**Does Soil Moisture Influence Large Herbivores’ Eating Behaviours in a Rewilding Landscape?**

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Abstract (300 words)

Introduction/Aim - What did you do and why?

Materials and Methods - How did you do it?

Observations/Results - What did you find?

Discussion - What do your results mean to you and why?

Conclusions - What new knowledge have you extracted from your experiment?

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# Introduction

The UK has been estimated to have lost significantly more nature over the long term in comparison to other countries, suggesting the UK to be amongst the most “nature-depleted” countries in the world (Hayhow *et al.*, 2016). These results coupled with farmland abandonment, due to the decrease of economic value, pose increasing threats to wildlife sustainability in the UK, as well as in Europe (European Commission, 2017).

### Trophic Rewilding

Rewilding is a pioneering method of conservation advocated by the UK government which aims to restore the natural-processes of the land with little human intervention to its “natural, uncultivated state” (Moorhouse and Sandom, 2015; Smit *et al.*, 2015; Rewilding Britain, 2019b). It has spurred the start of several large conservation projects and have inspired researchers to investigate the connectivity of species within of ecosystems and how they affect each other (Taylor and Ayres, 2003; Donlan, 2013). Rewilding emphasises the importance of reintroducing key-stone species which can aid the restoration of ecosystems via a trophic cascade (Donlan, *et al.*, 2006; Rewilding Britain, 2019b). A trophic cascade is an ecological phenomenon caused by the addition or removal of an ecosystem engineer inciting changes in other relative specie populations via the food change, which then effects the ecosystem structure and nutrient cycle (Bakker and Svenning, 2018; Carpenter, 2019). To reintroduce a specie to an ecosystem, native species previously present on the land and or finding closely related species as a proxy are researched (Cromsigt and te Beest, 2014; Svenning *et al.*, 2016; Nickell *et al.*, 2018). Famous examples of species reintroduction are predators, Wolves (*Canis lupis*), to Yellowstone National Park and recently large herbivores, such as Longhorn Cattle (*Bos primigenius*) who stand in for Auroch in lowland mosaic habitats (*Bos Taurus primigenius*) (Staff, 2011; Ripple and Beschta, 2012).

### Importance of Large Herbivores

Large herbivores have been deemed to be a key driver in maintaining a healthy ecosystem (Vera, 1994; Hanley, 1997; Olff and Ritchie, 1998; Kirby, 2004; Newman, Mitchell and Kelly, 2013). There is a large emphasis on variety of herbivores in rewilding as Vera explains how their cyclic eating behaviours encourages a diverse mosaic which supports the idea of the “half-opened” landscape Britain is thought to have had before human intervention (Vera, 1994; Hodder *et al.*, 2009). Although there is debate about large herbivores’ roles in creating historic landscapes, current research has found that they are driven by and influence vegetation structure at varying levels (Olff and Ritchie, 1998). Processes in how large herbivores encourage plant biodiversity is broken down in *table one* below. They influence plant mortality rate, recruitment and growth, which correlates with the plant diversity and density (Gibson and Brown, 1991; Nathan and Muller-Landau, 2000; Dando, 2018; Herrero-Jáuregui and Oesterheld, 2018). Without large herbivores, the ground plant composition and abundance changes significantly while with selective browsing positively influences the formation of wooded vegetation communities (Hanley, 1997; Newman, Mitchell and Kelly, 2013; Dando, 2018). Having a variety of large herbivore species is important as they have different effects on the landscape which is said to come down to herbivore body size, variation in their digestive system, spatial scale of effect and their vulnerability to predators (Olff and Ritchie, 1998; Vera, 2009). For example, cattle graze all year round and prefer to be in the open whereas, Red and Fallow deer feed on a combination of grasses, leaves and shrubs and Roe deer are specialised browsers (Gebert and Verheyden-Tixier, 2001; Vera, 2009; Krojerová-Prokešová, 2014; Knepp Wildland, 2019a). Red deer consume larger quantities due to their size in comparison to other species of deer, and have the ability to de-bark poisonous elder by neutralising the cyanide in their stomachs, something which horses and cattle cannot do (Knepp Wildland, 2019b). Pigs also graze throughout the summer months but when the soil softens throughout autumn and winter, pigs rootle the soil. They use their snout to turn the soil over in search for roots, invertebrates and rhizomes (Knepp Wildland, 2019e). This behaviour allows for pioneer plants, such as Sallow, to grow, increasing flora diversity (Knepp Wildland, 2019e). Studies have since found that large herbivores are in fact crucial for maintaining open landscapes and are being actively promoted as a form of wilderness development and conservation (Schulze, Rosenthal and Peringer, 2018).

Previous research exploring grazing management techniques have identified the lack of knowledge about forest systems and large herbivore space usage and how it affects plant biodiversity (Hester *et al.*, 2000). There are sites across Europe, such as Oostvaardersplassen in the Netherlands and Knepp Estate in England, that are dedicated to grazing experimentation, researching how intensive grazing effects the local plant diversity, especially in an agricultural context looking at how it effects the soil for growing produce (Olff and Ritchie, 1998b; Ross *et al.*, 2016; Marrs *et al.*, 2018). They have allowed large herbivores to roam free and regulate the ecosystem with no specified herbivore density with as little human interference as possible (Hodder and Bullock, 2009; Staatsbosbeheer, 2018). It has been found that large herbivore migration is often dictated by availability and quality of resources dependent on species preference (Van Beest *et al.*, 2010). However, this has caused an ethical uproar in Oostvaardersplassen due to it being a fenced enclosure, meaning large herbivores cannot migrate for more food resources so many have died due to malnutrition (Vera, 2009). This has called for the temporary need of population control until natural predators can safely be introduced (Vera, 2009; Lorimer and Driessen, 2014). Knepp Estate also intervenes in population control as it is too small to allow for “natural” population fluctuations so they have made it a part of their economic model to attract ecotourism (Greenaway, 2006).

|  |  |  |
| --- | --- | --- |
|  | **Effects of Herbivores** | |
| **Mechanism Increasing Diversity** | **Main Direction** | **Examples** |
| **Local Colonisation Processes** |  |  |
| Higher input of propagules of new species to a site | + | Enhances propagule dispersal through soil on hooves, seeds attached to fur and through faeces deposition |
| Higher availability of propagules to extant species | - | Removal of seed and reproductive structures |
| Availability of regeneration niches allowing establishment | + | Soil disturbances stimulate germination from the soil seed bank |
| - | Soil disturbance can also create unfavourable thermal conditions for plants |
| **Local extinction, competitive exclusion processes** |  |  |
| Less competition for limiting resources | + | Competitive interactions between plants are relaxed by herbivore consumption of competitively dominant plants |
| Different species are limited by different nutrients | + | Variations in resources allow for variation in present plant species |
| More spatial and temporal variation in resource supply | + | Localised urine and faeces deposition, aggregated soil disturbances through digging, trampling paths and wallows, etc. |
| Spatial and temporal variation in rates of biomass loss (disturbance) in which intermediate levels of disturbance prevent competitive dominance by the best resource competitors but do not create environments too extreme for rarer species | + | Selective grazing on patches with attractive plant species (especially when these are free of predators and enemies), creating spatial heterogeneity in attractive and unattractive plant species across landscapes |
| - | High grazing pressure may result in dominance of few tolerant species |
| - | Preferential grazing on rare, high-quality plant species |

Table 1. Overview of major processes determining local plant species richness in grasslands, and proposed effects of herbivores on those processes (taken from Olff and Ritchie, 1998).

### Large Herbivore Space Usage

Cattle and deer graze on a cycle by using their long-term memory to remember suitable grazing sites and their short-term memory to remember where has been visited recently (Lyons and Machen, 2012; Seidel and Boyce, 2015). This is important as large herbivores require a higher daily requirement, which cannot be fulfilled by short stalks, thus having to change pastures more often (Armstrong, 1996). Due to different dietary requirements, variety can be seen in species’ spatial preferences. Cattle tend to move as a herd so prefer opened land and require a water supply, therefore are likely to congregate near a wetland area on hot days (Armstrong, 1996). Red deer also range over larger areas but tend to prefer sheltered areas like woodland for shelter and forage (Armstrong, 1996). Red deer are thought to originally be riverine species but left due to human disturbance (Knepp Wildland, 2019b). Fallow deer have been observed to use a mixture of meadows and thickets, more active in meadows at night with a preference for grass, but it is likely that the use of closed habitats is underestimated (Borkowski and Pudełko, 2007; Dando, 2018). Roe deer tend to avoid open areas when human activity is high so stick to sheltered areas but are more active in meadows at night (Bongi *et al.*, 2008; Bonnot *et al.*, 2012). Tamworth pigs have been found to prefer open pastures to graze during the summer and feed on acorns during the fall (Knepp Wildland, 2019e). Differences in eating behaviours further support Vera’s “half-open” landscape theory as each large herbivore would influence the floral diversity and structure uniquely (Vera, 1994).

### Introduction to Knepp Wildland project

In the early 2000s, Knepp Wildland project began to filter fields out of agricultural use due to the inability to keep up with industrial farming (Greenaway, 2006; Tree, 2017, 2018). The aim was to follow the same “near-grazing” scheme as Oostvaardersplassen but on a smaller scale with the reintroduction of large herbivores that would have previously been seen on the historic hunting grounds (Greenaway, 2006). The project has shown signs of success early on and has been used as an eco-model for the government to suggest “mini-rewilding” projects around the UK for small periods of time of 25 years, as well as a business model to other landowners to show how rewilding can be made into a profitable business whilst encouraging biodiversity (Greenaway, 2006; Tree, 2018). Because of its successes, it makes it an ideal location to test a variety of theories relating to the underlying processes of grazing.

### Ecological trajectories of Knepp Wildland project – Water on site

It was always the plan to restore the natural watercourse and floodplain of the River Adur running through the Knepp Wildland project (Greenaway, 2006). Knepp has been found to have limited aquatic plant diversity and as of recently, there has been a decline in aquatic plant species in Sussex (Greenaway, 2006; Tree, 2018). The laggs running alongside flood-prone fields were originally there to benefit the fields for agriculture fields but they only ever provided poor quality grazing for large herbivores (Knepp Wildland, 2019d). It was predicted that plant diversity would improve when water was better retained into the laggs, some thriving alongside the high grazing pressure (Gowing, 2005; Greenaway, 2006; Tree, 2017). The Environment Agency helped restore 2.5km stretch of the River Adur and 5.5km of associated streams and brooks with the hopes in improving landscape dynamism and flood mitigation (Tree, 2017). So far, there have been several positive signs that the restoration is in the process of improving the land including; extremely high levels of earth worm species – 18 species and the increasing population of the Turtle dove which rely on clean waters (Tree, 2017). These are all signs that the land is in the process of water-purification, but the out-flow is yet to confirm this (Tree, 2017). Although these findings are outwardly positive, it has been identified that the introduction of a family of Beavers will have been equally as beneficial as hydrological engineers (Gowing, 2005; Tree, 2017; Knepp Wildland, 2019c). There has been discussion of beavers to be reintroduced to the southern block of Knepp Wildland project in the Fall of 2019. This suggests that the land is about to undergo another transformation but how will this affect the species already present? Namely, the large herbivores.

### Aim

So far, there have only been positive findings from the waterway restoration, but how this will affect the large herbivores eating behaviours has not been mentioned. Therefore, this study aims to see how the free-roaming large herbivores eating behaviours differ between laggs and fields.

### Hypotheses

From reviewing previous studies relating large herbivores’ eating behaviours, a prediction has been made that there will be differences in eating behaviours between the two conditions; wetlands and dry lands. More specifically;

1. Large herbivores will show a spatial preference for eating
2. Large herbivores will exhibit species specific eating behaviours
   1. Grazing will be exhibited in the fields than the laggs
   2. Cattle will prefer the fields
   3. Deer and pigs will prefer the laggs
   4. Large herbivores predominantly visit laggs to drink rather than graze

# 

# Methodology

### Study Site

The Knepp Wildland Project is 3,500-acre Estate that is based in the south of England in Horsham, West Sussex (50°58'18.7"N 0°21'46.5"W) where the soil is made up of heavy Low Weald clay over “a bedrock of limestone” (Knepp, 2019; Rewilding Britain, 2019a). This made the soil unsuitable for farming due to its hardness during the summer and muddy consistency in the winter, thus having to turn to other routes to make a profitable income (Knepp, 2019). The Estate took inspiration from Frans Vera’s Rewilding theory and applied it in 2002 to the previously intensively farmed land (Vera, 1994). The aim was to monitor and evaluate the changes in biodiversity and vegetation structure, which almost two decades later, has now been transformed into a lowland mosaic habitat (Greenaway, 2006; Knepp, 2019).

The Estate is split into three blocks (Northern, Middle and Southern) which each have different management types with a different variety of large herbivores (Knepp, 2019). This study uses the southern block as its experimental site which has free-roaming large herbivores within a large, fenced-off site. The reintroduction of large herbivores began in 2008, including Longhorn cattle (*Bos primigenius*), Roe deer (*Capreolus capreolus*), Fallow deer (*Dama dama*), Red deer (*Cervus elaphus*) and Tamworth pig (*Sus scrofa domesticus*) to the southern block of Knepp Estate. Refer to *table 2* for estimate population for each species in 2018. Although it is highly likely numbers are higher due to the time the experiment was carried out – towards the end of birthing season.

|  |  |
| --- | --- |
| **Southern Block** | |
| **Species** | **Estimated Population** |
| Longhorn Cattle | 94 |
| Roe deer | 164 |
| Fallow deer | 385 |
| Red deer | 48 |
| Tamworth pig | 7 |

Table 2. Estimate population levels for each of the large herbivore species present in the southern block at Knepp Estate (Tree, 2018).

As suggested by Vera (1994), each of the large herbivores reintroduced are native to the area or act as a surrogate to a previously native herbivore that is either now absent or extinct. For example, the Longhorn cattle and Tamworth pigs act as surrogates to large herbivores like the Auroch (*Bos Taurus primigenius*) which is now extinct and the Wild boar (*Sus scrofa*) which was hunted to extinction in the UK in the middle ages but have recently been (illegally) reintroduced (*Wild boar (Sus scrofa) - Woodland Trust*, 2019). The Fallow deer were native to England during the Pleistocene but went extinct in last Ice Age. They were later reintroduced by the Normans for hunting during the 11th Century (Aebischer, Davey and & Kingdon, 2011). Red deer are native to the area, occupying a wide diversity of habitats, as are Roe deer which mainly occupy woodland (*Britain’s Mammals: Introducing the Species*, 2019). Each large herbivore provides different techniques of grazing, browsing and rooting, encouraging diversity in vegetation structure (Greenaway, 2006). The grazing principles were taken and adapted from the Oostvaardersplassen project in the Netherlands but the populations are controlled by manual removal as a part of Knepp’s economic model rather than as a result of lack of food (Vera, 2009). This replaces the need for a predator that would normally regulate herbivore population numbers.

Camera Traps**[[1]](#footnote-1)**

The camera traps were active for two weeks throughout July 2019. They were set to take 20 second videos when motion triggered with an interval of 30 seconds to gain a larger data set and a more representative sample of behaviours form the present sample. Before placing a camera, the direction it would be facing was checked to be as close to North or South to reduce chances of glare from the sun in the videos. They were all positioned approximately one metre off the ground to ensure a good visual range. Distance sampling was performed by measuring out 30 metres from the camera and taking photos every five metres indicating the distance, starting at 5 – 30 metres[[2]](#footnote-2). This was to help estimate the distance of subjects from the camera when recording behaviours from the videos.

Originally, 20 camera traps were planned to be used, comparing lagg and field sites with the use of two camera types, evenly split across the conditions. Due to technical difficulties only 10 cameras were able to be used, all the same brand (Distianert DH-8 Trail Cam).

### Choosing Camera Trap Locations**[[3]](#footnote-3)**

A 1cmx1cm block grid (26cmx19cm) was drawn on top of a map of the southern block at Knepp Castle Estate. Each block that covered a lagg was numbered between 1-121. A random number generator was used to select 10 sites. If a number came up that was too close to a previously selected one, then a new number was generated. Each block that was selected decided the lagg site and the control field site – field in or closest to the selected block. As mentioned above, due to technical difficulties locations were later dictated by the data available.

INSERT MAP HERE

### Coding Data

The data will be recorded into an Excel spreadsheet that will be later analysed using SPSS. Table one, below, offers a break-down of each of the behaviours, how they were identified in the videos and which species were most likely to be observed performed said behaviour. Additional information recorded includes the date, camera, time, number of recording day, species and number of individuals observed in each of the videos. Each individual was recorded per video so number of sightings will not reflect population numbers. This was to ensure a representative sample of behaviours were collected whilst subjects were in each condition.

|  |  |
| --- | --- |
| **Eating Behaviours** | **Definitions** |
| Grazing + time (seconds) | Vegetation grazed above the moss layer - characterised via tearing of vegetation. |
| Browsing + time (seconds) | Tearing or pulling of vegetation at neck height upwards. |
| Drinking + time (seconds) | Head lower than knees with visual evidence of the gullet moving suggesting continuous swallowing. |
| Observing | Subject stops to observe local surroundings. |
| Passing Through | Subject was moving through the field to leave. |

Table 3. Eating behaviours coded within observation videos(Sandom, Hughes and Macdonald, 2013).

# Results

## Statistical Analysis

The data set was non-normally distributed, resulting in the use of a non-parametric test to be run. A Mann-Whitney U test showed that there was a significant difference (U = 854977.50, p <0.05) between the time length of drinking behaviour in the lagg and field conditions. This was to be expected due to the lack of water in the field conditions.

A second Mann-Whitney U test was run for the difference in time length of grazing between fields and laggs. It was significantly different (U = 1161579.50, p <.05).

Finally, a third Mann-Whitney U test was run for the difference in time length of browsing between fields and laggs. It was significantly different (U = 900124, p <.05).

The U values from each of the tests come across as high due to the large sample size. Therefore, we convert the *Z*-value to an effect size as interpreted by Cohen’s *d*. Drinking behaviours reported a very small effect size, d = 0.03, whereas grazing reported a slightly larger effect size in comparison but still considered small, d = 0.1 (Sawilowsky, 2009). Finally, browsing reported the smallest effect size of d = 0.01 (Sawilowsky, 2009). These effect sizes could be small due to the large variation of values within the sample size.

## Wetland versus Dryland Space Usage

Overall, Longhorn cattle were the most observed species along with Roe deer being the least observed (refer to *table 4*). The number of subjects recorded is not a representation of population levels as they were recorded for their behaviours only, although the numbers do suggest there to be species preference in site location.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Species** | | | | |  |
| **Condition** | **Longhorn Cattle** | **Roe Deer** | **Fallow Deer** | **Red Deer** | **Tamworth Pig** | **Total** |
| **Lagg** | 1134 | 24 | 273 | 78 | 39 | 1548 |
| **Field** | 888 | 1 | 152 | 0 | 144 | 1185 |
| **Total** | 2022 | 25 | 425 | 78 | 183 | 2733 |

Table 4. Total observations of each species in each condition.

*Fig. 1a & b* shows the spread of number of individuals per observation between the species, Longhorn cattle being the biggest and often in a herd of consistent numbers. Only two observations classed as outliers with a herd size of 16 and 18. The lagg conditions saw the biggest species diversity to be observed in comparison to the field conditions, especially for deer having observed all three species present at Knepp Wildland project. Tamworth pigs were rarely observed in the lagg conditions (*fig. 1a)* in comparison to the field conditions (*fig. 1b*).

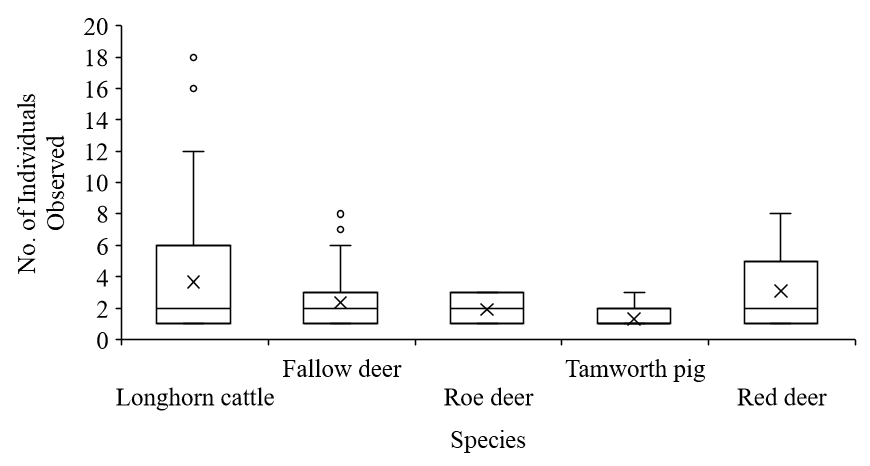


Figure 1a. Number of individuals observed per trigger by species within the lagg condition.

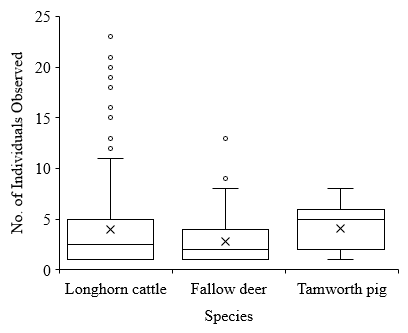


Figure 1b. Number of individuals observed per trigger by species within the field condition.

However, all three species, Longhorn cattle, Fallow deer and Tamworth pigs were seen to gather in larger herds and droves in field conditions (refer to *fig. 1b*). It must be noted though that the Tamworth pigs were often seen together with their litters, hence the increased number of individuals.

## Eating Behaviours

When comparing the behaviours by conditions, drinking occurred in the lag condition due to lack of water in the field conditions. Grazing behaviours were observed more in the field conditions than in laggs. Although there were few observations of browsing, more was observed in the lagg conditions (refer to *fig. 2*).

Figure 2. Mean number of times each behaviour was observed performed by all species in each condition (+ SD).

Similar results were found in *fig. 3* as *fig. 2* when comparing the mean length of time for each behaviour. Again, drinking was observed more in the lagg conditions due to lack of water in the fields. Browsing occurred more in the lagg condition therefore the mean time was longer than the field conditions (refer to *fig. 3*). The standard error bars in *fig. 3* show the potential upper limit of grazing time, though it surpasses the cameras’ capture time. This is due to the large spread of values.

Figure 3. Mean length of time (seconds) each eating behaviour was performed in each condition (+SD).

When looking at large herbivore behaviour occurrence in each of the species, it reveals specie specific eating preferences in sites which is in line with the second hypotheses. *Fig. 4a* reveals that Roe deer were observed to graze the most out of the five large herbivore species in the lagg conditions. This trend is seen among the deer species, however, Longhorn cattle exceeded Red deer due to their larger population numbers. Browsing behaviours were predominantly seen from the deer species which agrees with the third hypotheses. Drinking behaviours were seen most from Longhorn cattle and Tamworth pigs.

The Longhorn cattle findings disagree with the hypothesis that large herbivores tend to visit laggs only to drink as they showed greater preference for grazing, whereas Tamworth pigs showed little to no interest in grazing in the lagg conditions. *Fig. 4b* further supports the findings in *fig. 4a* in showing eating behaviour preferences via the length of time each behaviour was observed to be performed.

Figure 4a. Mean number of occurrences for each eating behaviour performed by each species in the lagg conditions (+/- SD).

Figure 4b. Mean length of time (seconds) each eating behaviour was performed by each species in the lagg condition (+/- SD).

Whereas, *fig. 5a* shows that Longhorn cattle, Fallow deer and Tamworth pigs all prefer to graze in fields when compared to *fig. 4a*. Drinking behaviours were not present due to lack of water in the field conditions and little to no browsing behaviours were observed. Roe and Red deer were not seen in the field conditions.

Figure 5a. Mean number of occurrences for each eating behaviour performed by each species in the field condition (+/- SD).

Figure 5b. Mean length of time (seconds) each eating behaviour was performed by each species in the field condition (+/- SD).

*Fig. 5b* further supports the findings of *fig. 5a* in that Longhorn cattle, Fallow deer and Tamworth pigs show preference for grazing in the field conditions than the lagg conditions.

# Discussion

This study compared five large herbivore species eating behaviours in wetland (laggs) and dry land (fields) at Knepp Wildland project through observation via camera traps. Seeing how their eating behaviours varied would allow predictions on how the land will evolve, especially after the waterway restorations that have taken place in the southern block. These results could aid the Knepp Wildland project in future decisions in a rewilding context, especially along with the possibility of beavers being reintroduced in the Fall and how the land could evolve. The variation in eating behaviours by each of the species and site preferences will be discussed in agreement with other literature, in addition to assessing potential environmental factors within the site that could be influencing the found results, such as specie-specific behaviours, vegetation diversity and structure. This study will fit within the gap in literature regarding large herbivore-plant interactions within a large scope of land in a rewilding context and the impact of their cyclic eating behaviours in two types of landscapes as well as how their behaviours vary (wetland and dryland).

## Findings

Behaviours observed between the lagg and field conditions were found to be statistically different, meaning the main hypotheses can be accepted. However, the effect sizes calculated were miniscule, which suggests further data would need to be collected in order to see whether the difference would still be statistically significant with a larger, more representative sample. This could also be done by extending the camera capture times as the calculated standard deviations suggested the maximum mean length of time observed is longer than the camera trap capture time of 20 seconds in this experiment.

### Wetland versus Dryland Space Usage

Each of the large herbivore species observed were found to have species specific behaviours along with site preferences for eating. It was commonly seen that Longhorn cattle, Fallow deer and Tamworth pig preferred to graze in field conditions. These findings are mostly in-line with the literature discussed earlier on. Longhorn cattle were seen most in the lagg conditions in smaller herds (Armstrong, 1996). This was likely due to the hot weather that was seen throughout July 2019 which led to the cattle in congregating around bodies of water (refer to *appendix E*). Fallow deer were the next most observed species behind Longhorn cattle, but this was most likely due to population sizes within the southern block in comparison to the other reintroduced large herbivores (refer to *appendix F*). They also followed the predicted behaviour as lined out by previous literature in that they preferred laggs, most likely due to the closed-in plant structure and tended to use meadows at night, again likely due to lack of human interference like Roe deer (Borkowski and Pudełko, 2007; Bongi *et al.*, 2008; Bonnot *et al.*, 2012; Dando, 2018). Red deer were exclusively observed in the lagg conditions which were predominantly closed sheltered in comparison to the openness of the fields which lines up with the suggestion that Red deer were originally riverine species (Knepp Wildland, 2019b). Tamworth pigs also exhibited behaviours as suggested by literature in that they preferred open fields to graze (Knepp Wildland, 2019e).

Although, as mentioned earlier, the number of individual Tamworth pig observations were increased due to the sows having given birth to their piglets. As well as preferring to graze in fields, it could be that the sows were grazing more due to their young. The litters observed were made up of between four and five piglets, therefore the mother needed to eat a lot more in order to produce enough food for her young, hence why the sows were often observed grazing for prolonged periods of time.

### Eating Behaviours

The findings of this study suggest there was a spatial preference for different eating behaviours, supporting the primary hypotheses. Drinking behaviours were always going to be limited to the laggs due to the obvious lack of water within the fields. However, there were fewer observations seen for drinking than originally expected, especially with the hot weather during July 2019. All species seen to drink, Longhorn cattle, Fallow deer, Red deer and Tamworth pig, only did so for a mean length of less than five seconds. Due to species size it would be thought that Longhorn cattle and Red deer would consume a lot more for longer, but Tamworth pigs were seen to drink more than both. This could be due to the hot weather and the sows being heavily pregnant when observed by the laggs.

Grazing behaviours were observed to be performed more in open fields than in the laggs, supporting part of the second hypothesis. Despite being observed more in the lagg, Longhorn cattle grazed more in the field conditions in larger herds than those seen in the laggs. They have been seen to actively select grassland habitats over those with dense shrubbery like brambles (Dando, 2018). These behaviours were expected to be seen from Longhorn cattle as they are an open habitat-grazing species and prefer fields with higher floral diversity (Olff and Ritchie, 1998b; Dando, 2018). However, it was surprising to find the Tamworth pig to show preference for the field locations when grazing as they are categorised as a mixed feeder who typically prefer denser vegetation. These findings reject part of the second hypothesis that pigs will prefer lag conditions over fields. Again, the change of the behaviour could have been due to the sows having given birth recently when observed, as mentioned earlier. It would be beneficial for a year-long study to be carried out, observing and comparing the behaviour changes in Tamworth pigs throughout the seasons, especially when pregnant, to further understand how the eating behaviours may differ, especially in a rewilding context.

Fallow deer were observed to graze equally between laggs and fields. Upon initial observation, grazing was often seen to occur during the night in fields and varied throughout the day in the laggs. Further study would need to be conducted to see if there was a significant difference between grazing location and time of day and the underlying reasons for this behaviour. Although, current findings are in line with previous research (Borkowski and Pudełko, 2007). These findings all support the primary hypotheses that large herbivores show spatial preference when eating.

Some species-specific eating behaviours were observed from each of the reintroduced large herbivore species. Grazing was performed by all the species but browsing was predominantly observed in the lagg conditions mostly by the three deer species – Red deer being observed the most. Deer, especially Red deer, are known to be specialist browsers so it is not surprising that these results follow previous literatures findings (Vera, 2009; Krojerová-Prokešová, 2014; Knepp Wildland, 2019b). The behaviour was likely to be observed most in the laggs due to the enclosed plant structure, making it more accessible and the deer more comfortable to browse in such areas. Furthermore, Roe deer were observed to graze the most out of the five large herbivore species in the lagg conditions, this further feeds into the likelihood that Roe deer prefer the enclosed areas of laggs than the openness of fields. Previous literature infer that said behaviour is to avoid disturbances but it could be useful to take note of the time each of the observations were taken and compare it to human visitation times as well as using drone data to look at plant structure in the different conditions (Bongi *et al.*, 2008; Bonnot *et al.*, 2012).

Interestingly, little to no browsing behaviour was observed by Longhorn cattle. The reason Knepp chose to reintroduce Longhorn cattle to the land over other species as a proxy for Auroch was because of their prevalent exhibit of browsing behaviour. However, these findings do not support the display of said behaviours. It was previously found that the Longhorn cattle have been seen to have established a few “home” sites where they graze extensively, only foraging lightly when travelling between them which would explain the reduction of grazing when in the lagg sites (Dando, 2018). Therefore, they are only affecting a small proportion of the vegetation on the site, but at a high rate due to their large population (Dando, 2018).

## Large herbivores in the rewilding context

The variety of eating behaviours performed by each of the reintroduced large herbivore species all contribute towards the restoration and building of a mixed-mosaic landscape, as originally aimed for by the Knepp Wildland project, despite some fields being favoured by species.

1. Write pointers of your overall results in notebook
2. How do these results fit into this paragraph (refer to notebook)
3. Relink to the aim of this study

So far, there have only been positive findings from the waterway restoration, but how this will affect the large herbivores eating behaviours has not been mentioned. Therefore, this study aims to see how the free-roaming large herbivores eating behaviours differ between laggs and fields.

## Future Implications - Beavers

Summary „The impacts of beavers Castor spp. on biodiversity and the ecological basis for their reintroduction to Scotland, UK“

This study is a meta-analysis of published studies on the effect of beavers on plants, invertebrates, amphibians, reptiles, birds and mammals to discuss the potential impacts of the reintroduction of beavers on Scotland's biodiversity.

Result:

“Beavers promote biodiversity through a variety of mechanisms, primarily by increasing habitat heterogeneity and creating unique habitats.”

„The meta-analysis showed that, overall, beavers have an overwhelmingly positive influence on biodiversity. Beavers‘ ability to modify the environment means that they fundamentally increase habitat heterogeneity. As beavers are central-place foragers that feed only in close proximity to watercourses, their herbivory is unevenly spread in the landscape. In addition, beaver ponds and their associated unique successional stages increase habitat heterogeneity both spatially and temporally. Beavers also influence the ecosystems through the creation of a variety of features such as dams and lodges, important habitat features such as standing dead wood (after inundation), an increase in woody debris and a graded edge between terrestrial and aquatic habitats that is rich in structural complexity.“

Habitats and associated plants

Due to the ability of the Beaver to fell very large trees and to construct structures such as dams, these animals have a greater influence on their habitat than many other mammals. In the meta-analysis, the authors found 10 studies investigating the effect of beavers on plant biodiversity. Of these, seven reported a positive and three a neutral effect on biodiversity.

Unknown Implications for Scottish biodiversity

An unknown factor is the influence of beavers on the age structure of affected woodlands. Old woodland with large trees are important for some species like saproxylic insects. If beavers change the age structure to younger growths, this could have a negative effect on overall biodiversity. Other species such as deer can prevent regrowth, depending on the amount of browsing and tree species.

“[…] woodland regeneration following beaver activity is possible at low to medium deer densities, but at the high deer densities currently experienced over many parts of Scotland, regeneration could be significantly affected.”

„By the end oft he 5-year Scottish Beaver Trial at Knapdale in mid-Argyll, 26 % of beaver-browsed tree stumps were showing regrowth. Regrowth was not equal between species.[…] By the end oft he study, 68 % of re-sprouting stumps of tree stems from four preferred species had been browsed by deer (Iason et al. 2014). This highlights how high deer density could reduce the regrowth of beaver-browsed woodland.“

Benefits of Beavers

Another example of successful herbivore introduction was the Eurasian beaver (Castor fiber) to an area in Scotland (Law *et al.*, 2017). After 12 years the plant biodiversity had increased by 148%, those associated with high moisture and light conditions increasing and nitrous plants decreasing. This occurred due both grazing and waterlogging by the beavers, areas of which changed the most. This longitudinal study shows the positive effects of rewilding with large herbivores(Law *et al.*, 2017).

Previous Projects

Future Planning

How they could effect Knepp?

Beaver Ecology

From “Reintroducing the European Beaver in Britain”

“A fuller description of beaver ecology can be found in Kitchener (2001)[...]”

“The European or Eurasian Beaver is a large (11-27kg for animals over three years), semi-aquatic rodent that was once found from the Chinese-Mongolian border in the east, to western Europe and Britain in the west. The fossil record indicates that the species was living in Britain 2 million years ago, 1.3-1.5 million years before the first humans. The other extant beaver species, the North American Beaver Castor canadensis, is superficially similar in appearance and requires close and expert examination to allow the distinguishing features to be determined. In places where they both occur in the wild, such as Finland, where the North American species was introduced in 1933-37, they appear not to hybridise.”

“Beavers do not eat fish. They are totally herbivorous and feed on a wide range of terrestrial and aquatic plant species. […] Species such as Aspen Populus tremula and willows Salix  are preferred but others are also taken, depending on availability. Conifers are rarely browsed or felled. Although much larger trees may also be felled, beavers tend to fell shrubs and trees with trunk diameters in the region of 3-8cm in order to feed on the bark, twigs and leaves and, when necessary, to use the wood for their engineering works. Woody material may be cached underwater to provide a winter source of food.”

“Beavers require two basic elements in their habitat: fresh water and broadleaved woodland. A large part of their lives are spent in or near water, and they usually forage little more than 10m from the water’s edge, and very rarely more than 100m.  Territory sizes vary, depending on the quality of the habitat concerned, and have been recorded as covering from as little as 0.5km of riparian edge per family to up to 12km or considerably more. “

“The animals live in family units, typically consisting of an adult pair with 2-3 young (kits) of the current year plus young from the previous year. Individuals leave their families when they are about two years old and set up their own territories. The Wolf Canis lupus can be a major predator, although there are records of kits being taken by such animals as Otter Lutra lutra, White-tailed Eagle Haliaeetus albicilla and Fox Vulpes vulpes. […] Beaver dens tend to be situated next to standing or slow-moving fresh water, with the entrance usually underwater to provide safety from predators. If water levels are low, beavers will dam streams less than 10m wide, using wood, stones, mud and other materials to create ‘beaver ponds’. Some reports suggest a tendency for the North American species to build larger dams than the European species. Dens may be dug directly into river or loch-side banks, or incorporated within constructed lodges. The beavers’ engineering skills can also extend to the construction of ‘canals’ to enable them to stay in water as they move around their territory.”

Potential effects of a reintroduction in Britain

From “Reintroducing the European Beaver in Britain”

Land use (agriculture, forestry, fisheries)

“There is little published information available on the interactions between beavers and agriculture. Intensively farmed fields simply do not provide good beaver habitat. We have come across no reports of beavers grazing grass crops to significant extents, but they have been reported as feeding occasionally on orchard trees, maize, corn, oil-seed rape, potatoes and sugar-beet near riparian zones, and sometimes causing localised flooding. “

For more information see the translated article "Living Together Beaver Management in Bavaria".

Hydrology, geomorphology, and water chemistry

“Beaver dams have been described as having the ability to ameliorate downstream flooding events during periods of high rainfall (particularly significant as climate change is expected to result in higher winter rainfall and increased incidences of flooding events) and to act as sediment and pollutant traps. “

“Damming of small rivers would result in an increase in open-water and wetland habitat, and reductions in the load of moving sediment, including suspended sediment. Sediments trapped behind dams may eventually form ‘beaver meadows’. Undammed stretches of river may become morphologically more complex as a result of the sediment-storage and energy-dissipation impacts of dams”

Biodiversity

“Studies have shown that the habitat changes brought about by beavers affect the other species present, the creation of beaver ponds favouring lentic (still-water) species over the lotic (runningwater) species that may have been locally present before.”

The effects of beavers on different species groups and habitats are well reviewed in „The impacts of beavers Castor spp. on biodiversity and the ecological basis for their reintroduction to Scotland, UK“. I buyed the study for you :)

Public health

“The most common public-health issue raised in relation to the beaver is Giardiasis (Galbraith & Gaywood 2002). [...] In North America giardiasis is often called, rather unfortunately, ‘beaver fever’. In fact, the major source of Giardia infection in humans in North American is other humans. The term ‘beaver fever’ was apparently invented by a section of the press in the 1970s and reflects the fact that beavers exist in areas where many people camp, hike and may, on occasion, become infected. [...]We have found no reported instances of European Beavers causing health problems in humans from Giardia or Cryptosporidium, nor have we found any situations where European Beavers are viewed as a significant human-health problem. However, as part of any future reintroduction, the precautionary advice would be to carry out pre- and post-release monitoring of private water supplies and watercourses in the release area.”

Summary “Qualitative and quantitative effects of reintroduced beavers on stream fish”

“This paper provides a systematic review of the impacts of beaver dams on fishes and fish habitat based on a meta-analysis of the literature and expert opinion. Research is regionally biased to North America (88%). The most frequently cited benefits of beaver dams were increased habitat heterogeneity, rearing and overwintering habitat and flow refuge, and invertebrate production. Impeded fish movement because of dams, siltation of spawning habitat and low oxygen levels in ponds were the most often cited negative impacts. Benefits (184) were cited more frequently than costs (119). Impacts were spatially and temporally variable and differed with species. The majority of 49 North American and European experts considered beaver to have an overall positive impact on fish populations, through their influence on abundance and productivity. Perceived negative effects related to the movement of aquatic organisms in tributary streams, including upstream and downstream migrating salmonids, and the availability of suitable spawning habitat. “

Impacts of beaver activity on fish

**Habitat**

Influence fresh water systems through the creation of lentic patches within a corridor of lotic habitat. This results in habitat heterogeneity which benefits a multitude of organisms, including fish.

**Barriers to fish movement**

“Beaver dams, comprising of wood partially sealed with mud and vegetation, create semi-permeable barriers to the upstream and downstream movement of fish. This may result in reduced access to essential spawning and rearing habitat, inhibited colonization and increased isolation of populations (Table 4). “

**Flow**

“Beaver dams stabilize river flow (Grasse and Putnam 1955; Halley 1995) by increasing the water-holding capacity of the watershed, dampening peaks in the hydrograph (Finnigan and Marshall 1997) and elevating the water table enabling the slow release of groundwater to maintain stream flow during periods of drought (Finnigan and Marshall 1997). Flow stabilization may, under some situations, benefit fish populations. “

**Temperature**

“Beaver activity can influence stream temperature regimes in two ways: by increasing the area of impounded reaches and thus increasing the time available for water to be heated by solar radiation, and by opening the river to sunlight (Cook 1940). “

“Higher water temperatures because of the presence of beaver ponds may benefit species in areas where fish distribution or productivity is temperature limited (Rasmussen 1941; Grasse and Putnam 1955; Gard 1961; Swales and Levings 1989; Baker and Hill 2003)[...]”

**Water quality**

“Detrimental effects on water quality within and below impoundments have been described (Rupp 1954), with reduction in dissolved oxygen the most frequently cited negative response (Cook 1940; Call 1966; Bryant 1984; Dolloff 1987; NRC 1995; Guignion 2009; Burchsted et al. 2010), resulting in transient anoxic conditions (e.g. Minnesota: Schlosser and Kallemeyn 2000; Ontario: Bertolo et al. 2008)”

**Species richness**

“In North America, beaver activity is associated with high fish species richness and diversity (Hanson and Campbell 1963; France 1997). Active and abandoned beaver ponds provide conditions conducive to high species richness (Snodgrass and Meffe 1998, 1999; Schlosser and Kallemeyn 2000) because of the provision of habitat diversity and increased complexity of food webs (Ray et al. 2004). In New Brunswick (Canada), the disturbance caused by beaver activity is the key driver for high diversity in systems that would otherwise be dominated by Atlantic salmon (Mitchell and Cunjak 2007). “

**Productivity, abundance and growth**

“The response of benthic invertebrate productivity to the presence of beaver is a key factor in determining the nature of beaver–fish interactions (Rutherford 1955; Gard 1961). Biological production is often enhanced as a result of beaver activity (Salyer 1935; Duncan 1984; Swanston 1991; Anderson et al. 2009), resulting in a high standing crop of aquatic invertebrates (Rasmussen 1941; Call 1966; McCaffery 2009). The abundance of some invertebrate species may be reduced when beaver ponds are formed, partly because of increased selective predation by trout, but overall productivity tends to increase (Cook 1940; NRC 1995). “

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In-Text

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## Future Suggestions for Studies

For future studies, there are a few additionally supplements that could be added to reveal more about the reasoning behind each of the reintroduced large herbivores exhibit specie specific behaviours and have preferential feeding sites in a rewilding context.

Camera observations could be performed in different seasons, Winter and Summer to see how the moisture of the soil effects their eating behaviours, especially in Knepp where it is made up of heavy Low Weald clay over “a bedrock of limestone” (Knepp, 2019; Rewilding Britain, 2019a). It would be interesting to see how the behaviours differ and how this could potentially affect the landscape during the seasonal months.

Plant surveys could also be performed to take estimate soil moisture levels. Due to the unpredictability of weather in the UK, it is better to look at the plants growing in different pastures to indicate whether field’s soil retains high or low moisture. Then, by comparing the observations of eating behaviours from the large herbivores, further inferences can be made about how soil moisture influences their eating behaviours.

Drone data could also be used to compare the sites vegetation structure. For example, a comparison within the lagg sites to see if deer species tend to visit one site more than other because its vegetation is more densely packed and closed-off. Similar comparisons could also be run for open fields to see if this influences which species of large herbivore is more likely to visit.

Finally, a longer capture time for each of the cameras should be considered to obtain more representative data about the behaviours observed from the large herbivores. Behaviours cannot be accurately predicted further than the cameras’ capture times and the findings from this study suggests the behaviours go on for longer than observed which could positively change the significance of the findings to further support current findings and hypotheses.

# Conclusions

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# Appendices

## Appendix A – Camera trap details & locations

**Distianert DH-8 Trail Cam**

* Covers 130° detection angle and 24.384 meters wide detection range.
* 1080p HD videos
* Night vision range of up to 19.812 meters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Field** | **Camera Number** | **Condition** | **GPS** | **Camera Trap Brand** | **Dates in Field** |  |
| Middle Link | 22 | Lagg | 50.96752626, -0.36438605 | Distianert DH-8 Trail Cam | 04/07/19- 18/07/19 |  |
| New Barn 3 | 4 | Field | 50.96701462, -0.37055623 | Distianert DH-8 Trail Cam | 04/07/19- 18/07/19 |  |
| Brookhouse 6 | 1 | Lagg | 50.96910583, -0.38484366 | Distianert DH-8 Trail Cam | 04/07/19- 18/07/19 |  |
| Brookhouse 7 | 11 | Field | 50.97230618, -0.38195922 | Distianert DH-8 Trail Cam | 04/07/19- 18/07/19 |  |
| Brookhouse 13 | 16 | Field | 50.97029065, -0.37512475 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| Brookhouse 13 | 17 | Lagg | 50.96875864, -0.37535865 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| 27 Acres | 12 | Lagg | 50.97457507, -0.37195872 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| East of Hammer | 21 | Field | 50.97536385, -0.36508720 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| East of Hammer | 18 | Lagg | 50.97632924, -0.36270161 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| Fresco East | 19 | Field | 50.97234891, -0.36612155 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |

## A tree in a forest Description automatically generatedA tree in a forest Description automatically generatedA close up of a tree Description automatically generatedA close up of a tree Description automatically generatedA person jumping in the air Description automatically generatedAppendix B – Example of Distance Sampling Images (New Barn 3 – Field)

Image of camera 4 view.

5 metres.

10 metres.

15 metres.

Image of camera 4 setup – New Barn 3 (Field).

A close up of a tree

Description automatically generated

20 metres.

A close up of a tree

Description automatically generatedA picture containing tree, sky, outdoor

Description automatically generated

25 metres.

30 metres.

## Appendix C – Details of Each Camera Trap & Overall species observation

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Brookhouse 13 (Field) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 2.75 | 44 | 16 |
| Fallow deer | 3.31 | 43 | 13 |
| **Total** | 6.06 | 87 | 29 |

Table C1. Mean number of species per trigger and total number of triggers in Brookhouse 13 field condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Brookhouse 13 (Lagg) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 4.11 | 273 | 53 |
| Roe deer | 1 | 3 | 3 |
| Fallow deer | 3.56 | 367 | 48 |
| Red deer | 2.34 | 8 | 7 |
| **Total** | 11.01 | 651 | 111 |

Table C2. Mean number of species per trigger and total number of triggers in Brookhouse 13 lagg condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – 27 Acres (Lagg) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 1.75 | 21 | 12 |
| Fallow deer | 1.8 | 9 | 5 |
| **Total** | 3.55 | 30 | 17 |

Table C3. Mean number of species per trigger and total number of triggers in 27 Acres lagg condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Fresco East (Field) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 1 | 2 | 2 |
| Roe deer | 1 | 1 | 1 |
| Fallow deer | 1 | 2 | 2 |
| **Total** | 3 | 5 | 5 |
| Table C4. Mean number of species per trigger and total number of triggers in Fresco East field condition. | | | |
| Camera Trap – Brookhouse 6 (Lagg) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 3.75 | 603 | 157 |
| Roe deer | 2.67 | 16 | 5 |
| Fallow deer | 3.33 | 50 | 22 |
| Red deer | 2.98 | 63 | 16 |
| Tamworth pig | 3.33 | 38 | 29 |
| **Total** | 16.06 | 770 | 229 |

Table C5. Mean number of species per trigger and total number of triggers in Brookhouse 6 lagg condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Middle Link (Lagg) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 1 | 18 | 18 |
| Fallow deer | 1.71 | 24 | 14 |
| **Total** | 2.71 | 42 | 32 |

Table C6. Mean number of species per trigger and total number of triggers in Middle Link lagg condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – New Barn 3 (Field) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Fallow deer | 2.65 | 45 | 17 |
| **Total** | 2.65 | 45 | 17 |

Table C7. Mean number of species per trigger and total number of triggers in New Barn 3 field condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Brookhouse 7 (Field) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 2.23 | 196 | 88 |
| Fallow deer | 2.70 | 54 | 20 |
| Tamworth pig | 4.09 | 143 | 35 |
| **Total** | 9.02 | 393 | 143 |

Table C8. Mean number of species per trigger and total number of triggers in Brookhouse 7 field condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – East of Hammer (Lagg) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 3.7 | 225 | 69 |
| Fallow deer | 2.29 | 55 | 24 |
| Roe deer | 1.75 | 6 | 3 |
| **Total** | 7.74 | 286 | 96 |

Table C9. Mean number of species per trigger and total number of triggers in East of Hammer lagg condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – East of Hammer (Field) | | |  |
| **Species** | **Mean No. of Individuals per Trigger** | **Total No. of Individuals** | **Total No. of Triggers** |
| Longhorn cattle | 5.47 | 634 | 116 |
| Fallow deer | 2 | 6 | 3 |
| **Total** | 7.47 | 670 | 119 |

Table C10. Mean number of species per trigger and total number of triggers in East of Hammer field condition.

## Appendix D – Breakdown of each eating behaviour by species

Figure D1. Mean number of times each eating behaviour was observed to be performed by Longhorn cattle in each condition (+/- SD).

Figure D2. Mean length of time (seconds) Longhorn cattle exhibited each eating behaviour in each condition (+/- SD).

Figure D3. Mean number of times each eating behaviour was observed to be performed by Roe deer in each condition (+/- SD).

Figure D4. Mean length of time (seconds) Roe deer exhibited each eating behaviour in each condition (+/- SD).

Figure D5. Mean number of times each eating behaviour was observed to be performed by Fallow deer in each condition (+/- SD).

Figure D6. Mean length of time (seconds) Fallow deer exhibited each eating behaviour in each condition (+/- SD).

Figure D7. Mean number of times each eating behaviour was observed to be performed by Red deer in each condition (+/- SD).

Figure D8. Mean length of time (seconds) Red deer exhibited each eating behaviour in each condition (+/- SD).

Figure D9. Mean number of times each eating behaviour was observed to be performed by Tamworth pigs in each condition (+/- SD).

Figure D10. Mean length of time (seconds) Tamworth pigs exhibited each eating behaviour in each condition (+/- SD).

## Appendix E – Daily Weather July 2019 (Broomer’s Corner, West Sussex)

|  |  |  |
| --- | --- | --- |
|  | **Temperature (C)** | |
| **Date** | **High** | **Low** |
| 4/07/2019 | 25 | 10 |
| 5/07/2019 | 26 | 14 |
| 6/07/2019 | 25 | 15 |
| 7/07/2019 | 19 | 14 |
| 8/07/2019 | 22 | 12 |
| 9/07/2019 | 22 | 14 |
| 10/07/2019 | 24 | 14 |
| 11/07/2019 | 25 | 15 |
| 12/07/2019 | 25 | 17 |
| 13/07/2019 | 22 | 14 |
| 14/07/2019 | 22 | 13 |
| 15/07/2019 | 21 | 12 |
| 16/07/2019 | 24 | 10 |
| 17/07/2019 | 24 | 10 |
| 18/07/2019 | 22 | 14 |
| 19/07/2019 | 18 | 10 |
| 20/07/2019 | 23 | 14 |
| 21/07/2019 | 22 | 13 |
| 22/07/2019 | 24 | 16 |

## Appendix F – Population levels (Taken from Dando, 2018)

Figure F1. Stocking levels from 2009 – 2017 of five reintroduced large herbivores at Knepp Wildland project in the southern block.

1. Refer to Appendix A for locations and details on cameras used. [↑](#footnote-ref-1)
2. Refer to Appendix B for an example of distance sampling images. [↑](#footnote-ref-2)
3. Refer to Appendix A for locations and details on cameras used. [↑](#footnote-ref-3)