Dead Hedges - Good for Small Mammals - The Assumption Tested.

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Abstract

Dead hedges are ancient countryside features that are still built today to utilize the logs and brash from woodland management work. This project tests the assumption generally made that dead hedges are a good habitat for small mammals. It compares the presence and activity levels at 12 study areas, six with hedges and six without, in Leyland, Lancashire (UK), using tracking tunnels and small mammal traps. It finds that at a species diversity level, presence of small mammals is the same for hedge and non-hedged sites, whilst activity levels are higher at non-hedged sites. The results suggest that small mammal activity is driven by a variety of factors including microhabitat structure, small mammal adaptations and the interaction of rats and mice more than by the presence or absence of dead hedges.

Acknowledgements

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1. Introduction

The charismatic appeal of small mammals for many is created by fable and film in childhood. To be able to create a home for these secretive creatures is something that catches the imagination of people of any age. Dead-hedging is an ancient craft that is still undertaken today by countryside professionals and volunteers as a way of using cut branches and logs from woodland management work (Beaman, pers. obs.; Auerswald, 1996; Woodland Investment Management, 2017; McKee, n.d.). Modern websites promote dead hedges (illustrated in figure 1.1) as good habitat for birds, invertebrates and small mammals (Greenway, 2015; RSPB 2017). This project aims to test this assumption on small mammals.

Figure 1 – Photograph to illustrate a dead hedge (Beaman, 2015)

The history of the dead hedge in England can be traced back to the Domesday Book (Albery, 2011). Originally constructed to protect crops and coppiced woodlands from damage by livestock, they were temporary structures that were removed post-harvest or once new woodland growth was established. They consisted of two parallel rows of wooden stakes infilled with bundles of branches. Dead hedges were superseded by the introduction of the fast growing and permanent Hawthorn (*Crataegus monogyna*) hedge in the 18th Century (Albery, 2011).

Whether dead or alive, hedges or hedgerows (the term is used interchangeably) are man-made landscape features found across the world (Baudry et al, 2000; Schlinkert et al, 2016). Originally used to delimit boundaries they also provided shelter and products for humans and animals. Today they are recognised for their cultural values and ecological benefits - hedgerows influence biodiversity; they act as habitats, refuges, corridors or barriers (Baudry et al, 2000; Schlinkert et al 2016).

1.1 Literary Review

Searches of relevant publications using Oxford University Solo, online databases of Scopus, Google Scholar, Research Gate and Conservation Evidence using search terms: dead hedges or hedgerows; brushwood hedges; vegetative barriers; fascines (Richet et al, 2017); artificial shelter breaks plus small mammals, revealed no academic studies in this area.

Maudsley (2006) associated 32 vertebrate species with hedgerows. Whilst Seibold et al's (2015) meta-analysis looked at 79 studies in deadwood biodiversity across 23 countries and found that only 6 focused on small mammals, amphibians, reptiles and other invertebrates.

The importance of dead wood, a product of forest disturbance (McComb & Lindenmayer, 1999), to biodiversity has been widely acknowledged (Seibold et al, 2015) for its long term ecosystem productivity such as contributing organic matter to soil structure, nutrient cycling and modification of microclimate (Sullivan & Sullivan, 2012; Sullivan et al, 2017). It is generally studied on two scales. Fine woody debris (FWD) is logs or branches <10cm diameter and can occur scattered or piled (Manning & Edge, 2008; McCay & Komoroski, 2004). Coarse woody debris (CWD) is the residue left after conventional forest harvesting (Sullivan et al, 2012) and consists of standing dead wood, downed wood and logs >10cm in diameter and >1.5m long (Manning & Edge, 2008; Loeb, 1999) at any stage of decay (Lee, 2012).

Working with these definitions of size, dead hedges are predominantly made from FWD with only small amounts of CWD (logs) being present in the base. Unfortunately, FWD as a forest component has received little attention in wildlife literature (Manning & Edge, 2008) and piles of FWD break down quicker as a result of decay and their structure changes, reducing the availability of air space and movement corridors (Chambers, 2002), thus reducing the potential for longer term studies.

In most forest enterprises excess woody debris is often cleared as a fire risk (Chambers, 2002). There is growing awareness of the importance of retaining CWD, in the form of piles or windrows, which may benefit biodiversity (Sullivan & Sullivan, 2014; Sullivan et al, 2017; Bowman et al, 2000; Lee, 2012; Fauteux et al, 2012). Dead wood adds complexity to the forest floor, increasing ground surface and below ground heterogeneity (McComb & Lindenmayer, 1999). It is a key structural element of the woodland (Fauteux et al, 2012) providing important habitat components (Chambers, 2002; Sullivan et al, 2012) and connectivity between habitats (Sullivan & Sullivan, 2012; Schlinkert et al, 2016). Any row of woody vegetation can be a corridor for ecological purposes (Baudry et al, 2000) and mitigate the effects of fragmentation (Schlinkert et al, 2016).

Associations have been recognised between decaying CWD and numbers of small mammals (Fauteux et al, 2012). Small mammals have multiple ecological roles in a woodland food chain – predator, prey and disperser of seed (Pauli, 2006; Schlinkert, 2016). Habitat type, effects of isolation and habitat structure influence the occurrence of small mammals (Schlinkert et al, 2016). A variety of microhabitats will increase small mammal abundance and species richness (Schlinkert et al, 2016). Piles and windrows increase the habitat for some small mammals (Chambers, 2002) as do variations in type of dead wood, its age and management history (Seibold et al, 2015). CWD provides nesting, cover and travel routes plus a source of food (Loeb, 1999; Sullivan et al, 2012; McComb & Lindenmayer, 1999; Sullivan et al, 2017), humidity (Fauteux et al, 2012; Gray, 2014), a source of moisture and a buffer to extremes of temperature (Seibold et al, 2015). Fauteux et al (2012) state that the level of decay is important and may determine use, whilst Bowman et al (2000) found no significant relationship between species and decay class of CWD – logs of all stages are used with equal intensity.

Whilst associations between habitat and species diversity are well known, the effects of the scale of the habitat structure and diversity of species are not (Adler, 1988). Most studies are done on a large spatial scale looking at whole forest systems (Seibold et al, 2015). Sullivan & Sullivan (2012) and Sullivan et al (2017), quote a lack of experiments of woody debris at a real world scale. Bowman et al (2000) and Butts (2000) state that studies directly relating volume and distribution of CWD to the presence and abundance of small mammals are limited and results inconclusive. McComb and Lindenmayer (1999) identify that virtually no studies quantify the relationship between log size or density and animal abundance.

Human impact has altered spatial and temporal dynamics of woodlands (Seibold et la, 2015). Whilst macrohabitat affects population stability and community composition (Adler, 1998), microhabitats are likely to vary over the home range of a single individual and the resources available will affect selection and population densities (Adler, 1988; McComb & Lindenmayer, 1999).

The majority of CWD studies have been done on naturally occurring dead wood and not man-made structures like dead hedges. The closest comparison is the work on windrows in British Columbia done by Sullivan (2012, 2014 & 2017). The windrows are constructed by machine at the time of forest clearance and measure six to nine meters wide and one to three meters high. Whilst on a much larger spatial scale than the dead hedges in this study, they compared sites with and without windrows and focused on small mammal abundance, species richness and diversity.

Sullivan & Sullivan (2012) hypothesised that the abundance of small mammals should increase with amounts of CWD but results were weak and variable, possibly due to the effects of climate, vegetation cover, seral stage, and the scale of the investigation. Sullivan et al (2012) claim to be the first study looking at the response of small mammals to constructed piles and windrows. Schlinkert et al (2016) showed that small mammal use of forest edges and hedges will depend on species-specific habitat adaptations, dispersal ability and ability to cope with habitat modification. Generalists thrive in many areas and show less habitat preferences. Forest specialists will avoid open areas and benefit from hedges as dispersal corridors.

Census methods for small mammals are varied and depend on the size of the species, activity, habitat, dispersion and catchability (Krebs, 1996; King & Edgar, 1977). Tracking tunnels are a widely used method for tracking small mammals to gain presence / absence data (Flowerdew et al, 2004; Palma & Gurge, 2007) and an index of density for pest species and have replaced the use of kill traps in New Zealand (Martin et al 2011; Blackwell et al, 2002). They have detected Giant Weta at more locations than visual searches (Watts et al, 2011). Tunnels are more efficient than trapping at gaining a relevant description of a small mammal community (Palma & Gurgel, 2007). They have limited interference in animal activity (tunnels stay in situ so sites are not disturbed), are non-lethal and fine for threatened taxa (Watts et al, 2011; King & Edgar, 1977). Tunnels can be used to assess small mammal communities in a wide range of habitats and at a spatial scale likely to reflect different management practices within a wider landscape (Yarnell et a, 2014; Glennon et al, 2002). Tunnels, used for preliminary surveys, are a more time efficient way of determining presence than trapping (King & Edgar, 1977). Tunnels have been used to survey hedgehogs (Williams et al, 2015), mice and rats (Knox et al, 2012 & Christie et al, 2015), rodents and stoats (Sweetapple & Nigent, 2011) plus weasel (King, 1980).

1.2 Project Aim and Questions

This project aims to test the assumption that 'dead hedges are good habitat for small mammals'. It will investigate the effect of dead hedge creation on small mammal presence and activity in urban parks in Lancashire by answering the following questions -

1. Do dead hedges affect small mammal presence/absence and distribution?
2. Does season or weather have an effect on their use?
3. Does day or night have an effect on their use?
4. Do the hedge characteristics (age, direction, surrounding land use type) have an effect on use?

2. Methodology

2.1 Study Area

Twelve study areas were identified in the Local Authority Borough of South Ribble, in Lancashire, UK (Figure 2).

Figure 2 - Map to show the location of the Borough of South Ribble in North West England (Beaman, 2017) Google Satellite Imagery (2017) (OSGB, 1936)

Dead hedges have been built on a number of urban park sites over the last decade and these sites will be compared to sites without dead hedges (but with the potential to build dead hedges in the future). Hedges are 0.5 to one metre wide and one to two metres high.

All sites are in the ownership of South Ribble Borough Council from whom permission has been gained to undertake survey work. All sites have public access 24 hours a day, seven days a week. They are referred to throughout by their site reference letter but local names and locations are given in figures 3 and 4. Photographs of all transect locations are given in figure 5. (A detailed overview of the study area is given in Appendix 1).

Site Ref	Site Name	Location	Grid Reference	Dead Hedge
A	Worden Park	Leyland, Lancashire	SD533209	No
B	Worden Park	Leyland, Lancashire	SD542206.	Yes
C	Fossdale Moss	Leyland, Lancashire	SD524225	Yes
D	Rhoden Road	Leyland, Lancashire	SD522225	No
E	River Lostock (North)	Leyland, Lancashire	SD527227	Yes
F	River Lostock (South)	Leyland, Lancashire	SD523216	No
G	Paradise Park	Leyland, Lancashire	SD 518225	Yes
H	Longton Brickcroft LNR	Longton, Lancashire	SD482252	No
I	Nixon Lane Woods	Leyland, Lancashire	SD509217	No
J	Malt Kiln Farm Walk	Leyland, Lancashire	SD515215	No
K	Moss Side Rugby Pitches	Leyland, Lancashire	SD522212	Yes
L	Walton Park	Bamber Bridge, Lancashire	SD548266	Yes

Figure 3 – Table showing an overview of the study areas

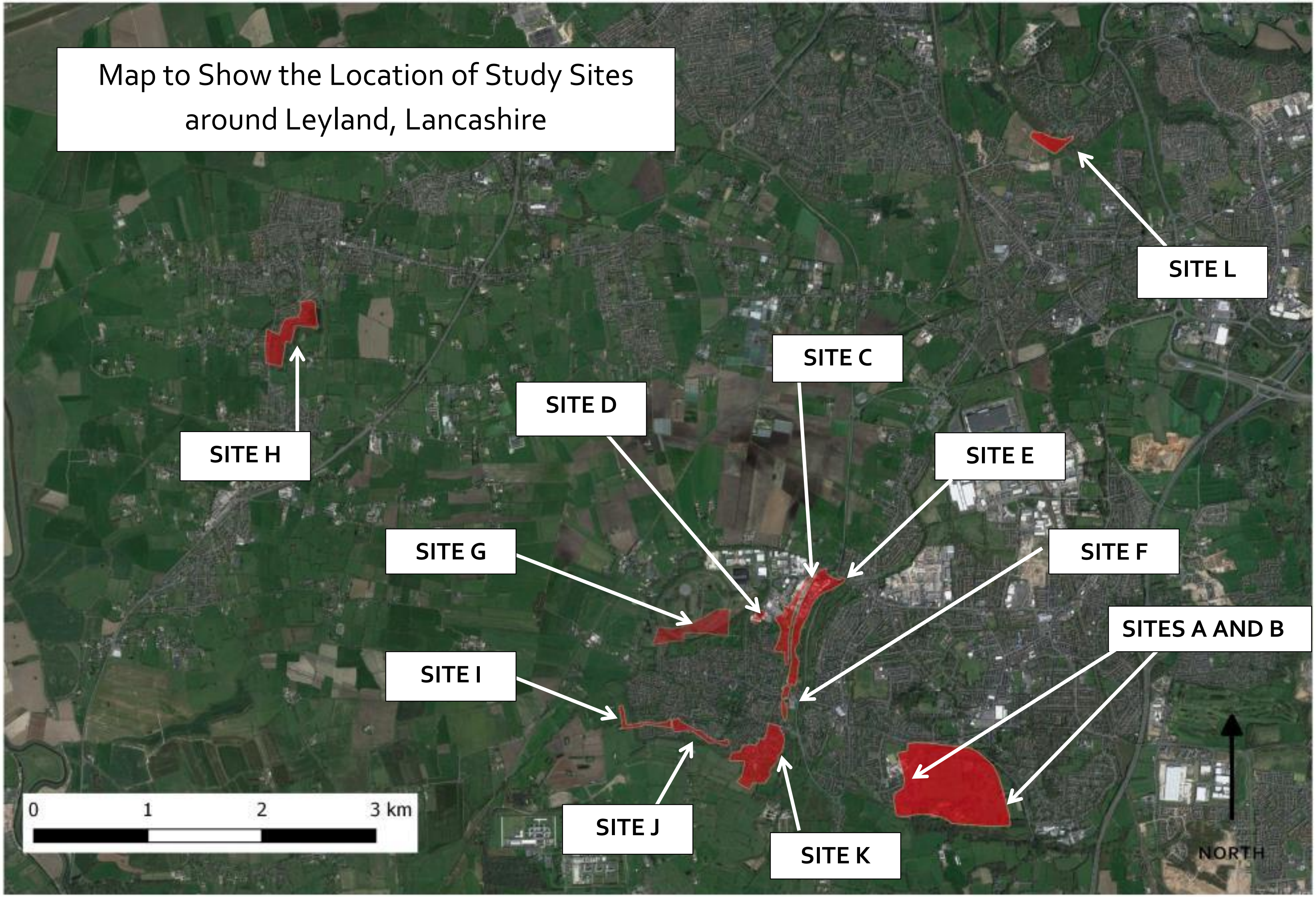

Figure 4 – Map to show the locations of the study sites (Beaman, 2017) Google Satellite Imagery (2017) (OSGB, 1936)

Figure 5 – Photographs of the Study Sites (Beaman, 2017)

Figure 5 (cont.) – Photographs of the Study Sites (Beaman, 2017)


Site E


Site F


Site G


Site H

Figure 5 (cont.) – Photographs of the Study Sites (Beaman, 2017)


Site I


Site J


Site K


Site L

WCA = Wildlife and Countryside Act (1981) (as amended)
BAP – Biodiversity Action Plan

2.2 Small Mammals in Lancashire

Species	Habitat / Habits	Home Range	Status and Protection	Presence
Bank Vole *Myodes glareolus*	Woodland and edges, hedgerows, thick cover, marshy ground. Active all year, day and night	0.05 – 0.73ha	Very common	Possible
Field Vole *Microtus agrestis*	Rough grassland, and at lower densities woodland and hedgerows. Active all year, day and night	100 – 1000m^2	Very common	Possible
Water Vole *Arvicola amphibius*	River banks and marshes. Active all year, day and night	30 – 150m	Fairly common Legally protected – WCA / UK BAP species	No known populations
Harvest Mouse *Micromys minutus*	Most areas of tall herbage. Mainly nocturnal summer, diurnal in winter	300 – 400m^2	Uncommon UK BAP Species	No known populations
Wood Mouse *Apodemus sylvaticus*	Woodland, hedgerows, arable fields, heathland & moorland. Active all year, mainly nocturnal	0.19 – 0.63ha	Very common	Possible
Yellow Necked Mouse *Apodemus flavicollis*	Mature deciduous woodland with dead wood and herbaceous layer. Active all year, nocturnal	0.5ha	Uncommon	Possible
Common Shrew *Sorex araneus*	Open areas with rich ground cover Active all year, day and night	ca. 370 – 630m^2	Common Legally protected – WCA	Possible
Pygmy Shrew *Sorex minutus*	Grassy and woodland habitats with thick vegetation cover. Active all year, day and night	ca. 1400 – 1700m^2	Very common Legally protected - WCA	Possible
Water Shrew *Neomys fodiens*	Banks of fast flowing streams amongst dense vegetation. Active all year, mainly nocturnal	ca. 20 – 30m^2 land ca. 60 – 80m^2 water	Uncommon Legally protected	Unlikely
Common Rat *Rattus norvegicus*	Hedgerows, waterways and field margins. Active all year, mostly nocturnal unless population high	134m^2	Introduced Very common	Possible
Hedgehog *Erinaceus europaeus*	Woodland edges, scrub and dense cover. Hibernates Nov – March, mainly nocturnal	100m^2	Common, declining Legally protected – WCA / UK BAP species	Possible
Stoat *Mustela ermine*	Edges of woodland, areas of cover in moorland and fields. Active all year, day and night	10 – 40ha	Fairly common	Possible
Weasel *Mustela nivalis*	Wide range of habitats where small mammals present including woodland, Active all year, day and night.	0.01 to 0.40 km^2	Fairly common	Possible
Grey Squirrel *Sciurus carolinensis*	Woodland of all kinds. Active by day year round but less so if very cold, hot or wet conditions		Introduced Common	Possible
Red Squirrel *Sciurus vulgaris*	Coniferous woodland > 50ha, Active by day, Year round	10ha	Locally common Legally protected – WCA / UK BAP species	No known populations

Couzens et al, (2017); Sibbald et al (2006); Williams et al (2015); Salek et al (2010); Reid et al (2016); Wildlife trust (n.d.); Mazamuto et al (2017); Oyedele et al (2015); CIEEM (2013a & 2013b)

2.3 Study Design

The study area contained six sites with dead hedges and 6 non-hedge sites where there is the potential to build dead hedges in the future (Sullivan and Sullivan 2014; Schlinkert et al, 2016; Carey & Johnson 1995). Dead hedges on all sites were predominantly constructed from Dogwood (*Cornus sanguinea*) and Elder (*Sambucus nigra*) apart from site B which was constructed from Laurel (*Prunus laurocerasus*). Unlike ancient traditions, the hedges in this study are interwoven and self-supporting removing the need for staking.

Survey methods were devised to return presence / absence data plus a measure of activity for small mammals. Two survey periods in Spring (April) 2017 and Summer (July) 2017 provided seasonal data (Christie et al, 2015; Flowerdew et al, 2004). Surveys took place over 3 weeks with 4 sites surveyed in each weekly block to allow simultaneous trapping at hedge and non-hedge sites (Zwolak, 2009; Knox et al, 2012; Nams & Gillis, 2003) (Figure 6).

	Spring	Summer
Week 1	Site A, B, C ,D	Site A, B, C ,D
Week 2	Site E, F, G, H	Site E, F, G, H
Week 3	Site I, J, K, L	Site I, J, K, L

Figure 6 – Summary of Survey Blocks

Each weekly survey took place over 5 days and 4 nights (Monday to Friday). A period of five days is sufficient to be confident that absence of prints at a site reflects a true absence of a species (Williams et al 2015; & Yarnell et al 2014; Blackwell et al, 2002; Glennon et al & Brown et al, 1996)

Twenty metre transects were used to sample dead hedges and compared with 20 metre transects on non-hedged sites. A combination of tracking tunnels and small mammal traps were used to collect data as camera traps were not viable for financial and security reasons.

Tunnels and traps were checked just after dawn (7am – 9am) and just before dusk (5.30pm – 7.30pm) in Spring and these times replicated in Summer to give daytime and night time data (Gurnell and Flowerdew, 2006; Pauli, 2006).

2.4 Small Mammal Presence and Activity

2.4.1 Tracking Tunnels

Twenty tracking tunnels were constructed following Mammal Society instructions. They were a triangular plastic tunnel containing a tracking plate with sections of A4 paper, and 2 strips of ink (black powder paint mixed with vegetable oil) painted on 100mm wide strips of masking tape (Figure 7). Animals passed over the inkpad and left prints as they exited (Williams et al, 2015).

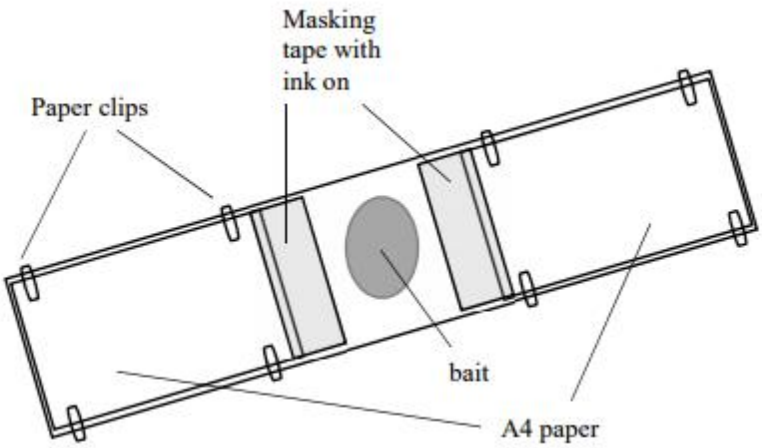

Figure 7 – Diagram to show the internal set up of the tracking tunnels (Mammal Society, n.d.)

Papers were checked twice daily and replaced when prints were recorded or if they became damaged (Yarnell et al, 2014). Tracked papers were analysed off site at a later date (King & Edgar, 1977). Tunnels were baited with hotdog sausages to attract hedgehogs and peanut butter to attract mice, rodents and mustelids (Muir and Morris, 2013; Christie et al, 2015; Blackwell et al, 2002 & Williams et al, 2015). Glennon et al (2002) state that five days of supplementary food would not be enough to alter small mammal abundance. Tunnels were placed flush with the ground in the most likely runways (Bowman et al, 2000; McKnight, 1998) along hedges (Figure 8) or concealed in vegetation on non-hedge sites (Figure 9), and secured with tent pegs. Five tunnels were placed in each hedge / transect at roughly four metre intervals, their exact location depended on the individual hedge structure and ground cover. Their positions were recorded using GPS to allow for relocation in the same place for the summer survey. Example data sheets are included in Appendix 2.

Figure 8 – Tracking tunnel placed in a dead hedge (Beaman, 2017)

Figure 9 – Tracking tunnel placed at a non- hedge site (Beaman, 2017)

2.4.2 Small Mammal Traps

To complement the data gained from the tunnels, 10 BioEcoss traps were used at a sub set of sites, to capture and identify mice, vole and shrew species. Traps were placed in pairs at roughly four metre intervals, on a linear transect along the hedgerow, beside or underneath natural features (Gurnell and Flowerdew, 2006) and supplied with mixed wild bird seed, mealworms and carrot with hay as bedding. Both survey methods were used concurrently and traps placed within one metre of tunnels (Christie et al, 2015). All traps were covered with local vegetation to keep them in the shade during the day and their locations recorded with GPS and marked by canes so that they could be found easily for checking.

Traps were positioned on the morning of day one; catches released that afternoon and then checked on the morning and afternoon of day two and the morning of day three (Sullivan et al, 2012; Sullivan & Sullivan, 2014; Flowerdew et al, 2016) and then moved to another site. All small mammals captured were identified then released immediately at the point of capture (Sullivan et al, 2017). Example data sheets are included in Appendix 3

All trapping conformed to English Nature Guidelines concerning the Wildlife and Countryside Act (1981) (as amended).

2.5 Weather and Hedge Characteristics

Data on dead hedge characteristics (age, direction - North / South or East / West and surrounding JNC land use classification) were recorded independently of the trapping sessions (Appendix 1). Weather (temperature, precipitation, wind speed) was recorded from the BBC weather website for Leyland on each survey day. This data was used to establish small mammal use and relationships between variables in order to answer the research questions.

2.6 Footprint Counts

All footprints showing sufficient details (Foresman & Pearson, 1998) were identified using diagrams from Muir & Morris (2013); Bullion et al (2014) and NPCA (2014). In some cases, accurate identification was difficult as many species had similar tracks and data was obscured due to over tracking and wet weather (King & Edgar 1977; Palma & Gurgel, 2007). It should be noted that in this survey it is not possible to differentiate the tracks of conspecific individuals in one or multiple tunnels. All prints of a given species in one tunnel are defined as a single record, not considering if they were left by different individuals. An increase in prints recorded means only an increase in activity not an increase in population size (King & Edgar, 1977). Data from the five tunnels on each site were pooled to give a total print count per species per site. Mammal body length was considered in assessing how much of the papers to count. Mean body lengths for all small mammal species was calculated at 9cm (Figure 10). Therefore, all the mouse, vole and shrew (MVS) prints recorded in the first 9cm of each of the A4 result sheets (Figure 11) were manually counted and recorded. Body lengths for the other mammal species were averaged and a decision made to count all prints recorded on the A4 sheet.

2.7 Statistical Analysis

A two-way analysis of variance (ANOVA) was used to evaluate the difference of hedge and non-hedge use by day and night for both Spring and Summer and any interactive effect (Fowler et al, 1998). Regression analysis and the coefficient of determination were used to establish if there was a relationship between small mammal activity and temperature (Fowler et al, 1998). All analysis used QED Statistics. Relative difference compares the change in means caused by the treatment relative to the control (Karban et al, 2014).

All calculations used mean number of prints per site, per day.

Species	Body Length (cm)		
	Minimum	Maximum	Mean
Bank Vole	8	12	10
Field Vole	9	11	10
Water Vole	14	22	18
Harvest Mouse	5	8	6.5
Wood Mouse	6	10	8
Yellow Necked Mouse	9.5	12	10.75
Common Shrew	5.4	8.7	7.05
Pygmy Shrew	4	6.4	5.2
Water Shrew	6.3	9.6	7.95
			Mean = 9.3
Common Rat	21	29	25
Hedgehog	30	30	30
Stoat	19	40	29.5
Weasel	17	25	21
Squirrel	24	28	26

Figure 10 – Table of mean body lengths

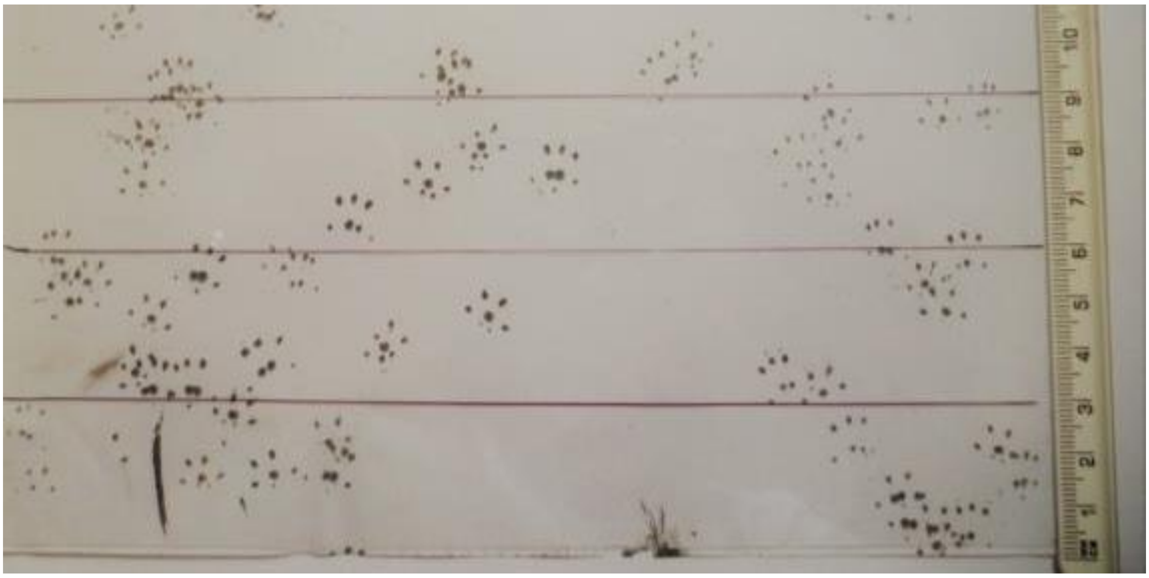

Figure 11 – Photograph to show the MVS counting system - there are 46 MVS prints in the first 9cm of the sheet.

3. Results

3.1 General Information

The overall assumption for this survey is that dead hedges would have a greater presence of small mammals than non-hedge sites.

3.1.1 Tunnel Results

Five tunnels were used at each of 12 sites over a three week period and were active for five days and four nights giving 45 tunnel events per site and 540 tunnel events across a season. With two seasons surveyed, tunnel events equalled 1080.

The data from the five tunnels at each transect have been pooled to provide a total for each transect for each species present. The total number of tunnels containing prints of each species is given in figure 12 and the overall response rates in figure 13. A summary of all the raw data is given in Appendix 4.

Species	Spring		Summer		Total	
	Dead hedge	Non-hedge	Dead hedge	Non-hedge	Dead hedge	Non-hedge
MVS	76%	78%	87%	94%	81%	86%
Rat	9%	0%	48%	4%	29%	2%
Hedgehog	4%	17%	7%	4%	6%	10%
Squirrel	13%	28%	15%	13%	14%	20%

Figure 12 – Table to show the percentage of Tracking Tunnels containing prints of each species

	Spring	Summer
Week 1	87%	95%
Week 2	74%	96%
Week 3	52%	79%

Figure 13 - Response rates – Tracking Tunnels

3.1.2 Trapping Results

Ten traps were used on each transect concurrently. The catches from all traps were summed to provide a total for all species present and is shown in figure 14. There were no fatalities recorded in any of the traps.

	Total number	
	Wood Mouse	Bank Vole
Non-hedge	21	15
Hedge	9	18

Figure 14 – Table to show the total trap catches

3.2 Visible Patterns from the Tunnel and Trap Data

Squirrel presence was detected at one hedged and four non-hedged sites (Figure 15)

Hedgehogs were present at three hedged and three non-hedged sites though print numbers were greater at non-hedged sites (figure 16)

MVS prints were found at all sites (figure 17), though higher numbers were recorded at non-hedged sites (86%) than hedged sites (81%). Trapping results showed a more consistent number of Bank Voles present at hedged (18) and non-hedged (15) sites, whereas Wood Mouse numbers were higher at non-hedged sites (21) than hedged sites (9).

Rats were found on five of the six hedged sites and numbers increased from spring to summer (Figure 18). Two sites returned only 2% of tunnels detecting rat prints on non-hedged sites compared to 29% of tunnels on hedged sites

The sites with the highest rat prints had the lowest MVS prints.

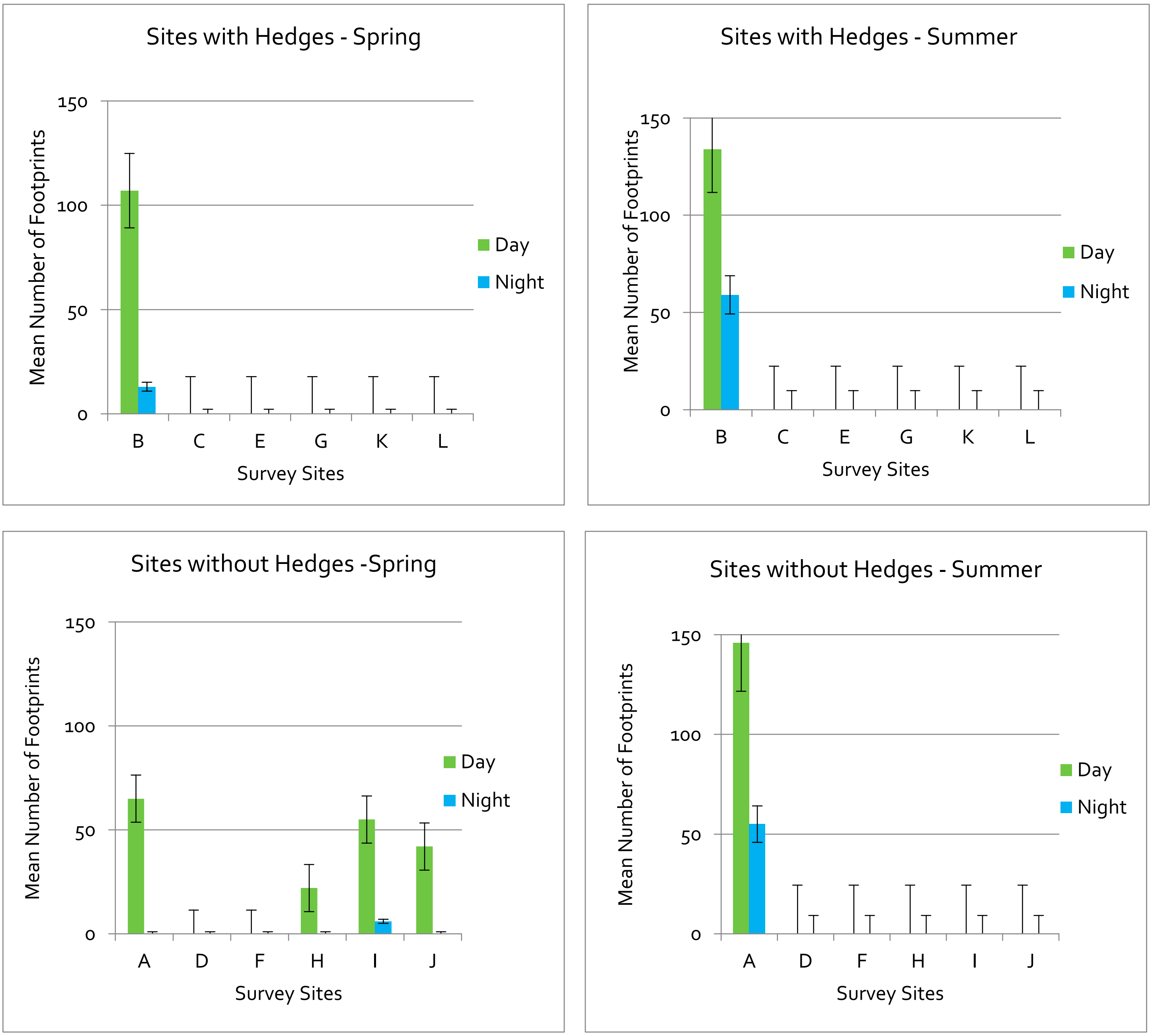

Figure 15 – Graphs to show mean Squirrel print counts for hedged and non-hedge sites in Spring and Summer

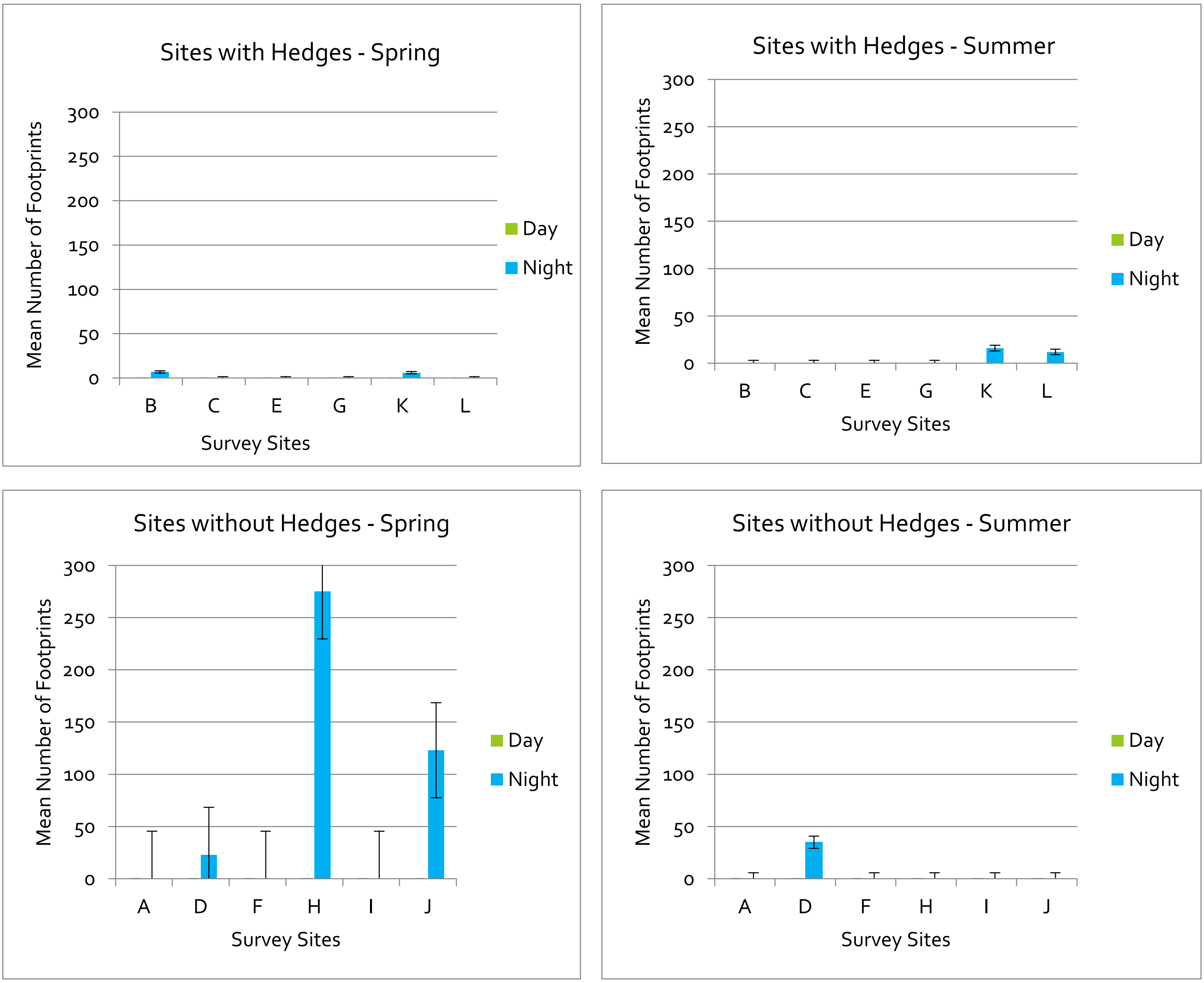

Figure 16 – Graphs to show mean Hedgehog print counts for hedge and non-hedge sites in Spring and Summer

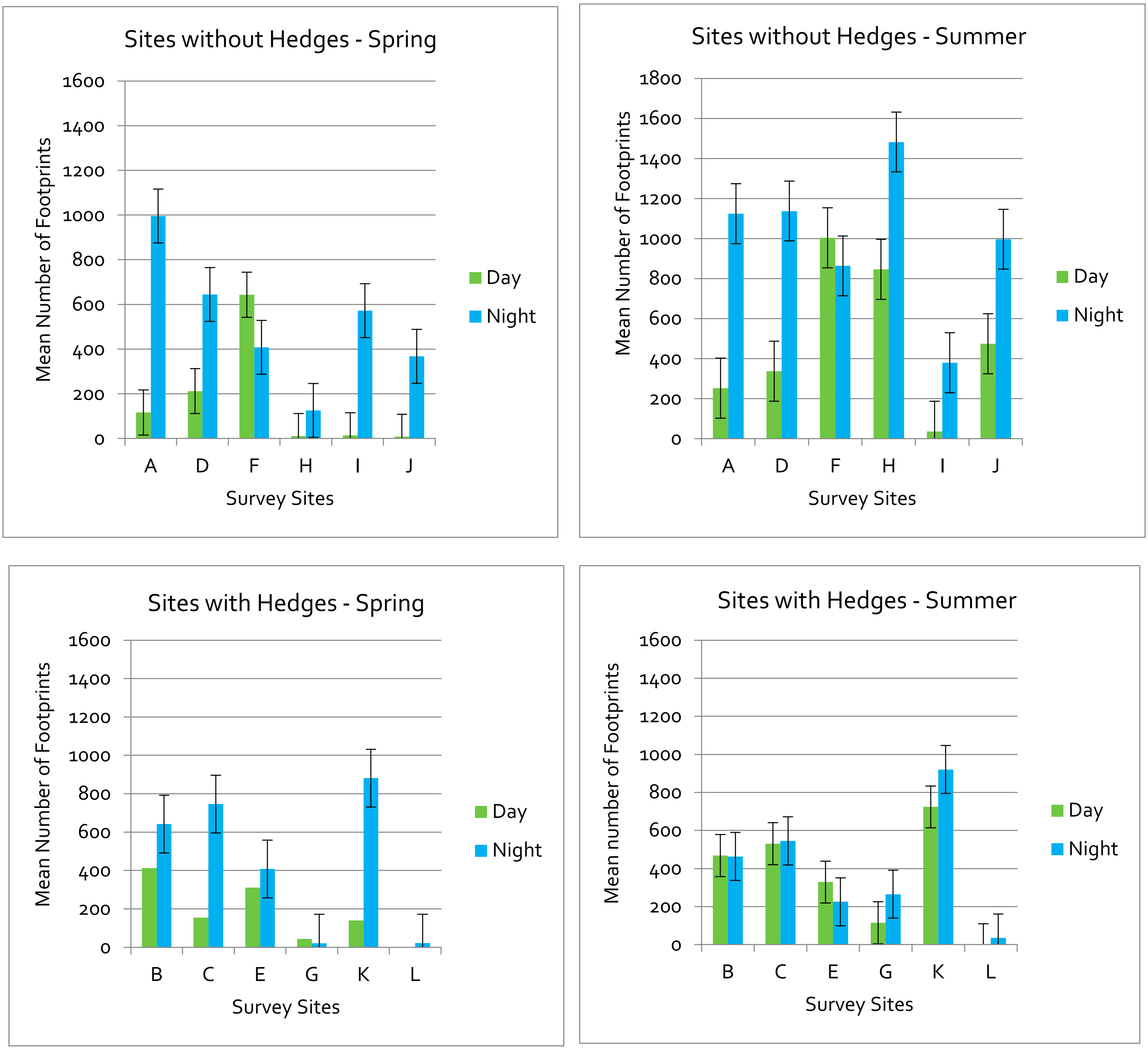

Figure 17 – Graphs to show mean MVS print counts for hedge and non-hedge sites in Spring and Summer

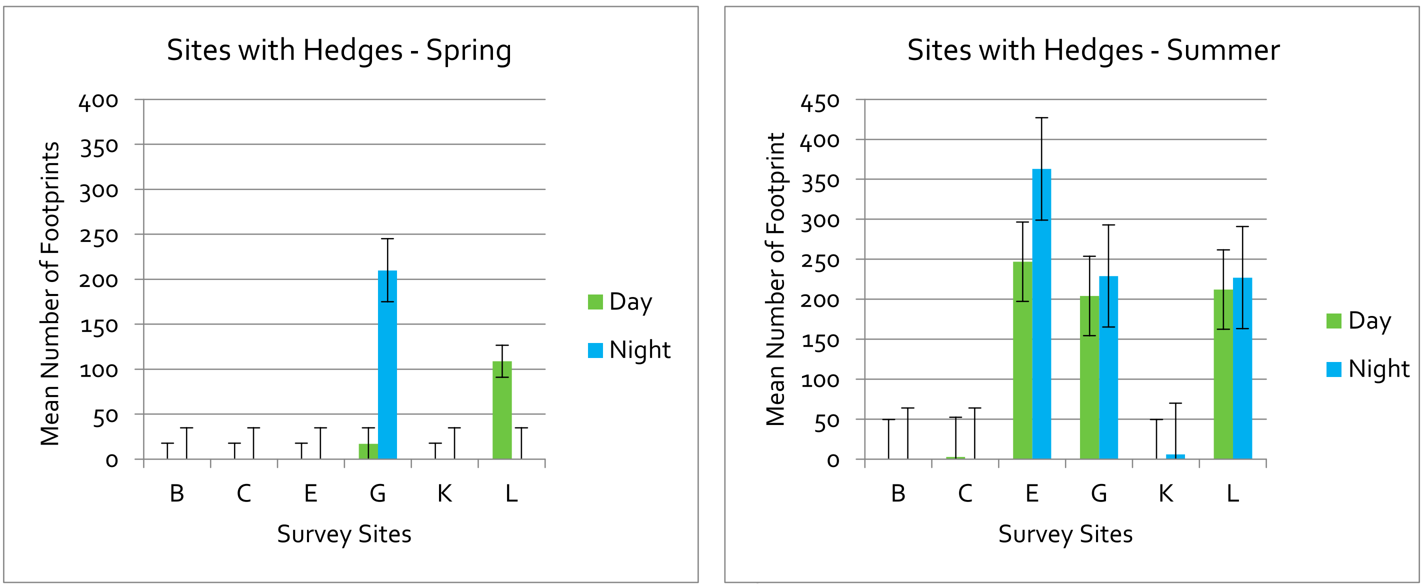

Figure 18 – Graphs to show mean Rat print counts for hedge sites in Spring and Summer

3.2 Effect of Hedges on Day and Night MVS Footprint Counts

Hypothesis 1 (Hedges)
Ho = There is no significant difference between the number of MVS footprints found in hedges and non-hedge sites H1 = There is a significant difference between number of MVS footprints found in hedges and non-hedge sites
Hypothesis 2 (Day and Night)
Ho = There is no significant difference between the number of MVS footprints found day and night H1 = There is a significant difference between the number of MVS footprints found day and night
Hypothesis 3 (Influence of Day or Night on Hedge or Non-Hedge use)
Ho = There is no influence from daytime or night time on the use of hedge and non-hedge sites H1 = There is an influence from daytime or night time on the use of hedge and non-hedge sites

Normality was tested using a Shapiro- Wilks test. The Spring data was transformed using a square root transformation to achieve normality. Summer Data did not deviate significantly from a normal distribution (Appendix 5)

Variances were compared using the F test with the transformed data for Spring and the raw data for Summer and found not to be significantly different (Appendix 5). QED Screenshots of results are in Appendix 6.

$$\text{Relative difference (\%)} = \frac{\text{Mean (Dead Hedge) - Mean (Non)}}{\text{Mean (non)}}$$

ANOVA tables are shown in Figure 19.

3.2.1 Hypothesis 1 – Hedge and Non Hedge

Spring

The null hypothesis is accepted, there is no significant difference between the number of MVS prints found in hedge and non-hedge sites (F = 0.10, df = 1,20, P=0.76)

Summer

The null hypothesis is rejected; there is a significant difference between the number of MVS prints found in hedge and non-hedge sites (F = 7.17, df = 1,20, P=0.01). The relative difference reveals 49% more prints are found in non-hedge sites.

Two-Way ANOVA Table Spring Data	Sum of Squares	Degrees of Freedom	Variance	F Value	Prob. >F
Between Day / Night Status	520.42	1	520.42	6.75	0.02
Between Hedges / Non hedges	7.62	1	7.62	0.10	0.76
Interaction	27.51	1	27.51	0.36	0.56
Within Groups	1543.03	20	77.15		
Total	2098.58	23	91.24		

Two-Way ANOVA Table Summer Data	Sum of Squares	Degrees of Freedom	Variance	F Value	Prob. >F
Between Day / Night Status	451827	1	451827	4.14	0.06
Between Hedges / Non hedges	783732	1	783732	7.17	0.01
Interaction	320397	1	320397	2.93	0.10
Within Groups	2.185 E006	20	109274		
Total	3.74 E006	23	162671		

Figure 19 – Two Way ANOVA Tables for Spring and Summer data

3.2.2 Hypothesis 2 – Day and Night

Spring

The null hypothesis is rejected; there is a highly significant difference between the numbers of MVS footprints found during day and night ($F = 6.75$, $df = 1,20$, $P=0.02$). More footprints are found at night.

Summer

The null hypothesis is accepted; there is no difference between the number of MVS prints found during the daytime and night time ($F = 4.14$, $df = 1,20$, $P=0.06$)

3.2.3 Hypothesis 3 - Influence of Day or Night on Hedge or Non-Hedge use

Spring

The null hypothesis is accepted there is no interaction between daytime and night time use in hedged and non-hedged sites ($F = 0.36$, $df = 1,20$, $P=0.56$).

Summer

The null hypothesis is accepted; there is no interaction between hedged and non-hedged sites, day or night ($F = 2.93$, $df = 1,20$, $P=0.10$)

3.3 Other Environmental Factors Affecting Numbers of MVS prints.

3.3.1 Hedge / Transect Direction

Mean number of MVS footprints were proportionate across both directions regardless of the presence of hedges apart from Spring night time use when Hedges angled North South visibly have more use than those angled East West or the non-hedged transect angled North South (Figure 20).

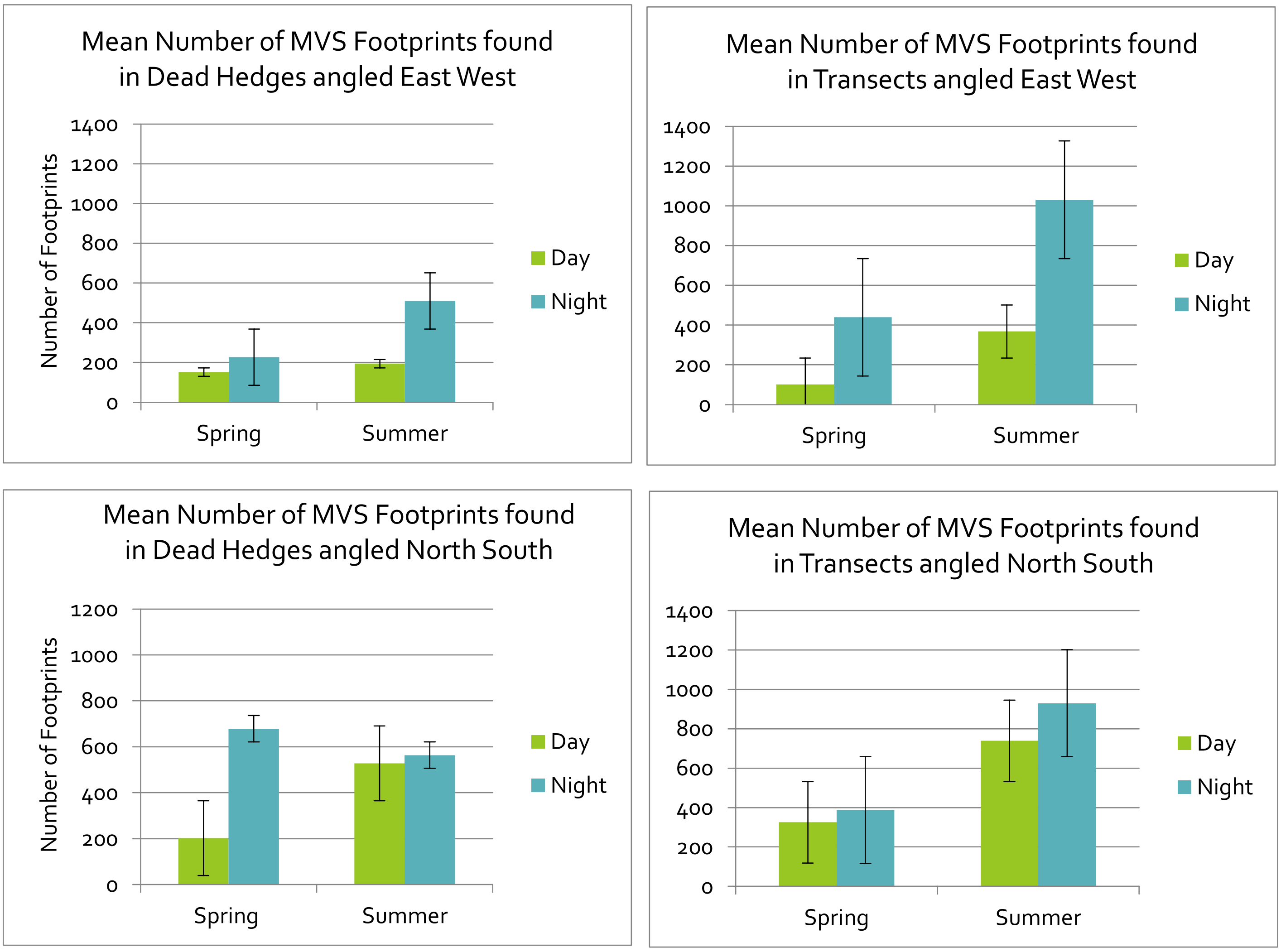

Figure 20 – Graphs to show mean MVS prints and hedge / transect direction

3.3.2 Age of Dead Hedge

There appears to be no link between the age of the hedge and the number of footprints recorded (Figure 21). The oldest hedge did record all four small mammal species.

Site	Total Mean Print Number	Year Hedge First Built	Comments
K	2697	2013	
B	2278	2008	All four species recorded in this hedge
C	1979	2015	
E	1883	2014	Highest rat numbers on these hedges
G	1104	2014	
L	617	2013	

Figure 21 – Table to show age of dead hedge and mean print numbers

3.3.3 Effect of Weather

Minimum and maximum temperatures (figure 22) did not fluctuate outside a range of 12°C in Spring and 14°C in Summer. Wet conditions do not appear to have an impact on the movement of MVS day or night, hedge or non-hedge (figure 23). There were not enough clear nights during the study period to make an analysis of cloud cover or the effect of moon phases viable.

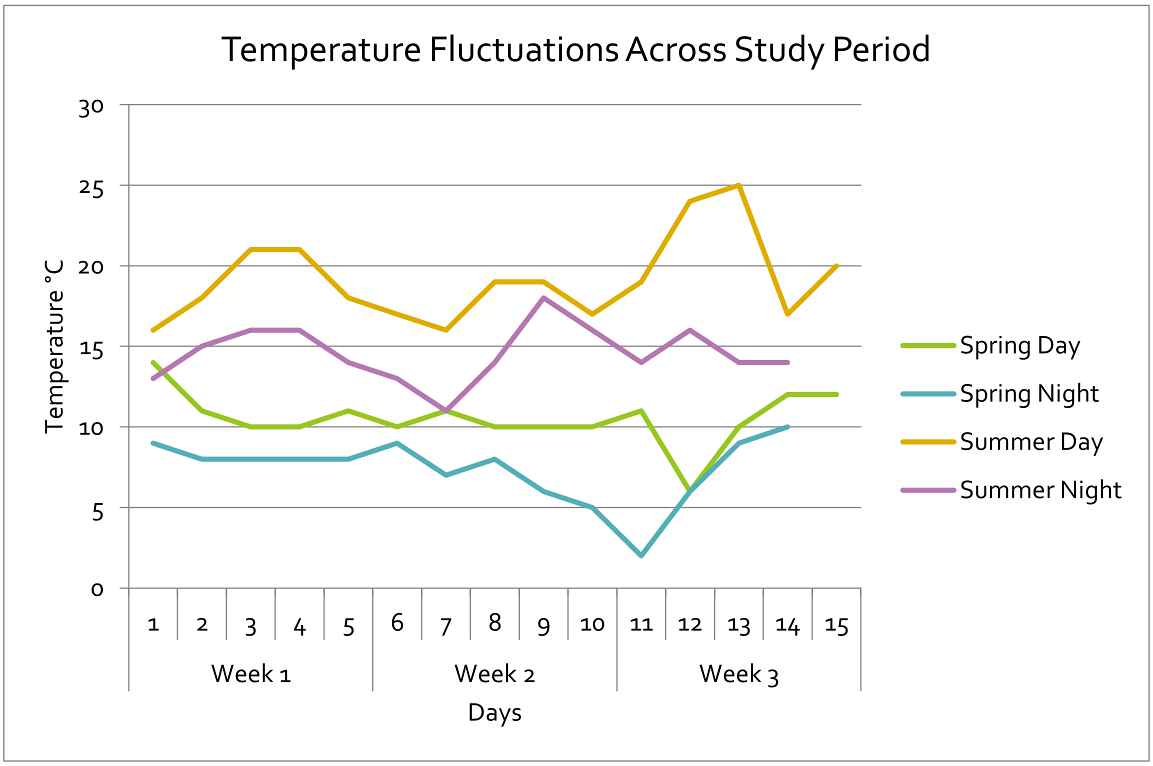

Figure 22 – Graph to show temperature fluctuations across the study period

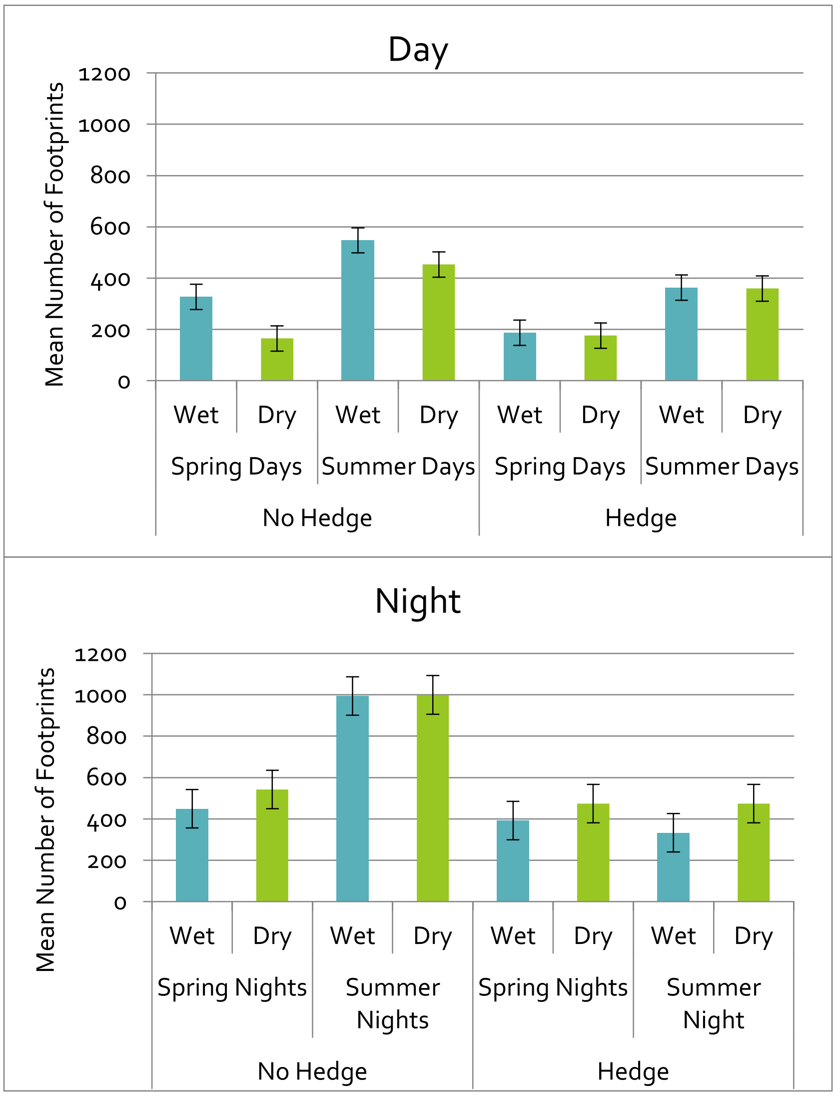

Figure 23 - Graphs to show the effect of dry and wet on MVS print counts

The effects of temperature on print counts were assessed using a regression analysis

Hypothesis
Ho = there is no linear relationship between footprint numbers and temperature H1 = there is a linear relationship between footprint numbers and temperature

Normality was tested using a Shapiro-Wilks test. The MVS, daytime, no hedge data was transformed using a square root transformation to achieve normality. All other data did not deviate significantly from a normal distribution (Appendix 7). QED Screenshots of results are in Appendix 8

A summary of results given in figure 24

	P	R^2
MVS Daytime Hedge	<0.001	0.29
MVS Daytime No Hedge	0.00	0.26
MVS Night time Hedge	0.77	0.00
MVS Night time No Hedge	<0.001	0.36
Rat Daytime Hedge	0.97	0.00
Rat Night time Hedge	0.70	0.02
Hedgehog Night time	0.15	0.15
Squirrel Daytime	<0.001	0.51

Figure 24 - Summary of Regression P and R^2 values

Footprint numbers and temperature at hedged sites were significant for MVS during the day (t = 3.37, df = 28, P<0.001), when temperature increases so do MVS footprint numbers. There was no temperature effect for MVS night time (t = 0.29, df = 22, P=0.77), or rat daytime or night time (t = 0.04, df = 10, P=0.97; t = 0.40, df = 10, P=0.70) at hedged sites.

Footprint numbers and temperature at non-hedged sites were significant for MVS during the daytime and night time (t = 3.16, df = 28, P<0.001; t = 3.56, df = 22, P<0.001) and for Squirrel (t = 4.30, df 18, P=0.00), as temperatures increase so do footprint numbers. There was no temperature effect on Hedgehog use of non-hedged sites (t= -1.51, df 13, P=0.1).

Scatterplots including regression equations for all variables are shown in figure 25.

The presence of dead hedges appears to negate the effect of temperature on night time MVS (R^2 = 0.0) and rats daytime (R^2 = 0.0) and night time (R^2 = 0.02)

Temperature accounts for 26% of daytime and 36% of night time variations in MVS footprint numbers in areas without hedges. Temperature accounts for 29% of daytime and 0% of night time variations in MVS footprint numbers in areas with hedges.

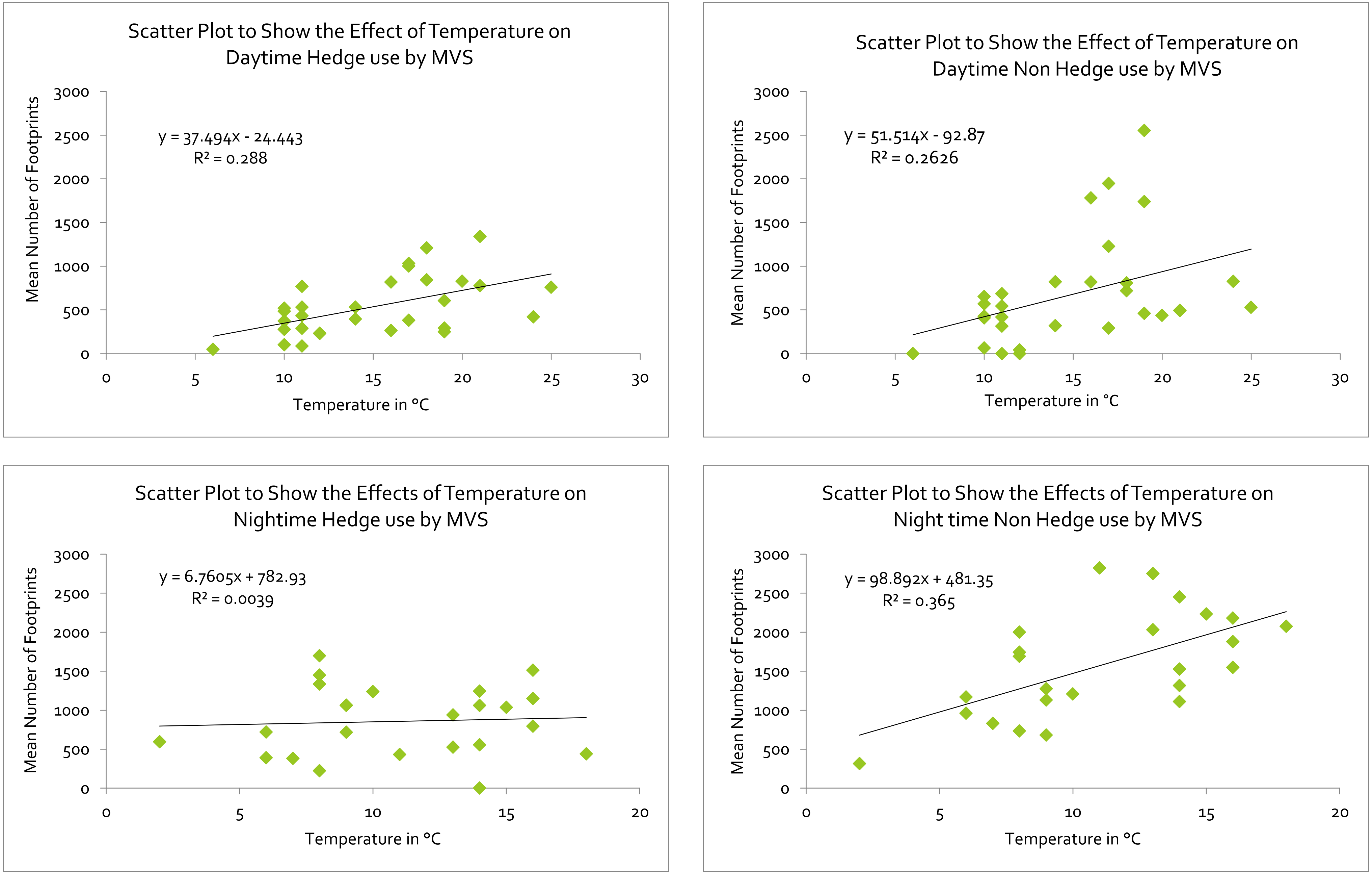

Figure 25 - Scatter Plots with regression line to show the effects of temperature on print counts

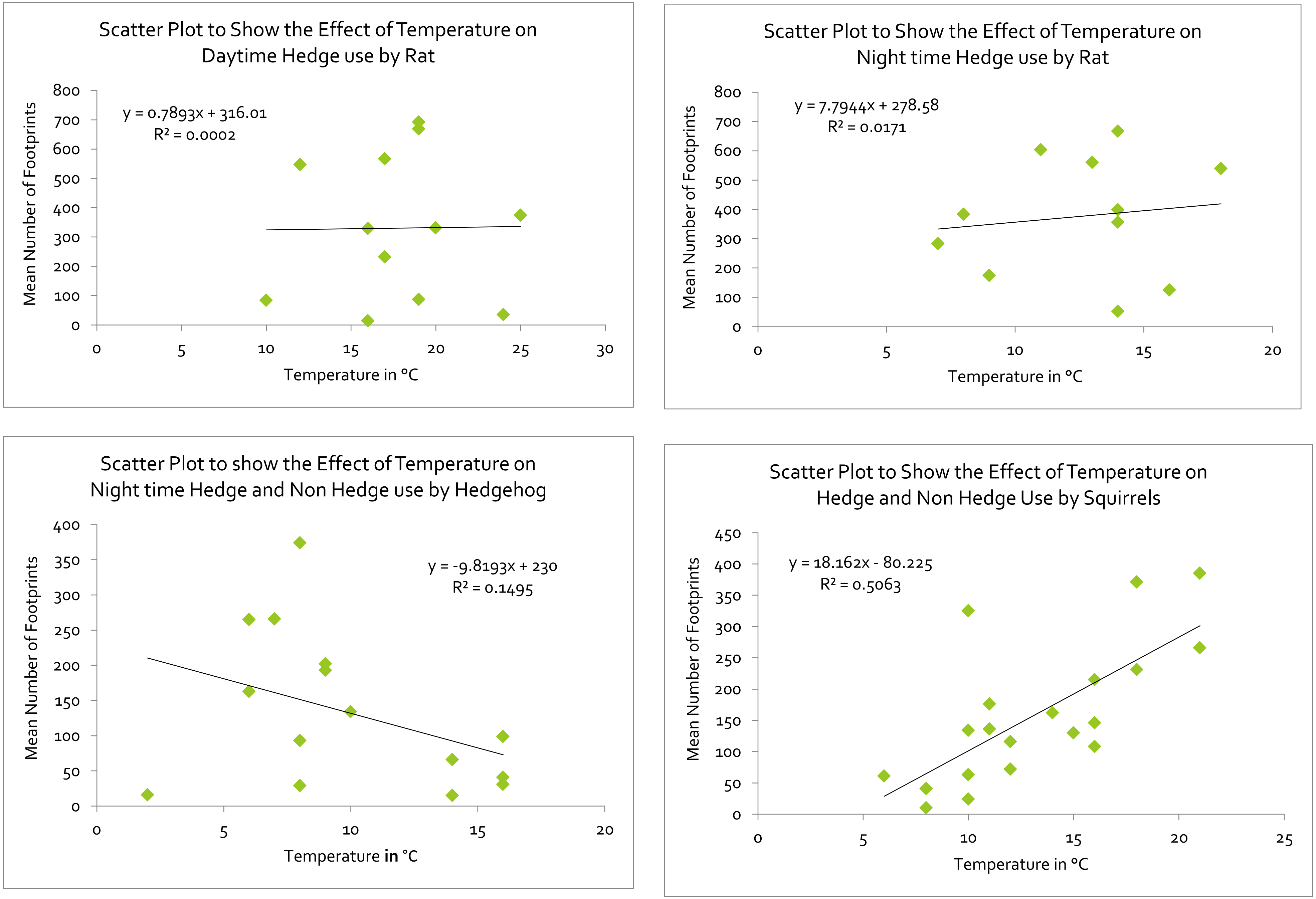

Figure 25 (cont.) - Scatter Plots with regression line to show the effects of temperature on print counts

4. Discussion

From a review of the literature on CWD and small mammals it would be expected that dead hedges would attract a greater number of small mammal species with higher activity levels than non-hedged sites. In answer to the specific project questions -

Do dead hedges affect small mammal presence/absence and distribution?

At a species level MVS, hedgehog, squirrel and rat are found in both hedged and non-hedged sites. When considering mean number of prints rather than species, more small mammals were found in non-hedged sites. Squirrel presence was greatest on sites A and B which were located at opposite sides of a large urban park 0.95km apart. On this site squirrels were often seen scavenging from bins and eating the remains of human food (Beaman, pers. obs.). The bait in the traps may have been the attraction here, account for the higher print numbers and explain why site B is the only hedged site to record presence of squirrel. MVS prints were found at all sites, though 49% more were recorded at non-hedged sites. Trapping showed a more consistent number of bank voles present at hedged and non-hedge sites, whereas wood mice numbers were higher at non-hedge sites.

Does season or weather have an effect on their use?

Spring MVS night time print counts were higher than day time counts. In summer, day and night prints were almost equal in hedged sites. Neither wet nor dry conditions impacted MVS print counts. Rat numbers were not affected by temperature, whereas MVS numbers increased as temperature increased except for night time hedges. The results infer that only 26% of daytime and 36% of night time non-hedge and 29% of daytime and 0% of night time hedge variation in MVS numbers was due to temperature. 64% or more of variations were due to other factors.

Does day or night have an effect on their use?

More MVS prints were found at night time in spring but numbers were equal day and night in summer. Rat prints were found day and night indicating a high population (Couzens et al, 2017). Dead hedges appear to negate the effects of temperature for rats and for MVS at night.

Do the hedge characteristics (age, direction, surrounding land use type) have an effect on use?

Age and therefore the effect of decay, did not have an impact on hedge use. The only visible effect of direction appeared in dead hedges angled North South where Spring MVS print counts were proportionally higher. The main sites where rats were found were in urban areas, adjacent to water bodies where members of the public regularly feed the ducks.

These results may be a result of a number of potential drivers.

4.1 Habitat Structure and Specialisation

MVS can be categorised into specialists (bank vole) and generalist (wood mouse) influencing species occurrence in different habitats (Schlinkert et al, 2016; Persons & Eason, 2017). Wood mice are more adaptable to habitat change and therefore should be found in more microhabitats than the specialist bank vole (Zwolak, 2009), which is associated predominantly with woodland. This was not the case in this study. Vegetation cover at dead hedge sites was low as a result of trampling during construction and an early seral stage. Non-hedge sites had a constant supply of litter and vegetation which improves the diversity of microhabitats. Bank vole numbers were slightly higher in hedged as opposed to non-hedged sites, confirming the findings of Sullivan & Sullivan, (2012 and 2014). Wood mice numbers fluctuated, high in non-hedged sites as expected but low in hedge sites, showing that factors other than specialisation and microhabitat may be affecting distribution.

4.2 Temperature

It is well documented that temperature influences small mammal activity (Flowerdew et al, 2016; Deitloff et al, 2010), with a small body size and high body surface area they are vulnerable to heat loss (Wróbel et al, 2015). As temperature falls, rodent activity increases as they forage more to attain the calorie intake required to maintain their body temperature (Wróbel et al, 2015). Short term fluctuations in temperature have less effect than long term climate trends which impact food production, consumption and breeding patterns (Deitloff et al, 2010; Esther et al, 2014; Sipari et al, 2016). The results of this study showed that MVS activity levels inexplicably rose as temperature increased, contradicting all previous studies, but as it accounted for less than 40% of variations in print numbers there are other factors to consider.

Woody debris is known to moderate ground temperature and provide thermal as well as protective cover (Pauli, 2006; Manning & Edge, 2008). Relative humidity increases foraging (Persons & Eason, 2017) so it could be expected that more activity would take place in dead hedges. This was the case for rats and MVS (night time) who may be making use of this temperature buffer.

4.3 Effects of Scale

All previous studies have been at a large spatial scale and have often proved to be limited or inconclusive in their results (Sullivan & Sullivan, 2012). There is nothing on the scale of this project with which to draw viable comparisons. Hedgerows and woody debris structures provide travel routes and corridors for small mammals (Loeb, 1999). It may be that dead hedges also act as linear routes allowing small mammals' safe passage between open foraging areas and which may account for the lower activity levels in the hedges themselves.

4.4 Interaction between MVS and Rats

The results of this study highlight an interaction between Rats and MVS on hedged sites. Where rats are present MVS numbers are low, a situation also documented by Sweetapple & Nigent (2011) and Brown et al (1996). The 'killing response' in rats is a biological phenomenon known as Muricide, and is observed in nature as well as the laboratory (Karli, 1956). 70% of wild rats are killers (Malick, 1975) but it is unclear whether it is predatory, aggressive or a combination of both (Kemble et al, 1985; Karli, 1956). Rats are fearful and defensive (Kemble et al, 1985) but do not appear to kill to defend their territory (Eistenstein & Terwilliger, 1984). Rats may kill mice but the majority are only partially eaten or not eaten at all, so is unlikely to be a response to starvation (Karli et al, 1956). Indeed, the presence of rats during day and night in this study indicates a high population which would not be supported if resources were low.

The variation in wood mice numbers at hedged and non-hedged sites may be explained by the phenomenon of Muricide. Indeed MVS numbers may have been higher in hedged sites were it not for the presence of rats. Mice are neophilic and unlikely to avoid the tunnels (Brown et al, 1996). If they were on site the footprints should have been recorded. As no evidence of 'kills' were found, maybe scent marking by rats was enough to cause MVS to avoid the hedges (Brown et al, 1996). Rat presence and MVS avoidance may have skewed all the data collected by reducing MVS numbers at five of the six hedged sites.

4.5 Study Limitations

As this was a retrospective survey, the hedges were already built and in situ and study areas had to be chosen from a limited number of sites. Additional surveying of dead hedges away from water sites would prove the relationship between rats and hedges is not biased by the presence of duck food. Time constraints only allowed survey work to be undertaken in Spring and Summer, whilst data collected at other times of the year may yield different results. If it were to be repeated, additional trapping or camera trapping may help differentiate between MVS species.

5. Conclusion

To answer the project question, it can be concluded that dead hedges do provide habitat for small mammals. However, despite the evidence that shows a link between CWD and small mammals, in the context of this study hedges are no better than non-hedged sites, which have higher activity levels for all species bar rats.

At any site, presence of small mammals is associated with variations in microhabitats, specialisation, predator prey interaction and effects of temperature and humidity. Dead hedges provide elements of these factors and confirm the phenomenon that mice do not like rats.

Dead hedges provide good linear pathways. It would be interesting to conduct this survey again in Autumn and Winter to see if the lack of a vegetation at non-hedged sites encourages more use of hedges. During these seasons dead hedges may provide greater cover and protection from temperature fluctuations.

The assumption that dead hedges are good for birds, invertebrates and small mammals has been tested in respect of small mammals and found to be true, though the evidence is inconclusive. Volunteers may not be so keen to build dead hedges to harbour rats rather than the more charismatic mammal species. It would be interesting to investigate the assumptions with regards to birds and invertebrates.

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Appendix 1 – Detailed Overview of the Study Sites

Site	Local Name	Grid Reference	Hedge / No Hedge	Approx date hedge created	Predominant Direction of transect	Land type 20m to North or East (Phase 1 Habitat Classifications)	Land Type 20m to South or West (Phase 1 Habitat Classifications)	Size of Site (Hectares)
A	Worden Park	SD542206	No hedge		North / South	Historic stone boundary wall J2.5	Meadow B Woodland A3.1	61
B	Worden Park	SD533209	Hedge	2008	East / West	Pond banking F2.1 Paths - stone & tarmac Pond G1 Woodland Edge A1.1 Football pitches J1.2	Arboretum A3.1 Rough Grass B	61
C	Fossdale Moss	SD524225	Hedge	2015	North / South	Rough Grass B Surfaced path Meadow B Young Woodland A3.2 Road	Woodland A3.1 Pastureland B	8
D	Rhoden Road	SD522225	No Hedge		East West	Road - unmade Housing / Industrial estate J3.6	Woodland A1.1 Mown grassland J1.2	1
E	River Lostock (N)	SD527227	Hedge	2014	North / South	Rough Grass B Surfaced path River banking F2.1 River G2	Woodland A3.1 Meadow B	10
F	River Lostock (S)	SD523216	No Hedge		North / South	Mown Grass J1.2 Surfaced path River bank F2.1 River G2	Woodland scrub A2.1 Road	1
G	Paradise Park	SD518225	Hedge	2014	East / West	Pond banking F2.1 Pond G1 Woodland A1.1	Pond banking F2.1 Surfaced path Mown grassland J1.2	11
H	Longton Brickcroft LNR	SD482252	No Hedge		East / West	Meadow B Pond margin F2.1 Pond G1	Woodland A3.1 Large gardens	11
I	Nixon Lane Woods	SD509217	No hedge		East /West	Woodland A3.1 Houses J3.6	Woodland A3.1 Horse field B	2
J	Malt Kiln Farm Walk	SD515215	No hedge		East / West	Rough grass B Surfaced path Maintained lawn J1.2 Housing J3.6	Rough grass B Path Ditch J2.6 Hedgerow J2.3 Farmland B	3
K	Moss Side Rugby Pitches	SD522212	Hedge	2013	North / South	Woodland A3.1 Path Meadow B	Woodland scrub A2.2 Pond G1 Pond Margin F2.1	15
L	Walton Park	SD548266	Hedge	2013	North / South	Meadow B Pond margin F2.1 Pond G1 Woodland A1.1	Path Woodland A1.1 Steep banking to tarmac path B	4

Appendix 2 – Example Data Sheet for Tracking Tunnels

				Tracking tunnels - bait and paper changed										
Date			03-Apr	03-Apr	04-Apr	04-Apr	05-Apr	05-Apr	06-Apr	06-Apr	07-Apr	07-Apr	07-Apr	
Site	Hedge		Placed	Day 1	Night 1	Day 2	Night 2	Day 3	Night 3	Day 4	Night 4	Day 5	Removed	GPS Location
A	No	1												
		2												
		3												
		4												
		5												
B	Yes	6												
		7												
		8												
		9												
		10												
C	Yes	11												
		12												
		13												
		14												
		15												
D	No	16												
		17												
		18												
		19												
		20												

Weather									
Temp									
Wind									

Comments

Appendix 3 – Example Data Sheet for Mammal Trap

Site Number	

Week Number	

Date						
Trap number	Day 1		Day 2		Day 3	
	Placed	Catches off	am	pm	am	Removed
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Trap number	GPS Location
1 & 2	
3 & 4	
5 & 6	
7 & 8	
9 & 10	

Comments:

Species codes

As	Wood Mouse	*Apodemus sylvaticus*
Af	Yellow necked mouse	*Apodemus flavicollis*
Cg	Bank Vole	*Clethrionomys glareolus*
Ma	Field Vole	*Microtus agrestis*
Mm	Harvest Mouse	*Micromys minutus*
Mus	House Mouse	*Mus domesticus*
Sa	Common Shrew	*Sorex araneus*
Sm	Pygmy Shrew	*Sorex minutus*
Nf	Water Shrew	*Neomys fodiens*

Appendix 4 – Raw Data Summary

No hedge - Spring

		M / V / S	Squirrel	Rat
Site A	Day 1	153	37	
	Day 2	102	80	
	Day 3	71		
	Day 4	235	150	
	Day 5	269	58	
TOTAL		**830**	**325**	
Mean		166	65	
Site D	Day 1	167		
	Day 2	212		
	Day 3	338		
	Day 4	194		
	Day 5	149		
TOTAL		**1060**		
Mean		212		
Site F	Day 1	821		
	Day 2	685		
	Day 3	570		
	Day 4	648		
	Day 5	493		
TOTAL		**3217**		
Mean		643		
Site H	Day 1			
	Day 2			
	Day 3		86	
	Day 4	6	7	
	Day 5	51	16	
TOTAL		**57**	**109**	
Mean		11	22	
Site I	Day 1			
	Day 2		61	
	Day 3	65	48	
	Day 4		65	
	Day 5	3	100	
TOTAL		**68**	**274**	
Mean		14	55	
Site J	Day 1		123	
	Day 2			
	Day 3		53	
	Day 4			
	Day 5	40	33	
TOTAL		**40**	**209**	
Mean		8	42	
TOTAL		**5272**	**917**	**0**
Σ Mean		1054	183	0

	M / V / S	Squirrel	Rat	Hegdehog
Night 1	992			
Night 2	1116			
Night 3	913			
Night 4	964			
	3985			
	996			
Night 1	138			
Night 2	573			
Night 3	829			
Night 4	1036			93
	2576			**93**
	644			23
Night 1	649			
Night 2	367			
Night 3	224			
Night 4	390			
	1630			
	408			
Night 1				193
Night 2				266
Night 3	69			374
Night 4	432			265
	501			**1098**
	125			275
Night 1	213			
Night 2	646			
Night 3	745			
Night 4	683	24		
	2287	**24**		
	572	6		
Night 1	103			16
Night 2	315			140
Night 3	529			202
Night 4	524			134
	1471			**492**
	368			123
TOTAL	**12450**	**24**	**0**	**1683**
Σ Mean	3113	6	0	421

Hedge - Srping

		M / V / S	Squirrel	Rat
Site B	Day 1	425	125	
	Day 2	538	56	
	Day 3	262	63	
	Day 4	393	175	
	Day 5	444	118	
TOTAL		**2062**	**537**	
Mean		412	107	
Site C	Day 1	107		
	Day 2	231		
	Day 3	224		
	Day 4	126		
	Day 5	88		
TOTAL		**776**		
Mean		155		
Site E	Day 1	396		
	Day 2	291		
	Day 3	278		
	Day 4	289		
	Day 5	301		
TOTAL		**1555**		
Mean		311		
Site G	Day 1			
	Day 2			
	Day 3			
	Day 4	85		84
	Day 5	132		
TOTAL		**217**		**84**
Mean		43		17
Site K	Day 1	86		
	Day 2	49		
	Day 3	102		
	Day 4	234		
	Day 5	230		
TOTAL		**701**		
Mean		140		
Site L	Day 1			0
	Day 2			0
	Day 3			0
	Day 4			0
	Day 5			547
TOTAL				**547**
Mean				109
TOTAL		**5311**	**537**	**631**
Σ Mean		1062	107	126

	M / V / S	Squirrel	Rat	Hegdehog
Night 1	464			
Night 2	625			29
Night 3	592	41		
Night 4	887	10		
	2568	**51**		**29**
	642	13		7
Night 1	601			
Night 2	711			
Night 3	858			
Night 4	812			
	2982			
	746			
Night 1	649			
Night 2	367			
Night 3	224			
Night 4	390			
	1630			
	408			
Night 1	69		174	
Night 2	15		283	
Night 3			383	
Night 4				
	84		**840**	
	21		210	
Night 1	595			
Night 2	719			23
Night 3	1060			
Night 4	1151			
	3525			**23**
	881			6
Night 1				
Night 2				
Night 3				
Night 4	88			
	88			
	22			
TOTAL	**10877**	**51**	**840**	**52**
Σ Mean	2719	13	210	13

No hedge - Summer

		M / V / S	Squirrel	Rat
Site A	Day 1		37	
	Day 2	360	229	
	Day 3	246	213	
	Day 4	247	147	
	Day 5	405	105	
TOTAL		**1,258**	**731**	**-**
Mean		252	146	-
Site D	Day 1	302		
	Day 2	524		
	Day 3	379		
	Day 4	201		
	Day 5	277		
TOTAL		**1,683**	**-**	**-**
Mean		337	-	-
Site F	Day 1	1088		
	Day 2	995		
	Day 3	1293		
	Day 4	660		
	Day 5	978		
TOTAL		**5,014**	**-**	**-**
Mean		1,003	-	-
Site H	Day 1	138		
	Day 2	786		
	Day 3	1259		
	Day 4	1078		
	Day 5	968		
TOTAL		**4,229**	**-**	**-**
Mean		846	-	-
Site I	Day 1			
	Day 2			
	Day 3	44		
	Day 4	45		
	Day 5	89		
TOTAL		**178**	**-**	**-**
Mean		36	-	-
Site J	Day 1	459		
	Day 2	827		
	Day 3	485		
	Day 4	248		
	Day 5	349		
TOTAL		**2,368**	**-**	**-**
Mean		474	-	-
TOTAL		**14,730**	**731**	**-**
Σ Mean		2,946	146	-

	M / V / S	Squirrel	Rat	Hegdehog
Night 1	1297		3	
Night 2	1213	99		
Night 3	988	119		
Night 4	998			
	4,496	**218**	**3**	**-**
	1,124	55	1	-
Night 1	1455			
Night 2	1020			
Night 3	1192		29	99
Night 4	881			41
	4,548	**-**	**29**	**140**
	1,137	-	7	35
Night 1	892			
Night 2	1057			
Night 3	785			
Night 4	719			
	3,453	**-**	**-**	**-**
	863	-	-	-
Night 1	1139			
Night 2	1767			
Night 3	1667			
Night 4	1356			
	5,929	**-**	**-**	**-**
	1,482	-	-	-
Night 1	111			
Night 2	146			
Night 3	593			
Night 4	666			
	1,516	**-**	**-**	**-**
	379	-	-	-
Night 1	1000			
Night 2	1402			
Night 3	933			
Night 4	649			
	3,984	**-**	**-**	**-**
	996	-	-	-
TOTAL	**23,926**	**218**	**32**	**140**
Σ Mean	5,982	55	8	35

Hedge - Summer

		M / V / S	Squirrel	Rat
Site B	Day 1	605	109	
	Day 2	155	142	
	Day 3	450	172	
	Day 4	705	119	
	Day 5	424	126	
TOTAL		**2,339**	**668**	**-**
Mean		468	134	-
Site C	Day 1	213		14
	Day 2	690		
	Day 3	326		
	Day 4	635		
	Day 5	786		
TOTAL		**2,650**	**-**	**14**
Mean		530	-	3
Site E	Day 1	672		
	Day 2	168		281
	Day 3	273		332
	Day 4	233		380
	Day 5	301		242
TOTAL		**1,647**	**-**	**1,235**
Mean		329	-	247
Site G	Day 1	359		
	Day 2	97		48
	Day 3	19		337
	Day 4	18		312
	Day 5	81		325
TOTAL		**574**	**-**	**1,022**
Mean		115	-	204
Site K	Day 1	607		
	Day 2	420		
	Day 3	760		
	Day 4	1003		
	Day 5	828		
TOTAL		**3,618**	**-**	**-**
Mean		724	-	-
Site L	Day 1			87
	Day 2			35
	Day 3			374
	Day 4			232
	Day 5			331
TOTAL		**-**	**-**	**1,059**
Mean		-	-	212
TOTAL		**10,828**	**668**	**3,330**
Σ Mean		2,166	134	666

	M / V / S	Squirrel	Rat	Hegdehog
Night 1	224	0		
Night 2	398	31		
Night 3	658	96		
Night 4	463	108		
	1,743	**235**	**-**	**-**
	436	59	-	-
Night 1	714			
Night 2	638			
Night 3	493			
Night 4	333			
	2,178	**-**	**-**	**-**
	545	-	-	-
Night 1	155		453	
Night 2	105		363	
Night 3	357		367	
Night 4	281		269	
	898	**-**	**1,452**	**-**
	225	-	363	-
Night 1	372		107	
Night 2	327		240	
Night 3	201		300	
Night 4	159		270	
	1,059	**-**	**917**	**-**
	265	-	229	-
Night 1	1187			
Night 2	1431			31
Night 3				34
Night 4	1061		25	
	3,679	**-**	**25**	**65**
	920	-	6	16
Night 1	57		52	15
Night 2	82		125	
Night 3	2		398	32
Night 4			331	
	141	**-**	**906**	**47**
	35	-	227	12
TOTAL	**9,698**	**235**	**3,300**	**112**
Σ Mean	2,425	59	825	28

Appendix 5 - Two-Way ANOVA Analysis

Shapiro – Wilks test for normality

	Spring Data	Summer Data
Hedge Day	W = 0.96, n = 6, P = > 0.05	W = 0.97, n = 6, P = > 0.05
Hedge Night	W = 0.83, n = 6, P = > 0.05	W = 0.96, n = 6, P = > 0.05
No Hedge Day	W = 0.85, n = 6, P = > 0.05	W = 0.95, n = 6, P = > 0.05
No Hedge night	W = 0.98, n = 6, P = > 0.05	W = 0.95, n = 6, P = > 0.05

F – Test – Comparison of variances

	Spring Data	Summer Data
Hedge Day / Hedge Night	F = 2.33, DF1 = 5, DF2 = 5, P => 0.05	F = 1.30, DF1 = 5, DF2 = 5, P => 0.05
No Hedge Day / No Hedge Night	F = 1.70, DF1 = 5, DF2 = 5, P => 0.05	F = 1.01, DF1 = 5, DF2 = 5, P => 0.05
Hedge Day / No Hedge Day	F = 1.46, DF1 = 5, DF2 = 5, P => 0.05	F = 1.86, DF1 = 5, DF2 = 5, P => 0.05
No Hedge Day / No Hedge Night	F = 1.70, DF1 = 5, DF2 = 5, P => 0.05	F = 1.01, DF1 = 5, DF2 = 5, P => 0.05

Appendix 6 – QED Screenshots of Two-Way ANOVA Results

Explore the Statistic: Two way ANOVA

Two Way ANOVA						
	DF	SS	MS	F	Prob.>F	Omega^2
Between Columns	1	520.421	520.421	6.74546	0.0172309	0.203733
Between Rows	1	7.62457	7.62457	0.0988261	0.756499	0
Interaction	1	27.5111	27.5111	0.356585	0.557109	0
Within Groups/Error	20	1543.03	77.1514			
Total	23	2098.58	91.2428			
Omega^2	0.148962					
	Means and Variability					
Group	ID	Mean	Variance	StdD	N	
Cell	Hedge day	11.4621	54.545	7.38546	6	
Cell	No hedge day	10.4481	79.8049	8.93336	6	
Cell	Hedge night	18.634	127.326	11.2839	6	
Cell	No hedge Night	21.9026	46.9298	6.85053	6	
Column	1	10.9551	61.3486	7.83253	12	
Column	2	20.2683	82.1208	9.06205	12	
Row	1	15.0481	96.6968	9.83345	12	
Row	2	16.1754	93.3904	9.66387	12	
	Total	15.6117	91.2428	9.55211	24	

	Homogenity of Variance Tests			
Test	Statistic	DF1	DF2	
Hartley Fmax	2.71311	4	5	
Cochran C	0.412584	4	5	
Bartlett Chi-square	3.33172	3		
Bartlett Probability > Chi-Square	0.343252			

Spring Data

Explore the Statistic: Two way ANOVA

Two Way ANOVA						
	DF	SS	MS	F	Prob.>F	Omega^2
Between Columns	1	451827	451827	4.13481	0.0554943	0.0889585
Between Rows	1	783732	783732	7.17218	0.0144537	0.175152
Interaction	1	320397	320397	2.93206	0.1023	0.0548271
Within Groups/Error	20	2.18548E006	109274			
Total	23	3.74143E006	162671			
Omega^2	0.318937					
	Means and Variability					
Group	ID	Mean	Variance	StdD	N	
Cell	Hedge day	361	72728	269.681	6	
Cell	No hedge day	491.333	135264	367.782	6	
Cell	Hedge night	404.333	94936.7	308.118	6	
Cell	No hedge Night	996.833	134167	366.288	6	
Column	1	426.167	99174.5	314.92	12	
Column	2	700.583	199881	447.08	12	
Row	1	382.667	76723.3	276.99	12	
Row	2	744.083	192159	438.359	12	
	Total	563.375	162671	403.325	24	

	Homogenity of Variance Tests			
Test	Statistic	DF1	DF2	
Hartley Fmax	1.85986	4	5	
Cochran C	0.309461	4	5	
Bartlett Chi-square	1.39257	3		
Bartlett Probability > Chi-Square	0.707278			

Summer

Appendix 7 –Regression Analysis

Shapiro – Wilks test for normality

Mice Daytime Hedge	W = 0.94, n = 30, P = > 0.05	Temperature	W = 0.94, n = 30, P = > 0.05
Mice Daytime No Hedge	W = 0.94, n = 30, P = > 0.05	Temperature	W = 0.94, n = 30, P = > 0.05
Mice Night time Hedge	W = 0.98, n = 24, P = > 0.05	Temperature	W = 0.95, n = 24, P = > 0.05
Mice Night time No Hedge	W = 0.98, n = 24, P = > 0.05	Temperature	W = 0.95, n = 24, P = > 0.05
Rat Daytime Hedge	W = 0.92, n = 12, P = > 0.05	Temperature	W = 0.95, n = 12, P = > 0.05
Rat Night time Hedge	W = 0.96, n = 11, P = > 0.05	Temperature	W = 0.93, n = 11, P = > 0.05
Hedgehog Night time	W = 0.91, n = 15, P = > 0.05	Temperature	W = 0.91, n = 15, P = > 0.05
Squirrel Daytime	W = 0.93, n = 20, P = > 0.05	Temperature	W = 0.95, n = 20, P = > 0.05

Appendix 8 – QED Screen shots for Regression Analysis

Daytime temperature MVS

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	2.96621	2.96621	9.98124	0.0037736
Residual	28	8.32098	0.297178		
Total	29	11.2872			
R =	0.512634				
R squared =	0.262794				
Adjusted R squared =	0.236465				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
No Hedge	0.0259044	0.512634	0.00819939	3.15931	0.0037736
Constant	3.22634				

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	191.231	191.231	11.3257	0.00223303
Residual	28	472.769	16.8846		
Total	29	664			
R =	0.536655				
R squared =	0.287998				
Adjusted R squared =	0.262569				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
Hedge	0.00768118	0.536655	0.00228242	3.36537	0.00223303
Constant	10.8678				

Night Time Temperatures MVS

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	1.4646	1.4646	0.0851208	0.773208
Residual	22	378.535	17.2062		
Total	23	380			
R =	0.0620823				
R squared =	0.00385422				
Adjusted R squared =	-0.0414251				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
Hedge Night time	0.000570106	0.0620823	0.00195406	0.291755	0.773208
Constant	10.5113				

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	138.691	138.691	12.6444	0.00176978
Residual	22	241.309	10.9686		
Total	23	380			
R =	0.604133				
R squared =	0.364976				
Adjusted R squared =	0.336112				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
No Hedge night	0.00369065	0.604133	0.0010379	3.55589	0.00176978
Constant	5.20875				

Day and Night Time Temperatures Rats

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Day time Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	0.03797	0.03797	0.00188317	0.966241
Residual	10	201.629	20.1629		
Total	11	201.667			
R =	0.0137216				
R squared =	0.000188281				
Adjusted R squared =	-0.0997929				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob. >t
Rat prints	0.000238555	0.0137216	0.00549724	0.0433955	0.966241
Constant	17.7546				

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Night time Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	1.99464	1.99464	0.156466	0.701644
Residual	9	114.733	12.7481		
Total	10	116.727			
R =	0.130721				
R squared =	0.017088				
Adjusted R squared =	-0.0921244				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob. >t
Number of Rat Prints	0.00219235	0.130721	0.00554243	0.395558	0.701644
Constant	11.7203				

Day and Night time temperatures Squirrel and Night time Hedgehog

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	179.5	179.5	18.4577	0.000434708
Residual	18	175.05	9.72498		
Total	19	354.55			
R =	0.711531				
R squared =	0.506277				
Adjusted R squared =	0.478848				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
Squirrel prints	0.0278762	0.711531	0.00648851	4.29624	0.000434708
Constant	8.72884				

Explore the Statistic: Linear Regression

Linear Regression Output from QED Statistics					
Dependent = Slope * Independent + Constant					
Dependent Variable: Temperature					
Analysis of Variance					
Source	DF	SS	MS	F	Prob. > F
Regression	1	38.7109	38.7109	2.28515	0.15454
Residual	13	220.222	16.9402		
Total	14	258.933			
R =	0.386654				
R squared =	0.149501				
Adjusted R squared =	0.0840784				
Variables in Model					
Variable	Coef.	Std. Coef.	Std. Error	t	Prob.>t
Hedgehog prints	-0.0152253	-0.386654	0.0100718	-1.51167	0.15454
Constant	11.9502				