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

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# Abstract

Rewilding is new form of conservation that aims to restore the natural-processes of the land with as little human interference as possible by allowing nature take control again to replicate previous ecosystems. This is achieved via the reintroduction or the removal of a key-stone species that incite changes in other areas of the ecosystem causing a shift in structure, such as species population via resource availability – also known as a trophic cascade. Rewilding emphasises the importance of large herbivores and how their cyclic eating processes are influenced and influences vegetation diversity and structure. The Knepp Wildland project has used rewilding and the reintroduction of five large herbivore species to the land to encourage a mixed mosaic habitat; Longhorn cattle, Roe deer, Fallow deer, Red deer and Tamworth pigs. Recently, Knepp has restored the River Adur which runs throughout the lands and its waterways to increase water flow throughout the fields in hope to encourage further biodiversity in all parts of the local ecosystem. This study aims to see how soil moisture influences large herbivores’ eating behaviours in hopes of being able to predict changes to the land. This was done through observations via camera traps over a period of two weeks throughout July 2019 at The Knepp Wildland project, comparing eating behaviours between study sites – wetland (lags) versus dryland (fields). It was hypothesised that there would be a difference in behaviours between the sites for each of the large herbivores along with each specie having a preferred eating site and performing specie-specific eating behaviours. The results found each of these hypotheses to be true although there was little evidence indicating what the underlying mechanisms were for each of these findings and what was influencing them. Previous literature was able to uncover specie eating preferences but this should be reinforced by evidence found at the site. Further research should be performed to establish why these behaviours occur and what influences them and whether they are consistent throughout the year, especially with the highly likely reintroduction of Eurasion beavers to The Knepp Wildland project.

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# Acknowledgments

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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 the up-rise of farmland abandonment due to the decrease of economic value and the lands’ inability to sustain intensive farming, pose increasing threats to wildlife sustainability in the UK, as well as in Europe (European Commission, 2017). Landowners are now turning to alternative ways of making money through their land, such as Rewilding (Navarro and Pereira, 2015).

### 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” before humans began to have an impact on the environment as the goal (Moorhouse and Sandom, 2015; Smit *et al.*, 2015; Corlett, 2016; 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 chain, which then effects the ecosystem structure and nutrient cycle (Bakker and Svenning, 2018; Carpenter, 2019). To reintroduce a specie to an ecosystem, they need to have been previously native to the land and or be closely related to the previous species to be used as a proxy (Cromsigt and te Beest, 2014; Svenning *et al.*, 2016; Nickell *et al.*, 2018). A famous example of reintroducing a species to an incomplete ecosystem are the predators, Wolves (*Canis lupis*), to Yellowstone National Park (Staff, 2011; Ripple and Beschta, 2012; Townsend, 2016). In Yellowstone National park, wolves were reintroduced to control the eating behaviours of large herbivores, Elk (*Cervus canadensis*), which had a wider impact on the environment, namely the rivers and waterways, allowing the vegetation to recover, encouraging the return of beavers and later a wide range of fish and other animals to the wild (Townsend, 2016). This is a primary example of the impact large herbivores can have on the surrounding landscape.

### 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 the herbivore’s 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 and eat thorny shrubbery, something which horses and cattle cannot do (Knepp Wildland, 2019b; RHS Gardening, 2019). 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 Wildand project in England, that are dedicated to grazing experimentation, researching how intensive grazing effects the local plant diversity (Olff and Ritchie, 1998b; Ross *et al.*, 2016; Marrs *et al.*, 2018). In Oostvaardersplassen, 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 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). Other potential risks the land faces with over-population is overgrazing, which can lead to soil erosion, land degradation, and the loss of valuable plant species that are not able to recover after intensive grazing and are often replaced with secondary, less nutritional plants (Rinkesh, 2019). These are the few of the issues Yellowstone National Park faced when Elk were left to populate the land without predators to enforce cyclic grazing and population control (Staff, 2011; Ripple and Beschta, 2012). To prevent this, Oostervaardersplassen has introduced the temporary need for population control until natural predators can safely be introduced (Vera, 2009; Lorimer and Driessen, 2014). Knepp Wildland project also intervene via population control by making it a part of the economic model and removing animals off the land, acting as a proxy for predators (Greenaway, 2006). The land is too small to allow for “natural” population fluctuations and cannot chance the potential spread of disease (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 of vegetation, 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, 2018a). 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, 2018a). 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, 2018a). The lags 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 lags, 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 an introduction of a family of Beavers would have been equally as beneficial as nature’s 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 lags 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 lags
   2. Cattle will prefer the fields
   3. Deer and pigs will prefer the lags
   4. Large herbivores predominantly visit lags 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, 2018a).

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 the 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

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 (refer to *appendix B* for an example of distance sampling images). 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 lag 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 and all the same brand (Distianert DH-8 Trail Cam) (refer to *appendix A* for details on the cameras used).

### Choosing Camera Trap Locations

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 lag 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 lag 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 (refer to *appendix A* for GPS locations of each of the cameras) .

INSERT MAP HERE

### Site Descriptions

#### Lags

A close up of a tree

Description automatically generatedA close up of a green field

Description automatically generatedA tree in a forest

Description automatically generatedLags tended to be smaller, enclosed areas surrounded by tall shrubbery and brambles. There were often breaks in the boundaries to allow passage between the fields and assigned lag areas. Grasses and plants tended to be taller and more over-grown. Examples of locations are shown as below.

27 Acres Brookhouse 6 Middle Link

#### Fields

Fields tended to be large, open areas of grassland with very little disturbance in the middle. Vegetation height varied in the middle of the fields from very short, to slightly taller patches of vegetation. Occasionally some fields had bramble shrubs sporadically placed throughout the field. Examples of locations are as shown below.

A close up of a tree

Description automatically generatedA close up of a tree

Description automatically generatedA close up of a tree

Description automatically generated

New Barn 3 Brookhouse 7 Fresco East

### 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 subject 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 lag 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 lags. 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 lags. 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** |
| **Lag** | 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.

*Figures 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 lag 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 lag conditions (*fig. 1a)* in comparison to the field conditions (*fig. 1b*).

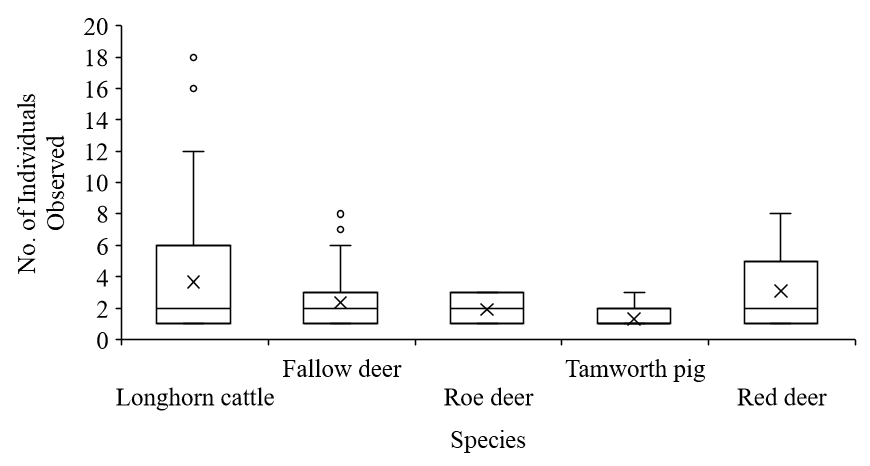


Figure 1a. Number of individuals observed per trigger by species within the lag condition.

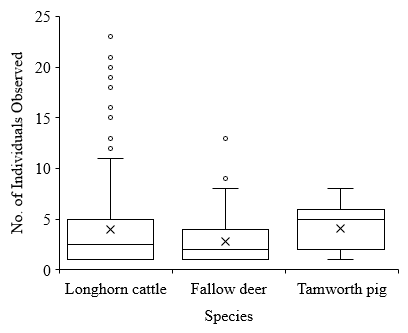


Figure 1b. Number of individuals observed per trigger by species within the field condition.

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 in the conditions, select behaviours can be seen more prominent in one than the other. 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 lags. Although, there were few observations of browsing, more was observed in the lag 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 *figure 3* as *figure 2* when comparing the mean length of time for each behaviour. Again, drinking was observed more in the lag conditions due to lack of water in the fields. Browsing occurred more in the lag condition therefore the mean time was longer than the field conditions (refer to *fig. 3*). The standard error bars for grazing in *figure 3* surpasses the cameras’ capture time, showing the potential upper limit of grazing 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. *Figure 4a* reveals that Roe deer were observed to graze the most in the lag conditions. All the deer species were seen to graze a considerable amount in the lag conditions, however, Longhorn cattle grazing observations exceeded the Red deer due to their larger population numbers in comparison, increasing their number of observations as each individual subjects’ behaviours per trigger was recorded. 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 findings presented in *figure 4a* somewhat disagree with the hypothesis that large herbivores tend to visit lags to drink. Most of the large herbivores showed preference to grazing and rarely ever visited the lags to exclusively drink or in conjunction with grazing. It was seen that Tamworth pigs did tend to drink at the lag sites; however, this was often when the pigs were seen wallowing in the lags on hot days (refer to *table 5*). There were only two cases where the pigs were seen drinking without wallowing in a video.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Drinking** | **Wallowing** | **Drinking & Wallowing** | **No. of Lag Observations** | **Total No. of Observations** |
| Tamworth pig | 6 | 15 | 4 | 39 | 183 |

Table 5. Summary of drinking and wallowing behaviours observed independently and together in lag conditions.

*Figure 4b* further supports the findings in *figure 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 lag conditions (+/- SD).

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

Whereas, *figure 5a* shows that Longhorn cattle, Fallow deer and Tamworth pigs all prefer to graze in fields when compared to *figure 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).

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

# Discussion

This study compared five large herbivore species eating behaviours in wetland (lags) 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 lag 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 lag 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 lags, 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 lag 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 lags 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 lags.

Grazing behaviours were observed to be performed more in open fields than in the lags, supporting part of the second hypothesis. Despite being observed more in the lag, Longhorn cattle grazed more in the field conditions in larger herds than those seen in the lags. 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 lags and fields. Upon initial observation, grazing was often seen to occur during the night in fields and varied throughout the day in the lags. 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 lag 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 lags 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 lag conditions, this further feeds into the likelihood that Roe deer prefer the enclosed areas of lags 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 lag 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. The results show how each of the present large herbivores all fulfil their niche within the ecosystem through their eating behaviours. Although, larger herbivore specie population size dictates the level of impact they have on the land through the speed of vegetation succession.

With the current studies’ findings, there was no obvious link to how the wetland affected the eating behaviours of the large herbivores but finding there was a variation. Upon further inspection of the results and considering previous literatures’ findings, it was suggested that the structure of the vegetation influenced the eating behaviours more so than the soil moisture. When these findings are reversed it echoes Vera’s theory, that large herbivores are a key drivers of vegetation succession through cyclic eating behaviours, eloquently (Vera, 1994, 2009).

With supporting evidence from previous literature, future predictions of how the land will evolve can be made. It could be inferred then with the success of the restoration to the waterways and the browsing activity of the deers, that the population and density of shrubbery is likely to increase over the upcoming years. Paired with the infrequent grazing behaviours from Longhorn cattle in the lag areas and the likely increase of deer population due to additional resources, this will result in the reduction of open grass in the lag areas (Stringer and Gaywood, 2016). However, as previously mentioned, Longhorn cattle were selected as a proxy due to their tendency to browse so they could adapt to the evolution of the landscape, balancing the growth of shrubbery with their larger appetites along with the specialist browsers, Red deer. This is an example of one of the few predictions that could be made with this studies’ findings with additional materials. Knepp provides an ideal location to conduct such experimentation and further observations should be conducted to monitor how the land will develop as a result of the restored waterways.

The hypothetical prediction above does not take into account the population control Knepp has over the present large herbivores. Due to lack of predators on site, site management controls population levels and have systems in place to prevent disease outbreaks, famines and droughts, allowing the project to adhere to ethical guidelines. If predation was present, this could alter the large herbivores’ behaviours due to the additional factors of landscape of fear which could in-turn change the rate of how the land evolves. Due to the Knepp’s population control, it makes this experiment applicable to most sites in the UK that also do not have natural free-roaming predators. Although, conducting a similar experiment in another grazing experimentation project with free-roaming predators would be provide evidence in how landscape of fear potentially influences grazing behaviours and vegetation succession.

## Future Suggestions for Studies

For future studies, there are a few additionally supplements that could be added to reveal more about the underlying mechanisms 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. Additionally, if the plant surveys were performed at the same positions as the distance sampling (every five metres from the camera until 30 metres) it would provide a better idea of the vegetation the large herbivores are feeding from, thus, showing any preferences in their diets further contributing towards the differences between site locations and seeing what is preferred by each species.

Furthermore, a direct comparison of sites would be useful to see what differences contribute towards a preferential site for each of the large herbivore species. This would be done by setting a camera up in a wetland site and another in the dryland counterpart. The comparison of behaviours, the length of time performed and when during the day would be beneficial for uncovering the underlying mechanisms for what constitutes a preferential feeding site for each of the large herbivores.

Drone data could also be used to compare the sites vegetation structure. For example, a comparison within the lag 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 as well as leading to more mature predictions about the development of the landscape.

## Future Reintroductions

Whilst discussing the potential future for the land at Knepp Wildland project, after the restoration of the river Adur and the waterways, there has been suggestions of reintroducing a family of Eurasion beavers (*Castor fiber*) back to the land as the next step, after their extinction in the UK due to hunting in the 16th century (Tree, 2018b; Knepp Wildland, 2019c). Beavers are considered “ecosystem engineers” due to their ability to have large impacts on the surrounding ecosystem (Gibson and Olden, 2014; Stringer and Gaywood, 2016; Law *et al.*, 2017). The beavers would be a cost-effective and sustainable way to ensure the waterways restoration would be well maintained without human interference and heavy machinery, suitable for a rewilding project (Kemp *et al.*, 2012; Pollock *et al.*, 2014; Knepp Wildland, 2019d, 2019c).

Previous studies have found that reintroduced beavers have had an outwardly positive effect on the surrounding ecosystems through increasing plant biodiversity and richness, thus having a positive impact on invertebrates, amphibians, reptiles, birds and mammals populations (Kemp *et al.*, 2012; Stringer and Gaywood, 2016; Law *et al.*, 2017; Tree, 2018b). They have well known effects on the hydromorphology throughout the land by building their dams into the waterways as well as feeding off the vegetation on the waters edges (Law *et al.*, 2017). Beavers construct their dams from “felled wood, stones and mud placed perpendicular to [the] water flow” which raises and stabilises the water levels, preventing flooding, and increasing access to resources (Rosell *et al.*, 2005; Simon, 2006; Law *et al.*, 2017). Although, his is all dependent on the availability of resources suitable for beavers (e.g. Willow, Birch and Aspen) and the extent current grazing routines of other herbivores and the current management of the land (Gibson and Olden, 2014). Beavers are central-place foragers, meaning that they feed close to the waterways which often result in the creation of “distinctive riparian habitats” that can be identified via areas of coppiced and open woodland with flooded emergent plants (Bulluck and Rowe, 2006; Stringer and Gaywood, 2016). This improves the heterogeneity of the land and creates space for plants that are associated with high-moisture levels and light conditions that in turn provides cleaner and better oxygenated water for the aquatic life (Stringer and Gaywood, 2016).

Beavers would be a perfect fit in Knepp. For example, the water-margins are reportedly beginning to silt and become “choked” with scrub and weeds so with the help of beaver coppicing the plants by the water edge and it would open up the water once again (Tree, 2018b). However, it is difficult to create predictions on the effects they will have on the land on a specific level as it all depends on where they set their habitats up on the waterways and how long for. Previous studies have also emphasised the importance some of the beavers’ actions can cause stress on the local land, such as tree-felling and waterlogging as it can have greater impacts on vegetation structure and composition than grazing (Law *et al.*, 2017). This is something that will need be to be carefully considered before the reintroduction and monitored afterwards on how it effects not only the land but its current inhabitants. The current study hopes to provide the beginning building blocks for research in how soil moisture effects large herbivores in a rewilding context.

# Conclusions

In conclusion, each of the large herbivores present in the southern block at Knepp Wildland project displayed preference in eating behaviours and eating locations between wet and dryland (lag and fields). It was found that vegetation structure was a good indicator as to where each of the species would perform specific eating behaviours. In the future, supplementary data would be beneficial to support these observational findings. Much of the findings reflect what has been said in previous research regarding large herbivore feeding habits. Longhorn cattle preferred to graze in the open fields in larger herds, though said fields were pre-selected, favoured “home” sites. Cattle were seen to be observed more in the lags but not for as long as the field conditions as they tended to graze for less time. Roe deer were exclusively seen in the lag conditions as they predicted to prefer quiet, secluded areas as a species. The seclusion of the lag sites was due to the high density of shrubbery and brambles making up the tall vegetation structures. The Red deer are originally thought to be riverine species and are specialist browsers which would explain why the prefer the lag sites. Additional vegetational data would further support these findings and uncover any potential underlying mechanisms in how vegetation diversity and structure can influence Red deer eating site preference. Much like the Longhorn cattle, the Fallow deer also preferred fields to graze though these findings could be due to their large population size so further observation would be beneficial. The Tamworth pig also showed preference for the fields, but this was observed after they had given birth to litters of four – five piglets, meaning their appetite had increased due to the need to feed their young. They were rarely observed in lags and when they were it was likely due to it being a hot day and being heavily pregnant. It would be advantageous to observe the differences in behaviour for Tamworth pigs over multiple seasons – especially whilst sows are pregnant and are raising new-born piglets in a rewilding context.

All these behaviours contribute towards the creation of a mixed mosaic landscape within the southern block at Knepp. The restoration of the river Adur and waterways have shown positive benefits so far with the increase of the lands’ biodiversity and the potential to improve the land composition, but further help would be beneficial with the possible reintroduction of the Eurasion beaver. From the current findings, predictions can be made as to how the large herbivores feeding habits could respond to the reintroduction, thus allowing Knepp’s management to prepare for the possible changes to come. It would be advantageous for further studies to be performed on site at Knepp Wildland project and at other large rewilding sites with beavers to see how other factors, such as predators, influence the composition of land. By focusing on large herbivores’ eating behaviours, a lot can be revealed about the relationships between large herbivores and plant diversity, structure and mortality, thus aiding in the restoration to a more natural world.

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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 | Lag | 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 | Lag | 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 | Lag | 50.96875864, -0.37535865 | Distianert DH-8 Trail Cam | 08/07/19- 22/07/19 |  |
| 27 Acres | 12 | Lag | 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 | Lag | 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 (Lag) | | |  |
| **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 lag condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – 27 Acres (Lag) | | |  |
| **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 lag 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 (Lag) | | |  |
| **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 lag condition.

|  |  |  |  |
| --- | --- | --- | --- |
| Camera Trap – Middle Link (Lag) | | |  |
| **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 lag 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 (Lag) | | |  |
| **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 lag 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.