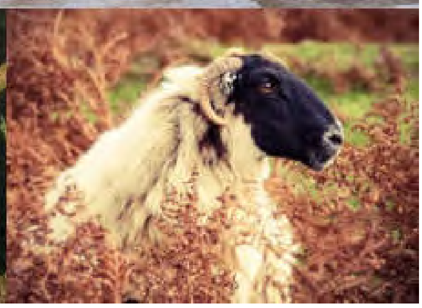
Dung Beetle Diversity and Abundance on Common Land Healthy Livestock Project – Dartmoor

by C.Turner & D. Attwell



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Contents:

1 Summary

- Dartmoor hosts one of the most diverse dung beetle communities in Europe. It has 60% of the British dung beetle fauna responsible for a wide range of significant economic and environmentally functions.
- The 2023 Dartmoor dung beetle survey was designed as an exercise in benchmarking the dung beetle community around two commons and their inbye farms with a view to providing insights into the current community composition and the impact of management regimes on the fauna.
- The survey provided significant data comparing 12 study sites with a local control site with an internationally important near-natural dung beetle community. In the study more than 86,000 dung beetles were identified by examining over 7500 litres of dung.
- Using a specialist biodiversity assessment methodology all sites had a relatively good dung beetle species counts when compared to the control but the commons had lower dung beetle diversity than the adjacent inbye farms, this was linked to stocking regimes and livestock treatments. The inbye had a dung beetle community 82% similar to the control whereas both commons were in a separate grouping being only 61% similar to the control. The variety of inbye management differentiated the inbye from the commons illustrating the importance of heterogeneous management. The positive impact of heterogeneous management was observed on the commons during the surveys but it did not strongly influence the analyses due to a dominant convergence of regimes.
- Using a quantitative ecological assessment methodology three inbye sites had a dung beetle community only 44% similar to the control, the remainder including the commons were only 35% similar. The cause of this difference was primarily dung beetle abundance with a secondary driver of species diversity. Dung beetle abundance across all sites was at best 26% of the Control, the majority much lower. Analysis indicated that livestock treatments was the likely primary source of this difference in abundance. This lower bioabundance may have wider food web implications especially for predatory wildlife like birds and bats.
- The impact of livestock species' dung was analysed with a mean of 358 dung beetles per litre in sheep dung, 186 for horse dung and 6 for cow dung. Analysis agreed with current consensus by demonstrating that most dung beetle species exist in all three dung types. However, the quantitative analysis demonstrated that 61% of the species chose their preferred dung more than 85% of the time, 50% of these species exceeded 90% in their preferred choice. Most dung beetles therefore exercise choice of dung and can therefore be defined as specialists. This is significant quantitative evidence proved the importance of multi-species multi-season grazing for dung beetle communities.

2 Recommendations

1. In order to promote dung beetle diversity and abundance on a landscape scale there is high importance attached to four season multi species grazing
2. Continued heterogeneity of stock, active graziers and land management regimes should be encouraged to maintain a mosaic of habitats and vegetation age and structure
3. Explore different treatment regimes that reduce toxicity and persistence of vet med treatments in livestock dung. Consider more holistic planning and interventions for vegetation management which include animal health and welfare amongst the objectives
4. Through collective commons health plans embed animal health and welfare within land management regimes to deliver better integrated biodiversity outcomes
5. Find ways to ensure the health and connectivity of dung beetle community refugia
6. Explore further research to establish relationships between abundance of dung beetles and vertebrate food webs on the common

Acknowledgements

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Finally, the project would not have been possible without the skills, knowledge and energy of our entomologist and national dung beetle expert Clive Turner.

3 Introduction

Our Upland Commons — a Foundation for Common Land project is working in four upland areas of England including Dartmoor where it is delivered in partnership with a range of local organisations including the Dartmoor Hill Farm Project. It aims to champion commons and the act of commoning 'turning challenges into opportunities' through varied work themes. The programme is funded by the National Lottery Heritage Fund with grants from Esmée Fairbairn and the Garfield Weston Foundations. In Devon local funders include South West Water, the Duchy of Cornwall, the Dartmoor Preservation Association and Devon Wildlife Trust. A local Project Officer is based at Dartmoor National Park Authority and The National Trust are responsible for area coordination of the project which is supported by The Foundation for Common Land.

Figure 3.1: The Healthy Livestock Group at Huccaby Farm – June 2023

The Healthy Livestock Project is working with active graziers to improve the collective health and wellbeing of farmed animals on two participating commons. This recognises the unique nature of shared spaces and the additional challenge placed on livestock by semi natural landscapes. Through a process of research, discussion and fieldwork the group have focussed on key issues with the aim of improving animal welfare and performance. The work to date has involved a range of specialists including local veterinary practices and staff of the Animal Plant and Health Agency based in Exeter. In 2023 the graziers opted to focus on dung fauna and specifically dung beetles. This reflected the broad range of benefits associated with the taxon and provided an opportunity to evaluate wider outcomes directly attributable with grazing livestock.

Dartmoor as a geographic locality is composed of contiguous areas of multi species grazing. Dartmoor is home to 35 species of dung beetle representing 60% of the British fauna (BRC; Mann & Lane 2016; Watkins & Mann 2020) making Dartmoor one of the most biodiverse areas in Britain for dung beetles and comparable to the best locations in Europe (Waßmer 1994). It is therefore an area of national and international importance for dung beetle diversity. With 30% of the British dung beetle species under threat (Lane & Mann 2016) there is a strong case for conservation management for dung beetle species in their refugia.

Fig 3.2: cow dung pat flipped over to show dung beetle tunnelling activity.

Fig 3.3: a female (left) and male (right) Minotaur Beetle – a predominantly autumn, winter and early spring active species

Dung beetles are a keystone invertebrate community comprising in Britain of 58 species all of which have their own ecologies, seasonality and interactions. The dung beetle community sits at the centre of a wide range of environmental interactions apart from being a beneficial invertebrate community in their own right. Both adults and larvae consume dung and are an effective part of the decomposer community, they are present all year round in various life stages. Dung beetles are being increasingly used as bioindicators of environmental change as well as exploring ecosystem quality and functioning (Spector 2006; Raine & Slade 2019). The role of dung beetles as food for vertebrates has been underplayed in the literature and is it accepted that we are currently in a phase of massive understatement of their benefit to wild animal species and populations (Spector 2006). In the western Palaearctic there are accounts of 110 bird species, 13 mammal species including 5 bats and 1 amphibian feeding on dung beetles (Spector 2006). The below visual representations present some of the interactions and benefits of dung beetles in the environment.

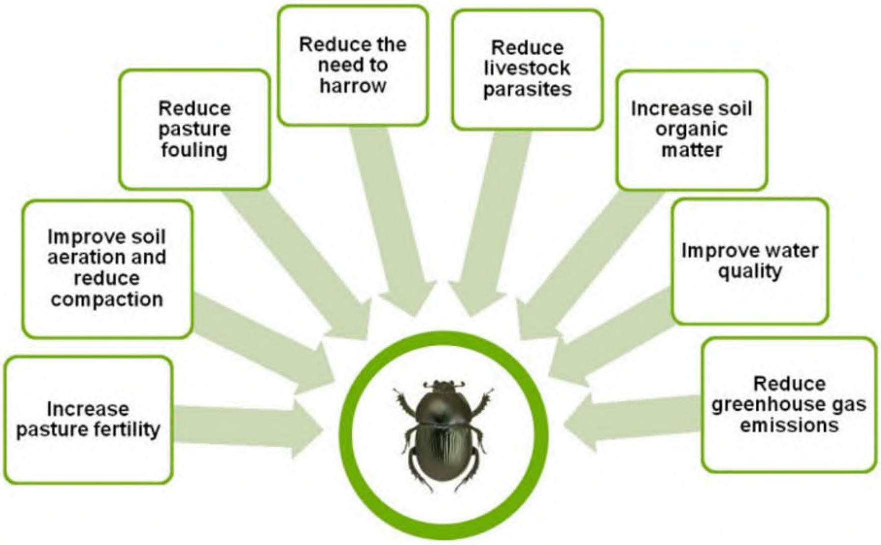
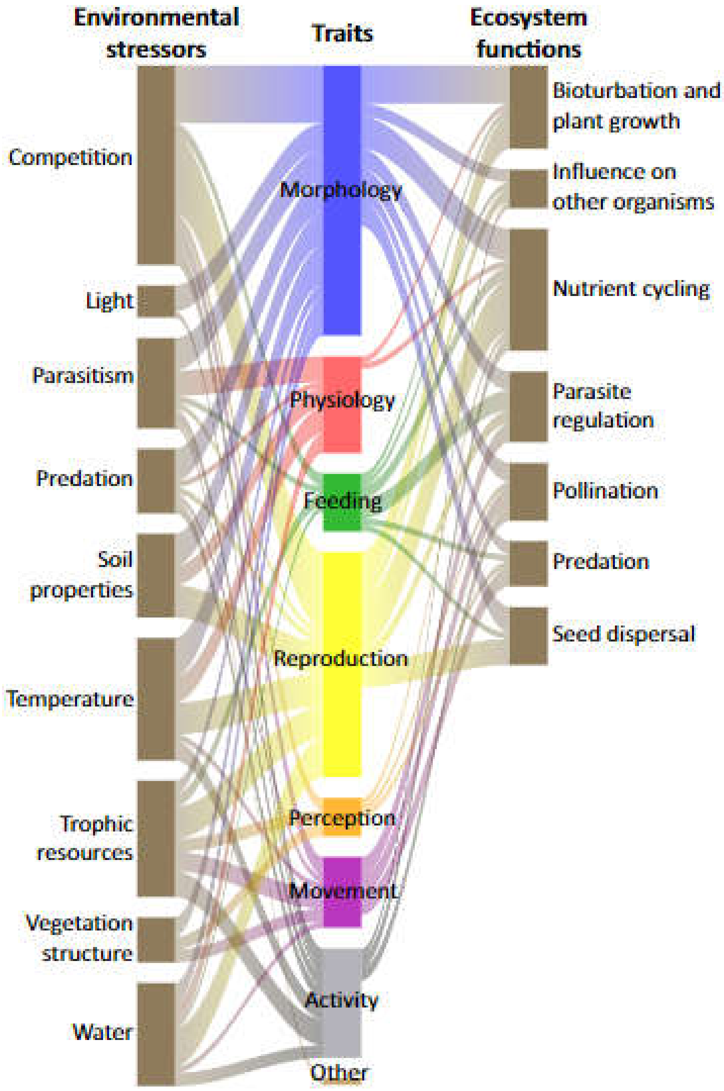


Fig 3.4: This illustration by Beynon *et al.* 2015 of some of the interactions displayed by dung beetles supports the central role of dung beetles

Fig 3.5: deCastro-Arrazola *et al.* (2022) presented a useful illustration of the relationships between dung beetle traits, responses to environmental factors and effects on ecosystem functions to illustrate the keystone ecosystem position of dung beetles.



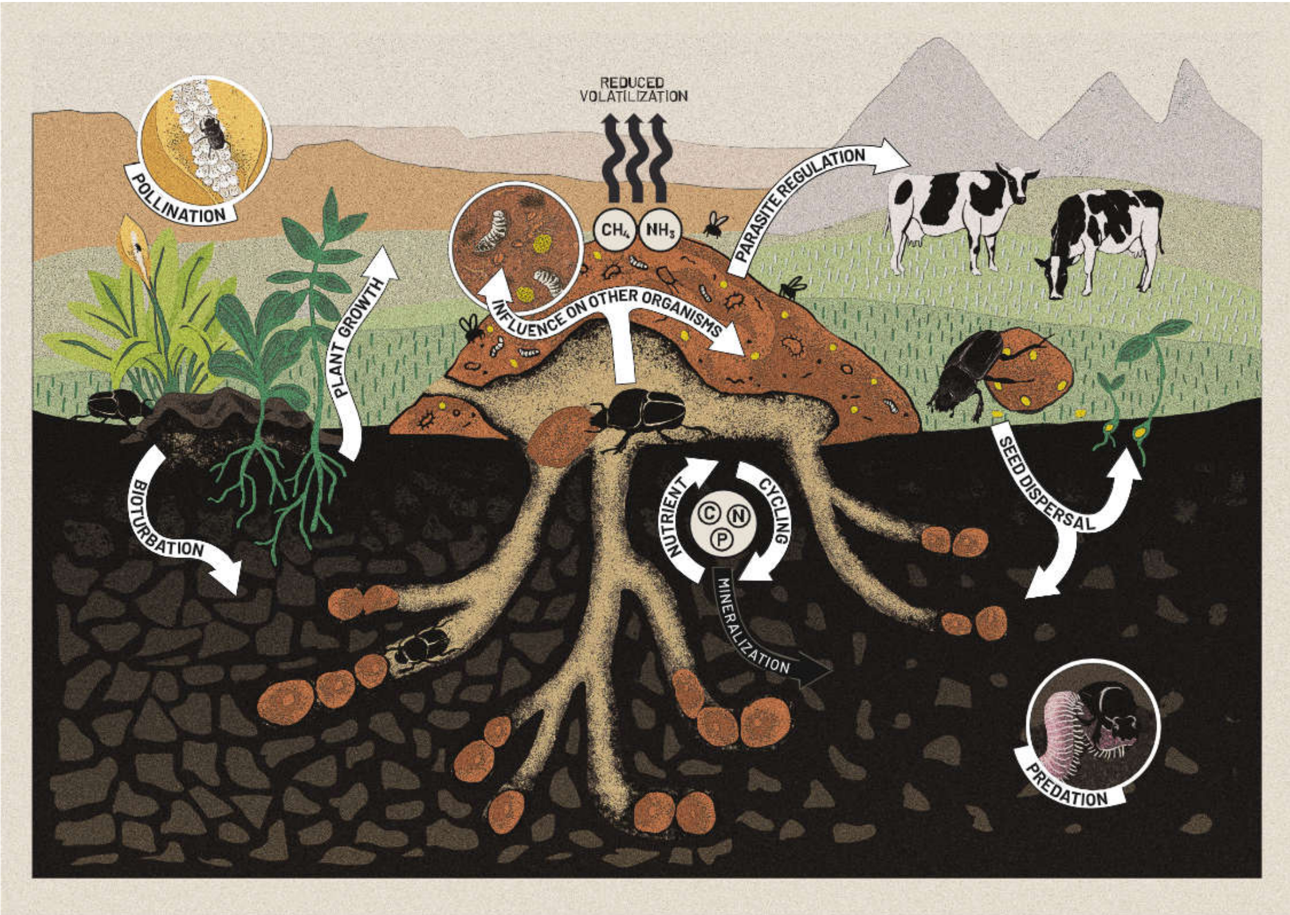


Fig 3.6 Some of the beneficial activities of dung beetles are effectively summarised in deCastro-Arrazola *et al*. (2022), the only cautionary note is the image of the dung beetle rolling dung away – in Britain we do not have any dung roller species although we do have one species that does move dung pellets away from the main deposit.

4 Method

4.1 Scope

This study was designed to establish a dung beetle baseline for two areas of Common Land and the associated inbye. The survey methodology was required to be repeatable for future monitoring purposes and the data was to be made available at a grazier, commons and project level. The study aimed to provide insights into the drivers of dung beetle community structure with a view to making recommendations on management practices such as animal health and welfare treatments, livestock movements and stocking strategies.

In particular, the survey was focussed on establishing:

- Species diversity – the number of different species present on the commons and in-bye land cross referenced to a control
- Abundance – ecological abundance cross referenced to the control site
- Management interventions – what role the current livestock management practices play in determining levels of dung beetle diversity and abundance

The outline project and methodology was discussed and agreed with the participating graziers on both commons. On Harford and Ugborough this included six of the seven graziers and on Holne Moor four of the eight active graziers. In addition, the landowners on both commons were consulted and regularly updated on progress over the course of the study period.

As part of the project each grazier was encouraged to join the entomologist in the field during the three survey periods and to meet with the Hill Farm Project to review veterinary medicine records and treatment strategies. Regular feedback and discussion sessions were held with the Commons Associations and as the project progressed the graziers met as a single larger group. This facilitated a broader interpretation of results including an interim report and presentation to the Fursdon Review Panel, as formal evidence for the Independent Review of Protected Site Management on Dartmoor. In addition to the main project team other specialists were invited to contribute including farm vets and staff from the Animal Plant and Health Agency.

Meetings were held on participating farms and were both informative and social occasions with catering and refreshments often supplied by the host graziers. A notable feature of the programme was the enthusiastic inter-generational engagement at these meetings and during fieldwork.

4.2 Survey Methodology

Fig 4.2.1: The author surveying for dung beetles

For the purposes of this study a dung beetle was defined as a dung associated member of the Scarabaeoidea which in the UK includes most members of the Geotrupinae, Aphodiinae and Onthophagini (Lane & Mann 2016). The survey compared dung beetle species and abundance between three large Commons and ten inbye farms. The recent location of livestock at all these sites defined the precise sampling areas within each site, this flexible approach was required due to the presence of dung fluctuating with livestock movements. The sites comprised of the two study site Commons Holne Moor and Harford & Ugborough Moors and the associated inbye farms. A third Common was utilised as a control site because of its exceptional status as an extremely high quality dung beetle site of the highest standing at National and northern European levels (Waßmer 1994). The control site is known to hold 58% of the British dung beetle fauna including nationally and regionally significant populations of several threatened dung beetle. The control site therefore served as a gold standard comparator for the study sites. The use of a second negative reference control was considered unnecessary because it would inevitably not contain a resident dung beetle community which rendered measuring it a poor use of resources.

Two types of survey were carried out. A specialist biodiversity assessment to establish the full range of species present at each site and an ecological assessment comprising of species and abundance. Each of these studies records different measures. The biodiversity assessment was important to be able to assess the relative true species diversity at each site, something that standardised ecological assessment methodologies have been shown not to achieve (i.e. Turner 2006; CT unpublished data). In contrast the ecological assessment of species and abundance provided additional understanding of the relative dung beetle community composition at each site. It is common to use dung baited pitfall traps in ecological studies (i.e. Newton & Peck 1975; Birkett *et al.* 2012). However, dung baited pitfall trapping was considered suboptimal in the context of this study where the large land area with free roaming

ig 4.2.2: Breaking up an older cow pat over a tray to find dung beetles

Fig 4.2.3: Digging out the larger tunnelling dung beetles, here a Dor beetle – *Geotrupes stercorarius* being examined to identify it to species

livestock would have inevitably resulted in less representative data and the range of microhabitats could not have been encompassed. In addition baited pitfall traps are known to bring their own bias to the dung beetle species data (i.e. Errouissi *et al*;. 2005; Larsen 2005; Bach *et al*. 2023) therefore undesirable for this study as near absolute biodiversity was considered important. An experienced specialist can choose to eliminate or consciously impose methodological bias when hand searching which is significantly different to trapping bias and easier to control.

Three survey periods were established from the species activity peaks derived from the national data sets (BRC; Watkins & Mann 2020). The survey periods were spring, early summer and autumn and once started each survey continued until all the sites had been surveyed. In addition, the survey initiation was determined from monitoring of the control site to establish when the seasonal species assemblages were active. Surveying was not started during heavy rain and showery conditions were also avoided. The dung beetles were identified in the field and often checked with a x10 achromatic loupe, when appropriate some individuals were retained for microscopic confirmation of their identity. Inbye site names have been anonymised in line with the project requirements. Prior to survey the methodologies were evaluated for suitability at the control site. Both survey types (4.2a & 4.2b) utilised an 11mm plastic riddle containing dung held over a plastic tray to observe the emerging dung beetles for identification ('Mann method' – D.J. Mann pers. comm.). Sheep and horse dung is placed into the riddle broken up and shaken, cow dung is only put in the riddle if it is firm and easy to handle. If the cow dung is wet then it is worked with a trowel from the edges and external crust to completely expose the underside of the dung and the ground underneath.

4.2a Species Diversity

There are a variety of measures of biodiversity but the most representative of true biodiversity is S diversity which is the number of species at a site, it is often argued as the most pure and factually meaningful presentation of biodiversity. S diversity can be measured by any technique where species are captured and identified however, a rigorous sampling regime is required to obtain a realistic measure. Dung beetles are associated with dung but the variety of types can make an adequate species survey challenging. This style of survey can only be carried out by very experienced specialist field surveyors for dung beetles. The technique involves working a range of dung habitats in all available situations to maximise the number of species encountered. The dung is worked with a riddle and tray or trowel as described above.

Fig 4.2.1: Breaking up sheep dung over a riddle and tray to examine the dung beetles

Fig 4.2.2: A small piece of sieved sheep dung in the autumn dominated by the dung beetle activity of *Aphodius contaminatus*. A normal observation in a close to natural ecosystem.

4.2b Ecological Abundance & Diversity

The ecological expression of the dung beetle community comprises of a comparable measure of species and their abundance, in this study it was expressed as number of each species per litre of dung. Each dung deposit is measured in three dimensions – length at the widest point, width at ninety degrees to the length axis and depth. Measurements were to the nearest 5mm and volume was worked out using basic volume calculations as a cylinder (for sheep and cow) and cone (for horse). Whilst this was not an absolute measure it was consistently applied and therefore considered a sound basis for comparative analyses. One dung deposit at a time was worked for dung beetles. Sheep dung was worked in the riddle in its entirety and the number of each species recorded. Horse dung was worked in the riddle and shaken once then the number of each species recorded, a further three shakes and counts were preceded by the dung being completely broken up by hand. If dry enough cow dung was worked in the tray in a similar way to horse dung but with a maximum of 5 minutes' examination. It the cow dung was wet it was worked in situ with a trowel but with a time limit of 5 minutes searching and identifying. During timed counts there is a pause to use a hand lens or other time-consuming actions, the clock was stopped and restarted with resumption of activity. A minimum of 5 samples per dung species (cow, horse or sheep) were taken per site per sampling period. This resulted in a minimum of 15 samples for a single species site or 45 samples for a site with 3 species grazing. The nature of dung is variable and the dung beetles constantly move actively from one piece to another, this creates a challenge to effective data collection. In order to reduce this effect in the data and maximise acuity a positive bias was applied where the better dung deposits containing dung beetles were selected for, this was to ensure as consistent as possible comparative data set was obtained across all sites.

Comparison between samples was on a calculated number of each beetle species per litre, for each site this facilitated an average value expressing abundance and number of species. The data was then analysed through the specialist statistical package PRIMER v.7.0. The diversity measures used were S diversity, the number of species, N – the abundance of individuals. The ecological diversity calculation utilised was the Brillouin index, other more commonly used measures of diversity like Shannon-Weiner are sensitive to collecting effort and not appropriate with this data set. Simpson's index would be the next likely choice but it is not suitable for standardised measures of abundance. The Brillouin index measures the diversity of a collection and was deemed the most appropriate measure of ecological diversity for the data. The HCA cluster analyses utilised Bray-Curtis similarity with complete linkage and the ordination was Non-metric Multidimensional Scaling.

Fig 4.2b: Measuring the dung dimensions

4.2C Animal Veterinary Medicine Treatments

Alongside the field survey work a record was made for each participating grazier of their veterinary and medicinal treatments used on their livestock. Information was captured for each species (cattle, ponies & sheep) recording the product name and the timing and frequency of use. Drivers for use and timing of specific products was also explored and noted down. Numbers of livestock de-pastured on the common and timings for grazing were also noted along with flock marks, herd numbers and approximate lears. This information was then referenced in the field during the surveys to interpret visual results with likely grazier treatments.

4.3 The Survey Area

During 2023 the survey area included two major areas within Dartmoor National Park. Dartmoor is the largest upland area in south west England and extends 23 miles north-south and 20 miles east-west occupying an area of 368miles^2 with a maximum altitude of 621m. Dartmoor's granite massif forms a dramatic landscape with a distinctive geology, flora and fauna which are of international and national conservation importance. Although human activity has modified the landscape over thousands of years, it retains a rare, rich and varied cultural heritage, fauna and flora which shows how people, landscape and wildlife have historically influenced each other. Common land covers 35,882 ha (37%) of Dartmoor National Park with largest area the Forest of Dartmoor (11,178 ha) occupying the high moorland surrounded by the 'home' commons.

This research focussed on two areas of Commons Holne Moor & Harford and Ugborough with the associated in-bye of the active graziers:

Holne Moor- Holne Moor covers 958 hectares (1560 acres) of moorland and is registered with the local authority as CL153 under the 1965 Commons Registration Act (CRA). It lies within the parish of Holne and is contiguous with both the Forest of Dartmoor and Buckfastleigh Common and has the River Dart as its northern boundary. The area is designated as a Site of Special Scientific Interest and contains a number of important habitats and key species of interest. The land is owned by three organisations and one individual who retain some mineral and sporting rights. There are extensive grazing rights registered for Holne Moor (under the 1965 CRA) for 47 separate holdings but only 8 active graziers. The active rights are for cattle sheep and ponies with a mix of breeds including registered Dartmoor Ponies, South Devon cattle and Galloways. Sheep tend to be of hardy upland stock such as Swaledale, Scotch Blackface and Cheviot although local breeds such as Whiteface Dartmoor are also turned out on the moor. There is an active Commons Association which meets regularly to discuss current and future agri-environmental schemes and to liaise with the landowners and Natural England. Traditionally the commoners have worked together to undertake swaling, manage archaeological features and leats, gather stock for clearance periods and attend to stray ponies and livestock. This has continued under the current Higher Level Stewardship agreement (see below) but restrictions on management activities have changed over time. Nearly all the active Graziers turn out sheep and cattle but some only exercise rights to de-pasture ponies. Livestock is identifiable by ear tags and flock marks and are 'leared' to certain parts of the common. Four of the six sheep and cattle graziers participated in the study and permitted inclusion of their inbye land.

Harford and Ugborough Moors (HUG) – these are unfenced open moorland forming a south-north transect about 11km long on the southern fringe of Dartmoor, from 215m to 450m above sea level and covering an area of 1670ha. Their combined width is 3.9km at the widest point in the south, and only 0.9km at the mid-point near Sharp Tor. A joint Commons Association manages them together as one unit due to their linear nature. These Commons are contiguous with Brent Moor (CL 161) to the east and the Forest of Dartmoor (CL164) to the north. The west side adjoining Harford Moor is bordered by the River Erme which forms a boundary against Stall and Penn Moors (CL112) The Northern part of both Commons is included in the South Dartmoor Site of Special Scientific Interest (SSSI) and the Dartmoor Special Area of Conservation (SAC). The two Commons have been in an Environmental Stewardship Agreement since 1999 and the Association encompasses 50 members who hold common rights on Harford & Ugborough Commons. There are five owners and 7 active graziers within the 50 members detailed above. The grazing over the past 15 years has been governed by the ESA/HLS agreement, with no cattle grazing on the Commons from 1st December until the 15th April each year. There are ponies, cattle and sheep grazing on the commons. Six of the seven graziers participated in the study and permitted inclusion of their inbye land in the study.

4.4 Site Management

The two participating commons have been active participants in agri-environment schemes since the 1990's. Dartmoor was one of 22 areas in England that were originally designated by the then Ministry of Agriculture, Fisheries and Food (MAFF, now Defra) as Environmentally Sensitive Areas (ESAs). Dartmoor was opened as an ESA in 1994 and Harford and Ugborough entered into the scheme in 1999 and has had continuous agri-environment agreements ever since. Both commons are currently in a combined Upland Entry Level (UELS) and Higher-Level Stewardship (HLS) scheme which is the forerunner to Countryside Stewardship (CS). These were originally ten year agreements but since Brexit the Associations have been 'holding over' on short term extensions.

Holne Moor is designated as a Site of Special Scientific Interest and contains a number of important habitats and key species of interest. It also lies within the Dartmoor Special Area of Conservation (SAC) which is designated for several key habitats including European Dry heaths and Blanket Bogs representing the southernmost blanket bog in Europe and 'typical' for south-west England. Harford and Ugborough also has the Northern part of both Commons included in the South Dartmoor Site of Special Scientific Interest (SSSI) and the Dartmoor Special Area of Conservation (SAC). As well as key habitats both moors have associations with notable species some of which require targeted management.

Both commons have a high density of archaeological remains from the Neolithic period to post war industrial sites with part of Holne Moor and Harford and Ugborough designated as a Premier Archaeological Landscape (PAL). There is extensive public access under the Countryside Rights of Way Act 2000 (CROW) and various footpaths and bridleways serviced on Holne in particular by a number of car parks. A key feature for Harford and Ugborough is the Redlake Tramway which provides a surfaced track from Bittaford out to the old clay workings on the high moor.

The stocking calendar and vegetation management on the commons is dictated by the agri-environment agreements with Natural England. This stipulates stocking rates for cattle, sheep and ponies and sets a timeframe within which animals can be de-pastured on the moor. There are clear differences between Holne Moor and Harford and Ugborough. These can be generalised as:

Holne Moor – as of autumn 2022 the main grazing period for livestock is May to November with the majority of sheep and all cattle removed by December. Stock lamb or calve on the in-bye and are then turned out onto the moor (spring calving) or are turned out with older calves at foot in May (autumn calving). Ponies are out year-round.

Harford & Ugborough – a proportion of sheep winter and lamb on the common only being removed for the Dartmoor Commons Council statutory clearance period of two weeks in November each year. Other graziers remove sheep for lambing and tupping periods only. Cattle tend to be turned out from May till the end of November with ponies out year round.

As both Commons Associations have areas of SSSI the agri-environment agreement also forms a group consent under Section 28E (5) of the Wildlife and Countryside Act 1981 (as amended). The HLS / UELS agreements require authorisation to 'swale' which has to be agreed in consultation with the landowners and Natural England and then adopted as part of a works management plan. The area swaled annually has been reducing year on year and restrictions on patch size and climatic conditions has also influenced outcomes.

In liaison with Natural England and the landowner's other programmes of management have been initiated outside of the agri-environment agreements on both commons. This has included works on mire restoration or re-wetting, Natural Flood Management interventions, repairs to leat systems, tree planting and scrub management associated with key species. A number of these have been initiated with the Our Upland Commons programme.

Fig 4.4a: Nofence collars have been used to monitor cow movements for four herds on Holne Moor. The collar has only been used for geo spatial referencing and not as an invisible shock collar.

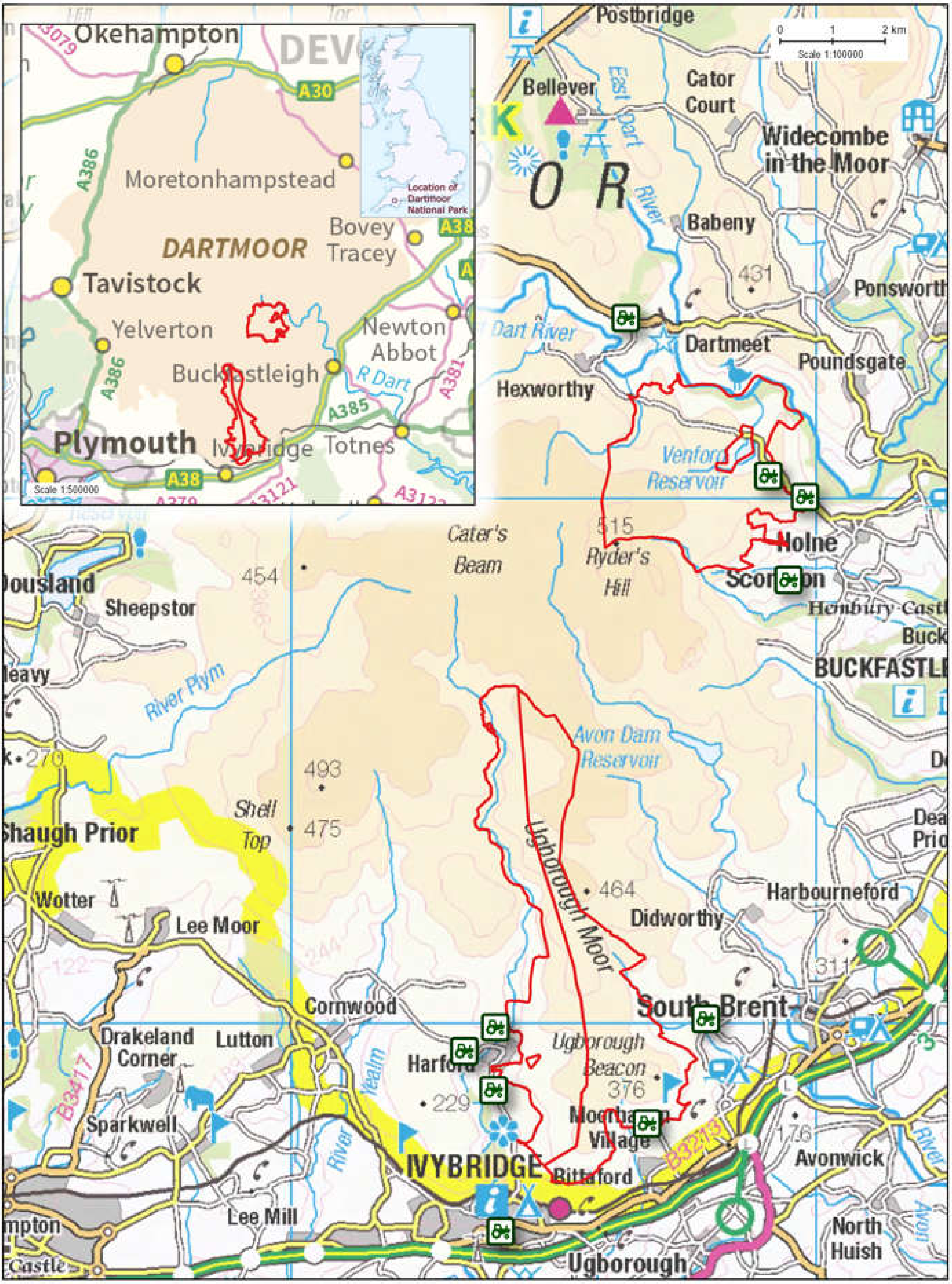


Fig 4.4b: The location of Holne (top red boundary) and Harford & Ugborough (bottom red boundary)

5 Results

Veterinary Medicine Treatment

Discussion with the participating graziers on motivations to use animal health products focussed on a simple metric of 'what, why and when'? The underlying motivation was to maintain overall welfare and performance by reducing exposure to environmental challenge. Treatments tended to target internal (worms) and external parasites in cattle and sheep often with different strategies for livestock on the in-bye and hill ground.

A key element in decision making for animals 'leared' on the moor is the restricted opportunities to gather and handle livestock in contrast to the 'home farm'. Whilst this was the primary limiting factor others also influenced treatment strategies and outcomes. These included:

- Product knowledge and availability
- Retail or professional endorsements i.e. range of products at local supplier of choice
- Access to facilities, labour and equipment i.e. dip
- Traditional versus modern practices
- Price point and economies of scale

Whilst some 'challenge' such as worm burden is considered lower risk in extensive moorland systems other such as ectoparasites greatly increases. This is influenced by the type and loading of vegetation and specifically a concern of tick related disease with Ixodes ricinus the 'sheep tick' being widespread on the commons. Ticks generally like most mild conditions (7 ^{o}C +) requiring a relative humidity of at least 80% to survive during its off-host periods. This restricts their distribution to areas of moderate to high rainfall with vegetation that retains a high humidity such as moorland and heath. A large number of tick species are associated with Bracken *Pteridium aquilinum* which is present on both commons either as dense stands or scattered fronds within grazed acidic grassland. Several graziers anecdotally cited an increase in tick related issues that mirrors the change (over 30 years) in vegetation communities and loading in response to agri-environmental prescriptions. A compounding factor highlighted on both commons was a significant reduction in swaling. Graziers indicated that light burns 'clean' ground of ectoparasites and encourage livestock to spend more time in shorter grassland where ticks find it harder to 'quest' (jump onto a host).

The main issues cited for the use of acaracides (tick killing chemicals) on sheep and cattle are predominantly tick, mite or fly related issues. These include Louping Ill, Tick Pyaemia, Tick Borne Fever, Sheep Scab, Lice and prevention of Blow Fly Strike. These products tend to use Deltamethrin, Alpha-cypermethrin and Cypermethrin (the synthetic pyrethroid chemicals) whilst full immersion plunge dips comprise of Organophosphate based chemicals. The impact of these products on fauna in sheep dung is little researched and poorly understood (Beynon 2012)

The start of the cycle for flocks and herds de-pastured on the commons is for animals to be treated at turn out or post lambing and calving. In sheep this often includes a broad spectrum wormer with some form of acaracide for ectoparasites. They are then treated again at clipping time (July – mid August) with the majority of flocks applying a second treatment of acaricide and some graziers use a targeted gastrointestinal wormers. Lambs are generally wormed at weaning along with replacement ewe lambs that are turned back on the common. At the end of the autumn period (or when the HLS / UELS agreement dictates) flocks are cleared (November) from the moor and a number of farms (4) plunge dip as a precautionary measure for scab or lice. Others opt to use an injectable with an active ingredient such as Moxidectin or Ivermectin. Dependent on the farm sheep that return to the in-bye prior to tupping are either batch or target wormed with some holdings using faecal egg counts to inform whether to treat. Finaly any lambs being finished off grass or cover crops may also receive periodic treatments over the winter period for a range of endoparasites from fluke to nematodes.

The active ingredients present in the medicinal products used on the two commons is shown in Table 5 broken down by species.

Active Ingredient	Application	Meat Withdrawal period
Cattle		
Closantel	Pour On	63 Days
Cypermethrin	Tags	0
Deltamethrin	Pour On	17 Days
Levamisole Oxyclozandide	Oral Drench	5 Days
Ivermectin	Pour On	15 Days
Nitroxynil	Injection	60 Days
Doramectin	Pour On	35 Days
Sheep		
Diazinon	Submersion / shower	49 Days
Moxidectin	Oral Drench	14 Days
Triclabendazole	Oral Drench	56 Days
Dycyclanil	Pour On	7 Days
Abendazole	Oral Drench	5 Days
moxidectin (0. 1%) and triclabendazole (5%)	Oral Drench	31 Days
Cypermetherin	Pour On	8 Days
Deltamethrin	Pour On	35 Days
Mebandazole Closantel	Oral Drench	65 Days
Alphacypermetherin	Pour On	49 Days
Cypermetherin	Pour On	8 Days
Ivermectin	Oral Drench	6 Days
Equines		
Moxidectin	Oral Drench	32 Days

Table 5: Summary of active ingredient and meat withdrawal days for products used across ten participating farms

Spring calving cows tend to have a lower level of treatment with most farms turning out in May with little formal treatment until gathering. Calves may receive a fly deterrent at de-horning and are then wormed post weaning or late autumn. Others tend only to apply an acaracide in mid to late season and use targeted worming of cows and calves on an ‘as and when’ basis. In contrast the autumn calving herd will treat calves in June and at weaning when the cows will also be wormed. Cattle are grazed on the commons until the autumn or no later than the end of November. Most farms will then treat with a flukicide towards the end of the grazing season or shorty after housing.

Those farms that kept ponies did so for ‘cultural’ or agri-environmental schemes and these animals received little or no medicinal input. The few holdings with domesticated equines that were of commercial value tended to treat in October and January for tapeworm, bots and insisted red worms using a Moxidectin drench.

A key finding from the vet med discussions was the diversity or heterogeneity of approaches applied across the ten farms. This could be attributed to multiple factors which includes:

- The uniqueness of each farm business
- Type, breed and value of livestock i.e. thoroughbred horse
- Grazing lear (location and vegetative cover) and period on the common (part or majority year)
- Spring or autumn calving cows
- Equipment knowledge and skills of the farmer i.e. use of faecal egg counts, EID etc.
- Labour and time constraints

Day to day veterinary advice is provided by a single practice for all of the holdings on Harford and Ugborough and two of the four graziers on Holne, with the remaining farms using different suppliers. Several of the graziers actively participate in discussion groups and knowledge transfer events both on farm and virtually which is reflected in their management strategies. A number were part of farm assurance schemes such as Red Tractor.

At the time of the survey none of the graziers were participating in the Sustainable Farming Incentive (SFI) Animal Health and Welfare programme.

Field Survey Results

The results are presented in sections describing different perspectives on the data derived from the two approaches – species diversity & ecological abundance and diversity.

Of the 35 dung beetle species known from Dartmoor 31 were included in these results.

In total over 86,000 dung beetles were identified from examination of over 4,700 dung deposits and 7,500 litres of dung.

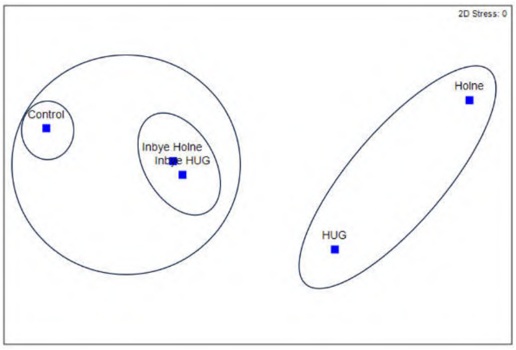
The ecological abundance and diversity study element comprised of 14,343 dung beetles identified to species from 797 dung deposits.

In the analyses abbreviations to the sites were used, some of which comprised of combined site data, these are defined in the key:

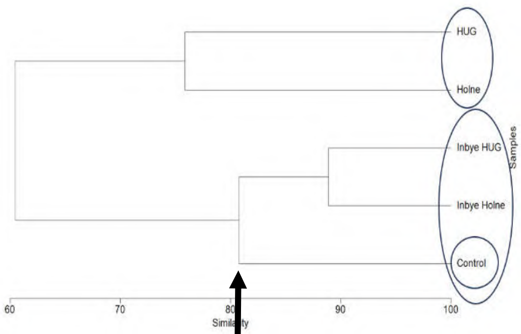
Key to sites:

Control = Control Site
Ho = Holne Moor
HUG = Harford & Ugborough Moors
Inbye Holne = Holne Moor inbye, a total of H01, H02, H03, H04
Inbye HUG = Harford & Ugborough Moors inbye a total of HU1, HU2, HU3, HU4, HU5, HU6
Inbye = a total of all inbye H01, H02, H03, H04, HU1, HU2, HU3, HU4, HU5, HU6
H01, H02, H03, H04 = each one an inbye unit for Holne Moor graziers
HU1, HU2, HU3, HU4, HU5, HU6 = each one an inbye unit for HUG graziers

Quick Guide to specialist analyses:

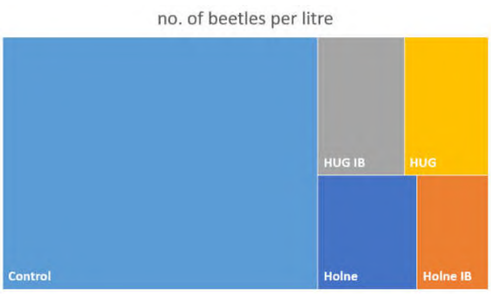


Non-metric Multi-Dimensional Scaling (=MDS) analysis (2D) produced as scatter plots in a 2 dimensional box.
This is a representation of the similarity between data. Look for the Control site as it is the gold standard reference – the greater distance from the Control the less similar the data points are to the control. Groupings of data points are within the circular lines, these groups can be nested.



Hierarchical cluster analysis =(HCA) analysis produced a similarity dendrogram where groupings of data correspond to each branch of the dendrogram. The node of each branch is the point of separation for each group. The more similar nodes of separation are to the right of the dendrogram. Groupings of data points are within the circular lines, these groups can be nested

Node of separation: This is the last point of similarity between the two data groups and represents the point at which the data separates into two distinct groups.



A **Treemap chart** presents the amount of space occupied by each data set. This enables easy visual comparison by showing the largest data point as the largest rectangle, the smallest as the smallest and the other in between in relation to their data. If all were equal the rectangles would be the same size.

5.1 Species Diversity

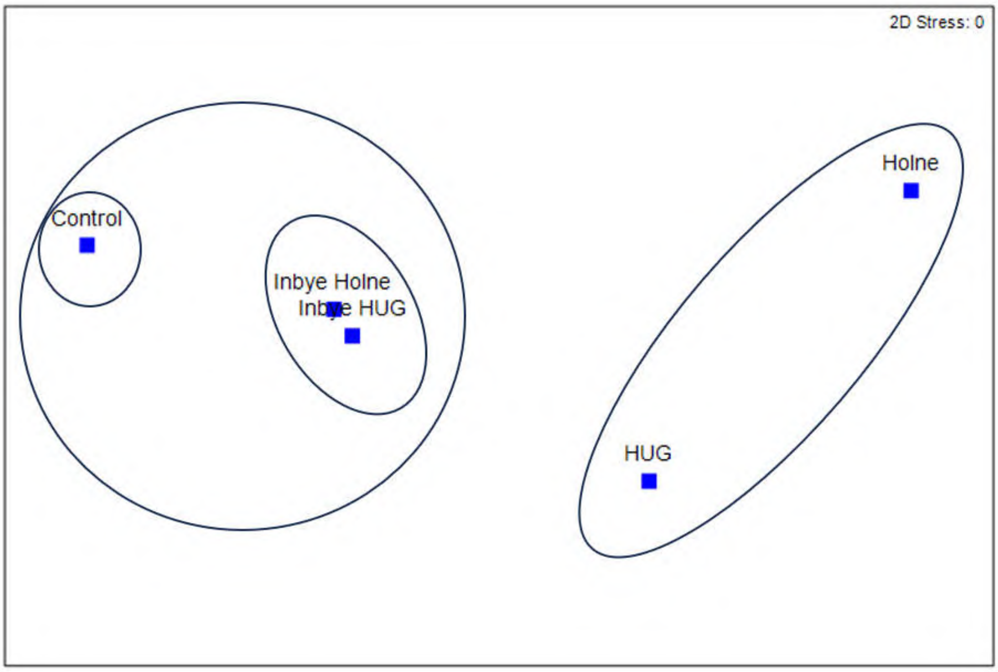


Fig 5.1.1: MDS illustrating the relationship between the dung beetle species composition of the Commons and Inbye in relation to the Control

MDS analysis (above) & HCA (below) of the dung beetle species for the Commons and grouped inbye for HUG & Holne:

- HUG & Holne inbye dung beetle species community is 88% similar in composition to each other and as a pair their species community is 82% similar to the Control
- HUG & Holne Commons dung beetle species community is 76% similar to each other and only 61% similar to the Control & inbye cluster
- The MDS plot illustrates these groupings and accentuates the relatively close relationship between the Control and combined Inbye communities versus the less similar grouping of the Commons.

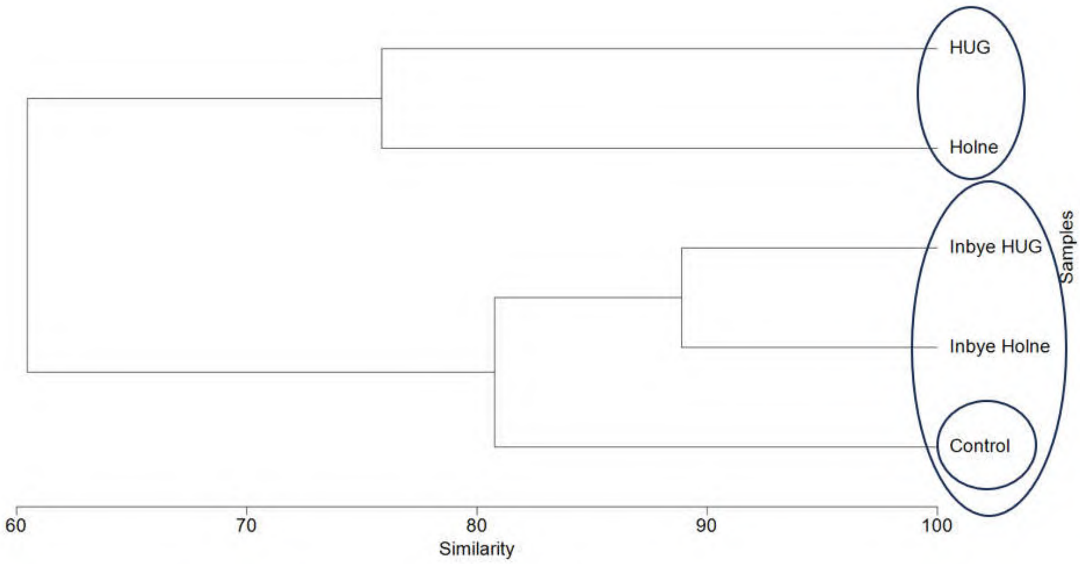


Fig 5.1.2: HCA illustrating the relationship between the dung beetle species composition of the Commons and Inbye in relation to the Control

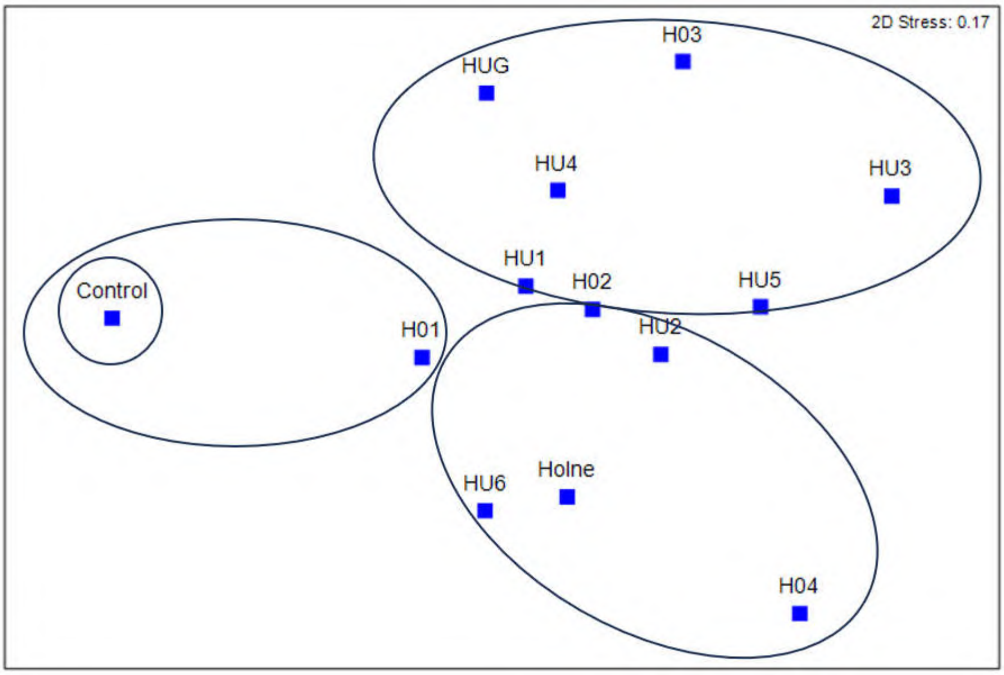
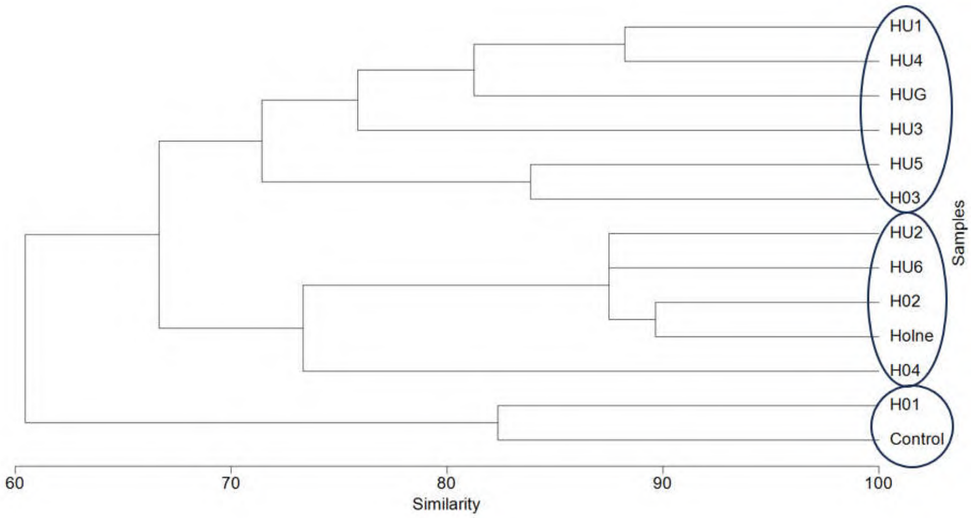


Fig 5.1.3: MDS illustrating the relationship between the dung beetle species composition of the Commons and Inbye in relation to the Control

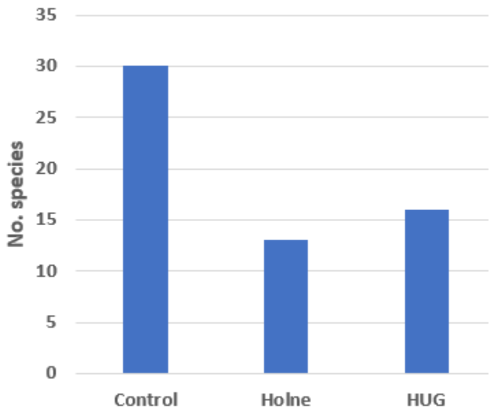
MDS analysis (above) & (HCA below) of the dung beetle species for the Commons and separate inbye farms:

- This more detailed analysis illustrates the underlying complexity of single site data where Commons and inbye similarity groupings (except H01) had a dissimilarity of 39% from the control & H01 group.
- The control group comprised of the control site and the 83% similar Holne inbye H01 indicating that H01 possessed a dung beetle community closest to the control community.
- The remaining Inbye and Commons formed two groups 66% similar in dung beetle species composition. The mixed nature of the Holne and HUG inbye and the two Commons expressed the heterogeneity of species composition between sites. This dissimilarity between the control and these two groups is shown in the above MDS where this separation is displayed as distance from the control. It is notable that H01 is proximal to the other groups in this MDS.

Fig 5.1.4: HCA illustrating the relationship between the dung beetle species composition of the Commons and Inbye in relation to the Control



5.1a The Commons



S diversity (number of species):

- The control site totalled 30 species of dung beetle with the Commons HUG 16 and Holne 13 respectively 53% and 43% of the control.
- The species not in Holne versus HUG were spring active taxa that prefer sheep dung (*Calamosternus granarius* with 94% preference for sheep dung; *Esymus pusillus* with 94% preference for sheep dung; *Planolinus borealis* with 97% preference for sheep dung)
-

Fig. 5.1a.1: A graph of the total dung beetle species found on the Control and Commons

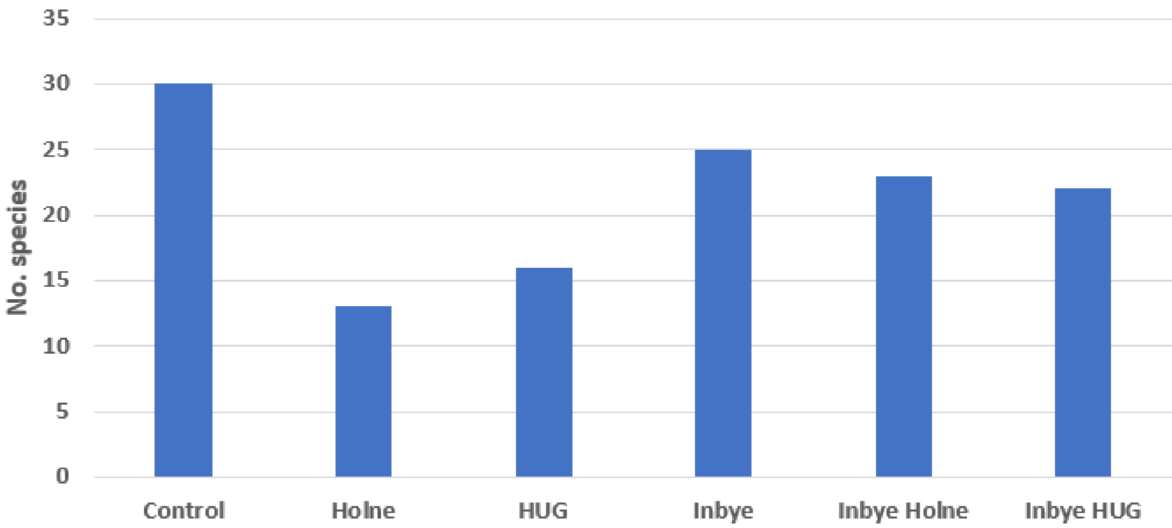


Fig. 5.1a.2: A graph of the total dung beetle species found on the Control, Commons & Inbye

S diversity (number of species):

- The Commons both compare unfavourably to the aggregated inbye dung beetle communities.
- The total inbye comprised of 25 species, 83% of the control, including one species *Onthophagus medius* found during the survey and not previously known from the control site and a new record for Dartmoor.
- The combined Holne Inbye dung beetle community comprised of 23 species, 10 more than the adjacent Holne Moor and 77% of the control community.
- The combined HUG Inbye dung beetle community comprised of 22 species, 7 more than the adjacent HUG Moor and 73% of the control community

5.1b The Commons & Inbye

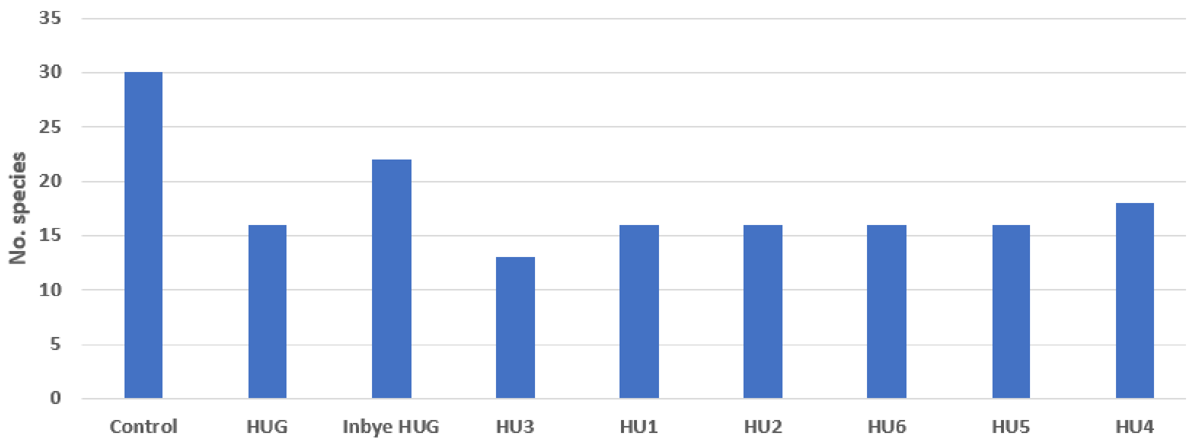


Fig. 5.1b.1: A graph of the total dung beetle species found on the Control, HUG Common & HUG Inbye

S diversity (number of species):
HUG Moor as a stand-alone site was relatively comparable to the adjacent inbye dung beetle communities where HUG's 15 species was close to the average for the inbye at 16 species. All three grazing species cow, horse & sheep were present on HUG.

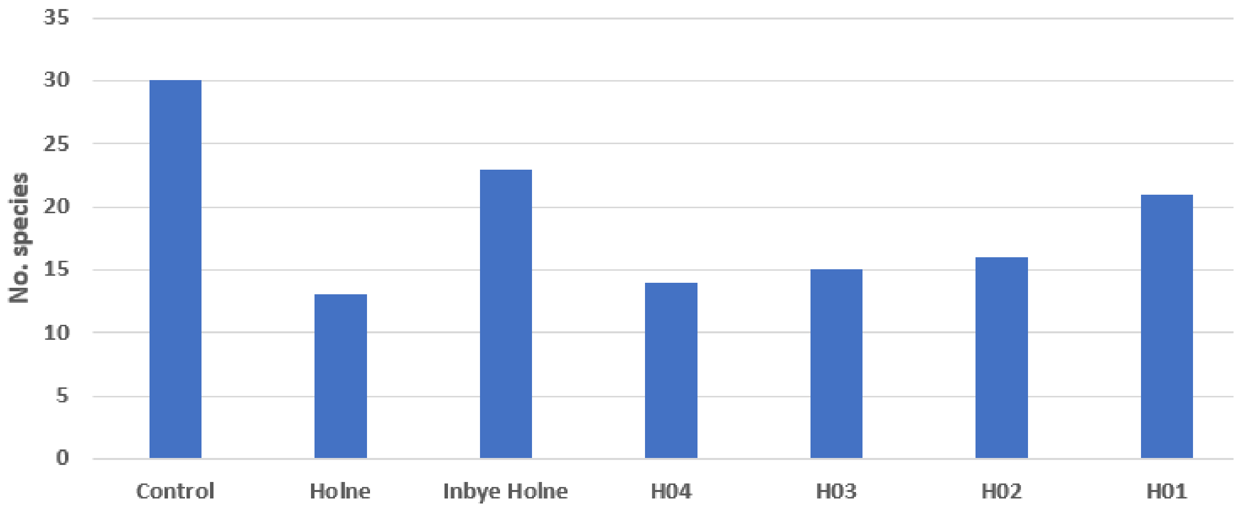


Fig. 5.1b.2: A graph of the total dung beetle species found on the Control, Holne Common & Holne Inbye

S diversity (number of species):
Holne Moor with 13 species performed unfavourably in terms of dung beetle diversity when compared to the adjacent inbye sites which, without exception held more species. All three grazing species cow, horse & sheep were present on Holne.

5.1c The Inbye

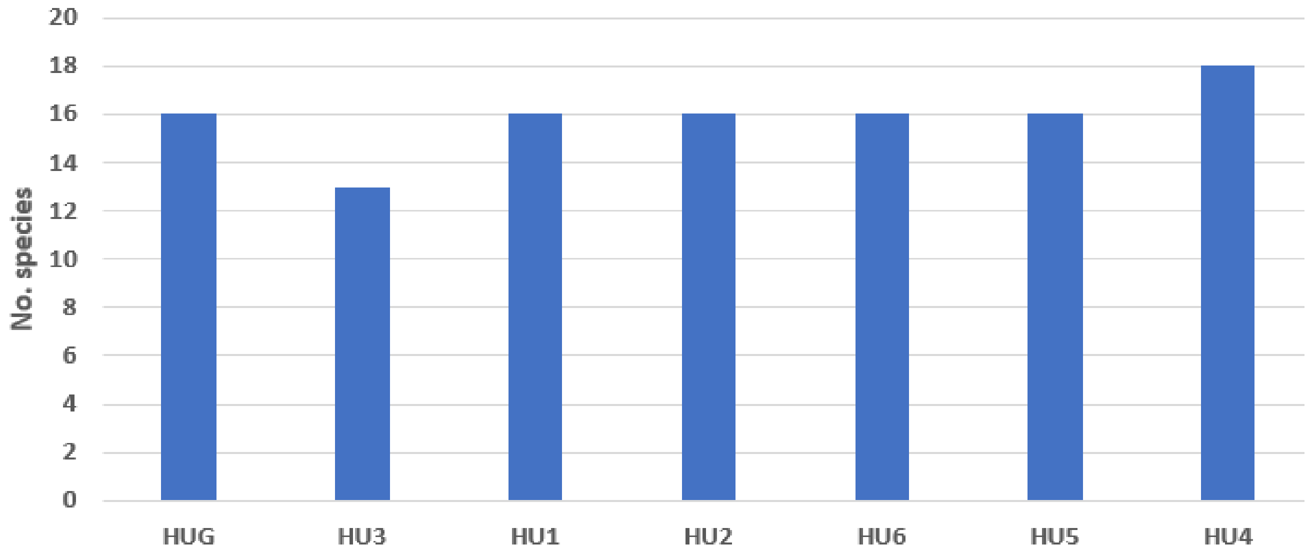


Fig. 5.1c.1: A graph of the total dung beetle species found on HUG Common & HUG Inbye

S diversity (number of species):

- The inbye varied from 13 species (43% of control) for HU3 to 18 (60% of control) at HU4 where those between had 16 species (53% of control).
- HU4 performed highly in the spring data but did not maintain the elevated species diversity throughout the year, although it was the only site with *Onthophagus medius*, new to Dartmoor.
- HU3 remained the only site to have a single species (sheep) on site throughout the survey whilst HU4 was the only HUG inbye to have all three species

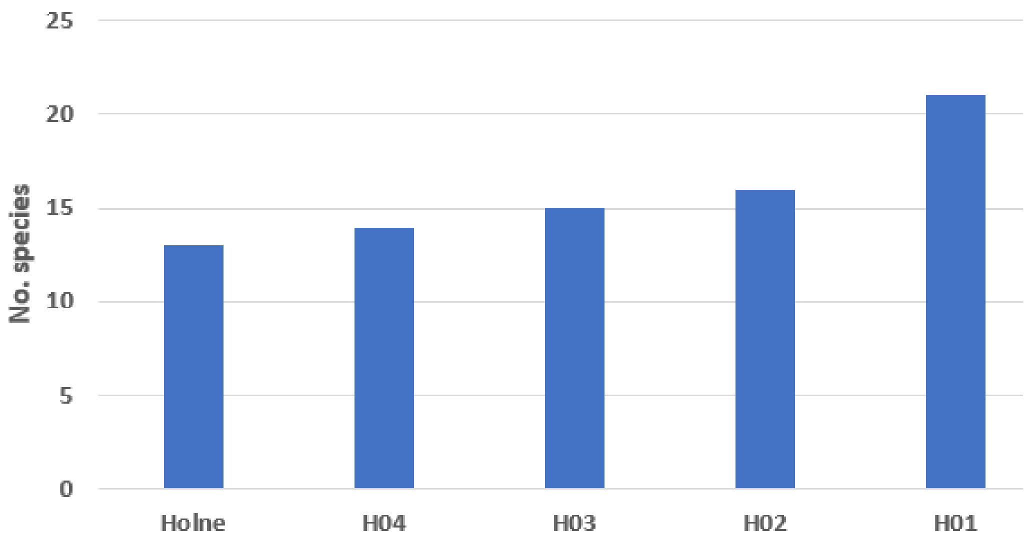
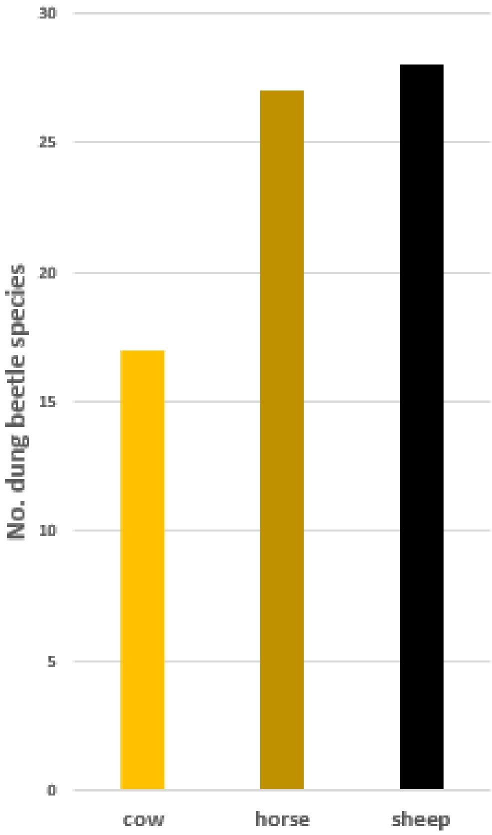


Fig. 5.1c.2: A graph of the total dung beetle species found on Holne Common & Holne Inbye

S diversity (number of species):

- H01 was notable in its high species count of 21 (70% of the control dung beetle community) with other sites recording for H04 14 species (47%), H03 15 species (50%) & H02 16 species (53%).
- H01 was the only Holne inbye site to keep all three species cow, horse and sheep on site for the whole survey, the others had just cow and sheep.

5.1d Stock Species



S diversity (number of species):

- The number of dung beetle species recorded for each species of herbivore revealed a dominance of sheep and horse with respectively 28 & 27 dung beetle species with 17 species in cow dung.

- Sheep dung contained the most dung beetle species.

- This data should be taken in addition to the context of section 5.2d where more insight is forthcoming.

Fig. 5.1d: A graph of the total dung beetle species found on each species' dung

5.2 Ecological Abundance & Diversity

In addition to the analysis types already presented measures of ecological abundance and diversity are presented in tables for each section. All three measures in the tables are sorted in descending order, the highest diversity score at the top.

Key:
S = number species (S diversity from the quantitative study)
N = number of beetles per litre (abundance)
Brillouin = calculated expression of ecological biodiversity index (= **HB**)

Site	S	Site	N	Site	Brillouin
Control	27	Control	183	Control	1.83
H01	17	HU1	48	HU4	1.47
HU4	16	HU5	37	H02	1.42
HU6	15	H01	34	HU6	1.37
Holne	15	HU4	30	HU5	1.24
HUG	15	Holne	26	HU2	1.18
H02	13	HU3	21	HU3	1.11
HU5	13	HU6	17	Holne	1.05
H03	13	H04	15	HU1	1.04
HU2	11	H02	14	H01	1.02
H04	11	HU2	13	H03	0.97
HU1	9	H03	12	H04	0.83
HU3	8	HUG	12	HUG	0.79

Table 5.2: The S diversity, number of beetles per litre and HB ecological diversity index for all sites and all species' dung

The above table presents the diversity and abundance measures for all the sites in the study.

- The control site scored the highest in all measures indicating a high biodiversity site with the highest dung beetle abundance and number of species
- S diversity presents a similar inbye result to that seen in section 5.1 with the highest species numbers in H01 & H04. Where as N presents a different view with H01 dropping to fourth & HU4 to fifth whilst HU1 & HU5 rise in the ranks. HB results in HU04 rising to second with a reorganising of the rankings.
- For the Commons the three measures are similarly inconsistent with HUG varying greatly in the ranks whilst Holne oscillates in the middle ranks because it possesses upper range S and mid range N whilst HUG had upper range S but low abundance (N) resulting in a low HB.
- This high level view of the entire data set presents a complex mix of rank shifts between each index which strongly suggests a series of factors are driving abundance and diversity

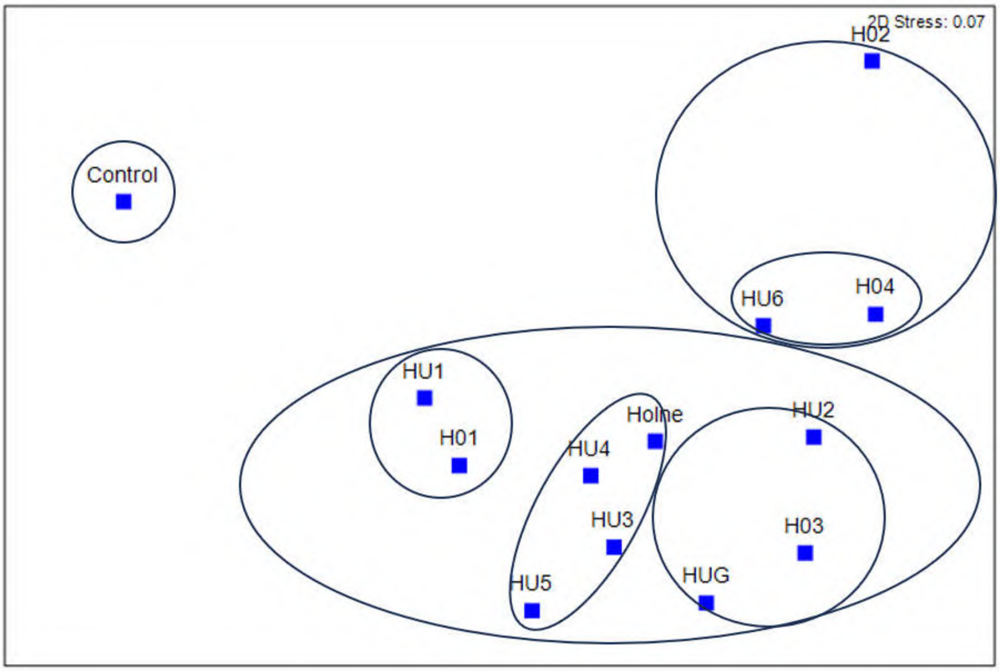


Fig 5.2.1: MDS illustrating the relationship between the dung beetle species and their abundance for all sites and species' dung

MDS analysis (above) & (HCA below) of the full data for dung beetle species and abundance for the Commons and separate inbye sites:

- Combined species and abundance data analysis placed the control 9% similar to the remaining study sites and an isolated site with little relation to the other sites
- Inbye sites H02, H04 & HU6 are 44% similar and form an isolated group
- The remaining sites produce are 35% similar and form a group comprising of 3 separate?
- Apart from the three high level groupings the analyses present a complex set of relationships in need of further analysis

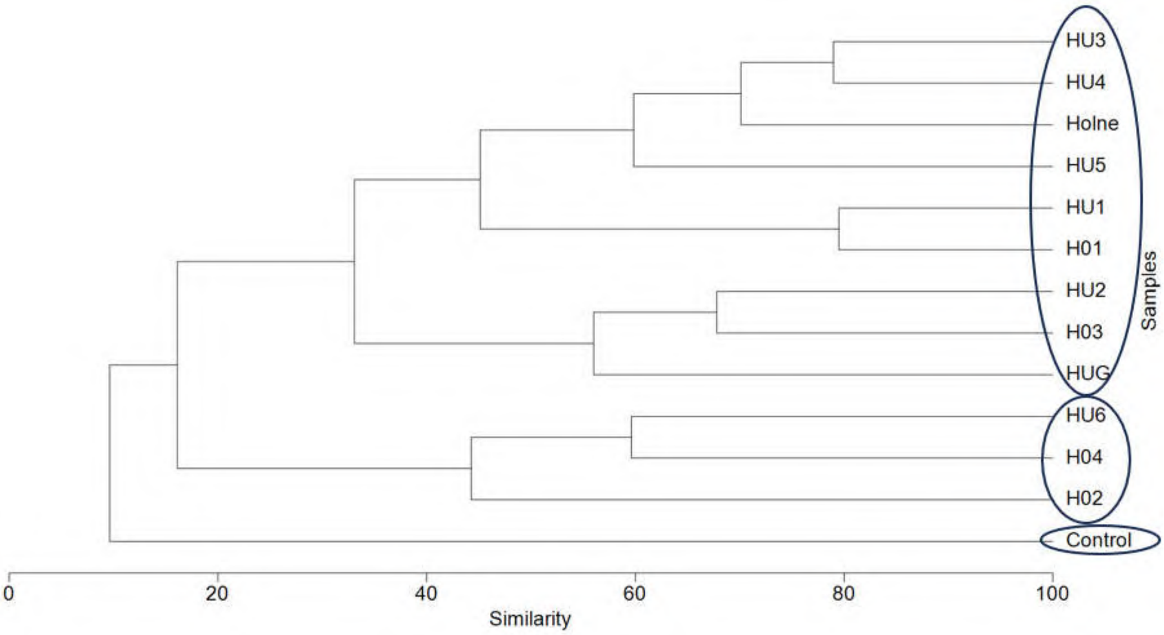
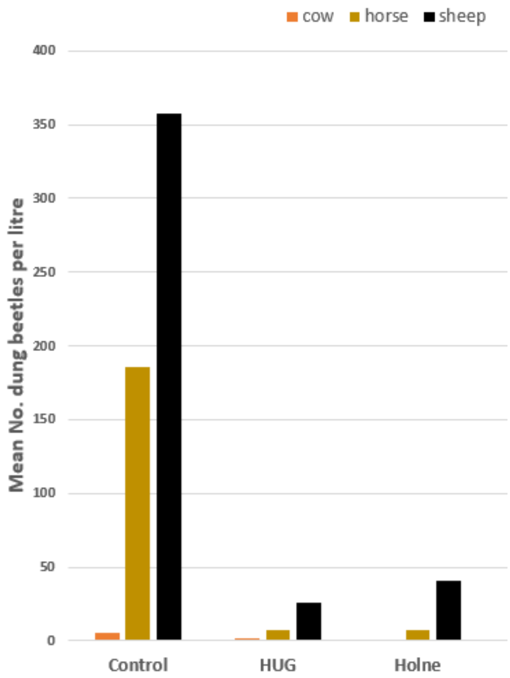


Fig 5.2.2: HCA illustrating the relationship between the dung beetle species and their abundance for species' dung across all sites

5.2a The Commons

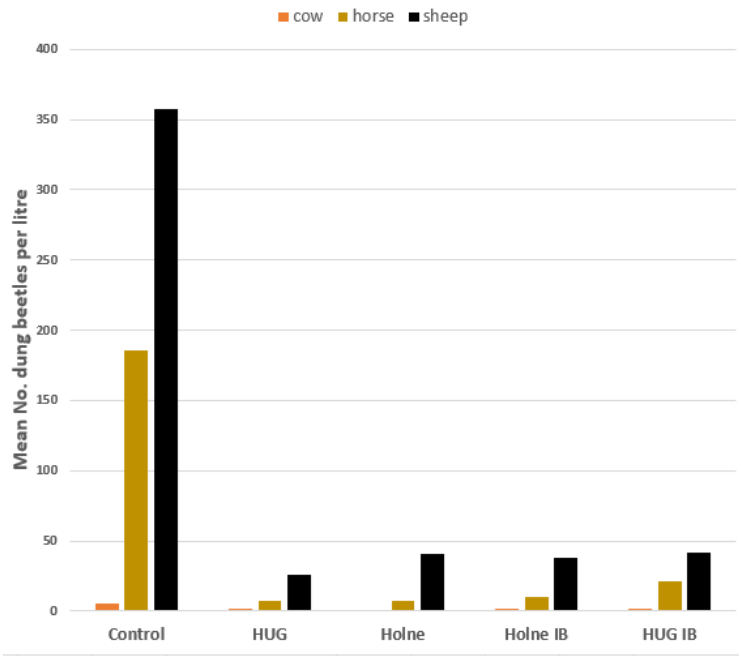


Abundance data presented as a comparative of mean number of beetles per litre:

- The abundance of dung beetles on both Commons is significantly reduced compared to the control, Holne at 14% and HUG 7% of the mean control abundance
- The three herbivore species abundance remains a similar profile across all three sites with sheep dominating in dung beetle abundance but suppressed abundance in horse dung
- HUG dung beetle abundance is 46% that of Holne

Fig. 5.2a: A graph of the total dung beetle species abundance for each species' dung on the Control & Commons

5.2b The Commons & Inbye



Abundance data presented as a comparative of mean number of beetles per litre:

- The combined inbye areas both exceeded the mean dung beetle abundance of their adjacent Commons, HUG inbye by 3% and Holne inbye by 1%.
- HUG inbye displays a three species profile close to the control unlike the other sites

Fig. 5.2b.1: A graph of the total dung beetle species abundance for each species' dung on the Control, Commons & Inbye

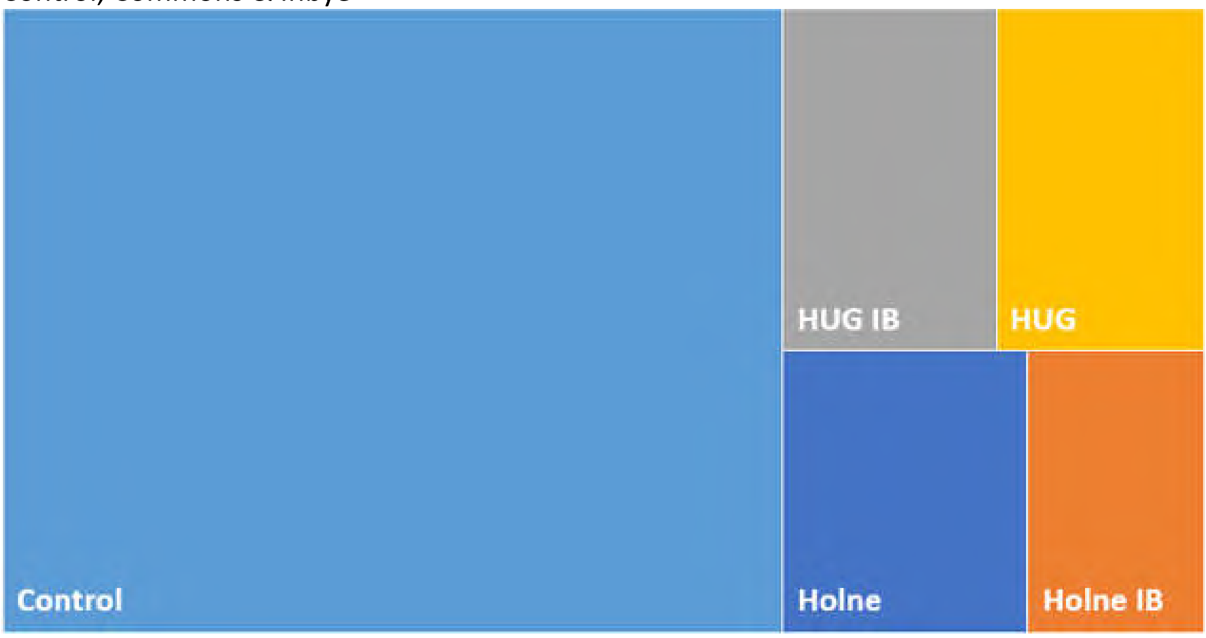
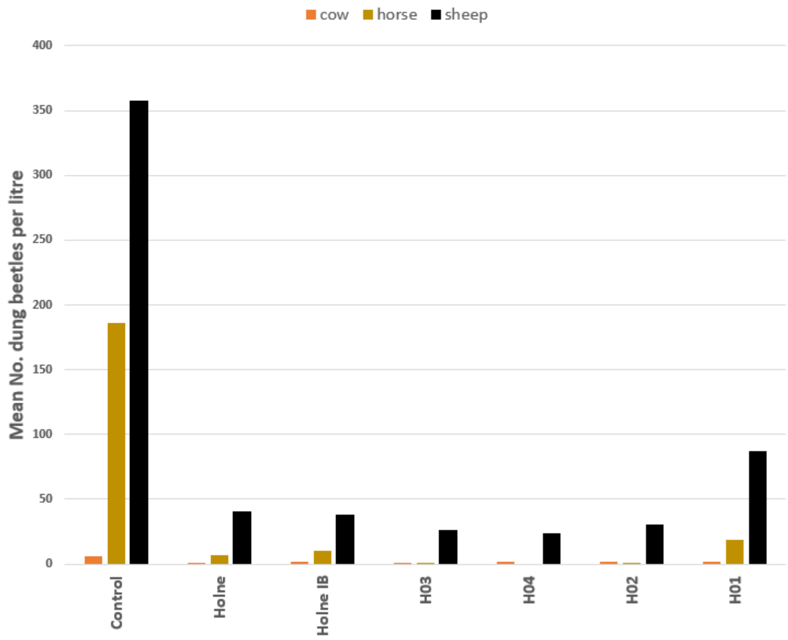


Fig. 5.2b.1: A Treemap chart of the total dung beetle abundance for all species' dung on the Control, Commons & Inbye. The tile sizes are defined by the number of dung beetles per litre of dung.

- Each shape represents the average number of dung beetles per litre.
- Dung beetle abundance in the control vastly exceeds that of each main sector of the study.

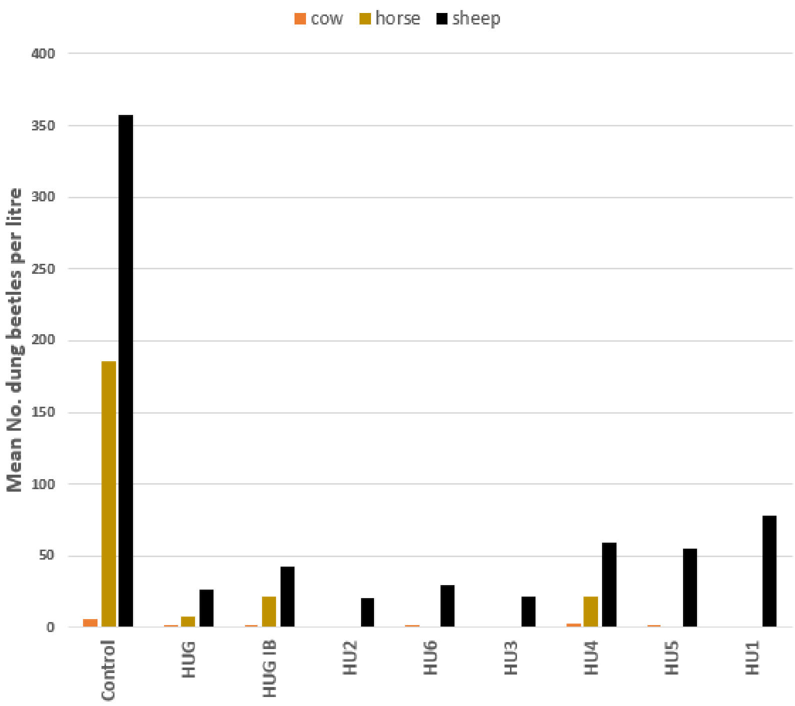
5.2c The Inbye



Abundance data presented as a comparative of mean number of beetles per litre:

- Mean abundances are comparatively low in the Holne inbye with H03 at 7% of the control, H04 at 8% & H02 at 8%
- HO1 had the third highest mean abundance of all inbye and commons at 18% of the control

Fig. 5.2c.1: A graph of the total dung beetle species abundance for each species' dung on the Control, Holne Common & Holne Inbye



Abundance data presented as a comparative of mean number of beetles per litre:

- HUG inbye HU1 had the highest mean abundance of all inbye and commons at 26% of the control. HU5 had the second highest at 20% with the remaining HUG inbye sites at HU4 16%,HU3 12%, HU6 9%, HU27%.

Fig. 5.2c.2: A graph of the total dung beetle species abundance for each species' dung on the Control, HUG Common & HUG Inbye

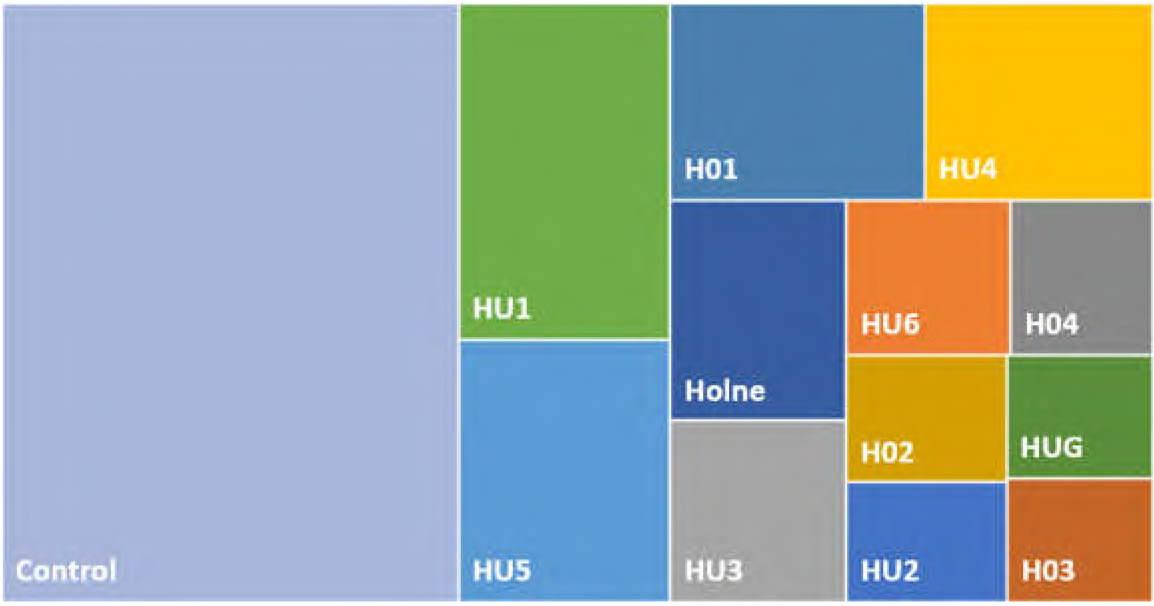


Fig. 5.2c.3: A Treemap chart of the total dung beetle species abundance for all species' dung on the Control, Commons & Inbye. The tile sizes are defined by the mean number of dung beetles per litre of dung.

- Each shape represents the average total number of dung beetles per litre.
- Dung beetle abundance in the control vastly exceeds that of each main sector of the study.

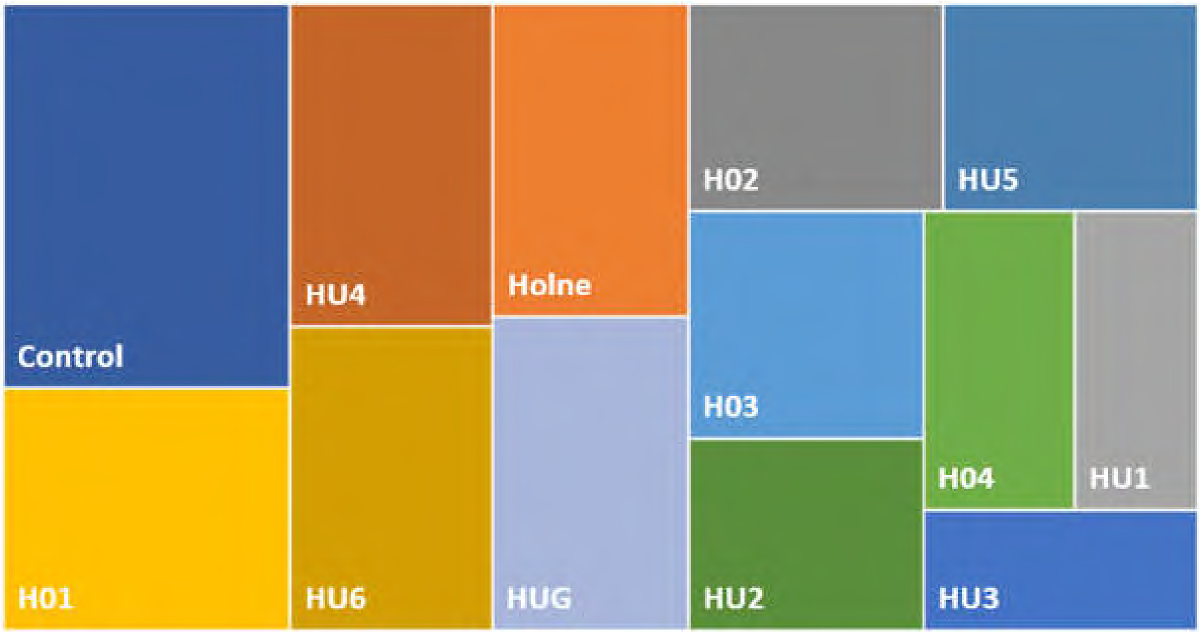
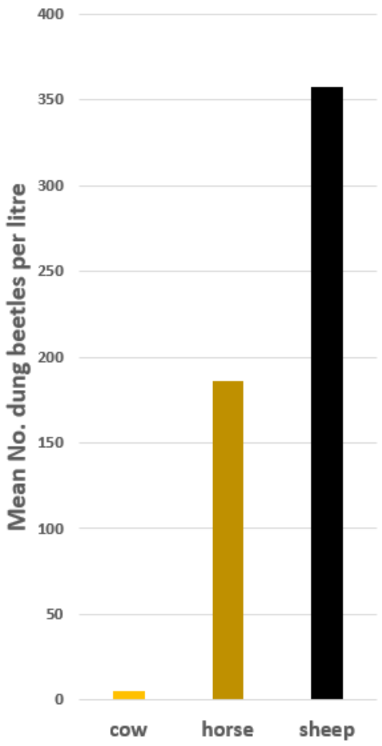


Fig. 5.2c.4: A Treemap chart of the total dung beetle species in the ecological survey for all species' dung on the Control, Commons & Inbye. The tile sizes are defined by the mean number of dung beetle species per litre of dung.

- Each shape represents the average number of dung beetle species per litre. This is a measure of ecological diversity it is different to the S diversity measure and facilitates an understanding of the average dung beetle diversity for each site.
- Dung beetle species in the control exceeds that of each main sector of the study with the nearest comparator being the Holne inbye site H01, the rest being much reduced.

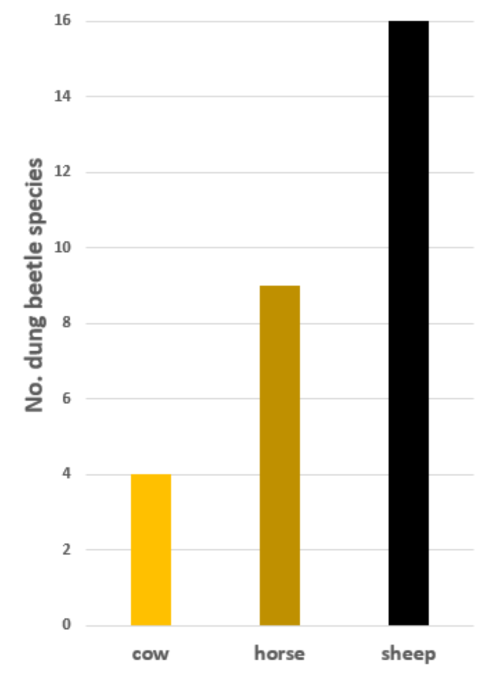
5.2d Stock Species



The number of dung beetles per litre of dung was established for the three species of herbivore in the study.

- Sheep dung was shown to hold the greatest number of dung beetles at a mean of 358 beetles per litre. Horse dung was next at a mean of 186 and cow 6 per litre.
- These results were from the control site where there is increased likelihood of natural representation. The study site data affirms that this hierarchy is replicated across in the wider data set.

Fig. 5.2d.1: A graph of the total dung beetle abundance for each species' dung



Following a whole-study analysis of the dung preference of each dung beetle species it was possible to rank the real number of beetle species associated with each herbivore dung in the study.

- Sheep dominated the food preference chart with 16 species of dung beetle, almost twice that of horses and four times that of cow.
- This data presents the preferred dung for each dung beetle species and strongly indicates that multi species grazing is essential to a thriving dung beetle community.
- 18 (61%) species of dung beetle chose their preferred dung more than 85% of the time, 14 (50%) of these species exceed 90% for their preferred choice of dung.

Fig. 5.2d.2: A graph of the number of dung beetle species that preferred to consume each livestock species' dung

The dung beetle species and abundance data presented complexity in the high-level analysis (5.2) and this was considered in part to be reflective of the impact of different herbivore species dung and the stock management regimes. The three herbivore species were each analysed:

Cattle:

Site	S	Site	N	Site	Brillouin
Control	17	Control	6	Control	1.10
HUG	12	HU4	3	HU4	0.60
HU6	10	H04	2	H04	0.35
H04	9	H01	2	H01	0.35
H01	9	H02	2	H02	0.35
H03	9	HUG	2	HUG	0.35
H02	8	HU2	1	HU2	0.00
HU4	7	HU6	1	HU6	0.00
HU5	6	HU5	1	HU5	0.00
Holne	6	HU1	1	HU1	0.00
HU2	5	H03	1	H03	0.00
HU1	5	Holne	0	Holne	0.00

Table 5.2d.1: The S diversity, number of beetles per litre and HB ecological diversity index for all sites - only cattle dung

The above table presents the diversity and abundance measures for cow dung at the sites in the study.

- The control site scored the highest in all measures indicating a high biodiversity site with the highest dung beetle abundance and number of species
- Holne Moor scored lowest in the HB index due to the second lowest S diversity and lowest beetle abundances.
- HUG Moor scored in the middle of the ranking elevated by the relatively high S diversity.
- Of the inbye the highest HB diversity was HU04 with 55% of the control diversity. The remining 4 inbye sites all scored the same at 32% of the control value.
- The three highest ranking inbye HU4, H04, H01 for beetle diversity all displayed a characteristic spring extended pause in chemical treatments.

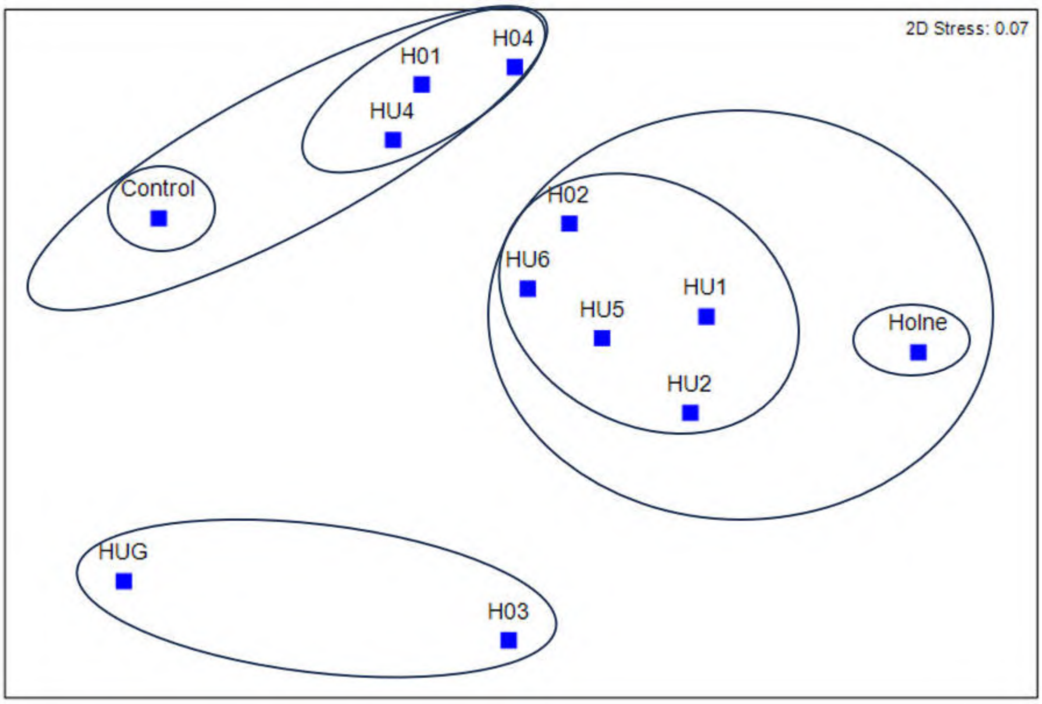


Fig 5.2d.3: MDS illustrating the relationship between the dung beetle species and their abundance for all sites - cattle dung only

MDS analysis (above) & (HCA below) of the cattle data for dung beetle species and abundance for the Commons and separate inbye sites:

- The control was nested within a HCA group of 38% similarity including the three top ranking sites that had a prolonged spring pause in stock treatments. The inbye sites HU4, H01 & H04 were 58% similar and formed a cluster proximal to the control
- The distinct group formed by HUG & H03 had in common the use of Deltamethrin (Spot On) although the treatment regimes are complex.

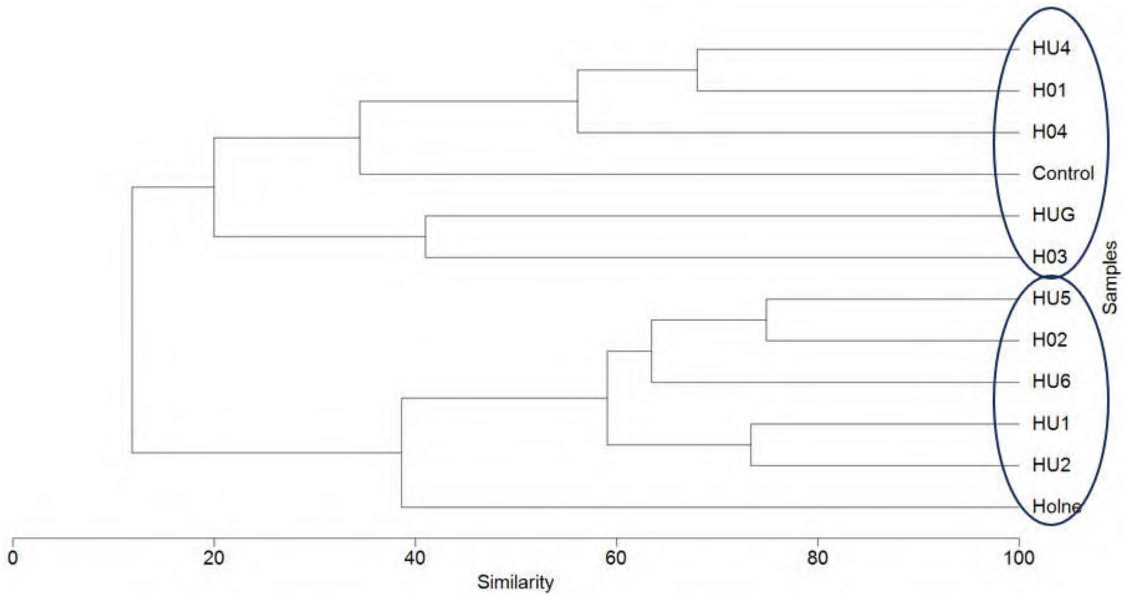


Fig 5.2d.4: HCA illustrating the relationship between the dung beetle species and their abundance for only cattle dung

Horse:

Site	S
Control	25
HU4	14
H01	12
Holne	11
HUG	10
H03	2
H02	1

Site	N
Control	186
HU4	22
H01	19
HUG	8
Holne	7
H03	0
H02	0

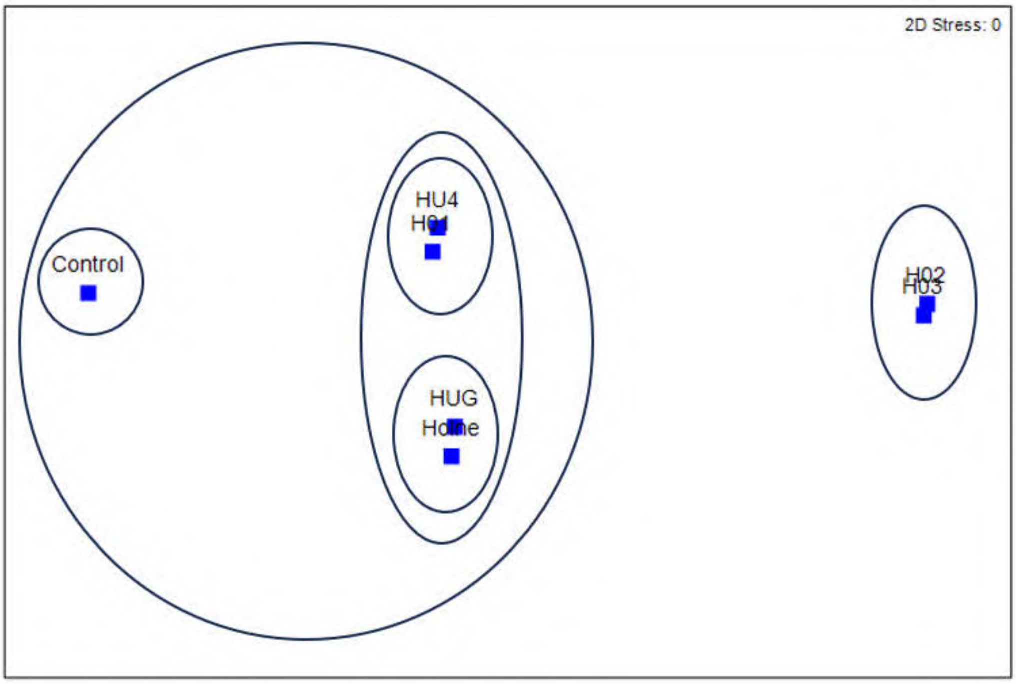
Site	Brillouin
HU4	1.38
Control	1.27
H01	0.89
Holne	0.53
HUG	0.50
H03	0.00
H02	0.00

Table 5.2d.2: The S diversity, number of beetles per litre and HB ecological diversity index for all sites - only horse dung

The above table presents the diversity and abundance measures for horse dung at the sites in the study.

- The control site scored the highest in two out of three measures (S & N) indicating a high biodiversity site with the highest dung beetle abundance and number of species but it scored second in the HB despite having the highest number of species it could not match the abundance of dung beetles in HU4 horse dung.
- HU4 HUG inbye scored highest in the HB diversity index indicating the highest ecological diversity in horse dung. This was a function of the relative species abundance in the sample.
- H01 of Holne inbye also scored relatively highly with the HB diversity index recognising its good number of species and abundance
- The inbye H03 & H02 scored low in all measures because both were sampled only in the autumn phase and H02 normally treats with Moxidectin in the month of sampling and the treatment in H03 were unknown for the newly incoming stock.
- The Commons were effectively at the bottom of the ecological measures for horse dung beetle diversity and abundance. There appears to be no clear reason for this given that they are free roaming stock and usually untreated. Without evidence to the contrary the suppressed dung beetle fauna of the commons in horse dung can only be an artefact of the general health of the dung beetles in the other dung types.

Fig



5.2d.5: MDS illustrating the relationship between the dung beetle species and their abundance for all sites - only horse dung

MDS analysis (above) & (HCA below) of the horse data for dung beetle species and abundance for the Commons and separate inbye sites:

- The grouping H02 & H03 should be considered outliers to the main analysis because they were only sampled in only one of the three seasons although there is a likelihood of treatment impact discussed above.
- The diversity and abundance measures are contradicted in part by the more sophisticated MDS and HCA analyses. Although related by 9% the control remains a distinct dung beetle community from the other sites. This is a function of the significantly higher species diversity and abundance.

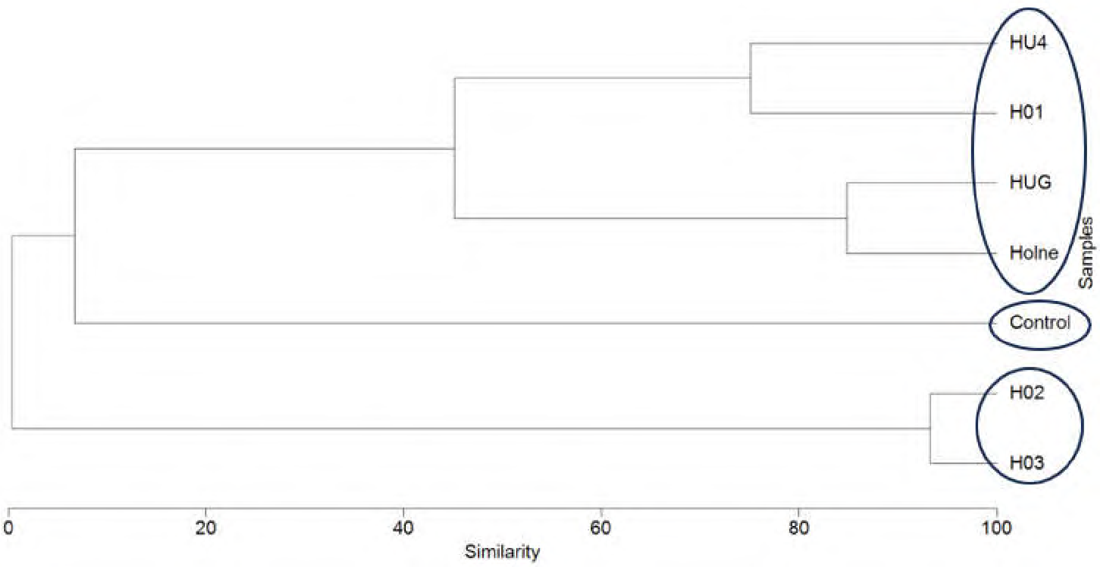


Fig 5.2d.6: HCA illustrating the relationship between the dung beetle species and their abundance for horse dung only

Sheep:

Site	S
Control	15
HU6	13
HU5	10
HU4	9
H03	9
HU2	9
H01	8
H02	8
HUG	8
HU3	8
HU1	6
H04	5
Holne	2

Site	N
Control	358
H01	87
HU1	78
HU4	59
HU5	56
HU6	30
H02	30
H03	26
HUG	26
H04	24
HU3	21
HU2	20
Holne	6

Site	Brillouin
Control	1.98
HU6	1.56
H02	1.50
HU4	1.45
HU5	1.27
HU2	1.22
HU3	1.11
H03	1.11
HU1	1.09
HUG	1.07
H01	1.03
H04	0.87
Holne	0.30

Table 5.2d.3: The S diversity, number of beetles per litre and HB ecological diversity index for all sites - only sheep dung

The above table presents the diversity and abundance measures for sheep dung at the sites in the study.

- The control site scored the highest in all measures indicating a high biodiversity site with the highest dung beetle abundance and number of species
- H01 & HU1 displayed the highest dung beetle abundances in line with their treatment regime only prior to release on the common leaving the inbye relatively treatment free. The third highest abundance at HU5 can be attributed to a long period of no treatment of inbye sheep during the autumn and spring.
- The S diversity after the control was led by HU6 which had an elevated autumn sampling diversity due to reaching the end of a 4 month summer period of untreated ewes. The next best site HU5 benefitted from more S diversity in the spring sampling at the end of a 4 month period of no treatment.
- The HB diversity measure for the control was 27% higher than the nearest best performing study site. This was driven by the much higher abundance in the samples.
- HU6 with the highest HB diversity measure after the control had obvious periods of staggered treatments with a notable clear period in the spring. H02 benefitted from an increase in both species and abundance in the summer sampling after pause in treatments.
- The data would benefit from further analysis to fully understand the impact of specific treatments. Some sites, for example H01 displayed relatively high abundance and diversity in spring after an extended treatment pause but the next sampling period freshly administered treatments reduced the dung beetle abundance and diversity. The timing of treatments across the sites was complex but it was felt that a deep dive into the data would reveal some useful insights into the nature of treatment impact on the dung beetles.

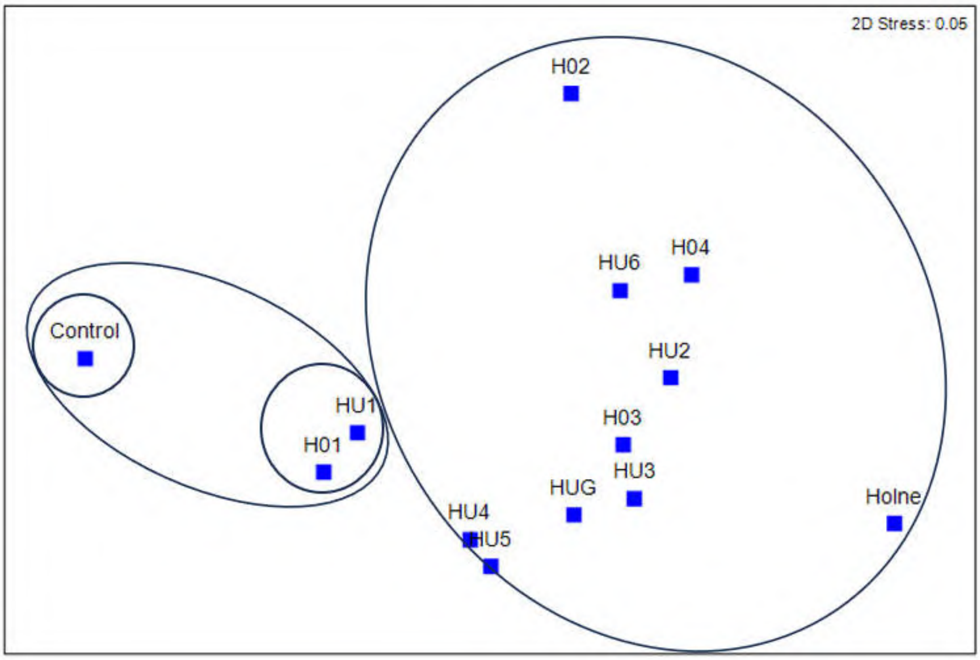


Fig 5.2d.7: MDS illustrating the relationship between the dung beetle species and their abundance for all sites - only sheep dung

MDS analysis (above) & (HCA below) of the sheep data for dung beetle species and abundance for the Commons and separate inbye sites

- The control formed a group 38% similar with H01 & HU1 both of which only treat stock before release onto the Common and displayed high beetle abundances as a result.
- The remaining sites formed a complex of subgroups clearly with some commonalities but with reasons for groups as yet unclear. Of note in the MDS is the proximity to the control of the sites HU4, HU5, HU6 & H02 all of which have extended period clear of treatments particularly in the spring part of their staggered treatment regimes.

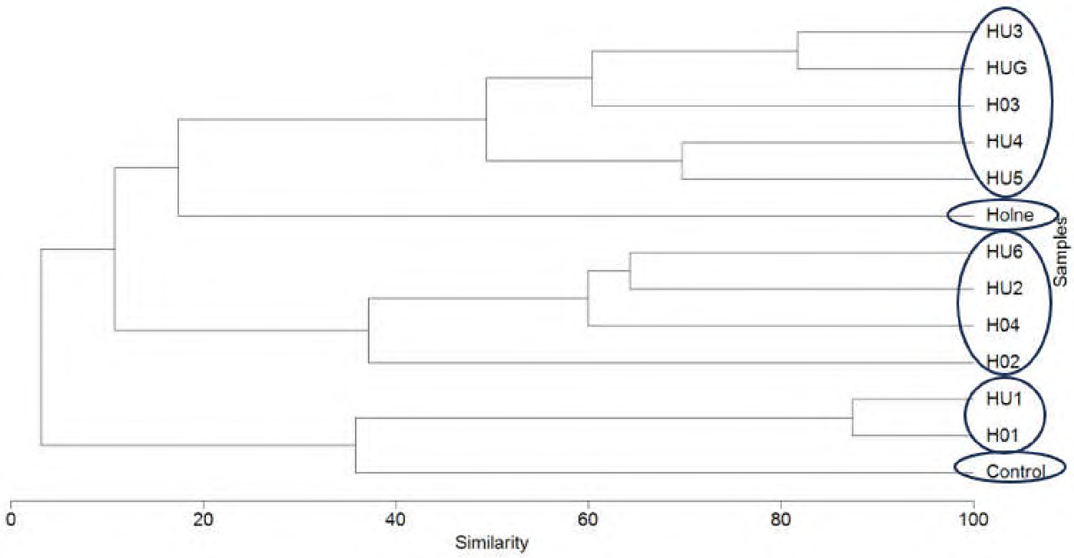


Fig 5.2d.8: HCA illustrating the relationship between the dung beetle species and their abundance for sheep dung only

6 Discussion

In terms of species diversity all sites performed relatively well when compared to the 'gold standard' control site with its best fit to a natural dung beetle community in a modern managed landscape. The ecological data revealed insights into the ecological health of the sites in terms of dung beetle communities to reveal the complexity and some understanding of the ecology we are explored.

6.1 The Commons (Results section 5.1a & 5.2a)

The Common's S diversity is much lower than that of the combined inbye groupings. Both Commons displayed a dung beetle community distant by a dissimilarity of 21% from the associated inbye farms and the control or 39% from the control alone. This disparity was explainable by the number of missing species with the control having 17 species (-47%) not on Holne and 14 species (-43%) not on HUG. Holne had 10 species less (-33%) than the adjacent Holne inbye and HUG had 7 species (-27%) less than the adjacent HUG inbye. The primary difference between the Holne & HUG commons was the lack of 3 spring active dung beetles with feeding preference for sheep dung on Holne Moor, the cause of this was the low numbers of sheep on Holne in the early spring and treated sheep following turnout. This is a facet of the HLS / UELS Stewardship Agreement which has reduced winter sheep numbers with the moor cleared from 1st March until the 31st of April. The S diversity results indicate that both Holne & HUG Moors when compared to the control and aggregated Inbye have a dissimilar and significantly less diverse dung beetle community than all the other sites.

The mean dung beetle abundance on the commons was low at 7% of the control abundance for HUG at the bottom of the abundance ranks and 14% for Holne in the midsection of the abundance ranks. The rank abundances should be put in context because the highest site abundance achieved 26% of the control mean abundance. The control abundance was not considered high but as close to natural as we can expect to achieve in a modern managed landscape. It is important to recognise that what is the 'gold standard' in a modern environment used to be normal and widespread. The control site was chosen for its outstanding dung beetle community to stand as a comparative benchmark. In this respect it was reassuring to observe relatively strong species diversity survey results but abundance was notably lower in the study areas.

6.2 The Commons & Inbye (Results section 5.1b & 5.2b)

In terms of S diversity HUG Moor was comparable to the inbye. Holne Moor scored lower than the inbye directly attributable to the absence of spring sheep and their associated specialist dung beetle species. Examination of the dung beetle communities revealed further dimensions to their composition. The two commons HUG Moor & Holne Moor in terms of S diversity were not materially differentiated from each other or separate from the inbye with all except for one site (H01) only 61% similar to the Control (Figs. 5.1.3 & 5.1.4). These separate groupings from the Control were indicative of an underlying heterogeneity between the diverse inbye sites which, when combined for the inbye create a dung beetle community much more similar to the control than the two commons (Figs. 5.1.1 & 5.1.2). This presents the conclusion that variety in the inbye stock management regimes is a primary force in shaping a resilient and more natural dung beetle community in terms of the number of species.

Combined inbye results for mean dung beetle abundance for HUG & Holne approximated to the Commons at respectively 10% & 15% of the mean control abundance and HUG inbye was the only site to exhibit a similar multi species abundance profile to the control.

6.3 The Inbye (Results section 5.1c & 5.1c)

The Inbye site H01 stood out in the species diversity survey as being 83% similar to the control community in species composition. H01 with its 21 beetle species was the most species diverse of the study sites other than the control. The MDS analysis reiterated the groupings from the HCA analysis but indicated that whilst H01 is close to the control in terms of dung beetle community it was placed between the control and the other study sites reflecting its divergence from the control.

The remaining inbye sites formed a separate community cluster that could be divided into two 66% similar aggregations. This formation expressed the heterogeneity in terms of dung beetle diversity between the sites which, when formed into an aggregation was favourable to the inbye as an expression of greater diversity.

Some of the variability between S diversity inbye results can be explained by the number of livestock species on the inbye, the highest scoring sites had cow, sheep and horse on site (3x species grazing) during the study. HU3 remained the only site to have a single species (sheep) on site throughout the survey and was the lowest scoring of the inbye sites.

The mean dung beetle abundance analysis for the inbye presented the highest abundance data with mean abundances ranging from a maximum of 26% of the control in HU1 to the lowest at 7%. The dramatically reduced abundance of dung beetles in the inbye contrary to the relatively good S diversity suggests that the dung beetle community in the inbye is restricted, this was also reflected in the ecological diversity data with one notable exception (H01).

6.4 Stock Species (Results section 5.1d & 5.2d)

Sheep dung contained the highest number of dung beetle species at 28 with horse dung a very close second at 27 and cow dung 17 (5.1d). This was in terms of S-diversity and is an expression of the number of dung beetle species found in each type of herbivore dung. The dung beetle species were rarely exclusively associated with a single type of herbivore dung. This reflects the published information generated from a multitude of qualitative field observations (Lane & Mann 2016). However, this characterisation can be misleading because dung beetles may have a preference for specific dung types whilst simultaneously being found in dung of other characteristics (Turner 2023).

The quantitative data collected in this study (5.2d) has facilitated characterisation of dung preferences by beetle species with the result that characterisation of food preferences were defined. The most species, 16, preferred sheep dung whilst a further 9 preferred horse dung leaving 4 species dominating cow dung. Amongst these dung beetle species the majority are single herbivore dung specialists with 61% choosing their preferred dung >85% of the time. With 50% of the dung beetle species being even more discerning by choosing their preferred dung >90% of the time. This true measure of dung beetle food choice reaffirms the assertion of Turner (2023) that the literature promotes a false understanding of dung beetle ecology. It is a widely described paradigm that species under ecological stress such as altered food sources, are more prone to extinction due to additional challenges (i.e. Bristow et.al. 1993; Samways 2005).

The abundance analysis of dung beetles by herbivore species demonstrated that per litre the sheep dung contains twice the number of dung beetles than horse dung and significantly more than cow dung. An important consideration when managing habitat for biodiversity as well as stock production. The analysis of feeding preferences defines sheep dung as the preferred food for the highest number of dung beetle species, other herbivore dung is also preferred by different species presenting a classic niche differentiation scenario. Therefore, multispecies grazing in a pastoral landscape is essential to maintain a diverse dung beetle community and associated biodiversity. The data collected during the course of this study affirms the natural normality of distinctly demarcated dung preferences by our resident dung beetle species and provides evidence for the local disappearance of species. The data also clearly present the distinctly elevated abundances exhibited by species occupying their preferred food source with direct implications for bio-abundance of dung beetles which are an important source of food for many predatory vertebrates. Evaluation and management for a favourable condition of the dung beetle fauna has obvious benefits to food webs and would be expected to assist in the restoration of populations of predatory animals particularly birds and bats all of which have negatively responded to the recent anthropogenic phenomenon of vast insect abundance and diversity losses (i.e. Goulson 2021).

6.5 Treatments (Results - all sections)

The chemical treatment of livestock and the impact on dung beetle communities proved difficult to link precisely at the current level of analysis but it was possible to establish some insight from the ecological survey data. Both Holne & HUG Moors have the lowest S-diversity, abundance and amongst the lowest ecological diversity scores considered to be as a result of the regular and consistent treatment of livestock. The study included inbye with the commons which was insightful through enabling comparison of the range of stock management regimes. The highest abundances and species diversities were found when treatments did not exist, had long pauses, especially in the spring or were staggered to ensure some stock were not treated at any one time. The dung beetles were clearly suppressed at the study sites in terms of both abundance and diversity with the most intense treatment regimes. Across all study sites compared to the control the best performing exhibited a quarter of the abundance of the control. Reassuringly the S diversity has remained comparatively good across all sites with many species remaining present albeit some in low numbers.

In line with best management guidance the graziers use acaracides to reduce ectoparasite burdens and specifically ticks. Young lambs do have some protection from maternal colostral antibodies (Moredun) and where tick numbers are low lambs can be left to be ‘challenged’. If this isn’t possible then the use of ‘pour on’s affords some protection as will full immersion dipping later in the season (6 weeks). An anecdotal but consistent theme highlighted by graziers was the loss of lambs close to, or post weaning. In some instances, this was accompanied by poor growth as lambs move onto in-bye pasture when in theory they should start to increase in daily live weight gain. The prevalence of Louping Ill and Tick Borne Fever may underlie some of these issues with stress and loss of colostral protection exposing the lambs to even greater challenge (Wells B. Personal Comms. 2023).

There have been various scientific papers published that look at the impact of routine health treatments on dung fauna. The majority of these have focussed on relationships between cattle dung and both Avermectin and Macrocyclic lactone treatments evaluating their impacts on arthropod populations (Suarez, V. H., Lilschitcz, A. L. L., Sallovitz, J. M. & Lanusse: 2003). The Royal Society for the Protection of Birds has also funded research related to the Chough *Pyrrhocorax pyrrhocorax* which looked at four regions in the UK evaluating different treatments and grazing strategies (Goodenough, Webb & Yardley: 2019). It concluded that the birds preferred higher intensity grazing with lower applications of veterinary parasiticides. In contrast there seems to be less research on the relationship between sheep dung and wider food webs. Relatively little is known about the impact on birds and other vertebrates through the loss of dung fauna. What research has been conducted in Europe suggests that some declining species such as Lapwing *Vanellus vanellus* (30% of diet) have dung beetles as a key part of their diet. This is mirrored by Curlew which probe deeply for Dor beetles *Geotrupes* and Cuckoo *Cuculus canorus* which also predate dung beetles (Newton I. 2018). This suggests that there is a clear relationship between livestock dung and the wider ecosystem.

The diversity, character and distribution of dung on the commons was also dictated by animal species. Cattle, sheep and ponies all graze in different patterns and the relationship between food, shelter, shade and water varies. They also have different forage preferences which through grazing patterns creates a more diverse and ecologically rich landscape in part influenced by stocking density and by active commons management. Survey evidence for dung fauna and invertebrate activity in general suggests large parts of the common have become monospecifically dominated communities i.e. *Molinia*. As a result, livestock are restricted to grazing an ever-decreasing area with a resultant loss of structural diversity within vegetation communities across the common. Where three species grazing persists, it promotes diversity within semi-natural habitats providing varied ecotones and increasing resilience to an increasingly homogenised landscape. The survey suggests this has direct benefits for dung fauna but also for wider biodiversity on the common.

The study data highlights the need to integrate animal health and welfare as an integral part of the wider management of the commons. Through the act of grazing, animals provide dung which supports a representative group of dung fauna with links to wider food chains. Importantly the research highlights the complexity of decision making on protected sites (SSSI condition status) and the need to carefully evaluate changes to livestock species, density and timing of grazing. This study suggests that winter grazing has a role to play in ecological diversity and condition of protected sites.

Through field observations and discussion, the ‘shrinking’ of the grazed area has also concentrated vertebrate activity (Turner C. 2023 personal comms.) resulting in ‘desert’ areas with little biodiversity interest. Addressing this challenge requires a fresh integrated approach where we consider livestock health and well-being as an integral part of vegetation management processes. A more informed strategy supported by the key partners with shared data and knowledge (vaccination, tick mapping etc.) could unlock enhanced outcomes for both dung beetles and dung fauna in general. The study recognised the value of maintaining a diverse and active grazier community highlighting that heterogeneity ensured that commoners did things in slightly different ways at different times. This built resilience to enhance diversity and abundance within the study group, all underpinned by three species grazing. This heterogeneity has also provided a future opportunity to better understand the impact of treatments on dung beetles held within the data, a more detailed analysis is recommended to develop deeper understanding of type and timing of treatments.

The study recognises that grazing is not a one-dimensional tool but provides a wider ecological benefit as illustrated by the Healthy Livestock Project. Currently under the Sustainable Farming Incentive (SFI) there is no 'commons' option for collaborative health schemes which could integrate other strands such as the Farming Investment Fund. This type of integrated offer could support further investigative work on the common and help to shape programmes of activity that in combination reduce the requirement for some vet med inputs.

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8 Species List

Species Name	Dartmoor	Holne	HUG	Inbye
Acrossus depressus (Kugelann, 1792)	Yes	Yes	Yes	Yes
Acrossus luridus (Fabricius, 1775)	Yes	Yes	Yes	Yes
Acrossus rufipes (Linnaeus, 1758)	Yes	Yes		Yes
Agrilinus ater (De Geer, 1774)	Yes	Yes	Yes	Yes
Agrilinus rufa (Moll, 1782)	Yes*			
Anoplotrupes stercorosus (Scriba, 1791)	Yes			
Aphodius fimetarius (Linnaeus, 1758)	Yes			Yes
Aphodius foetens (Fabricius, 1787)	Yes		Yes	
Aphodius pedellus (De Geer, 1774)	Yes	Yes		Yes
Calamosternus granarius (Linnaeus, 1767)	Yes		Yes	Yes
Chilothorax conspurcatus (Linnaeus, 1758)	Yes			
Colobopterus erraticus (Linnaeus, 1758)	Yes			Yes
Esymus merdarius (Fabricius, 1775)	Yes*			
Esymus pusillus (Herbst, 1789)	Yes		Yes	Yes
Euorodalus coenosus (Panzer, 1798)	Yes*			
Geotrupes mutator (Marsham, 1802)	Yes			
Geotrupes spiniger (Marsham, 1802)	Yes	Yes	Yes	Yes
Geotrupes stercorarius (Linnaeus, 1758)	Yes	Yes	Yes	Yes
Limarus zenkeri Germar, 1813	Yes			Yes***
Melinopterus consputus Creutzer, 1799	Yes*			
Melinopterus prodromus (Brahm, 1790)	Yes	Yes	Yes	Yes
Melinopterus sphacelatus (Panzer, 1798)	Yes	Yes	Yes	Yes
Nimbus contaminatus (Herbst, 1783)	Yes			Yes
Nimbus obliteratus Sturm, 1823	Yes			Yes
Onthophagus medius (Kugelann, 1792)	Yes**			Yes**
Onthophagus coenobita (Herbst, 1783)	Yes	Yes	Yes	Yes
Onthophagus joannae Goljan, 1953	Yes			Yes
Onthophagus similis (Scriba, 1790)	Yes	Yes	Yes	Yes
Otophorus haemorrhoidalis (Linnaeus, 1758)	Yes	Yes	Yes	Yes
Planolinus borealis Gyllenhal, 1827	Yes		Yes	Yes
Sigorus porcus (Fabricius, 1792)	Yes			
Teuchestes fossor (Linnaeus, 1758)	Yes	Yes	Yes	Yes
Trypocopris vernalis (Linnaeus, 1758)	Yes			
Typhaeus typhoeus (Linnaeus, 1758)	Yes		Yes	Yes
Volinus sticticus (Panzer, 1798)	Yes			Yes
Total Species Count	**35**	**13**	**16**	**25**

Notes:

* Not recorded from the part of Dartmoor covered by this study but previously recorded from the area
** First record for Dartmoor
*** A new second locality for this species in southwestern England