four locations.

Tree species	Knepp estate	Friston forest (grazed)	Friston forest (un-grazed)	Bakers farm
Alder (*Alnus glutinosa*)	-	-	-	10
Apple (*Malus sylvestris*)	1	-	-	-
Ash (*Fraxinus excelsior*)	109	-	-	70
Beech (*Fagus sylvatica*)	2	150	189	1
Douglas Fir (*Pseudotsuga menziesii*)	145	-	-	-
Elder (*Sambucus nigra*)	3	1	22	-
Field Maple (*Acer campestre*)	6	-	-	2
Goat Willow (*Salix caprea*)	7	2	3	-
Hawthorn (*Crataegus monogyna*)	31	2	3	8
Hazel (*Corylus avellana*)	190	-	-	28
Holly (*Ilex aquifolium*)	9	1	1	14
Hornbeam (*Carpinus betulus*)	15	-	-	1
Norway Spruce (Picea abies)	-	-	-	28
Oak (*Quercus robur/petraea*)	254	-	-	210
Scots Pine (*Pinus sylvestris*)	17	-	29	-
Silver Birch (*Betula pendula*)	190	2	-	350

Sweet Chestnut (*Castanea sativa*)	60	-	-	-
Sycamore (*Acer pseudoplatanus*)	29	12	41	-
Western Red Cedar (*Thuja plicata*)	-	3	-	-
Wild Cherry (*Prunus avium*)	-	-	-	52
Wild Service (*Sorbus torminalis*)	-	-	-	1
Wych Elm (*Ulmus glabra*)	1	-	-	-

Discussion

This study's finding that un-grazed woodland did not support a significantly greater number of bird species in winter opposes the result of Donald et al. (1997). However, this difference could be due to the fact that Donald et al. (1997) were studying sheep-grazed woodland, which as mentioned previously are known to have more diminished understories offering poorer structural heterogeneity. Consequently, this study can be said to support the argument that cattle are less damaging to woodland vegetation structure and less detrimental to woodland bird diversity than sheep.

In terms of the result for understory vegetation cover not being significantly lower in grazed woodland, it is likely that the moderately low stocking density (Mountford and Peterken, 2003) of the Friston forest grazing enclosure, approximated at 1 animal per 5 hectares, and the anecdotal observation that the Knepp estate cattle graze mostly within the pastureland, meant that the grazing pressure at both grazed woodlands was too low to significantly alter their understories. The implications of this result in terms of a growing interest in wood pasture restoration means that, potentially, small numbers of native livestock can be introduced into woodlands without either benefiting or adversely affecting bird diversity, in winter at least. This neither supports nor fully contradicts the opinion of Mitchell and Kirby (1990), who state that low levels of livestock grazing may create conditions for the highest diversity of plants and animals in British semi-natural woodlands. A result from this study that does support this theory, despite not being statistical or significant data, are the Shannon Indices of bird diversity which were highest for grazed woodland, and in particular the grazed woodland at Knepp estate.

An interesting result regarding dense understory forager abundance can be found in the absence of any Dunnocks at Bakers farm estate (Table 1). This being an un-grazed woodland, it should theoretically contain a more developed understory and so have a higher chance of recording this species. However, the low abundance of Dunnocks recorded across the other three woodlands (Table 1) reduces the significance of this finding. The Robin was another species in this guild who opposed the expected trend, being most abundant at a grazed woodland; Knepp estate (Table 1). Because the woodland at Knepp estate differs to the other 3 locations in that it is broken up into relatively small parcels, this result supports the findings of Vanhinsbergh et al. (2002) that Robins occur most frequently in smaller woodlands in winter.

As the results for understory vegetation cover show, there is a distinct difference between the mean Braun-Blanquet scale scores of the two grazed woodlands, with Knepp estate scoring lower. A possible explanation for this lies not only in that Knepp estate has a much larger herd size, but that also this herd consists only of cattle, whereas the majority of livestock at Friston forest are Konik ponies. The differences in diet preference of these two herbivores, with horses being found to graze mainly on grasses (Hubbard and Hansen, 1976) and monocots (Van Wieren, 1995) due to their lesser ability to digest fibre (Shingu, Kondo and Hata, 2010), whilst cattle are shown to survive year-round on a diet consisting predominantly of woody species (Bartolome, 2011), means that the 80-hectare Friston forest grazing enclosure theoretically only contained 4 individual animals (the English Longhorn cattle) capable of tackling its woody scrub. Moreover, as mentioned earlier these animals are not present onsite all year round, further reducing their impact on the understory. No comment can be made on the contribution of wild Roe deer to this discrepancy, other than that they were seen occasionally on visits to both sites.

One bird species whose occurrence is suggested by the results to be related to the presence of a particular tree species is the Chaffinch. This bird is known to frequently feed on Beech mast in winter (Chamberlain, Gosler and Glue, 2007), and so its occurrence would be expected to overlap with that of Beech. The results support this idea, with the location most abundant in Beech; the Friston forest un-grazed area, recording the highest number of Chaffinch, meanwhile the scarcity of Beech at Knepp and Bakers farm estates (Table 2) corresponded to a complete absence of Chaffinch. This theory however does not explain the low abundance of Chaffinch at the Friston forest grazing enclosure (Table 1), where Beech abundance was still very high (Table 2). Whilst this study could've done more to discern the influence of tree species composition on bird diversity, one conclusion that can be drawn is the suggestion that a high tree species richness did not necessarily correspond with a high bird species richness, demonstrated by the Friston forest un-grazed area scoring joint highest in bird species richness (Table 1) but lowest in tree species richness (Table 2).

This study's assessment of ground vegetation was limited in that no measure of vegetation height was taken. As a result, two quadrats with scrub of similar cover but varying in height would receive the same score despite being quite different understory habitats. This was indeed the case for a particular survey site at Knepp estate whose understory consisted of predominantly tall Blackthorn (*Prunus spinosa*) (approximately 150cm in height), and another survey site within the Friston forest grazing enclosure whose understory consisted of low bramble (approximately 50cm in height). Both survey sites recorded a mean Braun-Blanquet scale score greater than 4.5, however the Knepp estate survey site recorded three times the abundance of dense understory foragers. The use therefore of a model incorporating the percentage cover of different vegetation layers, similar to the one outlined by Herrando and Brotons (2002), might have identified differences between the grazed and un-grazed woodlands, such as whether the livestock are depleting certain understory layers. In addition, it would have determined a more accurate relationship between understory vegetation cover and dense understory forager abundance.

A repeat study should aim to survey a greater number of woodlands, including sites with a known higher grazing pressure and longer grazing history. This would not only increase the number of spatial replicates and therefore the reliability of results, but also allow for an assessment of woodland bird diversity and vegetation structure under varying levels of grazing, that could potentially pinpoint the stocking density or number of years of grazing where these features of a woodland begin to become significantly altered. This would then provide conservation grazing schemes with data enabling them to make informed decisions over matters such as herd size, as well as predict how the site is likely to change overtime.

References

Armstrong, H. M., Poulsom, L., Connolly, T. and Peace, A., 2003. A survey of cattle-grazed woodlands in Britain. Final Report. Woodland Ecology Branch. *Forest Research, Northern Research Station, Roslin, Midlothian, Scotland*.

Bartolome, J., Plaixats, J., Piedrafita, J., Fina, M., Adrobau, E., Aixas, A., Bonet, M., Grau, J. and Polo, L., 2011. Foraging Behavior of Alberes Cattle in a Mediterranean Forest Ecosystem. *Rangeland Ecology and Management*, 64 (3), 319-324.

Bernes, C., Macura, B., Jonsson, B. G., Junninen, K., Muller, J., Sandstrom, J., Lohmus, A. and Macdonald, E., 2018. Manipulating ungulate herbivory in temperate and boreal forests: effects on vegetation and invertebrates. A systematic review. *Environmental Evidence*, 7 (13).

Carrascal, L. M. and Diaz, L., 2006. Winter bird distribution in abiotic and habitat structural gradients: a case study with Mediterranean montane oakwoods. *Ecoscience,* 13, 100–110.

Carrascal, L. M., Villen-Perez, S. and Seoane, J., 2012. Thermal, food and vegetation effects on winter bird species richness of Mediterranean oakwoods. *Ecological Research,* 27, 293–302.

Chamberlain, D. E., Gosler, A. G. and Glue, D. E., 2007. Effects of the winter beechmast crop on bird occurrence in British gardens. *Bird Study*, 54 (1), 120-126.

Diaz, L., 2006. Influences of forest type and forest structure on bird communities in oak and pine woodlands in Spain. *Forest Ecology and Management,* 223 (1-3), 54-65.

Doherty, P. F. and Grubb, T. C., 2000. Habitat and landscape correlates of presence, density, and species richness of birds wintering in forest fragments in Ohio. *Wilson Bulletin,* 112, 388–394.

Donald, P. F., Fuller, R. J., Evans, A. D. and Gough, S. J., 1998. Effects of forest management and grazing on breeding bird communities in plantations of broadleaved and coniferous trees in western England. Biological Conservation, 85, 183-197.

Donald, P. F., Haycock, D. and Fuller, R. J., 1997. Winter bird communities in forest plantations in western England and their response to vegetation, growth stage and grazing. Bird Study, 44 (2), 206-219.

Forestry Commission, 1951. History of Friston Forest. [pdf] Available at: <https://www.forestry.gov.uk/PDF/FCFH083.pdf/$FILE/FCFH083.pdf>.

Forestry Commission, 2016. NFI Survey Manual: Chapter 15: Young Tree Assessments. [pdf] Available at: <https://www.forestry.gov.uk/pdf/15-Young-Tree-Assessments-V3.pdf/$FILE/15-Young-Tree-Assessments-V3.pdf>.

Forestry Commission, 2017. Explore Friston Forest. [leaflet].

Fuller, R. J., Noble, D. G., Smith, K. W. and Vanhinsbergh, D., 2005. Recent declines in populations of woodland birds in Britain: a review of possible causes. *British Birds,* 98, 116-143.

Hall, S. J. G., 2008. A comparative analysis of the habitat of the extinct aurochs and other prehistoric mammals in Britain. Ecography, 31 (2), 187-190.

Hardy, M. A., Vreeland, J. K. and Tietje, W. D., 2013. Vegetation associations of birds wintering in a California oak woodland. *Journal of Field Ornithology,* 84 (4), 345-354.

Herrando, S. and Brotons, L., 2002. Forest bird diversity in Mediterranean areas affected by wildfires: a multi-scale approach. *Ecography,* 25 (2), 161-172.

Hewson, C. M., Austin, G. E., Gough, S. J. and Fuller, R. J., 2011. Species-specific responses of woodland birds to stand-level habitat characteristics: The dual importance of forest structure and floristics. *Forest Ecology and Management*, 261 (7), 1224-1240.

Hill, D, A., Lambton, S., Proctor, I. and Bullock, I., 1991. Winter bird communities in woodland in the Forest of Dean, England, and some implications of livestock grazing. Bird Study, 38, 57-70.

Hinsley, S. A., Carpenter, J. E., Broughton, R. K., Bellamy, P. E., Rothery, P., Amar, A., Hewson, C. M. and Gosler, A. G., 2007. Habitat selection by Marsh Tits Poecile palustris in the UK. *Ibis,* 149 (2), 224-233.

Holt, C. A., Fuller, R. J. and Dolman, P. M., 2013. Exclusion of deer affects responses of birds to woodland regeneration in winter and summer. *Ibis,* 156, 116-131.

Hubbard, R. E. and Hansen, R. M., 1976. Diets of Wild Horses, Cattle, and Mule Deer in the Piceance Basin, Colorado. *Journal of Range Management,* 29 (5), 389-392.

Huang, Q., Swatantran, A., Dubayah, R. and Goetz, S. J., 2014. The Influence of Vegetation Height Heterogeneity on Forest and Woodland Bird Species Richness across the United States. *PLOS One,* 9 (8).

Johnstone, I., 2008. Territory structure of the Robin Erithacus rubecula outside the breeding season. *Ibis,* 140 (2), 244-251.

Khanaposhtani, M. G., Kaboli, M., Karami, M. and Etemad, V., 2012. Effect of Habitat Complexity on Richness, Abundance and Distributional Pattern of Forest Birds. *Environmental Management,* 50, 296-303.

Knepp, 2017a. Welcome. [online] Available at: <https://knepp.co.uk/>.

Knepp, 2017b. Farming at Knepp. [online] Available at: <https://knepp.co.uk/farming-at-knepp/>.

Martin, T. G. and McIntyre, S., 2007. Impacts of Livestock Grazing and Tree Clearing on Birds of Woodland and Riparian Habitats. Conservation Biology, 21 (2), 504-514.

Martin, T. G. and Possingham, H. P., 2005. Predicting the impact of livestock grazing on birds using foraging height data. Journal of Applied Ecology, 42 (2), 400-408.

McEvoy, P. M., Flexen, M. and McAdam, J. H., 2006. The effects of livestock grazing on ground flora in broadleaf woodlands in Northern Ireland. *Forest Ecology and Management*, 225 (1-3), 39-50.

Mitchell, F. J. G. and Kirby, K. J., 1990. The Impact of Large Herbivores on the Conservation of Semi-natural Woods in the British Uplands. *Forestry: An International Journal of Forest Research*, 63 (4), 333–353.

Mountford, E. P. and Peterken, G. F., 2003. Long-term change and implications for the management of wood-pastures: experience over 40 years from Denny Wood, New Forest. *Forestry: An International Journal of Forest Research*, 76, 19–43.

Post, P. and Gotmark, F., 2006. Foraging behavior and predation risk in male and female Eurasian Blackbirds (*Turdus merula*) during the breeding season. *The Auk,* 123, 162-170.

Putman, R. J., 1986. Grazing in temperate Ecosystems: Large Herbivores in the Ecology of the New Forest. Beckenham: Croome Helm.

Riutta, T., Slade, E. M., Morecroft, M. D., Bebber, D. P. and Malhi, Y., 2014. Living on the edge: quantifying the structure of a fragmented forest landscape in England. Landscape Ecology, 29 (6).

Schmölcke, U. and Zachos, F. E., 2005. Holocene distribution and extinction of the moose (Alces alces, Cervidae) in Central Europe. Mammalian Biology, 70 (6), 329-344.

Shingu, Y., Kondo, S. and Hata, H., 2010. Differences in grazing behavior of horses and cattle at the feeding station scale on woodland pasture. *Animal Science Journal*, 81 (3), 384-392.

Sorensen, A. E., 1981. Interaction between birds and fruit in a temperate woodland. *Oecologia*, 50 (2), 242-249.

Spencer, R., 1982. Birds in winter-an outline. Bird Study, 29 (3), 169-182.

Sussex Wildlife Trust, 2013. *The Trust's 4 longhorn cattle are now being grazed at Friston Forest #Eastbourne.* [Twitter] 11th December. Available at: https://twitter.com/SussexGrazing/status/410723791291944960 [Accessed 19th January 2018].

Sussex Wildlife Trust, 2014. *Friston Forest grazing project now has 11 Konik ponies alongside its 4 old English longhorns. #Eastbourne.* [Twitter] 17th October. Available at: https://twitter.com/SussexGrazing/status/523040603480010752 [Accessed 19th January 2018].

Sussex Wildlife Trust, 2017. Friston Forest Grazing Project. [online] Available at: <https://sussexwildlifetrust.org.uk/what-we-do/grazing/friston-forest-grazing-project>.

Sutherland, W. J., 2006. Ecological Census Techniques. 2nd ed. Cambridge: Cambridge University Press.

Tasker, E. M. and Bradstock, R. A., 2006. Influence of cattle grazing practices on forest understorey structure in north-eastern New South Wales. *Austral Ecology*, 31 (4), 490-502.

Taylor, P., 2005. Beyond Conservation. London: Earthscan.

Uytvanck,J. V. and Hoffmann, M., 2009. Impact of grazing management with large herbivores on forest ground flora and bramble understorey. Acta Oecologica, 35 (4), 523-532.

Vanhinsbergh, D., Gough, S., Fuller, R. J. and Brierley, E. D. R., 2002. Summer and winter bird communities in recently established farm woodlands in lowland England. *Agriculture, Ecosystems and Environment*, 92 (2-3), 123-136.

Van Wieren, S., 1995. Composition and cell wall content of diets selected by Roe deer, Red deer, Highland cattle and Konik ponies. *Annales de Zootechnie*, 44, 121.

Vera, F. W. M., 2000. Grazing Ecology and Forest History, Oxford: CABI Publishing.

Woodland Trust, 2012. Wood pasture: definition, restoration and creation. [online] Available at: <http://www.woodlandtrust.org.uk/mediafile/100263358/pg-wt-2014-woodwise-2012-winter.pdf?cb=2dd754bdd48e4ffcac5e8c923ffc6dbb>.