The impact of warmer, wetter winters on invertebrate food sources for hedgehogs in urban environments and the potential implications for hedgehog survival during winter waking.

Report for the Peoples Trust for Endangered Species, 2017, by Saadia Khan

(Author, 2017)

Study Area: Leicestershire

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1. Introduction

In 2016 data collected from over 50 well-respected wildlife and research organisations produced the 'State of Nature' report, which assessed the status of wildlife in the UK using the modern Red List criteria (RSPB, 2016). It was concluded that 15% of the 8,000-assessed species are extinct or threatened with extinction from Great Britain, which also ranked the UK 189 on the Biodiversity Intactness Index out of the 218 countries assessed (RSPB, 2016).

Presently, due to the increased levels of direct and indirect human interference, the loss of wildlife is occurring at an unprecedented rate (Hof, 2009; Hof & Bright, 2012). This has meant that the significance of studying more common species has been more widely recognised in conservation biology as small declines of common species can create absolute losses, disrupting whole ecosystems (Hof & Bright, 2012).

The West European hedgehog, *Erinaceus europaeus*, a once common widespread species in Britain, has been steadily declining in parts of the country since the early part of the last century (Battersby, 2005; Hof, 2009; Hof & Bright, 2012). Recent published research on these terrestrial mammals suggest that populations of hedgehogs have dropped by over a quarter in the past decade from an estimated 30 million in the 1950s to a conservatively estimated 1.5 million in 1995 (Wembridge, 2011).The Western hedgehog is currently classified as Least Concern on the IUCN Red List (IUCN, 2001) yet recent surveys documenting their decline has led to the species being included in the 2007 UK Biodiversity Action Plan (JNCC, 2008; *Hof et al.*, 2012) and listed under 'Appendix III' (protected fauna species) of the Bern Convention (Council of Europe, 2002).

There are many possible factors that may have contributed to the decline of hedgehogs, these include: agricultural intensification; changes in modern agricultural practices; habitat loss and fragmentation; increased use of agricultural chemicals; increased road traffic; predation; reduction in prey abundance and climate change (Hof, 2009; Dowding *et al.*, 2010; Wembridge, 2011).

Weighing less than 1.5 kg, the hedgehog is a mobile insectivorous mammal species which largely feeds on macro-invertebrates including ground beetles, earthworms, and slugs (Hof, 2009; Dowding *et al.*, 2010; Hof & Bright, 2012; Hof *et al.*, 2012; Haigh *et al.*, 2012b; Rautio *et al.*, 2015). Hedgehogs are nocturnal animals and are known to be largely active during the months of April to September and recorded to hibernate between the months of October through to March (Dowding *et al.*, 2010; Tysnes, 2016). Hibernation is an adaptive process of inactivity for surviving extended periods with little or no food availability by dropping the core body temperature, lowering the heart rate, and by reducing the metabolic rate (Chayama *et al.*, 2016).

Early arousal of these hibernating animals during warmer winter months can mean that fat reserves are diminished before the winter period is over (Moss & Sanders, 2001; Duffield, 2012; Chayama *et al.*, 2016). Based on data collected from UK Climate Impacts Programme (UKCIP), it is predicted that by the year 2050 rainfall will increase between 15 and 20% and the temperature will become 2% warmer in the winter months (Mitchel *et al.*, 2007), which may have a lasting impact on the long-term survival of the species.

Although hedgehogs have adapted to a wide variety of habitat types, research suggests that they are often associated with edge habitats such as hedgerows and field margins (Hof *et al.*, 2012). With human population growth expanding significantly within the United Kingdom, urban areas have also been increasing and are now understood to be a favoured habitat of the hedgehog due to their primary habitat becoming fragmented (Tysnes, 2016). Fragmentation is typically caused by features such as buildings, roads, and fences, reducing the total size of original area, which can isolate a species and influence its behaviour (Tysnes, 2016). In addition to their adaptations to urban habitats, hedgehogs are known to spend over 80 percent of their active time foraging, which suggests that their nightly movements are potentially dictated by climatic conditions due to the effect weather could possibly have on invertebrate prey availability (Dowding *et al.*, 2010; Hof *et al.*, 2012; Tysnes, 2016).

Aims of study

In this study, I assessed the availability of invertebrate food sources for hedgehogs in the winter and monitored hedgehog activity levels in response to these changing temperatures and food availability during winter waking. This study aims to fill this knowledge gap and has three main research questions:

(1) How common is winter waking in urban hedgehogs and is it related to temperature and rainfall?

(2) How abundant are invertebrate food sources (slugs, ground beetles, and earthworms) for urban hedgehogs in winter and are these related to temperature and rainfall?

(3) Is there a mis-match between the effect of warm spells in winter on hedgehog activity and food availability?

Existing research carried out by Bethan Mason and Dr Moya Burns at the University of Leicester is underway investigating the impact of hedgerow connectivity on hedgehog activity levels at sites representing a gradient of urbanisation across the city. This makes the University of Leicester an ideal site to carry out this study as there is already a known hedgehog population. Within the existing structure of 12 survey sites across the university's multiple urban campuses I continued footprint monitoring over the winter along with recording weekly temperature and rainfall to determine how frequently hedgehogs forage in the winter and whether it is related to local climate. I also implemented weekly standardised monitoring of hedgehog common food sources (ground beetles, earthworms and slugs).

The results from this survey aim to help us understand how a changing climate is affecting British hedgehogs. i.e. will increased warming also mean an increase of insect availability? I predict that warmer temperatures will mean more frequent winter waking in hedgehogs. However, due to the fact that many beetles survive winter as pupae, I suspect warmer temperatures will not lead to greater beetle availability. In contrast, slugs and earthworms are known to be active in winter and their activity levels are known to be related to temperature and rainfall, thus on warm, wet nights there may be an increase in slug and earthworm availability. Thus, changing climates could be having a complicated impact on hedgehogs as they may be waking more frequently but facing a winter food shortage problem if there is a miss-match of impacts on hedgehogs themselves and their food sources.

I also hope to understand the current value of urban environments for hedgehogs and to help identify mitigation strategies for future projects involving hedgehogs at the University of Leicester.

2. Methods

Study area

The study was carried out between January 2017 and April 2017 over sites spread across Leicester city. Six of the tracking tunnels were placed on sites chosen based on existing research already being carried out, which included tunnels 1 and 2 at Stokeswood Park, tunnels 3 and 4 at Leicester Campus and tunnels 5 and 6 at Brookfield Campus. The final six tunnels (7 to 12) were placed over three new sites at Oadby Student Village. Permission was granted for all study sides by the land owners.

Figure 1. Tunnels 1 and 2 at Stokeswood Park

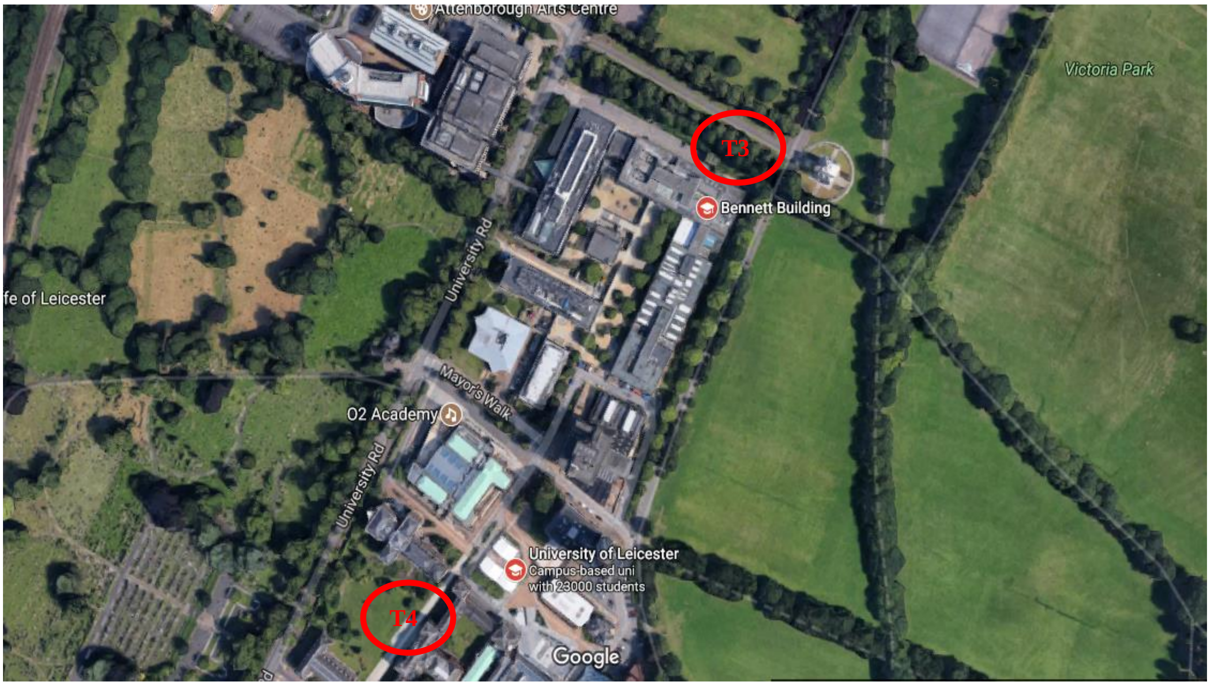


Figure 2. Tunnels 3 and 4 at the University of Leicester Campus

Figure 3. Tunnels 5 and 6 at Brookfield Campus

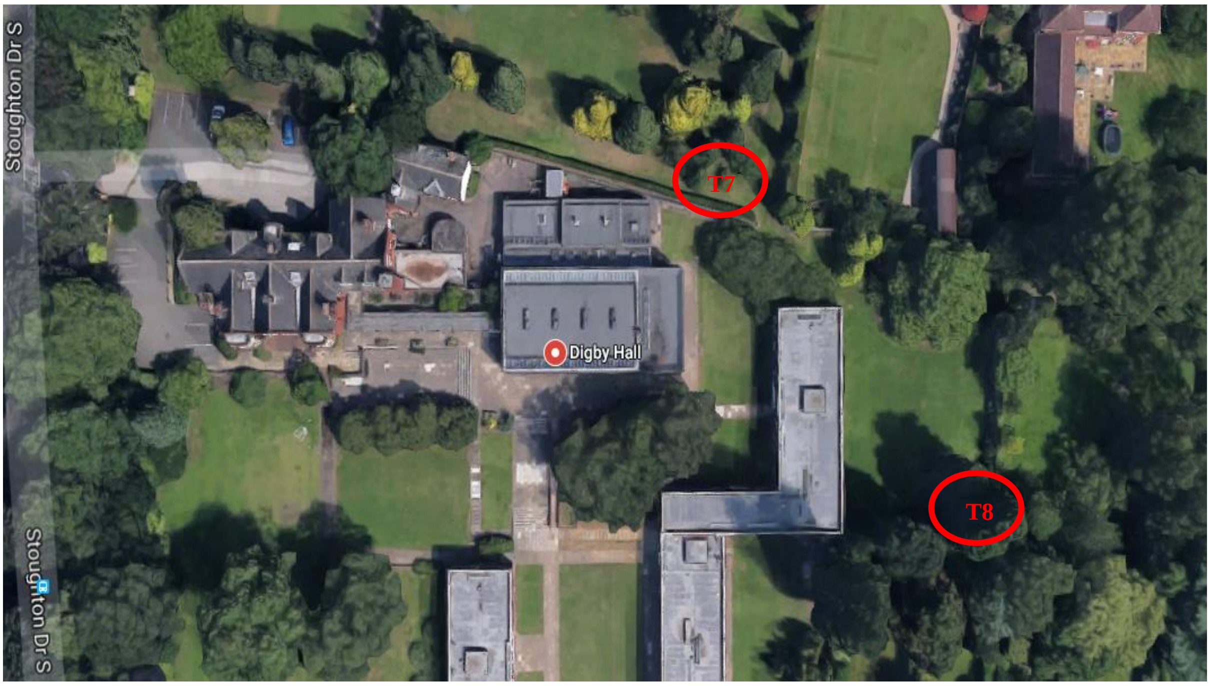


Figure 4. Tunnels 7 and 8 at Digby hall, Oadby Student Village

Figure 5. Tunnels 9 and 10 at Bowder Court, Oadby Student Village

Figure 6. Tunnels 11 and 12 at Inglewood, Oadby Student Village

Footprint tracking tunnels

There are several methods and tools that have been specifically designed for the purpose of tracking wildlife depending on the species, particular habitat being surveyed and under difficult weather conditions (Haigh *et al.,* 2012a).

Hedgehogs are inconspicuous by nature and can be especially difficult to detect as they are a nocturnal species (Johnson & Thomas, 2015). Employing footprint tracking tunnels is a new technique that has been introduced to determine whether hedgehogs are present or absent at a site without depending on visual surveys (Johnson & Thomas, 2015). Additionally, this system is a non-intrusive and cost-effective way of surveying hedgehogs over a significant period of night-time work (Johnson & Thomas, 2015).

Tracking tunnels are a 210 x 1200 mm board made from light, malleable plastic material that can be folded into a triangular tunnel (Figure 7) (Johnson & Thomas, 2015). At the base of the tunnel there is a removable tracking plate made of the same plastic material that contains two ink pads that are made from mixing charcoal powder and vegetable oil, two sheets of A4 plain paper to record the footprints and an area in the centre to place bait, which was used as an attractant (Haigh *et al.,* 2012a; Johnson & Thomas, 2015). Each tunnel was labelled with an A4 laminated 'do not disturb' sign.

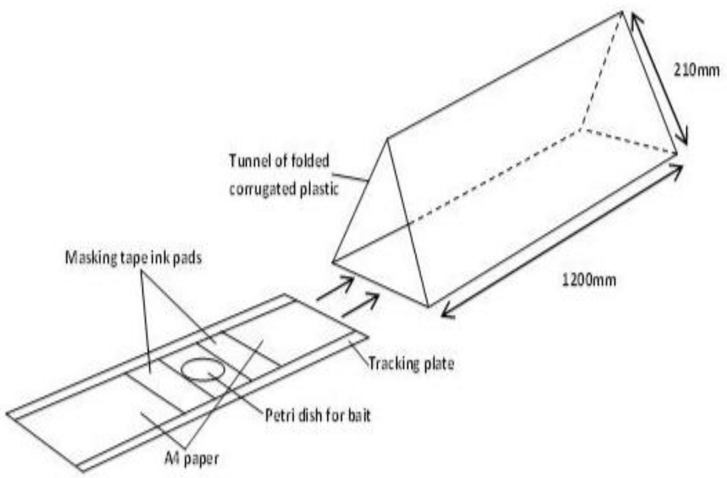


Figure 7. Schematic diagram of the hedgehog footprint tunnels to be used in this study (Johnson & Thomas, 2015).

The tunnel boards were secured into place using tent pegs along linear features and edge habitats. As their name suggests, hedgehogs are generally associated with edge habitats and in the UK, hedgerows were ranked as the most important habitat preference by hedgehogs (Haigh *et al.,* 2012b).

A total of 12 tunnels were deployed over 300 nights between the months of January through to April. Tunnels 1 to 6 were surveyed for a total of 180 nights and tunnels 7 to 12 were surveyed for a total of 120 nights. Tunnels 1 to 6 were surveyed for six days one week and then tunnels 7 to 12 were surveyed the following week for a further six days (Table 1). The tunnels were checked daily and, if used, the paper and bait were changed.

Table 1. Timeline for surveying tunnels

Prep. day	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Prepare equipment	Set up tunnels out in field	Check & rebait tunnels	Check & rebait tunnels	Check & rebait tunnels	Check & rebait tunnels	Final check for data with no rebait
	Night 1	Night 2	Night 3	Night 4	Night 5	

(Johnson & Thomas, 2015).

Hedgehog footprints are distinct and are easily distinguishable from other small mammals such as cats, rodents, squirrels and birds (Figure 8). Well-defined ink prints usually record four equally-spaced oval toe prints, which are joined to a centre pad print (Moss & Sanders, 2001).

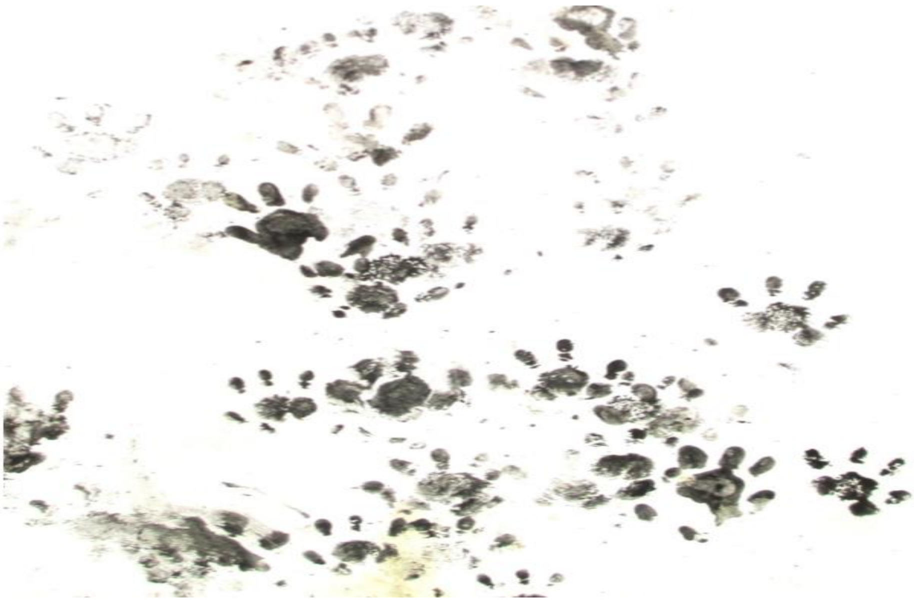


Figure 8. Adult hedgehog footprints (Johnson & Thomas, 2015).

Tracking tunnels are a recently developed method to surveying hedgehogs and it is therefore advantageous to understand the efficiency and suitability of this technique under different circumstances for future use (Haigh *et al.*, 2012a).

Weather

Local nightly temperature and rainfall data were obtained from the Leicestershire Met Office weather data.

Surface Invertebrates

Potential invertebrate prey was sampled around the footprint tracking tunnels. The macroinvertebrates surveyed throughout the data collection period were slugs, ground beetles and earthworms.

The availability of beetles was estimated using 33 pitfall traps, 3 of which were distributed randomly at each of the 12 tunnels throughout the study sites. Each trap consisted of a small plastic cup (diameter: 8 cm; depth: 14 cm) which was sunk into the ground so that the rim was level with the ground surface and then filled with a small amount of antifreeze so that any beetles captured could not predate on one another. Traps were protected with a small piece of mesh wire so small mammals such as mice were not accidently trapped or hurt.

Slugs were captured initially using 33 humane slug traps made from plastic food containers, which were baited with food as an attractant. Minimal slugs were caught using this method and so by week three the slug traps were then baited with a small amount of beer and it is for this reason that the first two weeks of slug data are not included in the analysis or graphs. All captured slugs were counted and weighed daily.

Earthworms were unearthed using a total of 33plots which were chosen at random, plots measured at 50 cm x 50 cm with a depth of 15 cm and were created using a handheld gardening spade. Worms caught were counted and weighed daily during the survey week and then released back into the area they were captured.

Statistical analysis

Some of the data collected for hedgehog activity was not normally distributed and so a regression analysis could not be implemented and instead a correlation coefficient analysis was applied.

3. Results

A total of 12 sites were surveyed over the 11-week data collection period during the months of January through to April. The number of visits per site varied, tunnels 1 to 6 collectively were surveyed a total of 60% whereas tunnels 7 to 12 were collectively surveyed a total of 40%. This was mainly due to no results being collected from tunnels 7 to 12 during week five when all data was skewed due to Storm Doris.

Hedgehog activity

Out of the 12 tracking tunnels deployed three (tunnels 3, 7 & 9) were used regularly by hedgehogs whilst the remaining nine picked up no activity. Tunnel 3, which was placed outside the Bennett Building (Figure 2), was the most used tunnel by hedgehogs as their prints were recorded on ten separate occasions. Hedgehog prints were recorded on a total of five occasions in Oadby at tunnel 7, which was placed at Digby Hall and tunnel 9, placed at Inglewood, successfully indicating their presence at the site, but occurrence was low, with a high incidence of use by non-target animals including rodents, birds and domestic cats.

Hedgehogs were never recorded using the two tunnels placed at the Brookfield Campus site despite the fact that there was evidence of their presence from previous research the year before. Tunnel use by non-target animals represented 66% of the records and no prints at all represented 29% of the data collected. On the remaining occasions, the food either remained in the tunnels the following day (28%) or the bait was gone but there were no footprints (3%). Hedgehog activity as recorded by the footprint tunnels was greatest at the beginning of the survey period and lowest at the end of the survey period (Figure 9). Weekly hedgehog activity was determined by taking all positive footprint records per week and dividing them by the number of nights the and amount of footprint tunnels which were running, giving a level of the average number of hedgehogs active per night

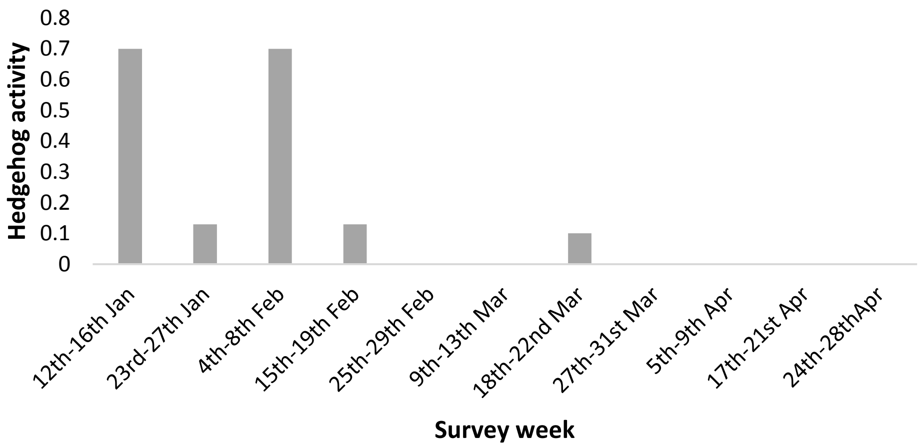
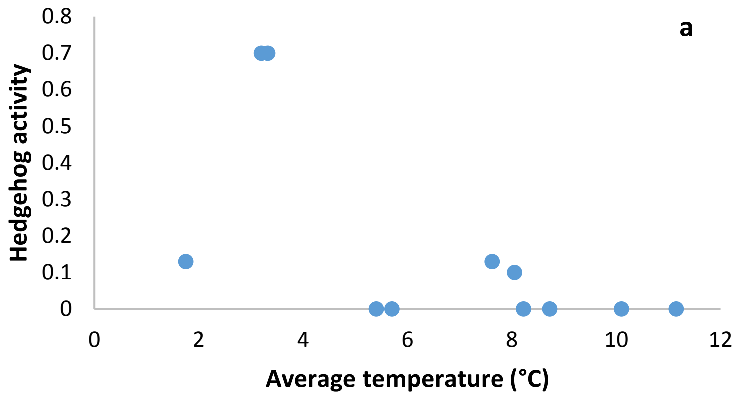


Figure 9. Average weekly hedgehog activity levels detected over the data collection period

Hedgehog activity declined with increasing temperature (Figure 10, a. Correlation coefficient -0.623). Whereas there was no strong relationship between hedgehog activity and rainfall (Figure 10, b. Correlation coefficient 0.323).



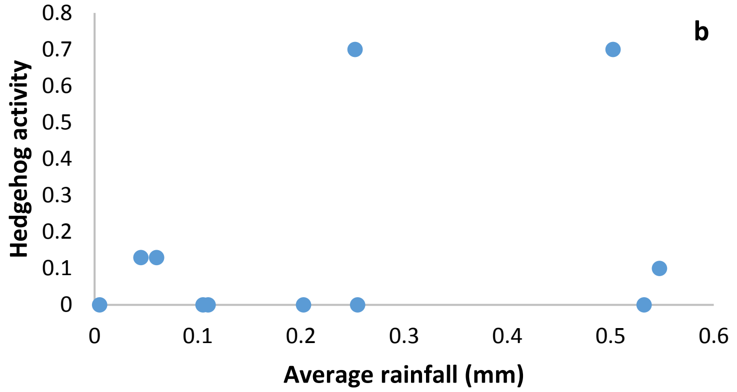


Figure 10. Average hedgehog activity levels detected in relation to average nightly temperature (a) and average rainfall (b)

Invertebrate activity

Slugs

Slug abundance increased over the survey period from a total of 36 in week three (4th-8th February) to 341 in week eleven (24th-28th April) (Figure 11).

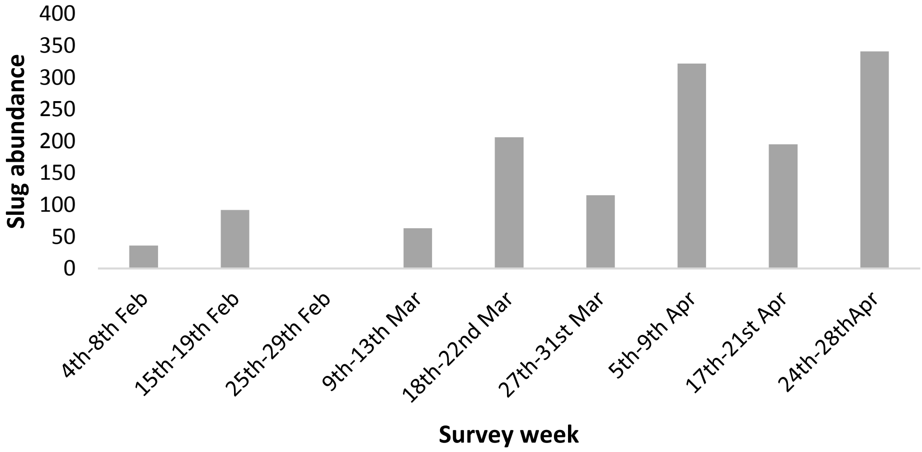


Figure 11. The total number of slugs detected over the data collection period

Slug biomass showed no significant relationship with increasing nightly temperatures (Figure 12, a.) (R^2= 0.297, 8 d.f., F=2.952, P= 0.129) or between nightly rainfall (Figure 12, b.) (R^2= 0.236, 8 d.f., F= 2.164, P= 0.185).

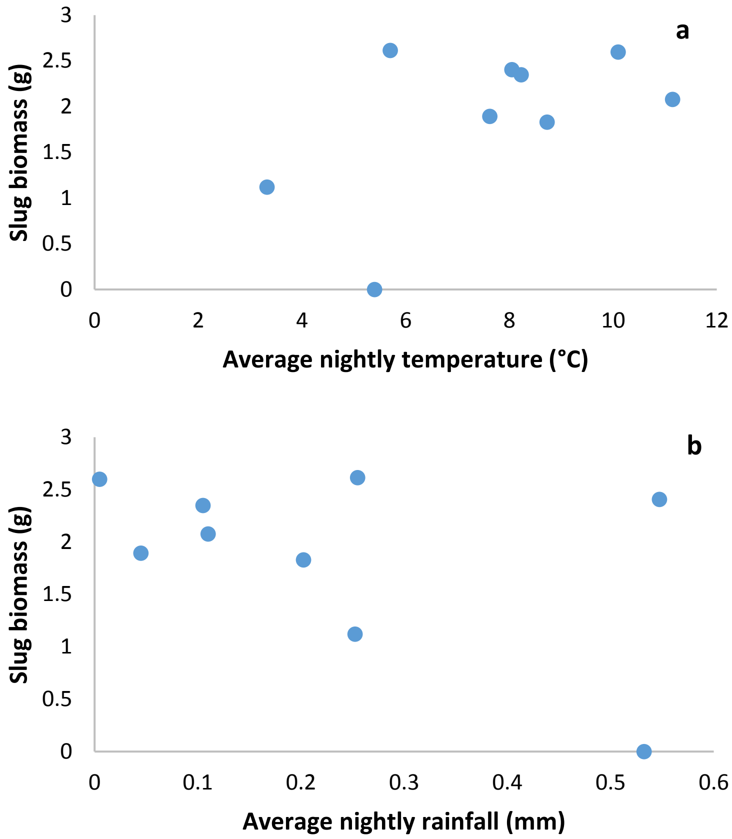


Figure 12. (a) Slug biomass in relation to the average temperature recorded (b) Slug biomass in relation to the average rainfall recorded

<u>Ground beetles</u>

Beetle abundance increased over the survey period from a total of 2 in week one (12^{th}-$16th^{th}$ January) to 137 in week eleven (24^{th}-28^{th} April) (Figure 13).

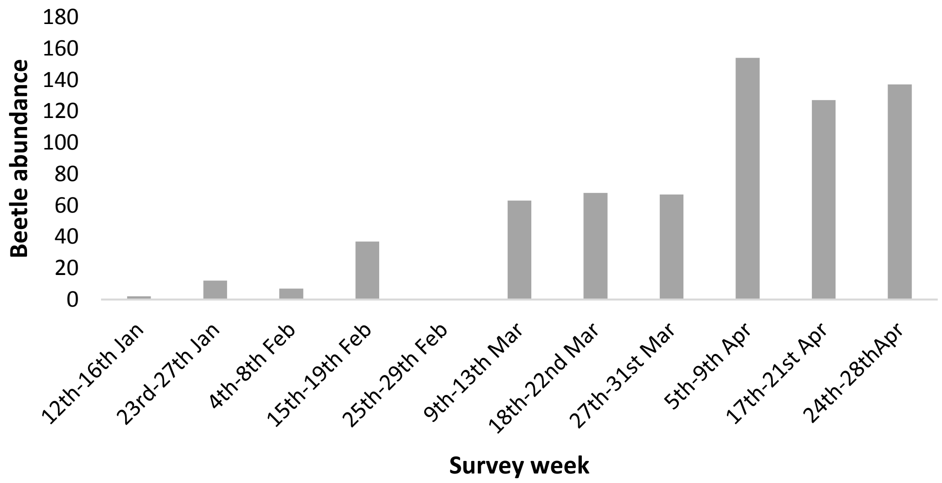


Figure 13. The total number of beetles detected over the data collection period

Beetle biomass increased with increasing nightly temperatures (Figure 14, a.) (R^2=0.514, 10 d.f., F=9.519, P=0.013), however there was no significant relationship between beetle biomass and nightly rainfall (Figure 14, b.) (R^2=0.224, 10 d.f., F=2.595, P=0.142).

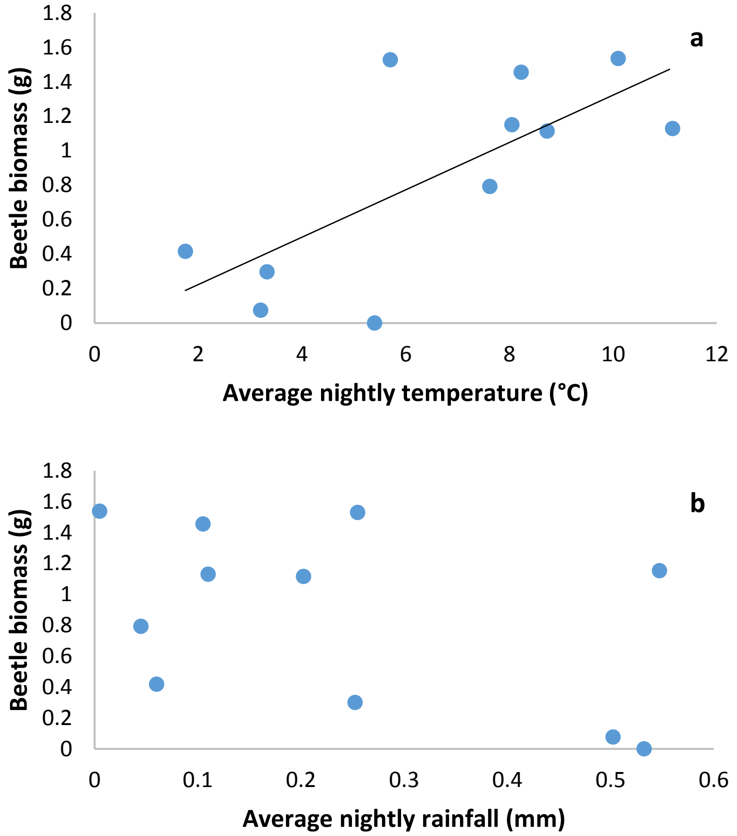


Figure 14. (a) Beetle biomass in relation to the average temperature recorded (b) Beetle biomass in relation to the average rainfall recorded

<u>Earthworms</u>

Earthworms were most abundant in the final week of data collection (24th-28th April) with a total of 42 worms recorded for that week however there was no relationship with worm abundance increasing over time (Figure 15).

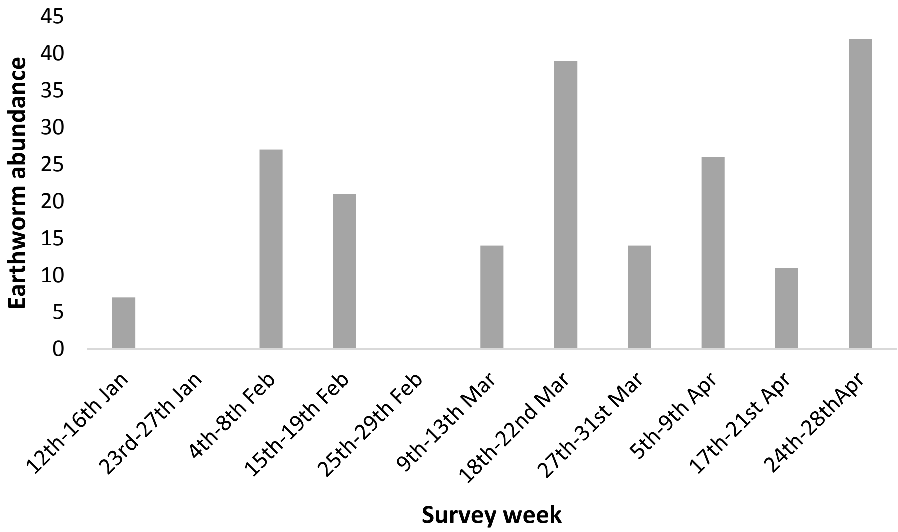


Figure 15. The total number of earthworms detected over the data collection period

There was no significant relationship between earthworm biomass and nightly temperatures (Figure 16, a.) (R^2=0.311, 10 d.f., F=4.066, P=0.075) or between earthworm biomass and nightly rainfall (Figure 16, b.) (R^2=0.024, 10 d.f., F=0.219, P=0.651).

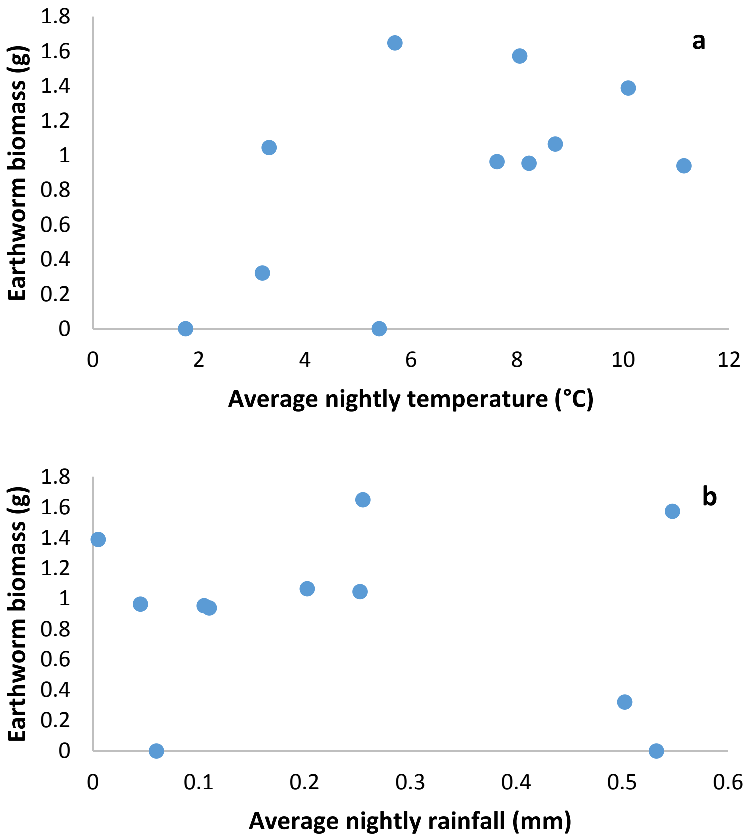


Figure 16. (a) Earthworm biomass in relation to the average temperature recorded (b) Earthworm biomass in relation to the average rainfall recorded

Hedgehog activity in relation to food availability

There was a weak negative correlation between hedgehog activity and slug biomass (Figure 17, a.) (Correlation coefficient -0.409), hedgehog activity and beetle biomass (Figure 17, b.) (Correlation coefficient -0.545) and hedgehog activity and earthworm biomass (Figure 17, c.) (Correlation coefficient -0.283).

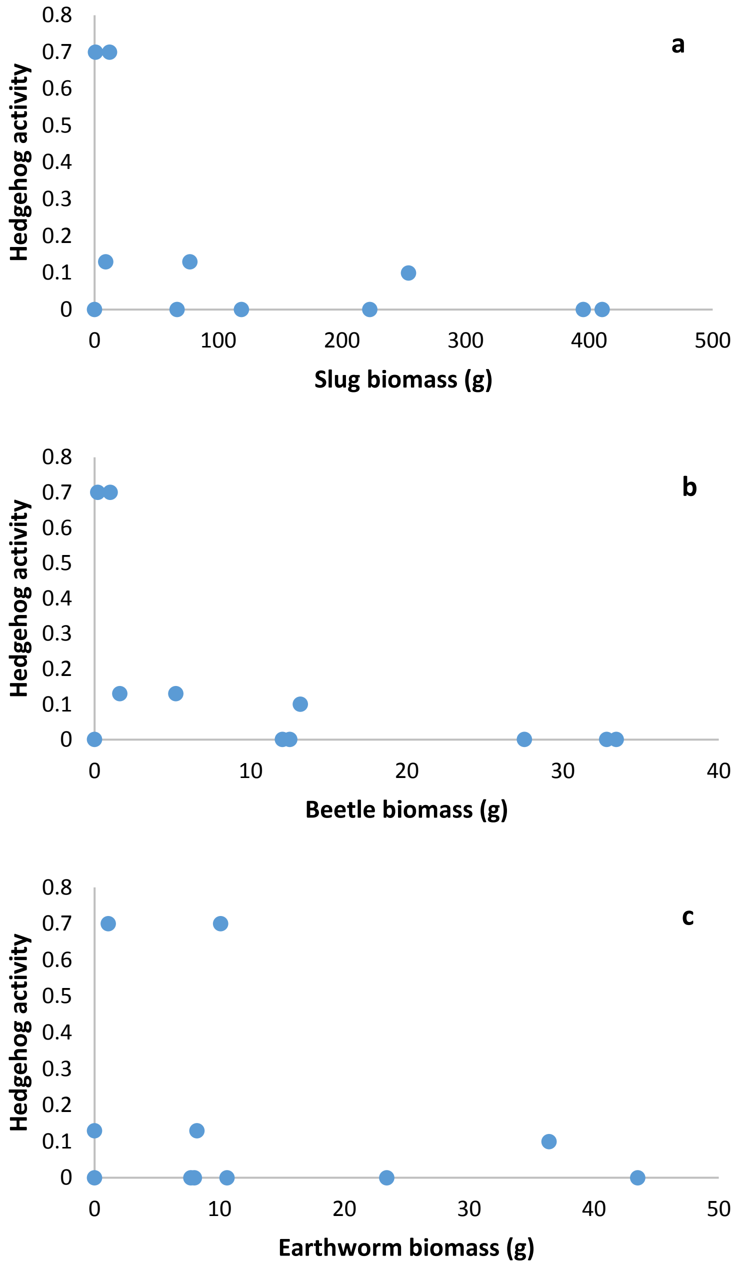


Figure 17. The average number of hedgehogs detected in relation to slug biomass (a) The average number of hedgehogs detected in relation to beetle biomass (b) The average number of hedgehogs detected in relation to earthworm biomass (c)

4. Discussion

Hedgehog activity

The hedgehog encounter rate was low, being recorded on three sites on 15 occasions. Previous research conducted in 2012a by Haigh *et al.,* into the techniques for detecting hedgehogs in a rural landscape has shown that spotlighting was the most effective method of detecting hedgehogs in comparison to the use of tracking tunnels. However, in 2014 Yarnell *et al.,* found that footprint tunnels were the most effective way of detecting hedgehog presence. Spotlighting may be more difficult in urban areas due to the already high presence of artificial lighting, which may go some way to explaining differences in their effectiveness. More studies comparing the efficacy of footprint tunnels versus other methods in varying environments are needed. Other detection methods that could be combined with footprint tracking tunnels and spotlighting include engaging members of the public through questionnaires and road kill surveys and by placing camera traps on foraging routes. All these methods of monitoring should be used long-term before declaring hedgehogs absent from a specific site. The long-term monitoring of species is therefore a valuable tool to detect possible declines, both in time and in space. It is recommended that research should continue at the 12 sites selected as studies often involve the re-sampling of sites in order to study changes in the presence or absence of the hedgehogs in Leicester city over time.

In contrast to expectations, greatest hedgehog activity levels were found in January and declined over the course of the study period. These findings are in contrast to Dowding (2007) who studied the impact of weather on the activity pattern of hedgehogs and the rate of admission to wildlife care centres. Her finding showed that hedgehogs increased their activity with increasing temperature and days without rainfall and that high temperatures and rainfall influenced hedgehog admission to care centres.

There are many possible explanations for the declining hedgehog activity levels observed in this study from January through to April. It may be that the activity picked up in January was of hedgehogs which had not reached sufficient weight to hibernate and which consequently died at some point over the study period. Without having spot-lighted and monitored these individuals directly this theory cannot be verified, but this could be a possible area of research for the future. Death due to other factors such as predation or traffic could also be a possibility.

Another explanation is that the hedgehogs which were active in January may have switched their foraging locations in spring as other areas may have become more suitable for foraging with the change in weather conditions. This could have included switching to food put out by members of the public, who may have ceased doing this over winter due to the assumption that hedgehogs will be hibernating at this time.

Invertebrate activity

Slugs

In this study slugs were the most abundant food source recorded along the tracking tunnels in the study field. It is not surprising that they were one of the dominant surface invertebrates as most of the study areas chosen had a well-established hedgerow with suitable ground cover, which are both important factors that are reported to increase slug abundance (Hegarty & Cooper, 1994).

Slug abundance increased from February through to April, however no significant relationship with rainfall or temperature was found. There are many reasons why we may not have detected a relationship between temperature or rainfall on slug biomass, in a study by Haigh *et al.,* they found that invertebrates such as slugs are particularly sensitive to environmental factors, such as temperature and humidity (2012b).

Ground beetles

Beetle abundance increased considerably from January through to April with total pitfall captures equating to double figures (37) in mid-February (15th-19th) to triple figures (154) at the start of the survey week in April (5th-9th). There was a significant relationship found with beetle biomass and temperature. Ground beetles are largely inactive during winter months as body fluids may freeze in low temperatures (Jaskula & Soszyńska-Maj, 2011), which could be the reason why fewer beetles were caught in the cooler winter months. The results in this study presented no significant relationship between rainfall on beetle biomass yet previous research has shown that certain abiotic conditions such as rainfall can have negative impacts on invertebrate population levels by significantly decreasing life expectancy and development (Pellegrino *et al.*, 2013).

Beetles can be an important food source for hedgehogs but it has been observed that soft-bodied prey such as slugs and earthworms are preferred over ground beetles due to indigestible chitin particles however soft-bodied prey as a food source are not as easy available (Rautio *et al.,* 2015).

Earthworms

Earthworm abundance increased from the start of January (7) to the end of April (42) but their total count dropped after Storm Doris which occurred during week five, this contradicts research which has reported an increase in earthworm abundance and activity at ground surface particularly after heavy rainfall (Baubet *et al.*, 2003). Unexpectedly no significant relationship with temperature or rainfall on earthworm biomass was detected despite research revealing invertebrates such as earthworms being particularly sensitive to environmental factors, such as temperature and humidity (Haigh *et al.*, 2012b).

Earthworms were the least abundant food prey recorded, this could be due to earthworms being able to disperse over significant distances at night along the soil surface (Haigh *et al.* 2012b). The majority of earthworms collected were recorded at the three sites across the Oadby Student Village, which could be associated with soil type and moisture content as this site was more extensively managed.

Hedgehog activity in relation to food availability

In this study, there was no significant correlation between hedgehog activity in relation to food availability which included slugs, ground beetles and earthworms. The data was collected from various sites in urban locations and so it is a possibility that some food may have been provided by humans in the surrounding areas. Furthermore, it is likely that there could have been competition from other insectivorous predators such as badgers. It is recommended that in future research on this topic that sites should be assessed further to recognise if any other insectivorous mammals are utilising the same areas. As hedgehogs can spend over 80 percent of their active time foraging (Hof, 2009) it is likely that their movements are dictated primarily by the distribution of prey but what is unclear is the numerous factors affecting the abundance of those food sources. Additionally, the role of climate change with respect to food availability needs to be investigated further as the impact of food availability itself upon the distribution of hedgehogs remains largely unstudied. Researching into the how and why of animal movements such as hedgehogs can be beneficial to the conservation of that species. Although climatic variations were not found to be significant in affecting the movements of hedgehogs and their prey there could be many other biotic and abiotic factors including the quality of habitat, surrounding man-made infrastructure and the presence of competitors, which may have affected their movement (Tysnes, 2016). While there have been considerable changes in climate within the UK over the past 30 years there have also been substantial reductions in habitat availability and quality, which can influence the complex interactions between hedgehogs and their food sources (Mossman *et al.*, 2015).

Limitations

As some of the prints had been obscured by certain weather conditions some of the records collected may be dubious.

5. **Conclusion**

The aim of this study was to examine the availability of invertebrate food sources for hedgehogs in the winter and to better understand hedgehog activity levels in response to these changing temperatures and food availability during winter waking in selected urban areas of Leicestershire. This investigation should be used as a preliminary study as it is an initial exploration of issues relating to the activity of hedgehogs over the winter period in Leicestershire and has highlighted key features to be addressed in the future under a more detailed study.

The research and results provided in this study is needed for successful future management of the European hedgehog in county of Leicestershire by identifying the areas of conservation concern and possible mitigation measures necessary to ensure the viability of hedgehog populations in this area.

Hedgehogs are an important indicator species, which are often used to monitor environmental changes and provide warning signals for impending ecological shifts (Siddig *et al.,* 2016). The rapid decline of hedgehogs has wider implications for the state of the UK's ecosystems because they are a generalist species, which is an organism that can survive under a wide variety of conditions, which therefore raises concerns about the overall quality of the environment for many other species of wildlife (Vaughan, 2013; Rautio *et al.,* 2015). It is therefore considered important to conserve all species within an ecosystem in order to conserve that ecosystem (Hof, 2009). With an increasing number of wildlife species residing in urban areas it is crucial to better understand the ecology and movements of urban mammals such as the hedgehog to minimise future human-wildlife conflicts (Tysnes, 2016).

This study is intended to provide the much-needed data and information on hedgehogs in urban environments in order to determine their future conservation management in the county of Leicestershire. The data collected for this research will be part of an on-going study within the University of Leicester.

6. Acknowledgements

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8. <u>Appendix</u>

Figure 18. Placing pitfall traps to capture ground beetles

Figure 19. Placing bait, ink and paper for footprint tracking tunnels

Figure 20. Hedgehog footprints

Figure 21. Processing and weighing ground beetles in the lab

Figure 22. Constructing humane slug traps

Figure 23. Placement of footprint tracking tunnel 11 at Inglewood, Oadby Student Village