IAgrE Student Awards

NOMINATION SUMMARY

IAgrE CNH Industrial Award

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MSc Agroecology and Sustainable Management in Agriculture

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Quantifying the Ecosystem Engineering of Yearling Cattle in Permanent Pasture

Details of material submitted with nomination:

Summary

With over 9 million cattle in the UK, the ecological impact of their presence is undeniable (DEFRA, 2026). Due to the loss of natural species and large herbivores globally, it is also critical to understand the impact cattle can have on an ecosystem, whether this is neutral, destructive or beneficial (Dettenmaier *et al*., 2017). Research suggests cattle are ecosystem engineers; however, the effects of cattle need to be quantified in a variety of environments to assess this (Derner *et al*., 2009; Dettenmaier *et al*., 2017). This study aimed to quantify the effects of Holstein x Angus x Blue cattle in permanent pasture using pre and post environmental surveys and behaviour studies.

This study measured the direct impacts of cattle behaviour including: pasture biodiversity, sward height, vegetation heterogeneity and, dung distribution. Pre and post surveys were undertaken while the cattle were in each paddock alongside an ethogram behavioural survey which was conducted to link behaviour to their impacts. Results showed that cattle reduced sward height by 19cm consistently, biodiversity was not significantly impacted, vegetation heterogeneity changed by 90%, dung distribution was not linked to location and cattle behaviour and distribution were dependent on location and time.

These results demonstrate that cattle behaviour and their impacts can be quantified into trends. Cattle behaviours are consistent with other ecosystem engineers meaning their effects are not always positive, they are profound. The 48-hour grazing regime at Harper farm succeeded in mitigating the impacts to biodiversity while maintaining productivity. It is recommended that further research builds upon this study by repeating this methodology with different pasture types and cattle breeds to create a large-scale meta-analysis, which could help farmers to

maximise sustainable productivity.	
SIGNED BY PROPOSER: *J. C. Cooper*	**DATE SUBMITTED:** 28.10.26

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TITLE: Quantifying the Ecosystem Engineering of Yearling Cattle In Permanent Pasture

by

NAME: Bethany Paddon

Being a thesis submitted in partial fulfilment of the requirements for the MSc Degree in Agroecology and Sustainable management in Agriculture

2026

Student Declaration Form for Submission with Masters Research Projects

Section 1

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Masters Research Project Title	Quantifying the Ecosystem Engineering of Yearling Cattle In Permanent Pasture
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Date: …14/09/2026……..

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Summary

With over 9 million cattle in the UK, the ecological impact of their presence is undeniable (DEFRA, 2026). Due to the loss of natural species and large herbivores globally, it is also critical to understand the impact cattle can have on an ecosystem, whether this is neutral, destructive or beneficial (Dettenmaier *et al*., 2017). Research suggests cattle are ecosystem engineers; however, the effects of cattle need to be quantified in a variety of environments to assess this (Derner *et al*., 2009; Dettenmaier *et al*., 2017)**.** This study aimed to quantify the effects of Holstein x Angus x Blue cattle in permanent pasture using pre and post environmental surveys and behaviour studies.

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These results demonstrate that cattle behaviour and their impacts can be quantified into trends. Cattle behaviours are consistent with other ecosystem engineers meaning their effects are not always positive, they are profound. The 48-hour grazing regime at Harper farm succeeded in mitigating the impacts to biodiversity while maintaining productivity. It is recommended that further research builds upon this study by repeating this methodology with different pasture types and cattle breeds to create a large-scale meta-analysis, which could help farmers to maximise sustainable productivity.

1.0 Introduction

In the UK, cattle are frequently associated with their primary use in agriculture (Banda and Tanganyika, 2021). Cattle function as a key source of revenue for UK farmers and rural communities who have built their livelihoods around cattle and cattle farming (Bettencourt *et al.,* 2015). This means society depend on cattle as a source of food and income. Cattle play an integral role in rural life and the food chain, which are narrowed down to basic functions on which rural communities depend. This means cattle have gone from playing a role as large herbivores influencing and being influenced by ecological factors and environments, instead only serving as generators of food and income. Traditionally cattle were grazed in an outdoor pasture however in the modern age, cattle can be farmed both in indoor intensive systems and outdoors. (Fisher *et al.,* 2026). The presence of large amounts of cattle in outdoor environments means they have an impact on natural systems such as vegetation composition, invertebrate populations and soil health (Boschi and Baur 2006; Beynon *et al.,* 2012; Niu *et al.,* 2025).

As society requires large volumes of cattle for meat and milk production, the impacts of the cattle on local systems from the soils to species populations are being profoundly affected by their presence. The influence cattle have on the environment has raised the question of whether they can be utilised as ecosystem engineers. These are organisms which have a significant effect on their environment through their behaviour (Derner *et al*.,2009)**.** This means the cattle influence both the abiotic and biotic factors which shape their environment to fit their requirements. Some approaches to farming such as regenerative agriculture aims to use cattle to benefit biodiversity while still contributing to the cattle's primary functions (food and economics) (Bettencourt *et al.,* 2015: Vivas and Hodbod, 2024). If this were achieved, the production of beef and dairy would be more sustainable and less degrading to the environment while still maintaining food security.

There is however debate as to whether the mainstream use of cattle is positive with some sources suggesting that cattle impact on biodiversity, through over-depositing of potentially harmful nutrients, stripping vegetation or weakening of soils (O'Brien, Markiewicz-Keszycka and Herron, 2023; Niu *et al.,* 2025). This means the application of cattle to an outdoor environment has the potential to either benefit or degrade the habitats and populations with which they interact. In order to enable farmers and countryside managers to use cattle effectively while mitigating their detrimental effects. extensive research and understanding of the drivers of their impacts is required. Many studies have researched their behaviour, dung distribution, impacts on biodiversity and sward composition (Whistance *et al.,* 2011; Eldridge, *et al.*, 2016; Rivero *et al.,* 2021 and Menegazzi *et al.,* 2026). The findings of these studies conflicted in their methodological approaches and contrasting outcomes. This necessitates further research to discover the trends in cattle behaviour and their implications for the environment to address this gap in research. This study aims to investigate how cattle behaviour during a 48-hour grazing period drives the changes of vegetation structure, nutrient distribution, and biodiversity in pasture systems.

2.0 Literature Review

2.1 Importance of ecosystems

As an island, space is limited in the UK and therefore this requires efficient utilisation of space to fulfil the housing, industrial and food requirements of the expanding population. According to the Office for National Statistics (2023), developed areas of the UK occupy around 8% of land use. While this seems like a small percentage of land use it does not include the area for roads. In order to feed this population and maintain export trade, land used for agriculture covers 69% of the UK (DEFRA, 2024). This means the total area left for wildlife and natural habitats is just 23% and with the development and expansion of industrial areas, this is likely to decrease. The natural world and the urban one are considered quite separate and, these statistics highlight the need for integration between the two because as development continues, nature will be pushed into the smallest corners and to its limits. The effects of habitat reductions are already being felt across the UK and according to the State of Nature Partnership in 2023, there has been up to a 54% loss of distribution and diversity across all taxa (species) in the UK since the 1970s. This further shows the limits to which nature is being subjected and the losses to biodiversity which are occurring as a result.

Commonly ecosystems that are thought of are marine, freshwater environments, forests and grasslands (Young *et al.,* 2025). These are some of the oldest and wildest types of habitats and ecosystems but with the population increase, these areas becoming scarcer. This means we have to adapt, finding habitats and solutions where nature and mankind can co-exist with both having their needs met. The ecosystem of farmland is a composite of habitats ranging from water bodies, grasslands, woodlands and hedgerows (Clough, Kirchweger and Kantelhardt, 2020). This shows that there can be room for nature while still being productive for human requirements. However, with the expansion of intensive farming, these habitats are being removed to make room for more cropland (Clough, Kirchweger and Kantelhardt, 2020). This not only means the loss of habitats and landscape connectivity but has also resulted in the loss of farmland specialists, which have adapted to live alongside agricultural practices (Šálek *et al.,* 2020). Therefore, even the species who have adapted to humanities presence are pushed out of the habitats we created for them.

Some agricultural practices are attempting to reintegrate nature and traditional practices back into agriculture. These include conservation and regenerative agriculture. Conservation agriculture attempts to use cover cropping, reduced tillage and crop rotations to improve soils, water quality and reduce greenhouse emissions (Mandal *et al.,* 2025). These conservation practices mainly focus on crop related agriculture however; regenerative agricultural practises encourage mixed farming. the definition of regenerative agriculture slightly varies between sources. Berthon *et al.* (2025) describe them as using livestock, minimising soil disturbance, maintaining soil covering, year-round rooting and generally increasing diversity. Whereas Fenster *et al*. (2021) suggest they should be limiting tilling, no bare ground, increasing crop diversity, using livestock, stopping the use of chemicals and maximising farm outputs. While all these goals are practical and would be beneficial for increasing sustainability, on many farms the discrepancies between principles for the practices are slightly inconsistent making it harder for the general public and farmers planning to implement these systems to understand the goals. The similarities between regenerative and conservation agriculture are both of these practices are based on the sustainable development goals set by the UN with the intentions of protecting the soils and utilising livestock (Fenster *et al.,* 2021; Mandal *et al.,* 2025; Congreves, 2025). This means both practices were developed with the intention of increasing sustainability in farming while still providing food for the population. If these practices could be implemented globally in an economically viable way, they could take the pressure off natural systems and reduce the degenerative effects of farming. However, implementing

regenerative or conservation practices can produce varying results depending on the context of the farm on which they are implemented (Berthon *et al.,* 2025). This highlights the requirement of more research into how farming practices are affecting the environment, as only with that understanding can more sustainable practices be developed and implemented.

2.2 Ecosystem Engineers

Ecosystem engineers are species which have a significant effect on their environment directly through expressing their natural behaviours and indirectly as a result of those behaviours (Derner *et al*., 2009)**.** This means organisms can manage the local habitats in positive ways such as increasing habitat heterogeneity or improving abiotic conditions like carbon sequestration or nutrient distribution (Derner *et al*., 2009; Badano Marquet and Cavieres, 2010; Niu *et al.,* 2025)**.** As a result, other species have more opportunities for exploitation through habitat diversity or modified nutrient availability (Badano, Marquet and Cavieres, 2010). The changes ecosystem engineers make to an environment, create more niches to exploit for a wider range of species, allowing for increased biodiversity. However, these impacts are not always beneficial to other species for example dominating similar species or over exploiting local habitats (Badano, Marquet and Cavieres, 2010, Muehleisen *et al*., 2023). This means other organisms could be pushed out through lack of available resources due to the over colonisation of a single species. Therefore, ecosystem engineers can have positive and negative impacts on their habitats and other organisms, which can contribute to their local population continuation or local decline.

Through the animal kingdom there are many examples of different ecosystem engineers who modify their habitat and influence other species in a variety of different ways. The most popular examples of an ecosystem engineer are beavers, whose natural foraging and dam building behaviours influence the flow of water, woodland density and create habitat for other organisms (Brazier *et al.*, 2021). The loss of beavers 400 years ago was profoundly felt and meant both human beings and wild species were impacted by the consequences. The resulting Flooding, dense woodlands, lack of dead wood and habitat uniformity meant a loss of biodiversity (Brazier *et al.,* 2021). This highlights the requirement and importance of ecosystem engineers; they act as the foundational blocks for ecosystem stability and without them, other species including human beings begin to struggle. Some ecosystem engineers such as large predators, exert influence over the environment through their presence and hunting behaviour, this is called top-down control (Dobson, 2014). A famous case of this is the reintroduction of wolves to Yellowstone national park, where the wolves changed the behaviour of large herbivoures and controlled their populations, in turn allowing for natural regeneration of vegetation (Dobson, 2014). This shows the changes made by ecosystem engineers is not always directly caused by their actions, which can indirectly cause wider change to the ecosystem. However, when the ecosystem engineer is not native to a region, their effects can be detrimental to the environment to which they were introduced. An example of this are invasive signal crayfish. Their ability to adapt has meant they can translocate around the globe and has also meant they can dominate other species using the same niches as them (Mathers *et al.,* 2016). Their natural behaviours which make them ecosystem engineers include the suppression of algal matts and reduction of detritus (Mathers *et al.,* 2016). However, their abilities to craft extensive river bank burrows displacing large amount of sediment can destabilise river bank integrity (Faller *et al.,* 2016). Therefore, showing that the actions of ecosystem engineers are not always positive and can be detrimental to their environment and other species.

2.3 Intermediate Disturbance Hypothesis

One of the corroborating hypotheses supporting ecosystem engineers is the intermediate disturbance hypothesis. This hypothesis suggests that an ecosystem with too little or too much

disturbance will plateau in diversity. This is either because there is too much disturbance and species cannot recuperate before the next event or the lack in disturbance allows dominating species to take over (Mougi, 2024). However, some researchers suggest this hypothesis is unfounded suggesting this is an over simplification of the complex drivers behind species diversity (Fox, 2013). This suggests that ecosystems and the drivers behind ecological change are complex and shift in reaction to different events and to suggest that intermediate disturbance is the only driver, lacks scientific reasoning and is dismissing other areas to be researched. Blanchette and Menge, (2026) agree with Fox, (2013) as they disagree with intermediate disturbance causing a hump curve (a peak in diversity after disturbance) in diversity. However, Blanchette and Menge, (2026) research on coastal disturbance found that moderate disturbance did increase species diversity. This provides evidence in favour of the intermediate disturbance hypothesis with practical scientific evidence to support it.

Shea, Roxburgh and Rauschert, (2004), found in their comprehensive review of literature that the hump curve was supported by evidence however they stated that it was mainly seen in species at the bottom of the food chain. Additionally, Shea, Roxburgh and Rauschert, (2004), align with Fox, (2013) in that there are more complex nuances behind disturbance ecology but suggest~~s~~ that this culminates into the intermediate disturbance hypothesis being accurate. This suggests that ecosystems are evolutionarily designed to be disturbed allowing for other species to gain a momentary advantage over more dominating species, creating balance and species diversity. This underlines the role of many ecosystem engineers who cause disturbance, such as elephants knocking over trees or beavers causing flooding (Brazier *et al.,* 2021; Trepel *et al.,* 2026); demonstrating the need for ecosystems to be disturbed and the necessity of ecosystem engineers to drive that disturbance. In summary this suggests the need for more research into which organisms are ecosystem engineers, what they are engineering and how they are received by their environments and other species.

2.4 Large Herbivores as Ecosystem Engineers

A variety of large herbivores have been defined as ecosystem engineers as their size and grazing behaviours have significant impacts on soil and vegetation (Derner *et al*., 2009)**.** Global examples of this include elephants influencing woodland composition by pushing over trees or rhinos keeping grasslands short which mitigates the spread of wildfires (Trepel *et al.,* 2026). This shows the essential and profound effects large herbivores can have on their environments through their size and feeding behaviours. In the UK, the only large herbivore in the wild is the red deer which function as engineers for predominantly woody areas, specialising in seed dispersal (Garcia *et al.,* 2025). However, without management from predators or countryside workers their engineering abilities have become negative, with them over defoliating woodland and impairing the replanting efforts of conservationists with their browsing (Dobson, 2014; Garcia *et al.,* 2025). This demonstrates that ecosystem engineers which are native and adapted to an environment, can move from being beneficial to their ecosystem to detrimental without management. The loss of fundamental parts of the ecosystems has both directly and indirectly contributed to the loss of biodiversity (Pringle *et al.,* 2023). This means there is a gap in ecosystem functions required for long-term suitability and ecological longevity.

In 2025 there were over 9 million cattle in the UK (DEFRA, 2026). This means as one of the largest and most abundant herbivores in the UK, it is important to understand their roles in the ecosystem and the quantifiable differences they can make if they are used effectively. Cattle have been characterised as ecosystem engineers because of the impacts they have on vegetation heterogeneity and their ability to distribute large amount of nutrients (Derner *et al*., 2009)**.** Their behaviour affects botanical species composition through disturbance of tall vegetation and provides nutrients to the

soil through faecal distribution. However, cattle can also have negative impacts on their environment through mismanagement (Dettenmaier *et al*., 2017). Cattle contribute to high levels of phosphate and nitrogen in soils, leading to runoff and impacts on grassland or aquatic biodiversity (O'Brien, Markiewicz-Keszycka and Herron, 2023). Their actions have also been linked to soil compaction and excessive removal of vegetation which limit carbon sequestration (Niu *et al.,* 2025). This means cattle behaviour can have negative effects on soil health, biodiversity and water ways if their grazing is mismanaged.

In order to create guidelines for good conservation minded grazing, it must be understood how to mitigate the negative impacts of cattle. This can be done through being able to quantify their effects on a paddock and the behaviours driving those effects. Research suggests that cattle selection of location to defecate or graze is not random but is individual preference (Whistance *et al.,* 2011; Gabrieli and Malkinson, 2025). This means that there may be some degree of variability of results between different individuals and herds as each may have their own preferences. However, there are some behaviours which will be similar between herds. Some studies suggest feeding spots are selected based on sward height, and some studies suggest behaviour is driven by shade/water seeking behaviour (Díaz Falú *et al.,* 2014; Rivero *et al.,* 2021). This means the spatial ecology of cattle is driven by paddock quality and homeostasis requirements rather than individual preference. These are the behaviours which need to be quantified in order to establish behavioural trends for uniform application of cattle in conservation and agriculture.

2.5 Behavioural ecology of cattle

The behaviour of animals is frequently surveyed using ethogram studies which involve cataloguing behaviours at intervals (Rousing and Wemelsfelder, 2006). However, it is suggested that as these behaviours are not standardised and can be surveyed by researchers of varying experiences, that they are subject to bias (Zhou *et al,* 2025). This means that scientific opinions may vary between surveyors particularly those with previous experience with that species. The mostly commonly used behaviours for cattle during an ethogram study include lying, standing, grazing, mounting, fighting, social grooming, allo grooming, drinking, urination or defecation (Rousing and Wemelsfelder, 2006 and Zhou *et al*, 2025). For definitions of these behaviours see Table 1 (Appendix 1). These behaviour studies can include depth methodologies with detailed descriptions of the behaviours being monitored. For example, Zhou *et al.* (2025) listed four different descriptors for how the cattle were moving (cantering, running, walking and trotting). Rousing and Wemelsfelder. (2006) included four different descriptors for the fighting behaviours of cattle plus the reaction of the non-aggressing cow. Detailed methods for these studies are quite labour intensive; are subject to interpretation and the usefulness all depends on the research objective of researchers' respective studies.

In order to understand trends in cattle behaviour, the driving factors behind these behaviours must also be understood. The behaviour of cattle can be influenced by many factors including breed, age, climate and season (Sahu, Parganiha and Pati, 2020). This can complicate a behavioural study through creating uncertainty around the driving factors of those behaviours. It can also make it challenging attempting to identify trends in cattle behaviour as what might have been true for one herd, may not be the case for another. McIntosh *et al*. (2023) compiled evidence about the behaviour of different cattle breeds noting that particularly in the UK, cattle's genetics are selected for their marbling and yield rather than their environmental adaption hence the phase out of traditional and better adapted breeds which yield less. This is corroborated by Berry, Wall and Pryce, (2014) whose meta-analysis found that cattle genetics were selected for meat and milk production over fertility and environmental adaption. This can mean that cattle's reactions to abiotic stimuli can

vary significantly due to genetic selection for larger meat size and more milk yield and not for resilience to temperature or weather.

The spatial ecology of cattle meaning how they use an area, can vary highly and is an important factor to consider when studying their behaviour. Raynor *et al.* (2021) suggests that cattle's spatial patterns are based on topography, availability of water, stocking density and quality of vegetation. Understanding how cattle will use their environment based on what will attract or repel them can help build predictive trends on how they will utilise an environment before introduction. In a previous research paper by Wallis de Vries and Daleboudt, (1994) they suggest cattle select grazing patches to complete a daily intake requirement, not actively avoiding areas of subpar forage. However, a more recent paper by Woodward, Parsons and Kirk, (2008) counters this finding that cattle are trying to fill their daily requirements but selection of bad foraging is only performed when looking for better forage. This showed a higher foraging rate with increased walking and trampling in search for grazing patches. The most recent paper Woodward, Parsons and Kirk, (2008) is more relevant however the research by Wallis de Vries and Daleboudt, (1994) is considered here because the two papers illustrate the differences in cattle behaviour when introduced into different environments. Wallis de Vries and Daleboudt, (1994) studied the behaviour of cattle on low input grassland which is relevant to the behaviour of cattle in a extensive conservation grazing regime. In contrast, Woodward, Parsons and Kirk, (2008) grazed cattle in a high input pasture which is similar to the practises of many conventional farms. These papers highlight the importance of considering the context of the space cattle are grazing, as the cows will modify their behaviours to best utilise their environment. They illustrate the need for more research in a wider range of environments as not every farm is the same and the grazing regime required will be different. If the cattle adapt their spatial ecology to suit an environment, then finding the trends for each environment and the overall similarities in their behaviours will be the key to maximising the grazing potential of cattle.

Many behavioural studies use a variety of methodologies to ensure accuracy and reproducibility. Some studies such as Hou *et al.* (2023) and Ninomiya, (2019) found reasonable accuracy in a time efficient manner by using instantaneous visual scans every ten minutes. However, research by Manfrè *et al*. (2024), found that this method was less accurate than their methodology of using continuous scanning (gathering data without intermission). The continuous scanning methodology is however considerably labour intensive and strenuous for the surveyor. Some research has also suggested that not conducting a full 24 hour a day study limits findings (Wark, Wierzal and Cronin, 2021).Instead, it only takes into account what the animals were doing during the 60 second interval - every ten minutes, which does not capture the full scope of the animal's behaviour (Wark, Wierzal and Cronin, 2021). While instantaneous behavioural studies do not capture the full spectrum of behaviours at all times of the day, they do however not require camera equipment or intensive analysis. Also, if the purpose of a study does not require capturing the full spectrum of behaviour, then focusing on cattle's diurnal behaviour in which they are most active and mostly inactive at night, may be sufficient (Thomas *et al.,* 2025). This means that monitoring and analysing behaviour overnight provides only marginal insight into answering a research objective and adds additional labour, analysis and equipment.

2.6 Behaviour of Heat Stressed Cattle

Cattle modify their behaviour when experiencing heat stress, with some studies finding that the cattle increase water consumption while decreasing grazing, social behaviours and self-grooming (Idris *et al.,* 2024). Other sources have found that cattle decrease lying behaviours in favour of standing in order to regulate body temperature (Leliveld *et al.,* 2022). These studies also suggest that during the hottest periods of the day, cattle will exhibit water and shade seeking behaviours. If

cattle favour, these areas this means that walking between them would increase trampling and focusing grazing around the areas with water and shade. Tonooka, Vasseur and Villettaz Robichaud, (2022) research linked increased water consumption with the cattle's increased bowel movements during periods of heat stress. Although there is no evidence to suggest that this is an intentional behaviour such as to reduce the chance of constipation. This is corroborated by Zoroaster *et al*. (2026), who suggested that the increase in water consumption is a thermoregulatory behaviour replacing the fluids lost from heat stress. Zoroaster *et al*. (2026), further investigated water consumption finding that cattle struggling with heat stress sometimes decreased water intake or increased it even more, linking this to various supplements such as niacin or betaine. This suggests that supplements and medications are an important factor to consider, as this artificially altered the cattle's behaviour outside their normal parameters. This should be considered when observing behaviour in cattle, to avoid bias through artificially driving behaviours in an unnatural direction.

Some research has suggested that heat stress affects other cattle behaviours such as feeding. Sahu, Parganiha and Pati, (2020) found in their literature review that heat stress does not affect grazing. In contrast, the findings of Idris *et al.* (2024) found that there was a significant decrease in grazing behaviours during heat stress. These conflicting results suggest there may be a secondary reason for differing behaviours which could range from paddock quality to cattle breed or age (Sahu, Parganiha and Pati, 2020; Menegazzi *et al*., 2026). differences in cattle behavioural study results, poses an issue for farmers, researchers and planners as it creates uncertainty in expected outcomes or cattle requirements during stressful events. As a result, further research is needed to provide more solid trends in cattle behaviour, especially during climate fluctuation as these are likely to become more common.

2.7 Grazing impacts on vegetation and biodiversity

There is much debate regarding the positive and negative impacts of grazing, with the results and observations varying between sources. Huaranca, Novaro, and Valdivia, (2022) suggested that based on meta-analysis of livestock impact, that grazing does not have significant effect on species richness. whereas Eldridge, *et al*. (2016) found in their global meta-analysis, that grazing impacted both species and plant abundance. These sources therefore support the claim that livestock, negatively or neutrally impact an environment in terms of biodiversity and species richness. Whilst having no negative impact is not inherently bad, it does not assist with ecological decline in the countryside. However, Dettenmaier~~,~~ *et al.* (2017) argue~~s~~ that this is likely due to management of livestock focusing on meat yield rather than ecological impact. This means that environments are being exploited for maximum energy extraction for livestock with little regard to ecological resilience and other species. This is corroborated by Török *et al* (2024) who found that when the correctly selected livestock are managed well, can be improved biodiversity. While farmers do have to keep yield and profit margins in mind, having a more rigorous grazing regime which is adapted to their site can be more beneficial both to them and biodiversity.

One of the larger challenges of regenerative and conservation agriculture is that there is no one size fits all methodology, for implementing ecologically minded yet profitable grazing. Dettenmaier *et al.* (2017) and Török *et al.* (2024) suggest that cattle and their management have to be selected based on the context of the site rather than for maximum production in order to mitigate ecological damage. This can be challenging as every farm is different both geographically and in terms of management styles. Pulley *et al*. (2021) found biodiversity was not significantly affected by cattle with stocking densities of 1 cow per hectare. This is an ideal example of conservation grazing, minimising the harmful effects of the cattle by having very few cattle on the land. Pulley *et al*. (2021) stated this stocking density is on par with the recommended stocking density of DEFRA (2018). This

means based on their research, 1 cow per hectare is the ideal carry capacity of most landscapes in England. However, Uberoi, (2024) in a document for the House of Commons found that herd sizes are increasing as farm sizes increase, with small holdings getting priced out. This means cattle herds are getting bigger, with larger farms capitalising on small holdings not being able to compete with their higher stocking densities. If stocking densities increase is it vital to research and quantify the future effects of larger herds, in order to be able to mitigate the negative effects on different landscapes.

Sward height (length of pasture grass) (AHDB, 2021), is a key to understanding cattle behaviour and how this will impact their environment. Some studies suggest that if the sward is of good quality and taller, then the cattle will feed less frequently (Menegazzi *et al.,* 2026). This means that the cattle's nutritional requirements will be met without over grazing the paddock. Menegazzi *et al.* (2026) also suggests that the regrowth of plants will be quicker if there is a higher amount of residual grass remaining after the grazing period. This would mean that when the cattle returned, there would be enough forage to meet their requirements without supplementary feeding or over grazing. However, research also suggests that cattle will actively avoid longer sward because of the increased digestion requirements versus the decreased nutritional reward (Clausecker *et al.,* 2025). The cattle's behaviour directly affects sward heterogeneity which in turn will affect species composition (Clausecker *et al.,* 2025). This is an example of how cattle can engineer a paddock through their behaviour both directly and indirectly. In summary, these studies found that sward height and biodiversity were less affected if paddock conditions were long and of quality. The gap in research here is being able to quantify what makes a quality paddock for each breed and suits the local environment.

Methods of Surveying sward height include using a rising plate meter – a plate on a stick which compresses the sward to measure height (Genever, 2017). This is an easier paddock-based survey which can be undertaken by farmers as a proxy for biomass, as a rising plate meter only estimates biomass while biomass testing calculates biomass accurately by taking cuttings but requires testing in a laboratory (Villalobos-Villalobos and WingChing-Jones, 2023). The rising plate is a less destructive, cheaper and less time-consuming method of calculating biomass, though it is only an estimate and not an accurate reading. Some research has however found that the rising plate meter's accuracy depends on calibration, species composition of sward, management (i.e. seeding and fertilising) and the rising plate is not suitable for all habitats (Mack *et al.,* 2023). This must be kept in mind when designing an experiment with a rising plate meter as while using it maybe be cost and labour effective, if mishandled can introduce bias and produce inaccurate data.

Some research suggests that the distribution of dung across paddocks can provide additional data on how cattle use paddocks. Yoshitoshi *et al* (2016), found that dung distribution is not random and unpredictable, in fact it will likely be concentrated around shaded areas, and water troughs. This suggests that faecal distribution is based on the cattle distribution and activity. Understanding how cattle distribute nutrients is important because cattle faeces are high in organic nutrients such as phosphate and nitrogen (O'Brien, Markiewicz-Keszycka and Herron, 2023). This is relevant because if the cattle are focusing their behaviours on certain areas of the paddock which maybe where faeces are distributed, nutrients in these areas will be disproportionate to the rest of the paddock. If the cattle have areas of preferred grazing this will in turn affect where they defecated as they tend to avoid grazing around their faeces (Whistance *et al*., 2011). As a result, this could create hotspots of high nitrogen and phosphate, which means not only will these areas be less grazed they will also be higher in organic nutrients due to the faeces. Based on this it can be assumed that areas with more faecal distribution will be less grazed, and have more areas of remaining tall vegetation.

2.8 Literature conclusions and gaps in research

Section 2.0 has concluded that ecosystems are struggling under increasing pressure from conventional agricultural practices, which has resulted in loss of habitats and biodiversity decline. This highlights the need for adaption in land management and agricultural systems to create balanced food production with ecological resilience. The cited evidence of the review suggests that ecosystem engineers play fundamental roles in maintaining ecosystem functions, these organisms create habitat heterogeneity and niches for other species exploitation through ecological disturbance. Large herbivores represent an important and often wide-spread function which contribute to long term ecological resilience. Some research has given evidence suggesting that cattle can be ecosystem engineers which can be effectively used as part of a regenerative or conservation agricultural system. These sources cite the cattle ability to influence vegetation structure, nutrient distribution and biodiversity either directly through their behaviour and spatial ecology, or indirectly as result of their behaviours. However, the literature also reveals considerable uncertainty regarding the magnitude and consistency of these effects. Compilation of these studies revealed that outcomes can vary according to stocking density, paddock characteristics, cattle breeds, seasonality, environmental conditions and management practices. Furthermore, while numerous studies have investigated cattle behaviour in conjunction with a few aspects of their impacts, relatively few have attempted to compile the directly linked behavioural patterns and comprehensive study of the direct impacts to an environment into one study. The direct impacts of cattle presence include grazing and herd distribution affecting sward height, vegetation heterogeneity and biodiversity, dung deposition which may indirectly affect nutrient deposition and invertebrate populations. This represents a significant knowledge gap, particularly as the use of cattle in regenerative agriculture and biodiversity-focused land management continues to increase. Creating a reproducible methodology which can quantify the effects comprehensively could result in the development of a large-scale meta-analysis which might allow farmers to apply their grazing regimes which fit with the context of their properties. Therefore, this study aims to quantify cattle behaviour and its influence on sward height, vegetation heterogeneity, biodiversity and nutrient distribution within a grazed paddock. This would contribute to a better understanding of how cattle can be managed as ecosystem engineers to support both agricultural productivity and ecological sustainability.

3.0 Methods

3.1. Research Aim

The aim of this study was to quantify and understand the direct impacts cattle can have on a 1-hectare paddock within 48 hours of introduction.

3.2 Research Hypothesis

Behavioural time budget - H1: The proportion of time cattle spend performing different behaviours differs according to time of day.

Herd distribution - H1: Herd distribution is associated with time of day and paddock location.

Dung distribution - H1: The distribution of dung differs between paddock zones.

Sward height - H1: Cattle significantly reduce sward height through grazing and trampling.

Biodiversity - H1: Plant community composition differs before and after grazing.

Behaviour–vegetation linkage - H1: Changes to vegetation is correlated to the measurement variation in dung area.

3.3 Study Design and Ethical Considerations

It was expected that the cattle's grazing behaviour would impact vegetation heterogeneity and biodiversity. This was examined through preliminary surveys to establish baselines for comparison (Berthon *et al*., 2025), and behavioural study was used to observe how and why cattle were using certain areas of the paddock (Rousing and Wemelsfelder, 2006; Zhou *et al.*, 2025). Finally post surveys were used to measure the direct changes the cattle had made to the paddocks. This would be implemented by repeating the original surveys as well as undertaking a survey for dung distribution (Yoshitoshi *et al*., 2016). This would provide a baseline for comparison, data on behavioural drivers of change and quantifiable results on how the cattle directly affected their environment and how that have impacted wider diversity.

The ethics for this project was approved by the ethics committee of Harper Adams University which included no contact with the cattle and not interrupting their routines as laid out by the Harper Farm grazing regime. While there are methods of gaining more accurate data for spatial movements such as using GPS collars, the AWC (2022), states various welfare implications to using these collars such as skin irritation. Based on this, it was decided that conducting a purely observational survey for behaviour was more ethical as it would avoid affecting the cattle physically and potentially altering their behaviour. Additionally, there was no physical interactions between the researcher and the cattle as this would potentially put the researcher at risk, violating the risk assessment and would cause disturbance to the cattle which would breach the ethical agreement for this study. the risk assessment can be seen in the Appendix 1. Any interactions between the cattle and the researcher or research equipment i.e. GPS collars, could impact the cattle's behaviour resulting in biased data, this will be discussed further in section 5.5.

3.4 Study Site

The study was conducted on Harper Farm at the Hinks fields located near Telford, Shropshire (52°44'40" N, 2°26'10.60" W). The Hinks fields constitute 21 paddocks with permanent pasture (Figure 1). The paddocks are currently grazed by 46 Holstein x Angus x Blue cattle on a 42-day rotation. This site was selected because compared to the other two herds of similarly aged cattle (around 1 year) it was most appropriate for reproducible analysis. Each paddock was separated by electric fencing to prevent movement outside the assigned paddock (see Figure 9 for image of the

cattle behind the electric fencing). The Bailey Hill herd was not selected for this experiment because the paddocks are seeded with a mixed sward meaning the species composition is artificial and can vary highly between sites and year of establishment. The Bailey Hill herd of around 30 Holstein x Angus X Blue cattle are slightly younger than the yearling cattle in the Hinks, these cattle are beginning puberty and displayed more hormonally driven behaviours such as mounting. This would add challenges and bias, making it harder to analyse natural behaviour of the cattle and their effects on their environment, along with reproducibility of this study. The Cottage herd was not used for this study because the herd comprised of 20 individuals which was deemed to be a small sample size for cattle behaviour. The Cottage herd which is made up of 20 post weaning Holstein x Angus X Blue cattle, displayed inquisitive behaviour exploring their environment while staying together as a group. Also, as these cattle are quite young, they are also supplementary fed meaning they would not be exerting their total potential for grazing pressure. Additionally, these cattle are on a forward grazing regime meaning instead of being moved between separate paddocks, the next paddock is opened while the access to the previous paddock remains. This was deemed inappropriate as it did not allow for individual paddock impact data as the cattle were free to remain in any section for unlimited amounts of time. This would mean there would be no replicates of this study for comparison, affecting reproducibility and analysis.

The current study was conducted in June 2026 which aligned with an amber heat warning in Shropshire (Met Office, 2026 A). Many studies have suggested this could impact cattle behaviour, for example, heat stressed cattle may spend less time lying down (Leliveld *et al.,* 2022). However, given the time constraints and potential for study of how cattle's reaction to environment stresses impact their behaviour and in turn impact their paddock, it was considered appropriate to continue with the study despite the heat wave.



Figure 1 - Image taken from Google Earth Pro and annotated to illustrate the boundary of The Hinks' site (red lines) and the surveyed paddocks (yellow lines).

3.5 Pre-grazing surveys

The pre grazing surveys for this study were conducted on the 22nd of June 2026. Preliminary surveys are necessary as they provide a baseline for the direct impacts of cattle on the paddocks (Berthon *et al*., 2025). In order to establish a baseline, vegetation was mapped, measured with a rising plate and surveyed for heterogeneity and biodiversity. This allowed for a study of conditions before cattle interference allowing for the calculation of significant change in vegetation composition.

Biodiversity of paddock species is an important baseline variable to measure because not only may cattle directly influence species richness but they may indirectly affect invertebrate life through reduced food availability (Shea, Roxburgh and Rauschert, 2004; Beynon *et al.,* 2012). Biodiversity was surveyed using a transect survey which followed the parameter of the paddock and cutting across the paddock in both directions diagonally. This method was considered to be the most time efficient while still surveying a reasonable and evenly distributed area of the paddock.

Sward height was calculated using a rising plate or plate meter which compresses grass and calculates height (Genever, 2017). This was useful for before and after comparisons as it indicated how much the cattle impacted vegetation through grazing and trampling. A rising plate meter survey is usually performed by walking a transect around a paddock in a W shape (Mack *et al.,* 2023). However, the methodology for this survey was based on the methods used by the Harper farm staff: taking readings every ten steps in a single diagonal line across each paddock. Since this method is already in effect in this paddock and time efficient, it was considered the most appropriate for the study.

To support the rising plate readings and biodiversity results, the vegetation heterogeneity was also mapped. This was done by measuring areas of tall or short vegetation as well as areas of bare ground. This allowed researchers to be able to quantify the impacts cattle can have on a grassland within 48 hours.

3.6 Behavioural observations

The behavioural studies for project started at 12pm on the 23rd of June 2026 until the 29th of June 2026. In order to gain an idea of how the cattle were using the paddocks, their behaviours were studied using an ethogram (see Table 1). Ethogram studies are a standardised method to research species specific behaviours at predetermined intervals for selected periods of time (Vivas and Vilanova, 2026). This allows researchers to be able to calculate the cattle's daily time activity budget. For the purposes of this study it allowed for insights into what areas the cattle were using more frequently, which would contribute to soil compaction and vegetation trampling. This also allowed for observations to be made on where the cattle were grazing, providing insight into which areas may have been more heavily grazed and perspective on why they focused on these areas such as shade coverage. Some researchers use the methodology of recording behaviours every ten minutes for one minute (e.g. reading taken at 12:09, 12:19, 12:29 etc) (Ninomiya, 2019; Wark, Wierzal and Cronin, 2021; Hou *et al.,* 2023). This allows for a balance between accurate behavioural readings without being labour intensive. This aligned with the requirements for this study, meaning it was the most appropriate methodology for the behavioural portion of the surveys. Using this method meant that results were taken every ten minutes (12:00, 12:09, 12:19 etc) for one minute between 12:09 to 12:10. This meant that 13 behavioural observations were taken during each survey.

The behaviour observations were conducted three times a day, recording eleven behaviours including lying, walking, standing, grazing, mounting, fighting, social grooming, allo grooming, drinking, urination or defecation (Rousing and Wemelsfelder, 2006 and Zhou *et al*, 2025). These were selected due to the ability to determine how the cattle were spending their time interacting

with each other and their environment. The definitions of their behaviours can be seen in Table 1. Additionally, data on herd distribution was also collected while recording behavioural data to ascertain if the time of day impacts social connection. An example of the herd being 'together' can be seen in Figure 9 in section 5.1. An example of the cattle being 'spread out' can be seen in Figure 10 in section 5.2. Some studies on captive animals conduct readings around feeding times (Greeson *et al.*, 2022). However, since the cattle in this study were grazed without supplementary feeding it was decided that the readings would be conducted at 6am-8am, 12pm to 2pm and 6pm-8pm, this allowed for even distribution throughout the daylight hours. Cattle have been found to react to temperatures changing their behaviours (Leliveld *et al.,* 2022). This meant taking readings before temperature increased (6am), while temperatures were high (12pm) and when temperatures started to cool (6pm) reflecting the cattle's reactions to changes in temperature. Due to this study's ethogram timings being built around temperature, the shade use of cattle was also recorded alongside the behavioural data. This was done to detail if the cattle were displaying heat stress through shade seeking behaviour. The amount of shade increased throughout the day, with none available at 6am and up to three quarters of the paddock being shaded by 8pm.

During the behavioural study when the ethogram data was collected, the data for environmental temperature at the time was also taken, using a generic (no brand or model number) soil and water probe. While this probe is designed for soil and water readings it contains a NTC thermistor sensor which can measure air temperature. The product was selected and tested to ensure it was fit for purpose by the laboratory technicians at Harper Adams. Temperature readings were taken to provide insight into environmental factors which might have influenced cattle behaviour. Additionally, the readings from the probe were cross referenced with up to date (refreshed every ten minutes when the readings were taken) temperature readings from the Met Office (Met Office, 2026 B). This was done in order to mitigate any skewed readings, though the Met Office and probe were aligned the majority of the time. Originally the plan for the temperature data was to statistically compare temperature to the behaviour and spatial data. However, researchers such as Beltran and Tarwater, (2024) and Quinn *et al.* (2021) argued that temperature is continuous numerical and suggest that it should instead be used as an interpretive covariant; therefore, it was decided not to statistically analyse temperature for this study. The study's main focus is the direct impact of cattle behaviour on their environment therefore it was felt statistical analysis of temperature would weaken the statistical power of testing and distract from the main hypothesis. Based on this, temperature was used for the interpretation and understanding of one of the drivers behind cattle behaviour.

Table 1 - The 11 cattle behaviours recording during this project's behavioural ethogram study and the definitions of those behaviours

Behaviour	Definition
Walking/running	Cattle were moving at the data collection interval
Standing	Cattle were standing still, not engaging in any other behaviour
Mounting	Cattle were engaging in a position associated with mating (climbing onto other cows back) either to engage in mating behaviour or as a show of dominance
Grazing	Cattle were actively biting or chewing vegetation
Urination	Cattle were urinating at the data collection interval
Defecation	Cattle were defecating at the data collection interval

Self-grooming	Cattle were licking and scratching themselves or rubbing themselves against an inanimate object
Allogrooming	Cattle were licking, rubbing against or scratching one another to groom each other
Drinking	Cattle were consuming water from the available source
Fighting	Cattle were chasing, butting heads, kicking or pushing each other in an aggressive manor
Lying	Cattle were lying on the ground at the time of data collection

3.7 Post-grazing surveys

The post grazing surveys for this project were carried out the same day as the cattle were removed from each paddock, this happened on the 25th, 27th and 29th of June 2026. The paddocks were resurveyed after the cattle had been moved onto the next paddock, the cattle were moved between 10am to 1pm. This was undertaken to assess how the cattle's behaviour had impacted the paddock. Surveys for biodiversity, vegetation heterogeneity, sward height and measurements of bare ground were taken with the same methodology as the pre cattle introduction surveys (refer to section 3.5).

Additionally mapping of dung distribution was carried out as corroborating data as to how the cattle used the paddock. The faeces were mapped using a Garmin Etrek 20 GPS system as it provided the most accurate coordinates for faecal location. The Garmin manual states that this system has been 3-10metres accuracy for the waypoints (Garmin Ltd, 2015), this was tested by Fator and Zomrawi, (2015) which confirmed that the Garmin systems usually have accuracy of around 3 metres. The faeces were mapped by walking right to left across the paddocks. The map of dung distribution across the three paddocks was made using QGIS 4.0.3-Norrköping and can be seen in Figure 7.

Measurements of 50 manure piles per paddock were taken with a reading of width x length. These readings were taken randomly across the paddock while collecting the dung distribution data. The measurements included the faecal spread from trampling or the mild rainfall which occurred once over night during the survey period. There were only a few piles which appeared to not be fresh (i.e. done before the surveying period), these were not included in the study.

3.8 Statistical analysis

All statistical tests were run with RStudio 2026.07.0+139 ("Pacific Dogwood").

Statistically significant results are those which produced a P value of $P < 0.05$ (Andrade, 2019).

This study was conducted outdoors, surveying biological and abiotic factors such as weather and animal unpredictability could influence results (Filazzola and Cahill, 2021). To maximise repeatability while remaining labour-efficient, three adjacent paddocks were used as replicates, following recommendations that three replicates provide sufficient power while limiting resource use (Vaux, Fidler and Cumming, 2012).

Behavioural data was analysed in two components: activity across the day and herd distribution across paddock zones. Herd distribution was tested using a Chi-square test because the data were categorical and the hypothesis concerned associations. A contingency table was developed from the Chi-square results to confirm test assumptions, after which Cramér's V quantified association strength as a post hoc. Proportion tests were used to express behavioural allocation, and time-budget data were also assessed with Pearson's Chi-square (McHugh, 2013).

Dung distribution was mapped by dividing each paddock into top, middle and bottom sections and analysing counts in Fiji/ImageJ. Percent coverage and proportional distribution were calculated for

each zone. Dung distribution across top/middle/bottom was tested using the Friedman test due to non-independence and non-normality (Beasley and Zumbo, 2003), with Holm-adjusted Wilcoxon tests for pairwise comparisons. Left–right comparisons used Wilcoxon tests because of small, paired samples (McKnight and Najab, 2010). Dung-pile size (area) was analysed using Kruskal–Wallis due to skewed, independent data, followed by Holm-adjusted Wilcoxon tests (McKnight and Najab, 2010). Percentage paddock coverage by dung was estimated from pile counts and area calculations.

Changes in sward height were tested using Welch's t-test because the data were continuous, paired within paddocks, and non-normal according to Shapiro–Wilk tests (Delacre, Lakens and Leys, 2017). Vegetation structure was analysed using proportional composition (Quinn *et al.,* 2021) and percentage change calculations, appropriate given the absence of within-paddock replicates.

Biodiversity data were multivariate presence–absence values, unsuitable for ANOVA or t-tests. A PERMANOVA based on Jaccard similarity was used (Anderson, 2012), requiring conversion of presence/absence to 0/1. An NMDS ordination assessed Jaccard distances, and betadisper tested homogeneity of dispersion (Liu *et al.,* 2019).

Finally, Spearman's correlation tested relationships between sward height and dung-size variation because both datasets were non-normal and non-parametric (Eden and Shepherd, 2021).

4.0 Results

4.1. Vegetation

In the pre grazing biodiversity survey across the three paddocks, there were paddock 1- 29, paddock 2- 26 and paddock 3 - 21 species, and after grazing there were 21, 20 and 21 species respectively. Not all the species present in the post surveys were recorded in the pre grazing surveys such as bladder champion which was found in paddock 2 after grazing. All grass species which were present in the pre grazing surveys were still present after grazing. Species such as chickweed which were present in all paddocks before grazing was not recorded after grazing. The results from the biodiversity survey analysed with the PERMANOVA test were ($F = 2.08$, $R^2 = 0.34$, $p=0.10$). This result demonstrates that there was 34% variation between pre and post grazing species abundance but that the results were not significant. Non-metric Multidimensional Scaling (NMDS) results showed low stress (0.098), indicating that the two-dimensional ordination was an accurate representation of the underlying Jaccard distance matrix. Stress values below 0.10 are generally considered to reflect a good fit, meaning that the multivariate structure of the species-composition data was reliably captured. The betadisper test results (average distances 0.2660 vs 0.2445) showed that homogeneity was accurate and the PERMANOVA test results reflect differences in community composition. Based on these results, the null hypothesis that there was no difference in species composition before or after grazing, was accepted. The results can be seen in Table 2 (Species turnover table).

Table 2 Botanical species turnover table showing the lost species (meaning they were not found in the post grazing survey), gain meaning they were not present in the pre grazing survey, or unchanged meaning the species had continued presence or no recorded presence

Species	**Paddock 1 Changes**	**Paddock 2 Changes**	**Paddock 3 Changes**
Nettles (*Urtica dioica*)	Unchanged	Unchanged	Unchanged
Purple Moor Grass (*Molinia caerulea*)	Unchanged	Unchanged	Unchanged
Poa (*Poa spp.)*	Unchanged	Unchanged	Unchanged
Greater Willow Herb (*Epilobium hirsutum*)	Unchanged	Lost	Lost
Creeping Thistle (*Cirsium arvense*)	Unchanged	Unchanged	Gained
Hairy Willow Herb (*Epilobium parviflorum*)	Gained	Gained	Gained
Oak (*Quercus robur*)	Unchanged	Lost	Unchanged
Hawthorn (*Crataegus monogyna*)	Unchanged	Unchanged	Gained
Wood Avens (*Geum urbanum*)	Unchanged	Unchanged	Lost
Curly Doc (*Rumex crispus)*	Unchanged	Lost	Unchanged
Chick Weed (*Stellaria media)*	Lost	Lost	Lost
Spiny Sow Thistle (*Sonchus asper)*	Lost	Lost	Unchanged

Ground Ivy *(Glechoma hederacea)*	Unchanged	Unchanged	Unchanged
Timothy *(Phleum pratense)*	Unchanged	Unchanged	Unchanged
Bitter Doc (*Rumex obtusifolius)*	Lost	Lost	Unchanged
Yorkshire Fog (*Holcus lanatus)*	Unchanged	Unchanged	Unchanged
Meadow Foxtail (*Alopecurus pratensis*)	Lost	Unchanged	Gained
Clover (*Trifolium repens)*	Unchanged	Unchanged	Unchanged
Lamb's Quarter (*Chenopodium album)*	Lost	Unchanged	Unchanged
Thyme Leaf Speedwell (*Veronica serpyllifolia)*	Gained	Unchanged	Unchanged
Lesser Stitchwort (*Stellaria graminea)*	Unchanged	Lost	Lost
Creeping Buttercup (*Ranunculus repens)*	Unchanged	Unchanged	Unchanged
Perennial Rye Grass (*Lolium perenne*)	Unchanged	Unchanged	Unchanged
Spear Thistle (*Cirsium vulgare)*	Unchanged	Unchanged	Unchanged
Dandelion (*Taraxacum officinale)*	Unchanged	Unchanged	Unchanged
Hogweed (*Heracleum sphondylium)*	Unchanged	Unchanged	Lost
Wavy Bitter Cress (*Cardamine flexuose)*	Unchanged	Unchanged	Unchanged
Cock's Foot (*Dactylis glomerata)*	Unchanged	Unchanged	Unchanged
Clever (*Galium aparine)*	Unchanged	Unchanged	Lost
Prickly Lettuce (*Lactuca serriola)*	Lost	Unchanged	Unchanged
Dog's Mercury (*Mercurialis perennis)*	Unchanged	Gained	Gained
Silver Weed (*Potentilla anserina)*	Lost	Unchanged	Unchanged
Pineapple Weed (*Matricaria discoidea)*	Unchanged	Unchanged	Unchanged
Garlic Mustard (*Alliaria petiolate)*	Lost	Unchanged	Unchanged
Sticky Mouse Ear (*Cerastium glomeratum)*	Lost	Unchanged	Unchanged
Ivy Leaf Speedwell (*Veronica hederifolia)*	Gained	Unchanged	Unchanged
Bladder Champion (*Silene vulgaris)*	Unchanged	Gained	Unchanged

Ash (*Fraxinus excelsior)*	Unchanged	Unchanged	Gained
Ivy (*Hedera helix)*	Unchanged	Unchanged	Gained
Marsh Foxtail (*Alopecurus geniculatus)*	Lost	Unchanged	Unchanged

Sward height decreased substantially following grazing across all three paddocks**.** Mean sward height before grazing was 38.2 cm in paddock 1, 41.5 cm in paddock 2 and 36.9 cm in paddock 3, reducing to 18.4 cm, 22.1 cm and 17.8 cm respectively after grazing. A Shapiro–Wilk test indicated non-normality (p = 0.034), requiring a Welch's t-test to be used. All three paddocks showed statistically significant reductions in sward height (paddock 1: p = 0.001, paddock 2: p = 0.002, paddock 3, p = 0.001), with mean decreases of 19.8 cm, 19.4 cm and 19.1 cm. These results demonstrate a significant difference in sward height before and after grazing. Based on this, the null hypothesis that grazing does not affect sward height was rejected. The results can be seen in Figure 2.

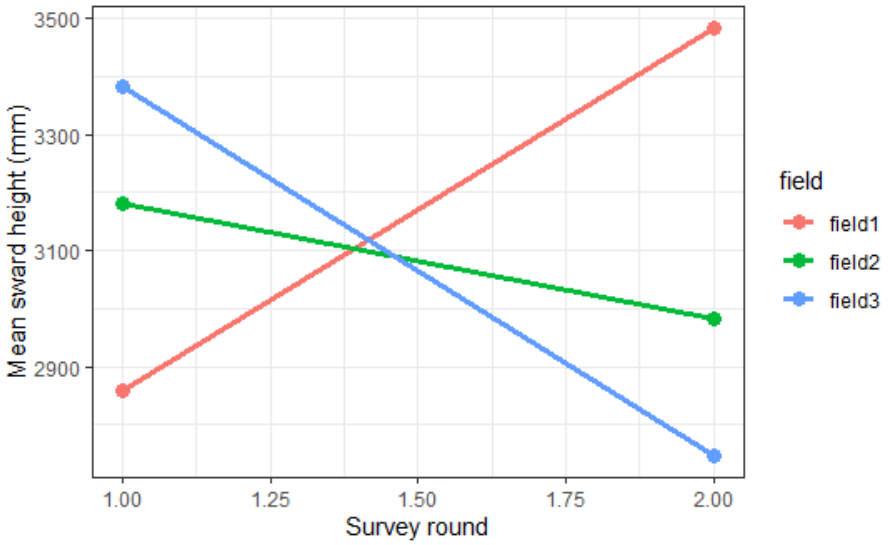


Figure 2 - – line graph representing the results of the rising plate meter surveys for fields 1,2 and 3 before and after grazing measuring sward height.

The composition of the paddocks changed significantly after grazing. Before grazing, tall vegetation dominated with 90.1-96.1% paddock coverage, while short vegetation covered 2.6-8.1% and bare ground covered only 1.2-1.8% of the paddocks. After grazing, these numbers changed to short vegetation taking up the majority of the paddocks increasing by 1080-3350%. Bare ground coverage also increased by 60-237% while tall vegetation area shrank by 95.2-99.5%. The results can be seen in Table 3 and Figure 3.

Table 3 - The composition of bare ground, tall grass and short grass before and after grazing across the three paddocks

Paddock	Habitat type	Before (ha)	After (ha)	Change (ha)	% Change
1	Tall vegetation	0.9250	0.0445	−0.8805	−95.2%
1	Short vegetation	0.0581	0.9120	+0.8539	+1470%
1	Bare ground	0.0172	0.0363	+0.0191	+111%
2	Tall vegetation	0.9007	0.0073	−0.8934	−99.2%
2	Short vegetation	0.0817	0.9645	+0.8828	+1080%
2	Bare ground	0.0176	0.0282	+0.0106	+60%
3	Tall vegetation	0.9378	0.0359	−0.9019	−96.2%
3	Short vegetation	0.0267	0.9225	+0.8958	+3350%
3	Bare ground	0.0123	0.0416	+0.0293	+237%

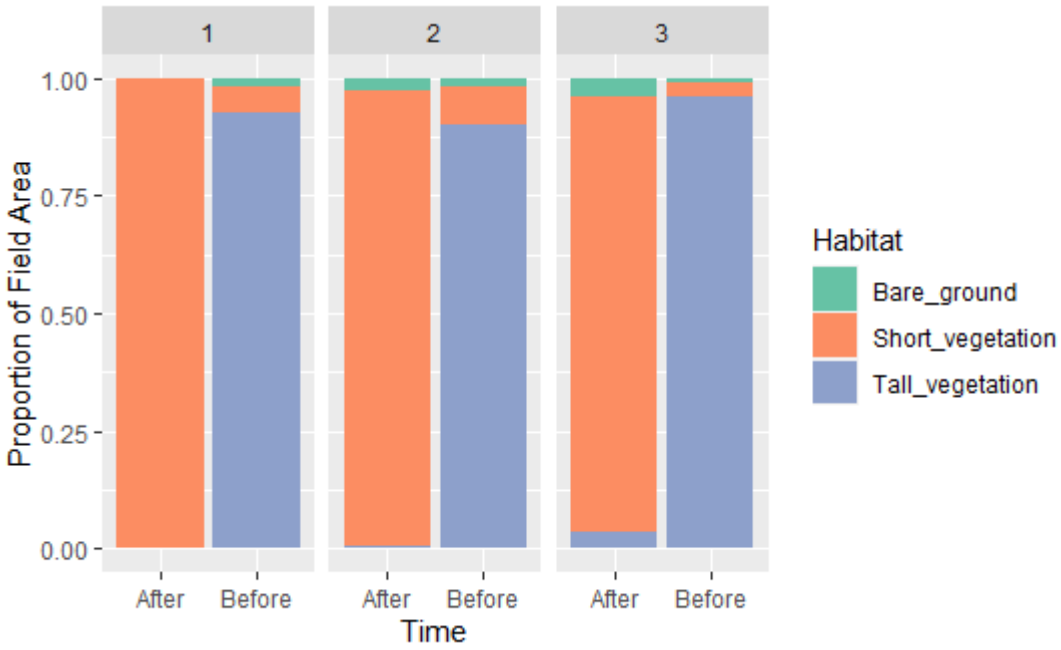


Figure 3 - grouped bar chart showing the changes to vegetation composition (short/tall grass and bare ground) before and after grazing.

4.2. Behavioural patterns

The location vs herd distribution vs time of day was analysed with two separate Chi-Square tests the investigated time ($\chi^2 = 17.14$, $p = 0.000189$) and the second addressed location ($\chi^2 = 17.14$, $p = 0.0001897$) both had a strong association with herd distribution. The corroborating results for the strength of the associations were tested with the Cramer's V post hoc testing, this test classifies a small association is 0.10, medium effect of 0.30 and a large effect size of 0.50+. This produced a

result of a large effect for Location (V = 0.5948) and a medium effect for Time (V = 0.2706). The contingency tables for herd distribution vs location and herd distribution vs time can be seen in Tables 4 and 5. The contingency tables illustrate a behavioural pattern of spending more time together and in the top end of the paddock at 6am and 6pm while usually being spread out when in the middle of the paddock at any time of day. This was reaffirmed by the portion analysis which also showed that cattle were together in mornings and evenings while spread out in the afternoons. Based on this, the null hypothesis that herd distribution is independent of time and location was rejected. The results can be seen in Figure 4.

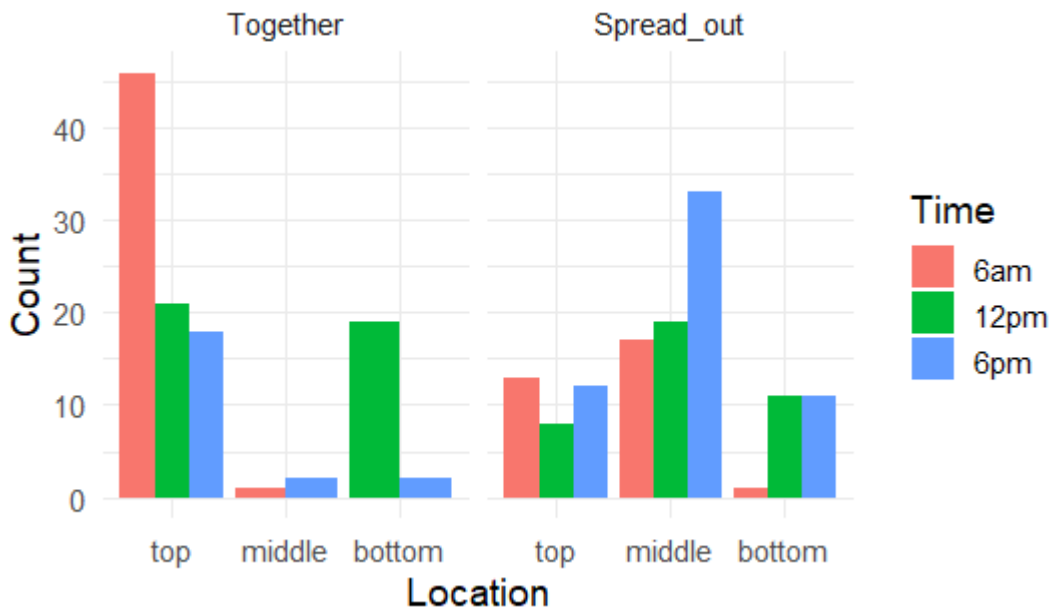


Figure 4 - grouped bar chart displaying the herd distribution of cattle at different times of the day and in different sections of the paddock.

Table 4 -Chi-square contingency table demonstrating the comparisons between herd distribution (together vs spread out) and location in field (top, middle or bottom of the paddock).

Location In Paddock	**Together**	**Spread Out**
Top	0.72033898	0.27966102
Middle	0.04166667	0.95833333
Bottom	0.47727273	0.52272727

Table 5 - Chi-square contingency table demonstrating the comparisons between herd distribution (together vs spread out) and time of day (6am, 12pm and 6pm).

Time of Day	Together	Spread out
6am	0.6025641	0.3974359
12pm	0.5128205	0.4871795
6pm	0.2820513	0.7179487

The data for the behavioural study resulted in 10764 data points with 3588 data points per time period. The proportional test showed that the cattle spent the majority of the time at 6am lying down (6am -2707, 12pm – 433, 6pm- 736) and at the other two-time intervals they spent their time

grazing (6am -1, 12pm – 1533, 6pm- 1598). The cattle walked or ran most at 12pm and 6pm (6am - 163, 12pm -471 and 6pm - 577) and spent more time drinking water at these times as well (6am - 19, 12pm - 59 and 6pm - 68). The results for shade usage were in shade (6am – 186, 12pm – 904 and 6pm – 1134) vs out of shade (6am – 3402, 12pm – 2684 and 6pm – 2454). The behaviour were analysed with a Pearson's Chi Square test which was found to be significant (X=831.47, df = 2, p-=2.2e-16). The results indicate that shade use is dependent on time of day. The Cramer's V result of V=0.2779314, means there was a moderate effect between shade and time of day. Based on this, the null hypothesis that shade use is independent of time was rejected. The results can be seen in Figures 5 and 6.

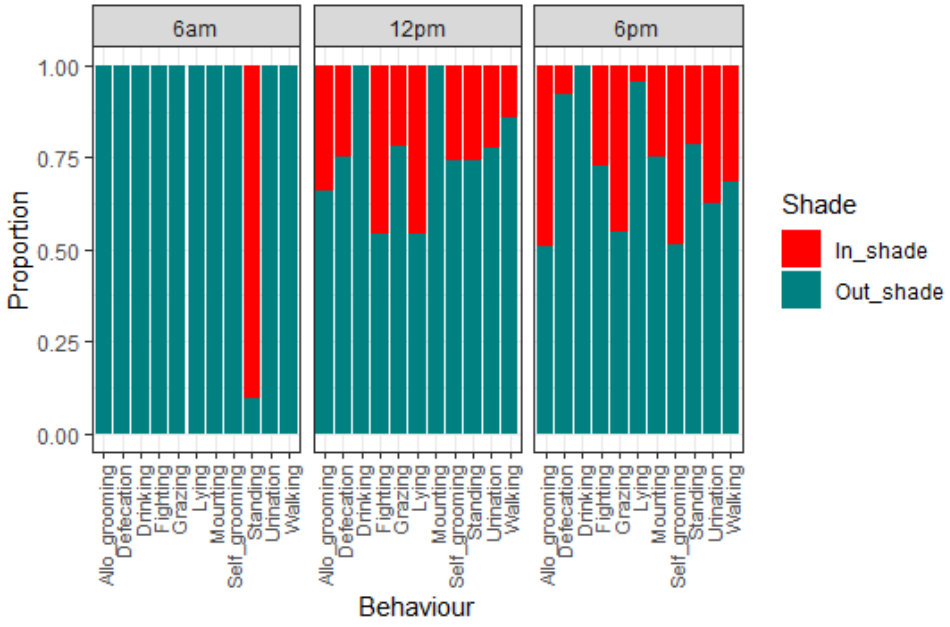


Figure 5 - Stacked bar chart representing eleven cattle behaviours and the proportion of these behaviours observed in and out of the shade.

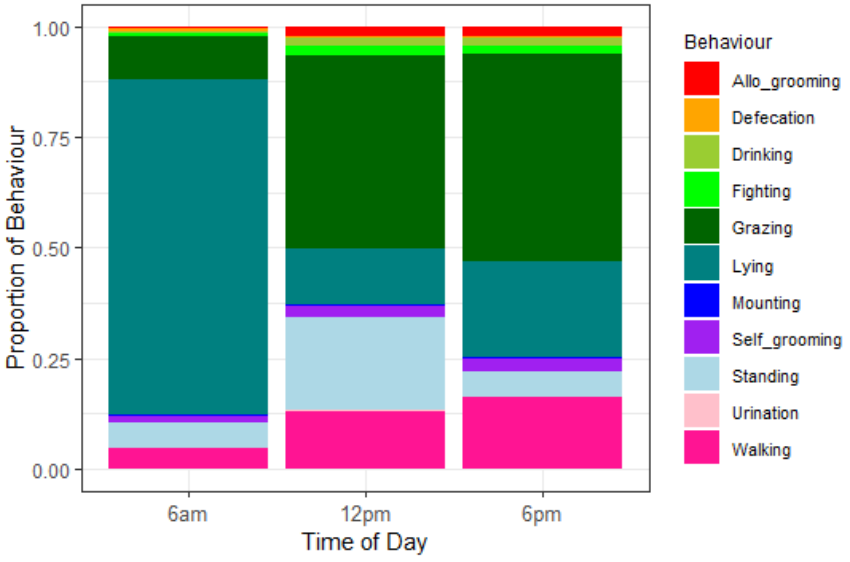


Figure 6 - Stacked bar chart showing the time budget of eleven behaviours of cattle at three different times of day.

As discussed in section 3.6 temperature was not statistically analysed instead it was used as an interpretive covariant. Temperature readings taken during the behavioural study totalled 234 readings (78 readings per time period). The results from the probe and Met Office averaged out to 19.2°C at 6am-8am, 28.3°C at 12pm-2pm and 26.4°C at 6pm-8pm. The temperatures at 6am-8am ranged from 13°C to 25°C. The temperatures at 12pm-2pm ranged from 20°C to 36°C. The temperatures at 6pm-8pm ranged from 18°C to 34°C.

4.3. Dung Distribution

A total of 3087 dung piles were recorded after cattle were removed from the paddocks. The results from the total number of dung piles across each of the three paddocks were paddock 1-1021, paddock 2 – 982 and paddock 3 - 1084. The raw data shows a visual difference with the top of the paddocks having around 500 dung piles and the bottom of the paddock having around 200 piles. Since the data from this survey was skewed, from a small sample size, dependent and non-parametric, a Friedman test was used to analyse the data. Despite the raw data suggesting otherwise, the Friedman test found there was no significant difference between the top, middle and bottom of the paddock (0.04979). The results of the post hoc Wilcoxon signed-rank tests (Holm-adjusted) were also not significant (p=0.75) with no difference between the sections. The Wilcoxon signed-rank test for right vs left dung distribution comparisons was also insignificant (p=0.75). This is consistent with the raw data as apart from paddock 1, there was an even distribution between right and left sides of the paddock. While not significant there was variation in the standard deviation (SD) and mean dung piles varied across the different zones. The map of dung distribution can be seen in Figure 7. The top had an SD of 40, middle = 104, bottom = 21, left= 102.8 and right =84. The mean dung piles across the paddocks were Top = 472 piles, Middle = 358.7 piles, Bottom = 198.3 piles, right = 545.7 piles and left = 483.3 dung piles. While not significant, descriptively these show the middle zone had the most variation across the paddocks while the bottom was most consistent. The heat map of mean dung distribution can be seen in Figure 8. Based on these tests, the null hypothesis that there was no difference in dung distribution between any sections was accepted.

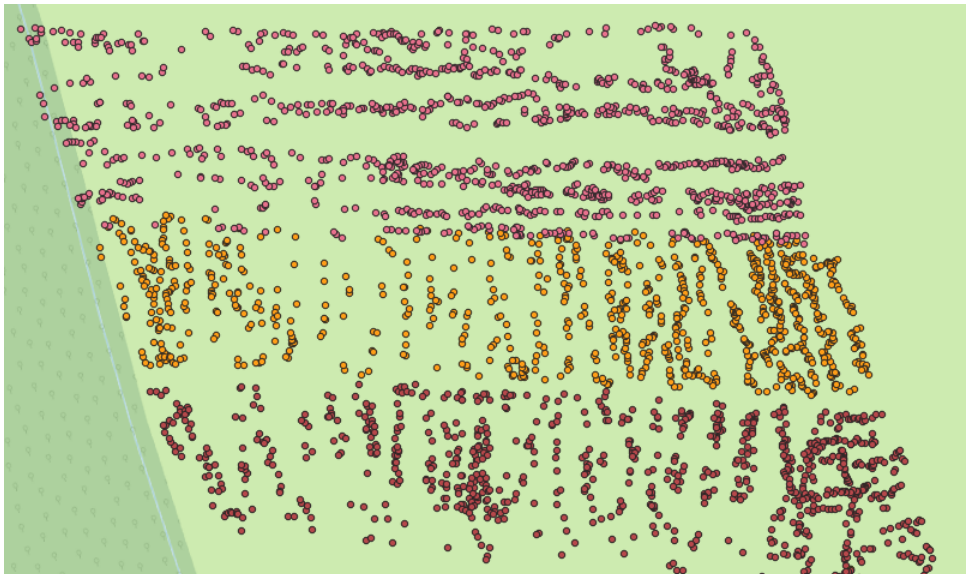


Figure 7 - Dung distribution map created using the raw data points from all three paddocks, red dots (paddock 1), yellow dots (paddock 2), pink dots (paddock 3).

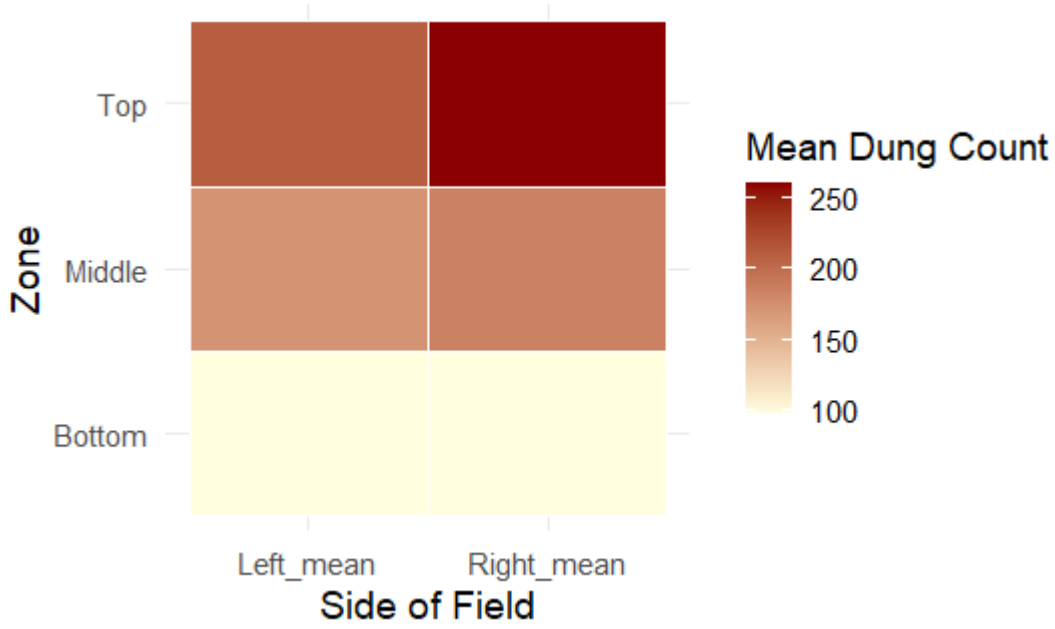


Figure 8 - Heat map of the mean dung distribution across the three paddocks divided into right vs left and top, middle and bottom of the paddocks.

5.0 Discussion

5.1. Cattle Behaviour

The aim of this study was to quantify and understand the direct impacts cattle by linking their behaviour to effects on their environment. The results of this study showed that cattle behaviour was driven by time, temperature and location. Leliveld *et al.* (2022) and Díaz Falú *et al.* (2014) suggest that the most grazing and movement will occur during cooling periods of the day which did occur during this study (Figure 9). The movement seen in this study was likely shade and water seeking behaviour, as the shade and water were located at opposite ends of the paddock. The results of this study align with the results from Schütz Cox and Tucker (2014), which observed shade seeking and water seeking behaviours of cattle, finding that cattle spent more time in shade when more shade was available (more shade was available from 6pm in this study) and that less anti-social behaviour would be observed when there was more shade available. This likely confirms that the cattle had modified their behaviour to adapt to stress from high temperature, exerting more trampling and grazing pressure on the paddock later in the day. The figures for this behaviour can be seen in Figures 5 and 6.



Figure 9 - Image showing the clustering of cattle in the shade between 12pm and 2pm

The total dung distribution in this study across all three paddocks showed that while not significantly different in the individual paddocks, there was a difference between dung distribution in the top and bottom of the paddock. This can be aligned to research by Idris *et al.* (2024) and Whistance *et al*. (2011) who similarly to this study, investigated the behaviour of heat stressed cattle. They suggest that the cattle faeces would have increased viscosity along with this the cattle will display increased movements which directly aligns with this study as the cattle frequently moved around the paddocks. This is explained through the behavioural data in this study as despite the high temperatures, the cattle spent more time out of the shade (in the middle and top of the paddock) than in the shade (at the bottom of the paddock), walking around and standing. This means that the faecal distribution of cattle was concentrated around where the water was located (top of paddock) and where they spent the most time walking (middle of paddock) avoiding their resting area when possible. This confirms that dung distribution is not random but is driven by behaviour.

Building upon the above-mentioned distribution of dung across the paddock, another trend which is important to study is how much faeces is being distributed in 48 hours. The cattle in this study only defecated 1021, 982 and 1084 (20 - 22 times in 48 hours). Some research from Tonooka, Vasseur and Villettaz Robichaud, (2022), found that the cows would spread manure around 36 times in 48 hours. This meant the cattle for this study only defecated 60% compared to other research predictions. The results of this study also conflict with other studies which suggest that if the cattle were experiencing heat stress, their effluent elimination would have increased due to more water content in faeces and increased movement (Whistance *et al.,* 2011; Ninomiya, 2019; Tonooka, Vasseur and Villettaz Robichaud, 2022). Therefore, the number of dung piles surveyed for this study is likely higher than if the cattle had not been heat stressed, which would be even lower than the results of other studies. This suggests that the difference in defecation seen from these results are likely due to factors such as the outdoor environment, pasture feeding or Holstein cross Angus or Blue breed. Based on this, further study would require repeating this study with a wide selection of cattle breeds and pasture types.

5.2. Biodiversity Implications

The results of this study were to examine whether rigorously managed cattle like these at Harper Farm had a significantly negative or positive effect on sward height, biodiversity and vegetation heterogeneity. The results of the biodiversity survey were not significant; demonstrating that the grazing did not unbalance species richness though there was a 34% change in species composition. This means there was a slight change in paddock 1 and 2. It was speculated that cattle can have a negative effect on biodiversity (Eldridge *et al*., 2016). However, the results of this study align with Huaranca, Novaro and Valdivia (2022) who found that cattle had a neutral effect on biodiversity. The differences the cattle made to vegetation heterogeneity and sward height were significant, completely changing the composition within the paddocks (90%) and decreasing the sward height by 19cm consistently. When considering that these changes occurred but biodiversity was not significantly affected, this suggests an underlying cause. In section 2.4 Dettenmaier *et al.* (2017) suggested well managed and correctly selecting cattle breed will mitigate biodiversity impacts. In relation to this study, it means that the strict grazing management done by Harper Farm was successful. The regime of short grazing periods per paddock and 42 days gap between grazing sessions allowing for regrowth, successfully mitigated short term impacts of cattle trampling and grazing.

The changes to sward height and vegetation heterogeneity mentioned above would lead to an assumption that there would be a change to biodiversity, which in the case of this study there was not any significant change requiring a species-specific analysis. Other research which also observed changes to sward height suggested that species richness is dependent on species composition, particularly in low grazing intensity paddocks where greater variability will be maintained among grazing tolerant species (Arévalo *et al.,* 2026). Species such as *Poa spp*. (meadow grass), *Lolium perenne* (perennial ryegrass), *Holcus lanatus* (Yorkshire fog), *Trifolium repens* (white clover), *Ranunculus repens* (creeping buttercup) which were found during this study are grazing tolerant (Pakeman, 2004). These species were all found before and after grazing, supporting that they are grazing tolerant and explain why biodiversity was maintained despite grazing pressure. Pakeman (2004) also found that some species could take advantage of the disturbance caused by grazing allowing for their growth. While not mentioned in their study specifically, species like *Silene vulgaris* (bladder champion), *Fraxinus excelsior* (ash) and *Veronica serpyllifolia and Veronica hederifolia* (varieties of speedwell) were only found after grazing in this study which could be explained through increased opportunities from disturbance of sward height and thinning of dominant species.

Many of the patches of tall vegetation which remained after grazing were composed of species such as spear thistle and nettles. See figures 10 and 11 for images of the cattle avoiding these plants. Gabrieli and Malkinson, (2025) found that the cattle in their study actually showed feeding preference to species such as thistle though their study did make comparisons to earlier and later in the grazing season, finding these preferences came later in the season. While Gabrieli and Malkinson, (2025) did not define what date early in the season was, they did reference the abundance of other vegetation which was the case of this study (research was conducted in June) when vegetation was abundant. This could suggest that the vegetation mosaic created by the cattle was not only driven by heat stress or preference for certain species of food, but also for species avoidance for food selection. This could also mean that the mosaic created by the cattle could also be different later in the grazing season when the species composition and grass quality changes. However, Pauler *et al.* (2020), suggested this could be feeding preference based on the cattle breed, their study found that the Angus x Holstein cattle selected for production actively avoided species such as thistles. This may also be possible as not only did the cattle in this study avoid grazing on

these plants, they also avoided trampling them suggesting their aversion to these plants is more than seasonal feeding aversion.



Figure 10 - Image showing the herd distribution of cattle in the sun during 12pm to 2pm, avoiding patches of nettles and thistles



Figure 11 Image of singular cow grazing between 6pm and 8pm avoiding areas with thistles and nettles

This study found that the cattle clustered around the areas surrounding the water trough and tree line (See Figure 9 for image of cattle clustering under shade). These areas already consisted of bare ground from previous grazing intervals increased in the 48 hours of grazing during the study. The heat stress likely increased their shade and water seeking behaviour as found by Leliveld *et al*. (2022) and Idris *et al*. (2024). The results of this study found that cattle spend a lot of time in these areas or walking between the two during hot periods. As a direct impact of this, the total area of

bare ground in each paddock increased from 123.36m², 172m² and 176.24m² (471.6m² total) to 282m², 363.28m² and 415.58m² (1060.86m²). This is a 125% increase in bare ground cover, aligning with the research from Venter, Hawkins and Cramer (2018) and Eldridge *et al.* (2016) who found that bare patches increase where cattle frequent due to trampling and grazing. This highlights the negative implications of grazing as cattle require shade and water so these impacts are difficult to mitigate but are a direct result of their presence and behaviour. This indirectly has implications for biodiversity if there is more bare ground there is less vegetation and subsequently less species (Venter, Hawkins and Cramer, 2018). This shows that grazing and trampling could impact botanical biodiversity but in the case of this study, the bare ground did not expand enough to impact biodiversity significantly. However, the effects of grazing and trampling are amplified when the ground is wet, causing increased expansion of bare ground areas (Donovan and Monaghan, 2021). This means that the negative impacts of grazing and trampling were potentially mitigated by the heat wave drying the soil. The results of this study may have shown more of an expansion of bare ground if the conditions had been wet and the soil was saturated. This would suggest the need for further research involving the repetition of this study during a variety of weathers.

5.3. Intermediate Disturbance Hypothesis

The debate over the intermediate disturbance hypothesis mentioned in section 2.2 of the literature review is continued here. The discussion over the hump curve theory as to whether diversity peaked directly after disturbance was investigated in this study and by other researchers. The diversity results from this study show either a drop in species visible or no change to the number of species visible. This is not consistent with the requirements for a peak in diversity or a hump curve however the biodiversity results for the post grazing survey were done the day the cattle were moved to the new paddock. This does not allow time for regrowth however it did allow other species such as Bladder Champion to become visible. The results of this study are more consistent with the findings of Blanchette and Menge, (2026) and Fox, (2013) who disagreed with the hump curve theory. However, it could be speculated that if a third survey was conducted after a short period of time which would allow for regrowth the results would perhaps be closer to the findings of Shea, Roxburgh and Rauschert, (2004) who found that species at the bottom of the food chain (in this case plants) would peak in diversity. However, this is purely speculative as the results of Török *et al* (2024), with Huaranca, Novaro and Valdivia, (2022) and Eldridge, *et al*, (2016) all had different results for the effects of cattle on short- and long-term biodiversity. This does not reflect positively in the favour of the hump curve theory; however, the cattle were last in the paddock 42 days before the surveys for this study and botanical diversity reached 29 species in the first paddock. While this is not extremely diverse it does demonstrate that diversity increases before the next cattle rotation.

5.4. Cattle as Ecosystem Engineers

While not the focus of this study, one of the surveyed elements of an ecosystem engineer is the impact these species have indirectly on other species (Derner *et al*., 2009)**.** The cattle's aversion to species such as thistles and nettles benefits species such as butterflies, bees and hoverflies as a host plant and food source (Buglife, 2020; Royal Horticultural Society, 2024). This shows that the cattle's avoidance behaviours benefitted pollinators during the summer season by not trampling or eating the thistles and nettles, leaving them for other species to use as a food source or host. However, some research has found that trampling, reduction in sward height, soil compaction and changes to habitat mosaic reduced snail populations (Boschi and Baur, 2006). This shows that the changes the cattle also made during this study because of their behaviour such as reduction of sward height and significantly altering the habitat mosaic may have negative effects on the invertebrate population.

This study examined the distribution and amount of faeces deposited across the paddocks with around 1000 piles being scattered across the paddock. It is important to consider the indirect effects this might have on biodiversity. The researcher observed there were large abundance of invertebrates such as beetles and flies clustered around the manure piles. This aligns with the data from other invertebrate focused studies. Cattle manure has been found to benefit invertebrate species such as beetles, earthworms and several species of flies acting as a food source for adults and larvae (Beynon *et al.,* 2012). This shows that the cattle's dung does not only benefit the botanical populations but also the invertebrate species by providing a food source. However, medications such as anthelmintics (dewormers) and several homeopathic alternatives which are used in cattle have been shown to have negative effects on many invertebrate species by directly poisoning invertebrates, decreasing attractiveness of manure or decreasing decomposition (Cooke, Morgan and Dungait, 2017). While this is not a naturally occurring problem and is a result of human intervention, it is done for the sake of animal welfare. According to the staff at Harper Farm this herd is treated only when there is a cause for concern such as a local spike in infection cases. This is more sustainable method of preventative treatment however, this does highlight an issue using cattle as a replacement ecosystem engineer, as the welfare of the cattle must always be kept in mind. However, using chemical or medications which cause environmental damage defies the rules of regenerative agriculture which stipulates against their use (Fenster *et al*., 2021). As a result, while using their medications can be beneficial for animal welfare and maintaining productivity, in terms of regenerative or conservation practises using chemicals which have been linked to actively causing declines in biodiversity can be counterproductive.

As discussed in section 2.2, whether cattle can be defined as ecosystem engineers and whether their impact is ultimately beneficial or negative, is somewhat debated. The results of this study showed that cattle exploited the paddocks to suit their needs as predicted by Schütz, Cox and Tucker, (2014) and Leliveld *et al.* (2022). This shows that the cattle used their environment to their own requirement which in this case was to maintain thermoregulation because of the heat wave. The raw data for this study shows that cattle deposited nutrients as they moved round the paddock to maintain thermoregulation which aligns with the theories from Idris *et al.* (2024) and Whistance *et al*. (2011). They suggested cattle move more when stressed from heat which is why the results were not significant statistically but did mean that manure was spread more evenly round the paddock. When compared against the ecosystem engineers mentioned in sections 2.2 and 2.4, this is similar to the effects of sea turtles, another ecosystem engineer who deposit nutrients in beaches through their nesting behaviours (Bouchard and Bjorndal, 2000). While a different mechanism of nutrient deposition, this aligns with a defined trait of ecosystem engineering. The cattle transformed the vegetation heterogeneity of all the paddocks reducing the height of vegetation but avoiding plants which were unsavoury to them and allowing for other species to take advantage of the changes. These seemingly destructive behaviours are similar to those of the other ecosystem engineers such as elephants or beavers which thin woodlands and cause flooding (Brazier *et al.,* 2021; Trepel *et al.,* 2026). While these engineers are based in woodlands and wetlands their destructive behaviours much like the cattle in this study create niches for other species to exploit (Derner *et al*., 2009)**.** This is one of the key definitions for an ecosystem engineer in which their behaviour directly and indirectly benefits other species.

However similar to the signal crayfish, the intensity of the cattle's activity had a detrimental effect (Faller *et al.,* 2016). This was seen in the expansion of bare ground in the paddock which while minor due to the heat drying the ground, could have been worse with heavier rain fall. This was the only significant result which could be considered negative meaning that, overall, with careful management, the cattle did have a profound impact on their paddocks aligning with the actions of

other ecosystem engineers. However, the other findings of this study support cattle being ecosystem engineers and their behaviours causing potentially positive or neutral impacts as a direct result of their presence such as changing vegetation heterogeneity, neutral impact on species richness and equal distribution of dung.

5.5. Methodological Reflections

The strengths of this study was the three phased approach providing a base line for cattle impacts, the behavioural study allowed for insight into behaviours which drove the changes and the in-depth post cattle surveys which attempted to quantify the cattle's impact. The rigorousness of the methodology for this study as well as lessons learnt from conducting it should mean that it is easily repeatable and can be improved upon. These surveys provided some statistically significant results for several tests allowing for insight into how the cattle change an environment within a short time frame. The rising plate surveys, biodiversity transect, dung distribution and vegetation mapping combined with the behavioural data provided insight into when the cattle were performing particular behaviour. The reliability of each individual result is supported by another dataset such as vegetation mapping support the rising plate meter results. This is further enhanced by linking behaviour with location, temperature and time of day helped to establish the drivers behind the behaviour which affected their environment directly.

There were several limitations with the methodology of this study which linked to time limitations, labour and equipment requirements. One limitation which was not considered in the experiment design was doing biomass testing as suggested by Villalobos-Villalobos and WingChing-Jones, (2023). This may have allowed for a more significant result from the statistical test comparing sward height to dung size variation, alongside providing more insight into quantifying the area cattle could distribute faeces across a 1-hectare paddock within 48 hours. Another limitation of this study would be the chosen sample size for dung size variation. It was estimated that cattle would only defecate five times a day (ten over 48 hours) so 50 faecal samples would have been 10%. However, based on the review by Tonooka, Vasseur and Villettaz Robichaud, (2022) who estimated that cattle distributed dung around 18 times a day (estimated 36 in 48 hours), 165 measurements per paddock would have been a more appropriate sample size. The sample size of 50 piles per paddock did produce some workable results however this insight will be useful for tailoring sample sizes for methodologies in future studies.

An error was made in the mapping of dung distribution which can be seen in Figure 7. The methodology for this study required walking left to right up the paddock but in the third paddock the surveyor walked up and down the paddock. However, this may actually have been a more effective method of mapping as it mimics the way the cattle were walking. The map reflects areas which were avoided at least for faecal distribution as there was less manure and areas where there was clustering, such as around the water source which had a slightly higher concentration of manure.

Some studies such as Rivero *et al.* (2021) and Bailey *et al*. (2018) found that using GPs collars on the cattle improved their spatial data as the collars would give continuous 24-hour data collection. This would allow for a greater understanding of how cattle were using their environment with higher accuracy at any time of the day. Some studies used cameras to monitor the behaviour of their animal subjects, stating that this also allows for 24-hour monitoring, removes the bias from subjects interacting with observers and observer bias (Huck and Watson, 2019). This study did experience some observer bias (see Figure 12) where on several occasions, 1 to 3 cows were observing the researcher; if this study used cameras as suggested by Huck and Watson, (2019), this may have been

avoided. However, both of these methods are costly, are subject to signal and battery life and result in a significant amount of data to analyse (Bailey *et al.,* 2018; Huck and Watson, 2019; Rivero *et al.,* 2021). If the labour time and equipment availability were amenable, cameras would improve the methodology of this study allowing for more accurate spatial and behavioural data collection, 24 hours a day with less bias.



Figure 12 - Image showing cattle majority of cattle lying down, while two cattle fight and two cattle stood observing the researcher.

6.0 Conclusion

The results of this study concluded that the cattle had a significant impact on their environment in every survey conducted including sward height, vegetation heterogeneity and nutrient distribution although there was a neutral influence regarding biodiversity and non-significance in site preference for faecal distribution. The shade and water seeking behaviours of the cattle aligned with previous research on the actions of heat stressed cattle which dictated how they used the paddocks. The consistency of cattle not significantly disrupting biodiversity and reducing sward height by 19cm across the three paddocks shows their actions can be quantified into trends linking with their behaviour. Repetition of this study with a variety of cattle breeds and different paddock types could allow for a large-scale meta-analysis which can be used as a concrete guideline for farmers building a sustainable grazing regime. This will mean farmers can maximise the use of their land without being disruptive to the environment.

While this study did not investigate whether the actions of cattle fit the hump curve associated with the intermediate disturbance hypothesis, it has provided evidence of whether cattle fit the definition of ecosystem engineers. This study found that cattle can have a profound effect on their habitat such as changes to vegetation heterogeneity and can have a destructive impact on bare ground expansion if mismanaged. However, they do have the ability to potentially benefit their environment similar to other named ecosystem engineers. This means cattle can be used as ecosystem engineers if managed appropriately.

6.1 Recommendations

To build on the findings, improvements could be made by repeating this study using more paddocks in order to gain a larger sample size per study. Additionally, more in-depth analysis could be made

using soil sampling, conducting biomass testing rather than using a rising plate meter and using camera/ GPS collars. This would allow for closer monitoring of cattle behaviour, paddock usage and the direct impacts on soil and sward change to be investigated. Along with investigating the direct impacts of cattle, this study could be expanded to quantify the indirect effects of cattle introduction such as surveying for invertebrate diversity changes. Finally, repeating this study at different times in the grazing season, in different paddock types and with different breeds would allow for more in depth results. This would allow for further data around how cattle's behaviour changes throughout the season and how different breeds react to different paddock types.

Based on the results of this study, the 48-hour grazing period per paddock provided a sustainable and non-degrading system with the stocking density. This meant there was minimal disturbance to biodiversity without over grazing. However, this study was conducted during a heat wave so the increase of bare ground was minimal. Repeating this study during a period of heavy rainfall would allow for data collection on how this grazing regime impacted the expansion of bare ground when the ground is saturated.

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Appendix

Harper Adams University — RISK ASSESSMENT TEMPLATE		**Likelihood** multiplied by **Severity** equals **Risk Rating**. NB: Calculated after taking in to account
School/Service/Department: postgraduate		
Details of Task/Activity/Area: Observations, measurements and cattle fields		
Assessed By: (Bethany Paddon)	Signature: BP	
Approved by: (Gemma Charlton)	Signature: G. Charlton	
Date of Assessment: (12/05/26)	Review Date:	
HAZARD	HOW IS PERSON AT RISK	

Severity / Likelihood	Insignifi-cant (1)	Minor (2)	Moder-ate (3)	Serious (4)	Fatal / Critical (5)
Almost Certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5
CONTROL MEASURES	RISK RATI	A	R	A	ACTI ON

			L	S	R		L	S	R		
Interactions with cattle The surveyor	Physical trauma and injury	The surveyor will maintain a distance from the cattle at all times, using binoculars when necessary. The surveyor will not make any attempt to interact with the cattle,	1	3	3						

		Observations will be made from the other side of the fence line when possible. If entering the paddock, the surveyor will have an escape route planned. The surveyor will bring a first aid kit and seek medical attention if required										
Interactions with insects The surveyor	Bites, stings and Lyme disease	The surveyor will bring insect repellent with them during the survey. The surveyor will keep legs, arms and ankles covered when in the field. The surveyor will check intermittently for ticks while surveying, the surveyor ill also thoroughly check after completion of each survey. The surveyor will monitor any bites or stings and seek treatment if required.	2	3	6							
Weather changes The surveyor	Heat stroke, sun stroke, hypothermia	The survey will bring appropriate clothing based on the weather forecast (hat, shoulder cover, coat, sunglasses). The surveyor will bring sunscreen and plenty of water. The surveyor will end the survey if conditions become unmanageable.	1	3	3							

		The surveyor will take breaks when necessary. The surveyor will seek medical attention if they become unwell.										
Slips, trips and falls The surveyor	Physical trauma and injury	The survey will wear appropriate clothing for the terrain (boots with grip and ankle support). The surveyor will be mindful of where they are walking during the survey. The surveyor will not attempt to enter areas where holes other hazards may not be visible due to long grass or other causes. The surveyor will not enter areas affected by wet weather or contain a body of water. The surveyor will bring a first aid kit and seek medical attention if required.	2	2	4							
Interactions with fences The surveyor	Mild electrocution, lacerations, tetanus	The surveyor will wear rubber bottomed boots The surveyor will not interact with fences and maintain a safe distance The surveyor will bring a first aid kit and seek medical attention if required	1	3	3							
Lone working The surveyor	Increased duration until	The surveyor will provide their location with a what three words code.	3	2	6							

	assistance can arrive	The surveyor will make regular check ins with staff. The surveyor will have a charged phone on hand in case of any incidents during the survey. The surveyor will wear a high visibility vest.									
Interactions with zoonotic contaminated substances The surveyor	Gastrointestinal , systemic or skin infection	The surveyor will avoid contact with visibly contaminated surfaces where possible. The survey will bring hand sanitiser with them during the survey. The surveyor will wash their hands thoroughly before eating or drinking during or after the survey. The surveyor will seek medical attention if required	2	2	4						