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The Vegetation of the Pig Rootled Areas at Knepp Wildland and their use by Farmland Birds

Ivan de Klee

CID: 01441758

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Declaration of Own Work

I declare that this thesis, “The Vegetation of the Pig Rootled Areas at Knepp Wildland and their use by Farmland Birds”, is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature ______________________________

Name of student: Ivan de Klee

Name of Supervisors: Marcus Rowcliffe, Emma Stobart and Penny Green

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ABSTRACT

Rewilding is an ecological restoration movement that is gaining momentum as a positive conservation solution across Europe with the Knepp Wildland as a leading project in the United Kingdom. By using large herbivores to shape the landscape Knepp has seen a return of various endangered species such as the Nightingale, Turtle Dove and Purple Emperor Butterfly. The proxy of the wild boar (*Sus* Scrofa) and its ecosystem engineering behaviour is played by the Tamworth Pig and is seen as key to the increase in biodiversity at Knepp.

This study aims to assess the impact of the pig's rootling behaviour on vegetation composition and to analyse if this change in composition has any effect on farmland birds. It aims to reveal if pigs hold the key to the success of the Turtle Dove (*Streptopelia Turtur)* at Knepp by encouraging the growth of arable weeds essential to their survival that have now become scarce across Britain.

70 vegetation surveys were conducted across 35 locations, each consisting of a rootled plot and a non-rootled control plot. Each of these plots were also monitored by camera traps to assess visiting bird numbers.

The rootled sites were significantly more plant species diverse than the non-rootled control sites, however there were few significant differences found in the birds' behaviour. Despite not photographing any Turtle Doves, the vegetation surveys revealed that key arable weeds in their diets such as common mouse-ear (chickweed), speedwell sp. and scarlet pimpernel were all significantly more abundant in the rootled areas.

This study supports the use of pigs as a proxy for the wild boar in extensive wilding systems, their rootling behaviour encourages the growth of diminishing and endangered arable weeds and provides a rich food source for seed feeding birds including the endangered Turtle Dove.

KEYWORDS

Rewilding, Turtle Dove, Arable Weeds, Disturbance, Pigs.

INTRODUCTION

Rewilding is an ecological restoration movement that is growing both in practice and in the public sphere (Sims et al. 2014; Lorimer et al. 2015) with the aim of restoring natural landscapes using large mammals to shape ecosystems (Donlan et al. 2006; Lorimer et al.

2015). Different large mammal species play an important and different role from one another through their differing feeding behaviours (Vera 2000; Merckx & Pereira 2014) in turn having knock on trophic effects on other species elsewhere in the system. A range of other species are then able to utilise and benefit from the new conditions. Rewilding thus in theory addresses the trophic cascades caused by historic herbivore and predator extinctions (Vera 2000; Lorimer et al. 2015).

In Northern Europe the Wild Boar (*Sus Scrofa*) plays an important role in rewilded and natural landscapes alike, with distinct 'ecosystem engineer' behaviours that shape the landscape (Sandom et al. 2012; Sims et al. 2014; Lorimer et al. 2015). Wild Boar's foraging by 'rootling' through the soil is particularly impactful, described by Sims et al. (2014) as the "excavation of the surface soil layers in the course of foraging for food, creating localised disturbance that appears similar to mechanical ploughing". It not only disturbs the bulbs, soil organisms and roots under the soil (Tierney & Cushman 2006; Sims et al. 2014) but creates areas of bare ground which in turn has various impacts on plant communities (Welander 2000; Vera 2000; Sandom et al. 2013a, 2013b; Sims et al. 2014).

The wild boar went extinct in the UK (Yalden 1999; Goulding & Roper 2002) and it is illegal to keep them as domestic animals due to the Dangerous Wild Animals Act (Great Britain, Dangerous Wild Animals Act 1976) however in some places across the UK they are beginning to return and recolonise, perhaps due to accidental releases (Wilson 2008; Sims et al 2014). One place they have not returned to though is Knepp Rewilding Project in West Sussex, which in terms of biodiversity regeneration has been hugely successful (Newton et al. 2013; Tree 2017, 2018; Overend & Lorimer 2018). With huge resurgences in endangered UK species such as Nightingales, Purple Emperor Butterflies and Turtle Doves, the project has seen swathes of new life return to what was previously a conventional arable and dairy farm (Newton et al. 2013; Tree 2017, 2018; Overend & Lorimer 2018; Stares 2016; Preston 2018; Lowrie 2018).

To play the important proxy of the omnivorous wild boar in the system, Knepp have released Tamworth pigs onto the project which are a large breed of domestic pig. They rootle the ground in a similar way to the wild boar (Diaz et al. 2006, Johnson 2011, Tree 2017, Overend & Lorimer 2018) and are considered the most similar to the ancient indigenous species the 'Old English Forest Pig' but are generally docile in behaviour (Tree 2017; RBST nd; BPA nd), making them an ideal choice for a project with public access such as Knepp. In a study on the rootled areas at Knepp from 2005-2006, Diaz et al. found that the foraging of the Tamworth pigs created significant differences in plant composition between the rootled areas and the non-rootled. The study found no difference in invertebrate populations in the same sites.

Arable weeds and legumes have been disappearing from the UK countryside since the 1970s (Sutcliffe & Kay 2000; Robinson et al. 2009) in part due to changing agricultural practices including changes in seasonal sowing and increases in the use of pesticides and chemical fertilisers (Siriwardena et al. 1998; Browne & Aebischer 2003; Storkey 2006) this has often been associated with a decline in farmland bird species (Siriwardena et al. 1998, Chamberlain et al 2000, Atkinson et al 2005). Definitions of arable weeds are very broad, ranging from defining weeds as “a plant in an undesired place” (Clarke et al. 2015), to “the set of wild plants found in agro-ecosystems that are well adapted to disturbed environments” (Gaba et al. 2017) and to “the flora of arable land” (Sutcliffe & Kay 2000). This study will refer to arable weeds as any non-grass species to avoid confusion over the term.

One of the trophic effects of the pigs rootling could be on bird populations that feed on arable weed species, especially granivores such as the endangered Turtle Dove (*Streptopelia Turtur*) and omnivorous corvids like the Jackdaw. According to Diaz et al 2006 the rootled areas are recolonised by seed rich white clover and common field speedwell which are valuable sources of food for granivores and omnivores alike (Murton 1958; Holyoak 1968; Browne & Aebischer 2003; Dunn et al 2018). Turtle Doves are on the UK Red List of conservation (International Single Species Plan 2018) and have seen a 94% decline in the UK since 1994 (BTO BBS 2018) in part due to these changes in agriculture that have removed arable weeds from their systems (Browne & Aebischer 2003; Dunn et al 2013; Dunn et al 2017). Weeds such as scarlet pimpernel, speedwell, white clover and chickweed are a very important seed source for the Turtle Doves (Murton et al 1964; Dunn et al 2018). This study will ask if the pigs hold the key to their success, creating enough disturbance to allow these key arable weeds to regenerate.

Various studies point out the engineer traits of the wild boar or pigs in the rewilding system (Diaz et al 2006; Johnson 2011; Sandom et al. 2012a, 2012b; Sims et al. 2014; Overend & Lorimer 2018) however none as yet attempt to analyse the link between weed diversity and birds. Whilst Diaz et al. (2006) found that three species of ‘early successional’ plant species benefitted from rootling the previous winter, they did not examine immediate species composition changes. This paper examines whether Tamworth pig rootling behaviour creates a higher density and diversity of endangered arable weeds, which in turn creates favourable foraging habitat for granivorous and omnivorous birds such as the Turtle Dove or the Jackdaw.

To explore the connection between Tamworth pigs, vegetation diversity and birds at the Knepp Rewilding Project the author conducted vegetation surveys on rootled sites and control non-rootled sites at the same location. These sites were also monitored with camera traps in order to assess the preference of any farmland birds visiting the sites. This study asks the questions, are the pig rootled areas more plant and arable weed species diverse? Is there a link between bare ground and species composition? Is there any difference in bird visits between the rootled sites and their controls and do granivorous birds favour weedy areas?

METHODS

Study Area

Knepp Rewilding Project is split by two main roads and is therefore cut into three blocks of approximately 1000 acres each. Each block had differing conditions during the transition from agriculture to the extensive wilding system. The vegetation of the Southern Block was given a 5-year head start before the large herbivores and the omnivorous pigs were introduced. This is where the majority of exciting changes have taken place including the resurgence of the Turtle Doves, Nightingales and the Purple Emperors and it is therefore where I focussed my study (Knepp nd; Stares 2016; Tree 2017, 2018; Preston 2018; Lowrie 2018).

Site Selection and Camera Trap Strategy

In order to understand the interactions between the Tamworth pigs' rootling, plant diversity and farmland bird species I plotted an array of 70 paired cameras across 35 location in the Knepp Wildling Project Southern Block. Each pairing had a rootled plot and a non – rootled control plot in which I ran vegetation surveys and monitored for bird visits using the cameras. Combining the camera trap images with the vegetation surveys enabled us to not only assess if the pig rootling caused greater plant and arable weed diversity but also if farmland bird species visited either rootled or non-rootled control sites more often. It was important that the vegetation surveys of rootled and control areas were conducted at the bird camera trapping sites; I therefore chose the vegetation plots based on exactly where cameras were placed.

The general sample site locations were set at regular intervals (Ahumada et al. 2011) selected using QGIS which I used to find the best fit for the 35 locations across the Knepp Southern Block. Starting at a distance of 70m from the North West boundary the best fit returned 55 sites at 490m intervals running along 10 rows from West to East. Each row was 245m apart from North to South. I then removed all sites that fell outside of the shapefile boundary and any sites in pig exclusions zones such as farm buildings and the South Western tip of the property leaving us with the total of 35 twinned locations or 70 camera sites (Fig 1). I chose 35 sites in order to utilise the 14 cameras most efficiently; deploying 2 cameras at 7 sites for approximately ten days at a time before changing their locations to another 7 sites and then repeating the process over a period of exactly 50 days. The first camera was deployed on 14/05/2019 and the last collected on 03/07/2019.

The exact location was found using a Garmin eTrex 10 GPS and then the closest rootled area had to be found, which usually fell within 50m of the original point. This is a technique often used to find the nearest/best game trail to a random location (Bowkett et al 2008; Tobler et al. 2008; Ahumada et al 2011; Cusack et al. 2015), the camera trapping design therefore is largely random but incorporates some targeted placement (Bowkett et al. 2007; Cusack et al. 2015).

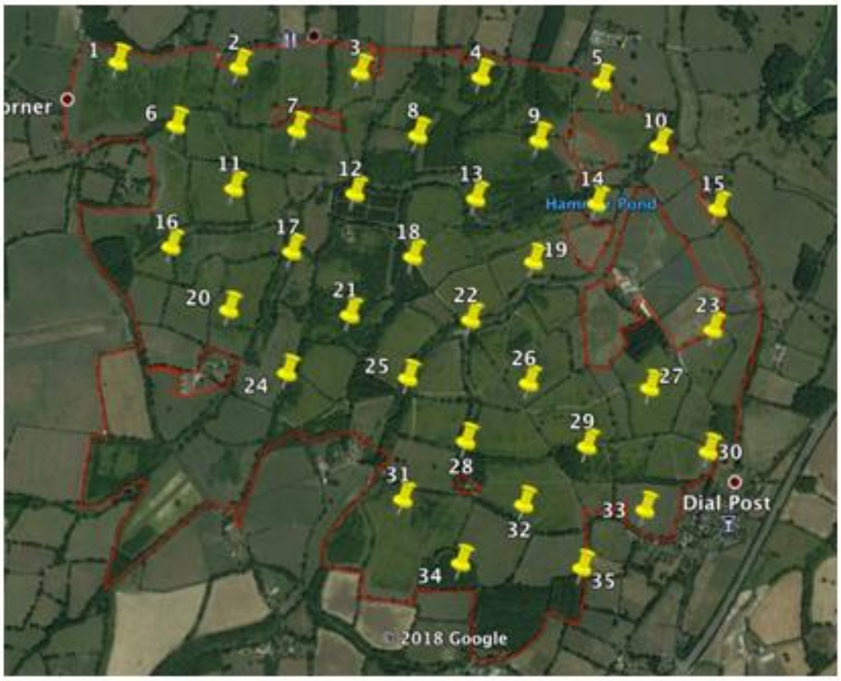

Fig. 1. Map of Knepp Wildling Project Southern Block, with red border showing the perimeter of the property and yellow pins displaying the locations for each pair of cameras.

I used Reconyx HC500 and HC600 Hyperfire cameras; at each site two cameras were positioned on one short chestnut post hammered into the ground. One camera facing toward the rootled (A) plot, the other facing to the non-rootled control (B) plot. I chose to situate the cameras in exactly the same position to allow for local differences in conditions that might affect both the vegetation and bird behaviour.

The cameras were set on a time-lapse taking a photograph every minute from 05.00 to 22.00. They were not set at night to save battery and to avoid too many empty photos. The cameras were then left for an average of 10 days before being moved to 7 new sites. The cameras were set to timelapse and not motion activation due to the small size of the target species. With birds being small in size I expected low trigger potential and a shorter detection range and therefore a smaller return of data, whereas the timelapse gives a much deeper range and therefore yields more data on the target species. Trials were conducted before the cameras were deployed to confirm this expectation.

Fig 2a. Camera trap image showing a pig rootled area at Knepp Wildland.

Fig 2b. Camera trap image showing a non-rootled control area at Knepp Wildland.

Vegetation Surveys

The vegetation surveys were all conducted in the same month as the camera trapping, July, in order to allow for direct comparisons and because it is easier to identify weeds when they are flowering ensuring a more reliable and comprehensive survey.

A measurement was taken from the camera post to the edge of the rootled area, this same distance was then measured from the post to the non-rootled control plot. A 1m x 1m quadrat was laid down on each plot and the survey was then conducted.

A judgement was made of the percentage cover of bare ground, of grass species, of non-grass species and of any animal dung, the average sward height was also measured (Lewis et al 2019). It is important to note here the total of the bare ground, grass, non-grass and dung could add up to over 100% due to the fact that there are different growth rates at different levels. Individual species were then noted and given a score, also out of 100. Unidentifiable grasses without a flowering or seeded head were marked down as Grass Sp. whilst Meadow Grasses and Bent Grasses were each grouped together as Meadow Grass Sp. and Bent Grass Sp. due to difficulty in identification.

Data Analysis

A total of 519,108 photographs were taken by all camera traps across the study area, many of the cameras however were disturbed by animals, particularly the English Long Horn Cattle (who play the proxy of the Auroch – Europe's extinct bovine ancestor (Tree 2018)). These cameras were often then pointing the wrong way or the batteries dislodged, so to account for this in the count of 'useable images' I discounted any faulty images, which left us with a total of 496,899 'usable' images across all cameras.

Of the 496,899 images that were deemed useable any photo with at least 1 bird in it totalled 6498, whilst the total count of birds (<u>including</u> repeat visitors) was 9746. The main metric that the study used in its analysis was the total amount of individual bird visits <u>excluding</u> repeat visitors which totalled 4772.

To tag and sort all the images, first all photographs without birds in them were manually deleted then, then I used Digicam Photo tagging software to tag all the images with the species name and if the bird was a new or repeat visitor. This was to avoid distorting the results by repeatedly counting the same stationary individual at a particular site which would give the appearance of multiple visitors of the same species to a site. A new individual was deemed so if 5 minutes had passed with no image of the same species. For example, if a stationary Wood Pigeon was photographed every minute for 8 minutes the 2^{nd} - 8^{th} photo would be marked as a repeat visitor. If though, a second bird were to join the Wood Pigeon, this would of course not be tagged as a repeat visit photo. If a Wood Pigeon was photographed every minute for 8 minutes, left the shot for 5 minutes and returned, it would be deemed a new visit as there would be no way of telling if this was the same bird.

Two Thrush species, Mistle Thrush (*Turdus viscivorus*) and Song Thrush (*Turdus philomelos*) were combined in the analysis due to difficulty in identification between the two groups.

To analyse the bird data Generalised Linear Models were used to compare the proportional usage between the rootled and non-rootled sites for each bird species (Bowkett et al. 2007). Proportional usage of a site was calculated as the number of images of a given species divided by the total number of useable images taken at that site. To test this, I used a binomial generalised linear model with the dependent variable composed of number of photos containing the bird species as the numerator, and total number of useable photos at that site as the denominator.

The R vegan package (Oksanen et al. 2019) was used for the vegetation analysis using a Canonical Correspondence Analysis (Iturrate-Garcia et al. 2016) to characterise how plant community, composition and bare ground differ between rootled and non-rootled control sites.

Shannon-Weiner Diversity Index was used for measuring plot diversity (Shannon 1948), which combines richness and evenness, to help understand if the pigs are helping to create more abundance and a richer variety of plants through their rootling. To test the significance of the difference between the rootled and control sites for diversity I used a paired T -Test.

Alongside Shannon diversity I also tested average percentage coverage for specific weed species. White Clover (*Trifolium Repens)*, Creeping Buttercup (*Ranunculus Repens)* and Common Field Speedwell (*Veronica Persica Poiret*) which were selected due to being referred to as colonisers of rootled areas in Diaz et al's (2006) study. Whilst Birdsfoot Trefoil (*Lotus Corniculatus*), Common Mouse-ear (*Cerastium Fontanum*), Scarlett Pimpernel (*Anagallis Arvensis*) and Thyme Leaved Speedwell *(Veronica serpyllifolia)* were selected due to their prevalence in the Turtle Dove diet (Murton et al 1964; Dunn et al 2018). I transformed the % coverage using arcsine square root to account for over dispersion and tested the significance of the results using a paired T – Test. All statistical analysis was done using R Version 3.5.1 (R Core Team 2018)

RESULTS

Vegetation

Rootled areas were significantly more species diverse (Paired t-test: $t = 5.4371$, $df = 34$, $p < 0.0001$) than the non-rootled control sites. Both in terms of all species (Fig 3a) and in arable weeds (non-grass) alone (Fig 3b).

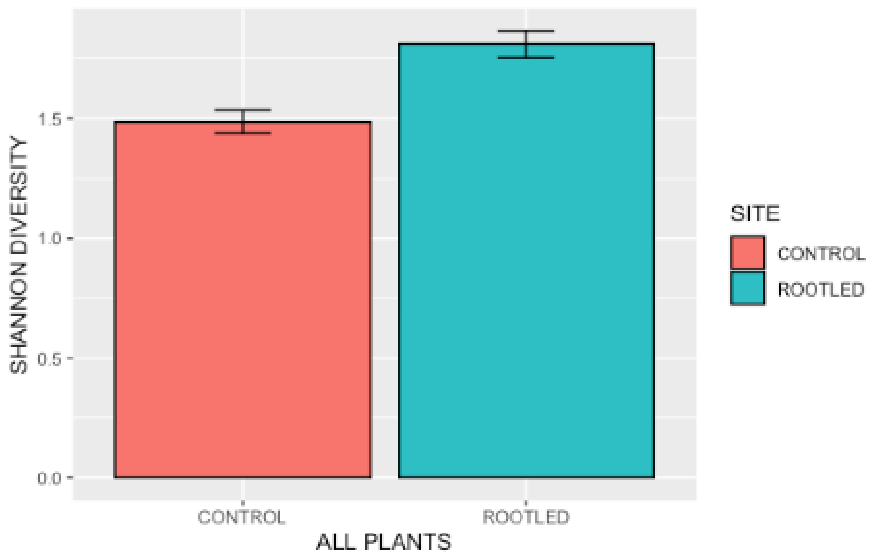

Fig 3a. Box plot showing the mean Shannon – Weiner vegetation diversity of rootled and non-rootled sites across the Knepp Wildland Southern Block. The rootled areas being significantly more diverse.

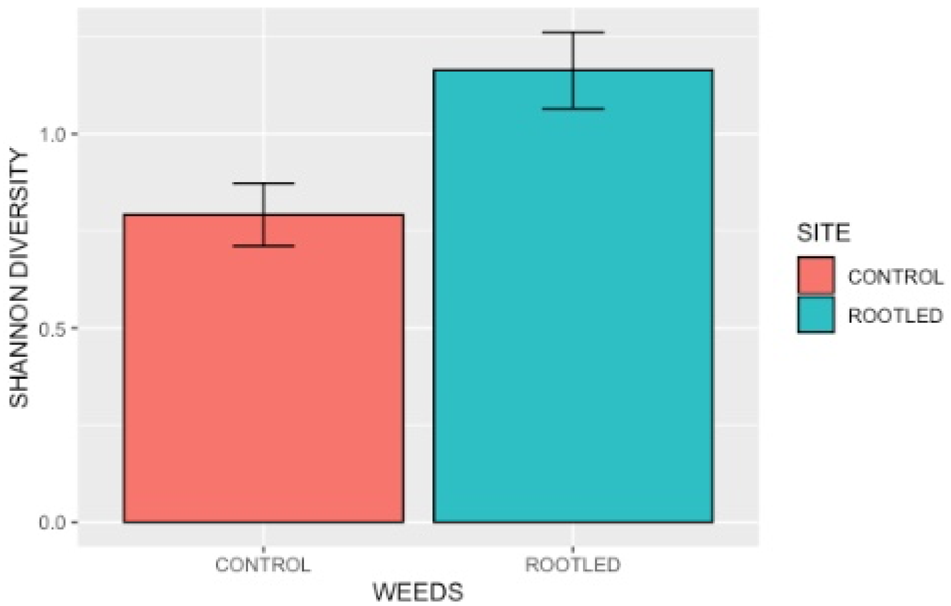

Fig 3b. Box plot showing the mean Shannon – Weiner vegetation diversity of non-grass species in rootled and non-rootled areas across the Knepp Wildland Southern Block. The rootled areas being significantly more diverse.

This is even clearer having used a Canonical Correspondence Analysis (CCA). The results of the CCA display a very visible and distinct association between the control plots (black) with grass species and the rootled plots (Red) with bare ground and weeds (Fig 4).

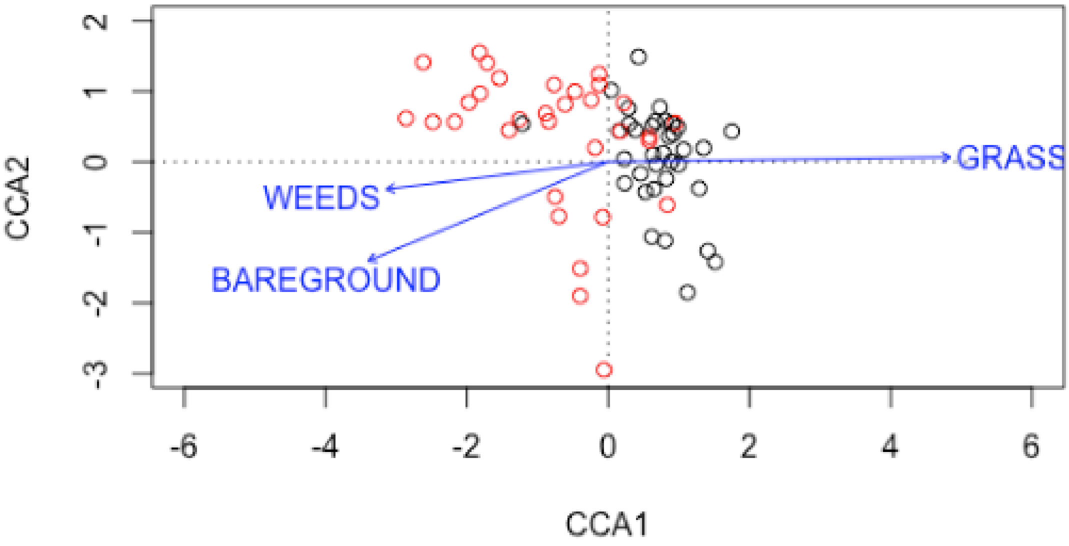

Fig 4. CCA displaying the relationship between rootled sites (red) with weeds and bare ground and the non-rootled sites (black) and grass species.

The rootled areas on average had a fairly even spread between Bare Ground, Grass Cover and Non-Grass species (Table 1) as compared to the non-rootled sites which were dominated by grass species.

	Bare Ground (%)	Grass Cover (%)	Non – Grass (%)
Rootled	39.7%	36.4%	27.886%
Non-Rootled	0.4%	77.3%	25%

Table 1. Table showing mean percentage cover of bare ground, grass and non-grass species for Rootled and Non-Rootled control sites across the Knepp Wildland Southern Block.

Individual Plant Species

	Trifolium Repens (White Clover)	*Ranunculus Repens* (Creeping Buttercup)	*Lotus Corniculatus* (Birdsfoot Trefoil)	Cerastium Fontanum (Common Mouse-ear)	*Anagallis Arvensis* (Scarlett Pimpernel)	*Veronica Persica Poiret* (Common Field Speedwell)	*Veronica serpyllifolia* (Thyme Leaved Speedwell)
Rootled	21	18	3	12	14	14	11
Non-Rootled	26	19	3	6	2	2	1

Table 2. The count, out of a possible 35, of specific weed species found at the rootled and non-sites.

The legume White Clover was the most frequently found plant of all non-grass species at both site groups. It was found at more control sites (n=26) and also had a significantly higher mean % cover (P= 0.0004) (Table 2, Fig 5a). Creeping Buttercup was found at only 1 more control site and showed no significant difference in % cover (P=0.74) (Table 2, Fig 5b). Birdsfoot Trefoil was found at the same number of sites and showed no significant difference in % cover (P=0.9).

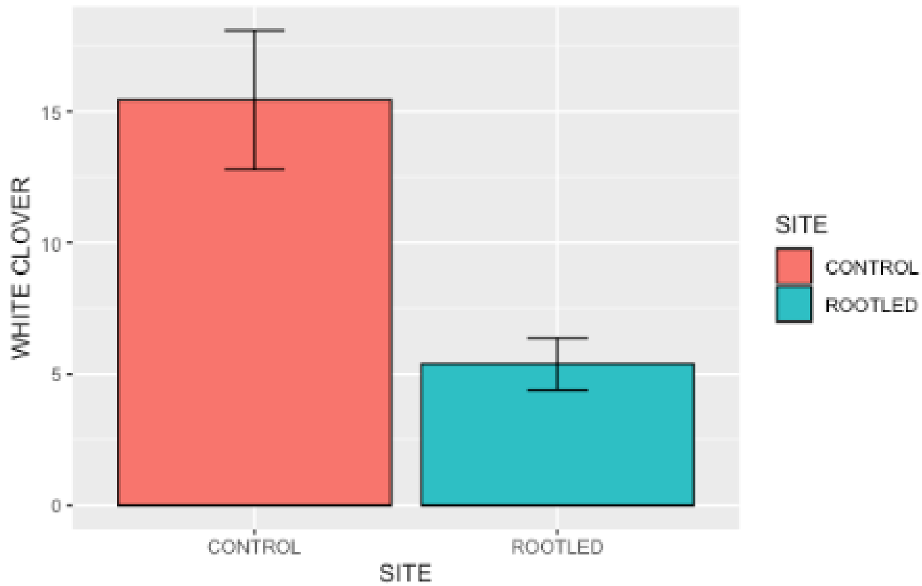

Fig 5a. Boxplot showing the average percentage cover of *Trifolium Repens* (White Clover) at rootled and non-rootled control sites.

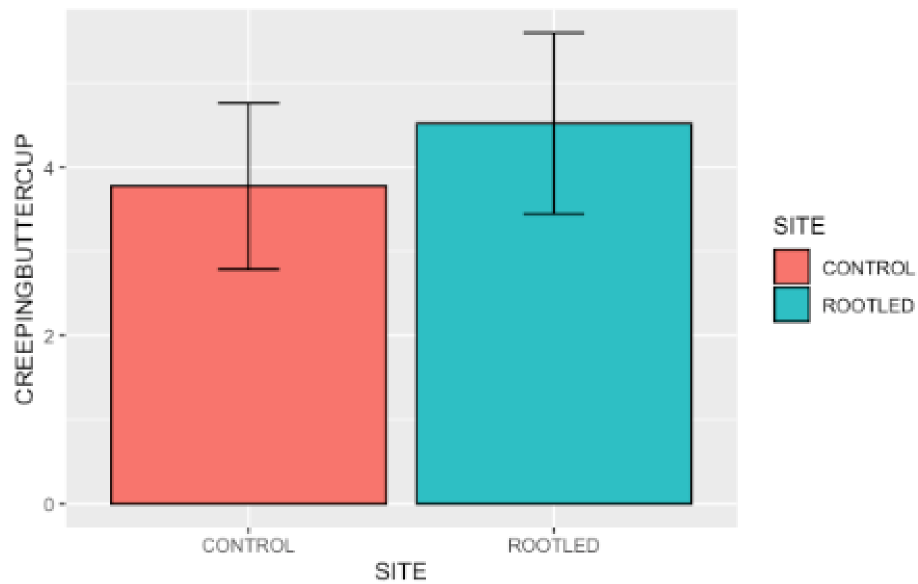

Fig 5b. Boxplot showing the average percentage cover of *Ranunculus Repens* (Creeping Buttercup) at rootled and non – rootled control sites.

Of the other individual arable weeds that were tested, Common Field Speedwell, Thyme Leaved Speedwell, Common Mouse-ear, and Scarlet Pimpernel were all found at significantly more rootled sites (Table 2) and showed a significant difference, in terms of %

cover, all favouring the rootled areas (Fig 6). All had p values of less than 0.05 when testing their arcsine transformed values with a paired T Test.

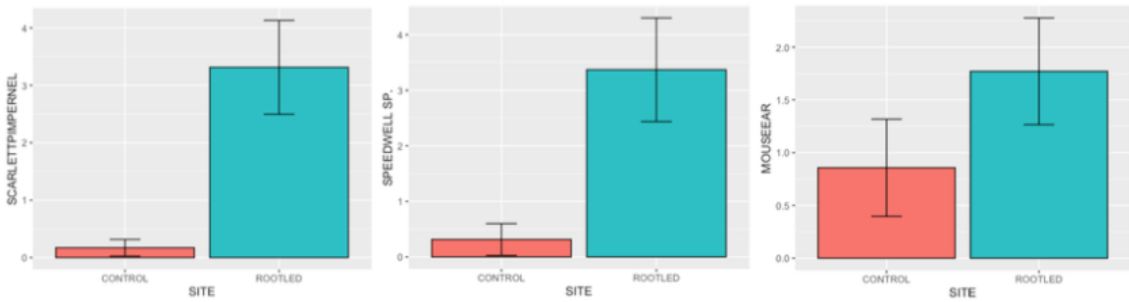

Fig 6. Displaying from left to right the mean percentage cover of Scarlett Pimpernel, Speedwell Sp. and Common Mouse-Ear across rootled and non-rootled control sites. Each displaying a significantly higher coverage across rootled sites. Thyme Leaved Speedwell and Common Field Speedwell are combined in the central boxplot into Speedwell Sp.

Birds

A total of 21 bird species were photographed (Table 3), of these 12 species that were photographed at three sites or fewer were discounted giving us a total of 9 species (shown in bold in Table 3) with sufficient data to analyse.

SPECIES	SITES	MEAN PROPORTION OF VISITS		DIET
		ROOTLED	CONTROL	
Pyrrhula pyrrhula (Bullfinch), *Cuculus Canorus* (Cuckoo), *Prunella Modularis* (Dunnock), *Parus Major* (Great Tit), *Motacilla Alba* (Pied Wagtail), *Alectoris Rufa* (Red Legged Partridge) *Troglodytes Troglodytes* (Wren)	1	**-**	-	-
Columba Oenas (Stock Dove), *Sturnus Vulgaris* (Starling), *Ciconia Ciconia* (White Stork)	2	-	-	-
Erithacus Rubecula (Robin), Picus Viridis (Green Woodpecker)	3	-	-	-
***Garrulus Glandarius* (Jay)**	**6**	0.0000428	**0.0000674**	"Mainly acorns, nuts, seeds and insects, but also eats nestlings of other birds and small mammals"
***Corvus Frugilegus* (Rook)**	**8**	**0.000403**	0.000226	"Worms, grain, nuts and insects, small mammals, birds (especially eggs and nestlings) and carrion."
***Turdus Philomelos, Viscivorus* (Thrush sp.)**	**10**	**0.0000786**	0.0000141	"Worms, Snails, Insects, Fruit."
***Turdus Merula* (Blackbird)**	**11**	0.000171	**0.000249**	"Insects, Worms, Berries."
***Phasianus Colchicus* (Pheasant)**	**16**	**0.000142**	0.0000861	"Seeds, Grain, Shoots, Insects"
***Columba Palambus* (Wood Pigeon)**	**21**	0.00124	**0.00174**	"Crops, Buds, Shoots, Seeds, Nuts, Berries."
***Corvus Monedula* (Jackdaw)**	**24**	0.00384	**0.00440**	"Insects, young birds and eggs, fruit, seeds and scraps."
***Pica Pica* (Magpie)**	**25**	**0.000967**	0.000693	"Omnivore and Scavenger"
***Corvus Corone* (Carrion Crow)**	**33**	**0.00281**	0.00246	"Carrion, insects, worms, seeds, fruit, eggs"

Table 3. Bird Species photographed across the Knepp Southern Block, the number of paired sites that they were captured at and the mean of the proportion of Species' visits to the respective rootled and control sites (higher number in bold). The Table also displays the species favoured diet according the RSPB online Bird Guide.

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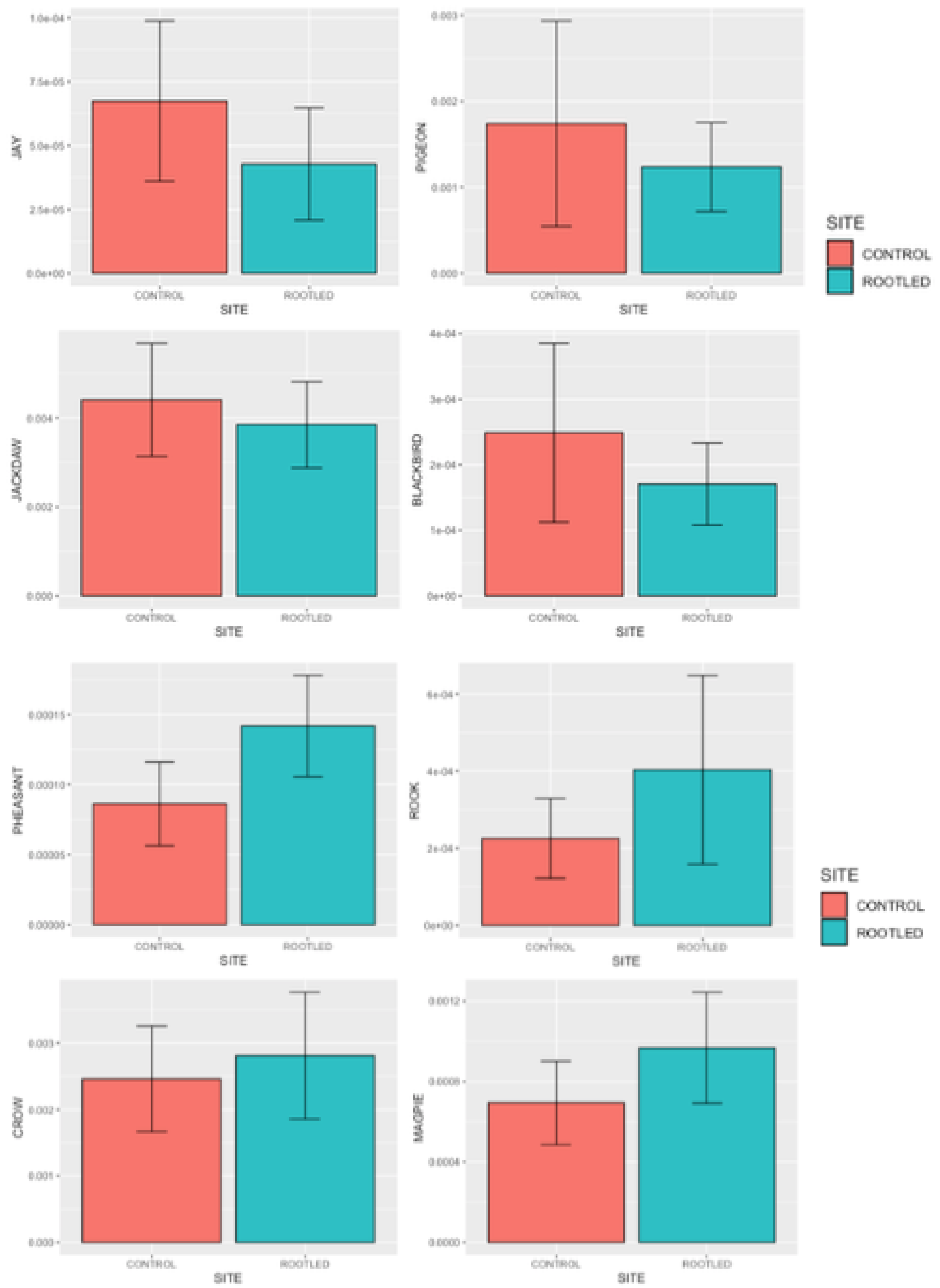

Fig 7. Boxplots with standard error bars showing the means of the proportion of images in which a given species is captured, across pig rootled and non - rootled control sites. The boxplots show 8 species of farmland bird and are ordered by preference, the first 4 favouring control sites and the following 4 favouring rootled areas. None of the differences are statistically significant.

The proportion of visits is the amount of timelapse images captured of a certain species from the total useable photos at that site. Comparing the means of the proportion of visits of the 9 species found at 6 or more locations it is a fairly even split between bird species that preferred rootled sites (n=5) and those that preferred control sites (n=4). However, the standard error bars (Figs 7 and 8) reveal that only the Thrush shows a statistically significant difference (p= <0.05) which is confirmed by the p-values (Table 4), tested using quasibinomial generalised linear mixed models testing differences between rootled and control plots.

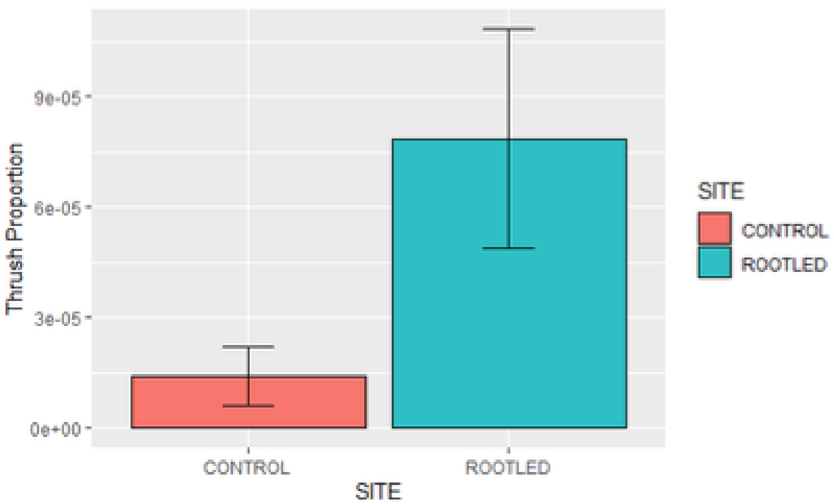

Figure 8. Boxplot with standard error bars showing the means of the proportion of images in which a Thrush species is captured, across pig rootled and non -rootled control sites.

Species	**P Value**
Carrion Crow	0.81
Magpie	0.359
Pheasant	0.433
Rook	0.663
Thrush sp.	0.0152*
Wood Pigeon	0.888
Jackdaw	0.753
Blackbird	0.786
Jay	0.507

Table 4. P Values resulting from quasibinomial generalised linear mixed models testing differences between rootled and control plots in the proportion of timelapse images capturing visits from nine species of English farmland birds.

DISCUSSION

The results confirm the hypothesis that the rootled areas are much more plant and arable weed species diverse, however there does not seem to be an apparent or immediate impact on the usage of these areas by local farm bird populations. With the exception of the Thrush Sp., no bird species showed a significant preference for either site. We did not photograph any Turtle Doves at all despite there being a thriving population on the property at the time of the study, however, the results did confirm that the pigs' rootling creates a large amount more availability and abundance of important and endangered arable weeds that form part of their diet.

The higher diversity in the rootled areas and its association with bare ground are shown clearly in the CCA, supporting the theory that the soil disturbance pigs create with their rootling behaviour plays a major role in restructuring plant composition (Kotanen 1995, 2004; Welander 2000). The disturbance creates recruitment opportunities and the bare ground restricts the ability of the grass to suffocate and outcompete the weed species (Hobbs and Huenneke 1992; Kotanen 1995, 2004). This is also demonstrated clearly in the CCA by the association of non-rootled control sites and grasses.

In terms of specific non-grass species, the data revealed that although Diaz et al. 2006 were correct in concluding that Field Speedwell, White Clover and Creeping Buttercup would grow well in the rootled areas – of these only Field Speedwell fared significantly better in the rootled areas. There was both a higher average coverage and a higher frequency of White Clover at control sites whilst there was no significant difference for Creeping Buttercup.

This high availability of White Clover and Creeping Buttercup across both the control and the rootled sites may give an explanation as to why there was no significant differences in the behaviour of the granivorous and omnivorous bird species. Clover is not only eaten by Wood Pigeons (Murton 1958; Murton et al. 1964) and Turtle Doves (Murton et al. 1964; Browne & Aebischer 2003; Dunn et al 2013; Dunn et al 2018) but also by the corvids including Rooks, Crows, Magpies and even more so by Jackdaws (Holyoak 1968). Creeping Buttercup, according to The New Atlas of British and Irish Flora (2002), has been "virtually eradicated" from Lowland England pointed out by Walker et al. (2007) in their study on 'The conservation of arable plants on cereal field margins'. Buttercup also historically formed an important part of the Wood Pigeons Diet as Murton (1958) explains in his study on 'The Breeding Populations of Wood Pigeons' and is a seed source for the Turtle Dove (Murton et al. 1964, Dunn et al. 2018). One possibility could be that the pigs rootling over a period of 15 years, since the project has been running, has caused the recolonisiation of the pasture with White Clover and Creeping Buttercup. This project looked at recently rootled areas but an area for further study would be to analyse the community composition of historically rootled areas.

The studies of Murton (1958), Murton et al. (1964), and Holyoak (1968) all pre-date the 1970's, the time associated with large scale agricultural shifts that has since been linked with the decline in farmland bird species (Sutcliffe & Kay 2000; Robinson et al 2010; Atkinson et al 2004; Buckingham et al 2006). It is important therefore to use these historical studies as it is in part what the Knepp Wilding system has returned to (Tree 2018).

As the cameras did not capture any images of Turtle Doves, the results cannot absolutely confirm the hypothesis that the pigs hold part of the key to the Turtle Doves success at Knepp. However, specific weeds favoured by the Turtle Dove were tested in the analysis which included Thyme Leaved Speedwell (Dunn et al 2018), Scarlett Pimpernel (present in 81% of Turtle Dove diets (Dunn et al 2018)), Common Mouse-Ear (considered one of the Turtle Dove's most important diet components (Browne & Aebischer 2003; Dunn et al. 2013; Dunn et al 2018)) and Birdsfoot Trefoil (Browne & Aebischer 2003; Dunn et al 2013). Speedwell, Pimpernel and Mouse-Ear were all significantly more abundant and were more commonly found in the rootled areas, supporting the theory that the pigs' presence may indeed be positively influencing the burgeoning population of Knepp Turtle Doves. Especially considering the demise of these arable weeds elsewhere in England (Sutcliffe & Kay 2000; Walker et al. 2007) and the fact that their disappearance has been linked with the demise of the Turtle Dove (Dunn et al 2013). Birdsfoot Trefoil showed no significant difference in either area. Complementing these weeds in the rootled areas is the high abundance of White Clover and Creeping buttercup elsewhere which also form a key part of the Turtle Dove's diet.

Further study should include a comparison of the populations of the farmland birds captured in this study to the surrounding areas and farms to understand if this high availability of seed rich weeds across the rootled and non-rootled areas has an impact on their populations. We know that Turtle Doves have a higher population at Knepp as they are not known elsewhere in the area but the other species require further study to confirm this. The specific diets of the birds that forage at Knepp should also be studied and analysed to help unpack which plant species are supporting which birds.

The lack of statistical significance for the birds is supported by the spread of omnivorous corvids between the sites; Rooks and Carrion Crows were shown to slightly favour the rootled sites whilst Jackdaws were found to prefer the control sites. Their similar diets (Holyoak 1968) would suggest this is unlikely, Jackdaws of the three species is said to eat more of the seed producing weeds and therefore would have been more likely to prefer the rootled areas (Holyoak 1968). Tucker (1992) found that livestock positively affected the use of fields by Magpies and Jackdaws; another area for further investigation would be to assess how many Jackdaws and Magpies followed livestock through the camera images collected for this study.

The only bird that showed a significant preference for either area was the Thrush Sp., its' favouring of the rootled areas could be linked to a preference for open ground and therefore exposed invertebrates where it can feed on its diet of worms, slugs, insects snails and fruit (RSPB nd.). This is an area that requires and merits further research not only due to the lack of research currently published, but if this result were true, it would be expected that other species with a similar diet such as the Blackbird (*Turdus merula*), would also significantly favour the rootled areas, which according to my results they did not. A potential limitation of this result is that the Thrush category was two individual species grouped together, both Mistle (*Turdus viscivorus)* and Song Thrush (*Turdus philomelos*). Despite their similar behaviour and feeding habits this may have affected the results.

Despite the focus of this study being on all farmland birds, if the project had been more focussed on the Turtle Dove it may have been a better strategy to use a targeted camera trapping approach. Targeting rootled sites around the Turtle Dove territories rather than systematically placed through the property. Despite the fact that many of the camera locations were in Turtle Dove territories due to the nature of the design, perhaps a higher concentration of cameras would have yielded some images of the Doves feeding.

Despite the fact that the results did not confirm the hypothesis that seed eating birds would prefer the pig rootled areas, this study showed that pig rootling can cause much higher species diversity in terms of plant and arable weed composition. It is fair then to present this study as support for pigs in extensive and wilding systems in order to increase plant diversity and encourage the growth of endangered arable weeds which form a key component of the historic British countryside and the diet of endangered species such as Turtle Dove.

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