Assessing population abundance and distribution of terrestial small mammals throughout Lagan Valley Regional Park, Northern Ireland.

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Abstract: As a fundemental element of terrestial ecosystems, the study of small mammal abundance and distribution is crucial for focusing necessary conservation management strategies. Areas of Outstanding Natural Beauty, such as Lagan Valley Regional Park, provide important habitats needed to support and encourage a healthy population of small mammals. This study examines current populations of small mammals observed throughout the park, as well as exploring the external environmental factors which could potentially influence species detection. In total, 63 mammal footprint tunnels were placed along the park's towpath, from which 10 different mammal species were identified from their footprints. Of the species detected, mice were the most prevalent, forming over 58% of the total number of detections. Species of particular conservation significance, such as hedgehog, otter and irish stoat, were also detected at points within the park. Overall, the results of this study confirms and highlights the signficance of the park for small mammal populations, and the need for continued conservation efforts to protect and ensure the success of these populations for future generations.

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1. INTRODUCTION

1.1 SMALL MAMMAL DIVERSITY WITHIN NORTHERN IRELAND

Whilst small mammal populations form a fundamental element of terrestrial ecosystems, assessments into their distribution across the UK is extremely inadequate. Often, limited surveying efforts are focused primarily on listed and protected species such as the hazel dormouse (*Muscardinus avellanrius*). As a result, this narrowed approach results in other small mammal species being overlooked; potentially leading to detrimental impacts (Sibbald, Carter & Poulton, 2006). Since the start of the 21st century, the population size of several small mammal species have declined at a concerning rate; water vole and hedgehog populations have decreased by approximately 66% since 2002 (Mathews *et al*., 2018). These alarming rates of decline are frequently attributed to factors such as climate change, increases in road traffic volumes, habitat loss through development and increasing pesticide usage.

Despite being part of a small and isolated island, Northern Ireland has a great range of geographic diversity which supports a large breadth of habitats. As a result, the country hosts a wide variety of biodiversity (Cooper, McCann and Rogers, 2009,) including species such as pine martens and red squirrels, which are threatened elsewhere within the mainland UK (O'Mahony, O'Reilly and Turner, 2012). Due to Northern Ireland's large agricultural sector, a significant proportion of the land area forms important ecological habitats. Unlike the rest of the UK, Northern Ireland's agricultural land is largely grassland, as opposed to arable land (Feehan, Gillmor and Culleton, 2005). Additional habitats highlighted for their ecological significance include large quantities of inland water bodies (such as loughs, rivers and streams) as well as bogs, moors and fens (Henderson *et al*., 2010). However, despite this, there is concern surrounding the current state of the country's loss in biodiversity (Benton, Vickery and Wilson, 2003; Yates, Payo Payo and Schoeman, 2013). Northern Ireland has witnessed a prolonged period of biodiversity declination, which is often attributed to the loss in coverage of woodland throughout the country (Hall, 1998; Fuller, Gaston & Quine 2007; Newbold *et al*., 2015). Only 0.04% of land area is covered by ancient woodland, whereas comparatively the rest of the UK averages at 2% ancient woodland coverage (UK NEA, 2011). This loss of species can be quantified by the Biodiversity Intactness Index (BII), which assesses the loss of nature attributed to anthropogenic activities which can be traced back to early human settlements (Newbold *et al*., 2016). It is theorised that countries with a calculated BII value that fall below 90% cannot reliably support societal needs. The BII for

Northern Ireland was calculated at 80%; ranking lower than any other UK Country. Additionally, in excess of 1400 species found in Northern Ireland have recently been assessed using modern Red List criteria. This assessment has highlighted that presently, 295 species (approximately 20% of all species assessed) are at severe risk of extinction throughout the entire island. It is worrying statistics such as these that illustrate the importance and requirement of conservation strategies within Northern Ireland. However, despite this evidence, the monitoring of small mammal populations is still extremely restricted. Whilst data for bats and otters is regularly collected, surveys for other species (such as hedgehogs, for example,) are rarely undertaken (Battersby & Tracking Mammals Partnership, 2005).

1.2 LEGISLATION SURROUNDING SMALL MAMMALS

As with most European countries, Northern Ireland has strict wildlife laws that aim to protect valuable habitats and species. The Wildlife (Northern Ireland) Order 1985 (the order) and the subsequent amendment, The Wildlife (Amendment) (Northern Ireland) Order 1995, strictly prohibits the internal killing, taking, or injuring of certain wild animals. The Conservation Regulations (2007) additionally states that it is an offence to purposefully capture, injure or kill an animal that is protected by Schedule II of the European protected species regulations (which particularly refers to bat species and otters within Northern Ireland.) Likewise, Schedule 5 lists a number of small mammals (such as badger, pine marten and red squirrel) that are afforded protection at all times. However, mammals listed in schedule 9 (including fox, hare, hedgehog, mink grey squirrel and Irish stoat,) are subjected to article 15, which affords less protections and simply prohibits the sale of these animals.

1.3 LAGAN VALLEY REGIONAL PARK

In 1965, the wider Lagan Valley region was awarded the designation of an Area of Outstanding Natural Beauty (AONB) under the Amenity Lands Act (NI) 1965. As a result, the park was subsequently formed to conserve the high quality of the surrounding landscapes whilst simultaneously enhancing opportunities for recreational usage. Hence, in 1967, Lagan Valley Regional Park (LVRP) was established as Northern Ireland's first and only regional park, as well as one of three semi-urban regional park designations within the UK at that time. Spanning across a mosaic of landscapes and important habitats including rolling hills, managed parklands and farmlands, the regional park has an impressive number of open spaces, natural heritage sites, cycling trails and footpaths. At the centre of the Lagan Valley is the River Lagan and its subsequent canal systems, which form a significant wildlife corridor and the main point of access for the large, surrounding human populations centres of Belfast and Lisburn. Whilst in recent years the park has continued to develop, the original aims are still at the heart of the LVRP management; focusing heavily on the protection of the area's rich biodiversity and natural heritage. In 2006, the park became part of the Heritage Lottery Funded Landscape Partnership Scheme which facilitated the development of a significant number of projects throughout the park; including a number of outreach projects to improve the relationship between the park and its surrounding communities. As a result, LVRP welcomes a high frequency of visitors to the park every day. In 2013, nearly 1.4 million visitors were recorded along the towpath alone. According to interviews completed by visitors, tourists are particularly attracted to the park for its ability to provide fresh air, relaxation, a high quality of wellbeing, attractive areas for walking and an excellent opportunity to explore the local natural heritage (Lagan Valley Regional Park, 2017). Presently, the management team at LVRP are particularly focused in understanding, preserving and enhancing the biodiversity of the park (Lagan Valley Regional Park, 2013). LVRP provides a safe place for nature to prosper as well as education opportunities for the public, including conservation workshops and educational lectures hosted by the ranger team and conservation volunteers (Lagan Valley Regional Park 2018). Owned by the Department of Culture, Arts and Leisure, the Lagan Towpath (as depicted in figure 1) offers an opportunity to enjoy the tranquillity of the countryside between the heavily urbanised areas of Belfast and Lisburn. Areas of particular noteworthy value for biodiversity include Lagan Meadows, Belvoir Park Forest, Clement Wilson Park, Minnowburn, Sir Thomas and Lady Dixon Park, McIlroy Park, Moore's Bridge and Union Locks.

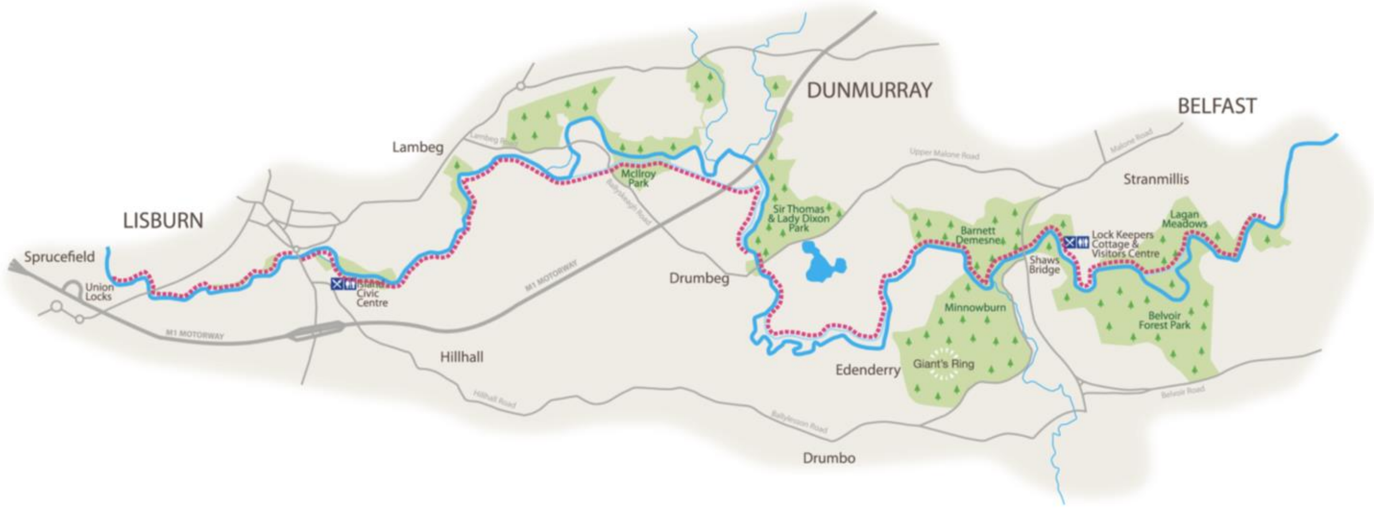


Fig. 1: Map of Lagan Valley Regional Park (LVRP, 2018) displaying the route as covered by the Lagan Towpath (red route).

1.4 PREVIOUS MAMMAL RECORDS AT LVRP

In order to direct the course of this study, previous mammal detection records were obtained from the Centre of Environmental Data and Recording (CEDaR). From 23597 records representing 3391 species (including mammal, bird, invertebrate and plant species), the most relevant and recent entries of small mammals are presented in table 1.

Taxon Common Name	Taxon Latin Name	Most Recent Event Record	Event Location
American Mink	*Mustela vison*	April 2011	Shaw's Bridge
Badger	*Meles meles*	June 2005	Belvoir Park Forest
Brown Rat	*Rattus norvegicus*	January 2014	Belvoir Park Forest
Eastern Grey Squirrel	*Sciurus carolinensis*	January 2018	Lambeg

Eurasian Red Squirrel	*Sciurus vulgaris*	May 2014	Belvoir Park Forest
European Rabbit	*Oryctolagus cuniculus*	July 2018	McIlroy Park
European Otter	*Lutra lutra*	July 2018	Lagan Towpath
Red Fox	*Vulpes vulpes*	July 2016	Belvoir Park Forest
West European Hedgehog	*Erinaceus europaeus*	October 2016	Lisburn
Irish Stoat	*Mustela erminea subsp. hibernicus*	June 2014	Lagan Valley Regional Park, Main Site
Muntjac	*Muntiacus reevesi*	December 2015	Purdy's Burn, River Lagan
Pine Marten	*Martes martes*	December 2018	Sir Thomas and Lady Dixon Park
Pygmy Shrew	*Sorex minutus*	August 1998	Minnowburn Beeches
Wood Mouse	*Apodemus sylvaticus*	March 2015	Sir Thomas and Lady Dixon Park

Table 1: The most recent records obtained from Centre for Environmental Data and Recording (CEDaR), illustrating the vast diversity of species that have been observed and recorded throughout LVRP over the past years.

Whilst the reliability of the sources providing this data can be questioned (as species may be easily misidentified and incorrectly recorded), what becomes clear from observing these records is the apparent lack of up to date, species specific data. Records of species that can often be observed on a regular basis, such as wood mice, are outdated.

1.5 FOOTPRINT TUNNELS AS AN EFFECTIVE INDIRECT SURVEYING TECHNIQUE

In order to implement effective wildlife management and conservation strategies, it is important to understand the population diversity and have estimates of size. Unfortunately, due to their elusive nature, small mammals are particularly challenging to directly observe. Whilst historically, live trapping was a preferred method of surveying, it has since been criticised due to the complexity of its methodology as well as the potential to harm any individuals that are captured (Rosenberg & Anthony, 1993; Getz *et al*., 2004). Subsequently, indirect surveying techniques have been designed to remove all risk to the target species whilst surveying. These methods fundamentally observe key field signs of a target species as a means to determine species presence or absence from a given survey area. Indirect techniques are sometimes preferred over more direct observations as they are easily applicable, cause limited ecological disturbance and can be extremely cost efficient.

The use of footprint tunnels to survey small mammal populations has recently grown in popularity, especially amongst citizen scientists, as it is an extremely simple yet fairly effective technique (Drennan, Beier and Dodd, 1998; McDonald *et al.*, 1997; Glennon, Porter & Demers, 2002, Hasler *et al*., 2004). Limited training is required, and the footprints tunnels and relevant equipment are readily available and can even be handmade. The results can be collected in the field and then analysed at a later date, allowing for accurate footprint identification and verification when needed. Traditionally, footprint tunnels are regularly used to detect small mammal species such as the hazel dormouse and hedgehogs (Williams, Stafford and Goodenough, 2015; Mills, Godley and Hodgson, 2016); however more recently, there has been research towards utilising similar techniques to identify invertebrate, reptile and amphibian species (Palma and Gurgel-Goncalves, 2007; Watts *et al*., 2010; 2013; Jarvie & Monks, 2014). When surveying for hedgehogs, results collected from 10 footprint tunnels placed within a $1km^2$ area, over 5 consecutive nights area, are believed to reveal species presence or absence to a 95% confidence (Johnson and Thomas, 2015)

1.6 PROJECT OUTLINE

Although park rangers and management staff at LVRP can roughly estimate which species can be found within the park, there is a need for cohesive, evidence-based material, strictly detailing abundance and distribution, in order to effectively support conservation measures; hence the importance of this study.

The overarching **aim** of this project was to assess terrestrial small mammal population occurrence and distribution throughout Lagan Valley Regional Park. In order to do so, the specific **objectives** were to deploy footprint tunnels at multiple sites along the length of the River Lagan towpath throughout Lagan Valley Regional Park, recording species presence/absence on five consecutive trap nights. The **hypotheses** under test were:

1. **Species occurrence will vary between habitats with lowest occurrence likely in grassland and highest in woodland**
    a. *Based on the theory that small mammals would prefer areas where shelter and protection from predators was provided by the high density of vegetation found in woodland areas (Dickman and Doncaster, 1987) .*
2. **Species detectability will be related to environmental conditions during the survey i.e. occurrence will vary with illumination of the moon, precentage of cloud cover, and levels of precipitation.**
    a. *As most small mammals are nocturnal, their activity can be influenced by the visibility provided by the moon and cloud cover. Bright moonlight is believed to greatly increase the risk of predation for prey species (Prugh and Golden, 2013)*
    b. *High levels of precipitations are likely to negatively impact species detection rates, as most small mammal species would be expected to be sheltering from the rain.*

3. **Species occurrence will vary with distance of the footprint tunnel from the towpath**
    a. *Due to their timid nature, it is probable that small mammal species are unlikely to be commonly observed in areas of high human disturbance.*

Therefore tunnels positioned closer to the towpath are likely to yield a low number of detections than those placed further away.

The consequences of this project are hoped to assist rangers at Lagan Valley Regional Park identify the present species apparent within the park, as well as helping to concentrate recommended conservation strategies for future implementation.

2 METHODOLOGY

2.1 SITE SELECTION

Spanning across 4,200 acres of countryside, Lagan Valley Regional Park sustains a rich biodiversity of species supported by a network of varying habitats. As seen in figure 2, the park is situated between Country Antrim and Country Down; notably between the two population hotspots of Belfast and Lisburn. The park is easily accessible at all points via the designated towpath and local connecting road networks.

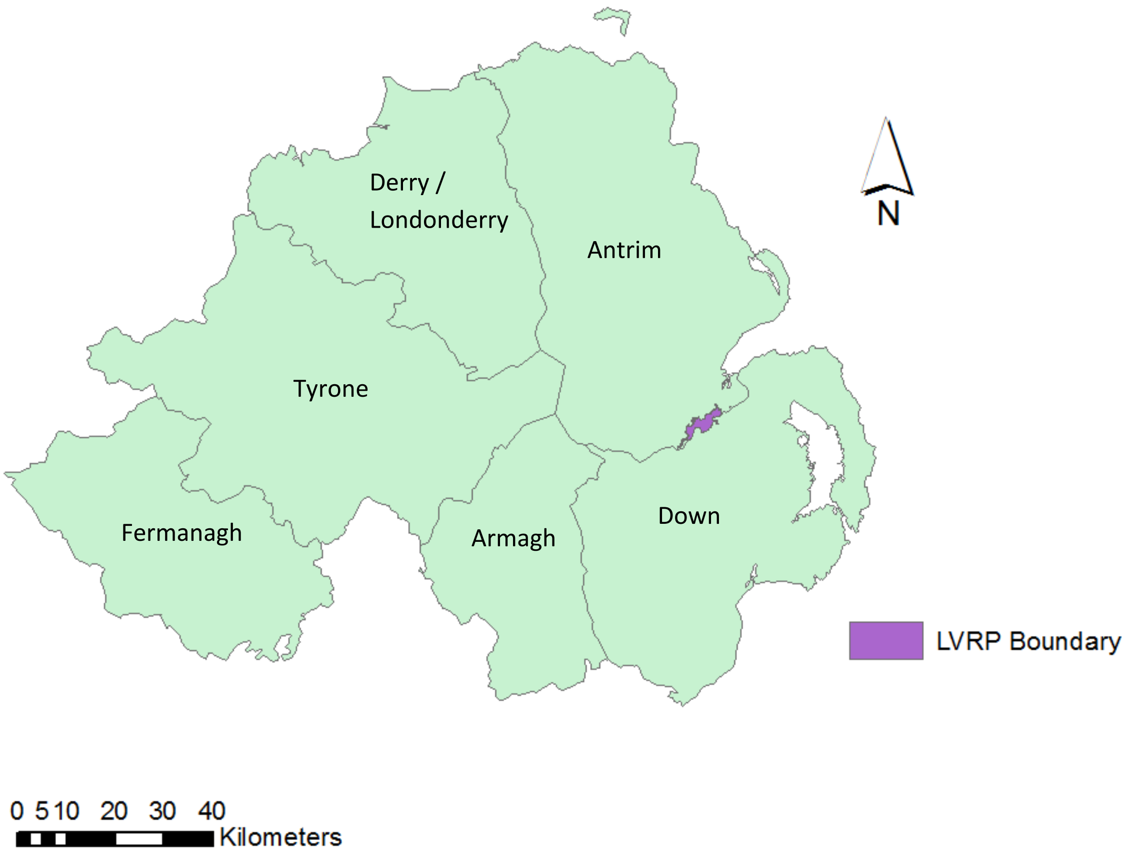


Fig. 2: A map depicting the location of the Lagan Valley Regional Park in relation to the counties within Northern Ireland (ArcGIS 10.2, ESRI, California, USA).

The towpath itself predominately follows the course of the River Lagan which stretches across 17km from Stranmillis, Belfast, to Union Locks, Lisburn. In order to ensure frequent site visitations, the core of the project was concentrated along the towpath. A Mac Allister 9999m measuring wheel was used to measure the distance at regular intervals of approximately 250m along the path, where appropriate. This form of systematic sampling was selected in order to produce a realistic overview of small mammal populations throughout the park, whilst attempting to eliminate the quantity of repeat counts (De Bondi *et al*., 2010). However, occasionally it was not possible to place the tunnels at strict intervals, as the towpath was intercepted by roads, hence the tunnels would be placed at the nearest opportunity. Once the tunnels were positioned, a GPS coordinate was recorded using the My GPS Location app (Digrasoft UG, 2019). In total, there were 63 individual tunnel sites positioned along the towpath. Figure 3 shows the positioning of each of the tunnels along the Lagan Valley towpath.

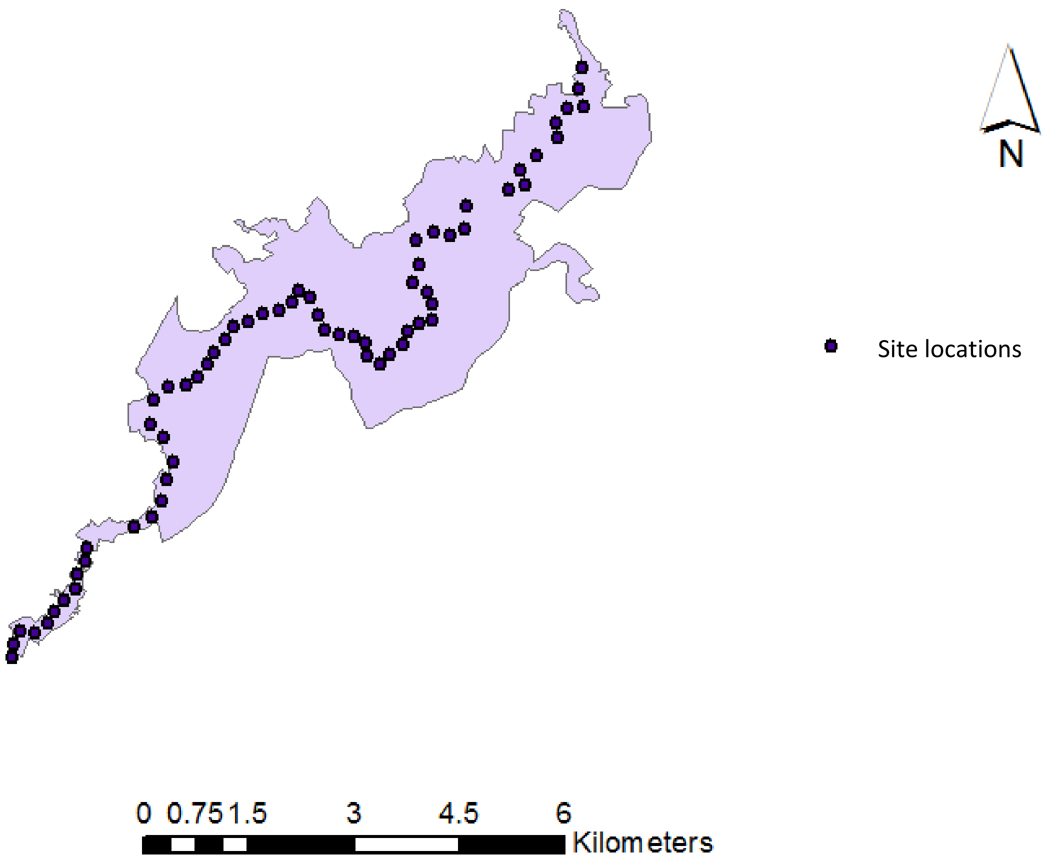


Fig. 3: Outline of Lagan Valley Regional Park detailing the individual positioning of each tunnel site.

2.2 APPLICATION OF FOOTPRINT TUNNELS

Once the site locations were designated, tracking tunnels were positioned lengthways using linear features (fence lines, hedges, river etc.), hidden with scrub if necessary (to minimise interference by public disturbance), and secured with tent pegs. The tracking tunnels themselves are fairly simplistic in design, as illustrated in figure 4. Standing at 13cm in height, this form of footprint tunnel was originally designed to survey for hedgehogs and was selected for this survey in order to best suit a greater range of small mammals. Smaller variations of the tunnels are available however, these designs are better suited to surveying for smaller rodents such as dormice, and would hence restrict the project.

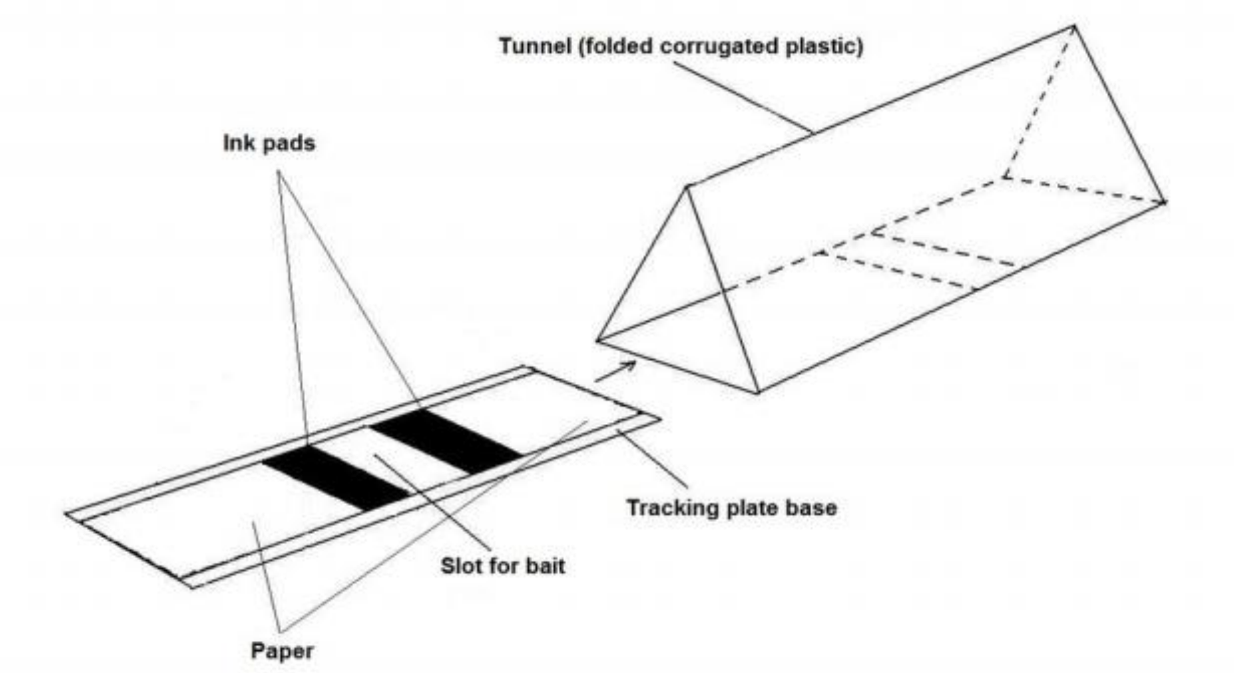


Fig. 4: Generalised design of the tracking tunnels and sliding plate used to capture the footprints of small mammals throughout this study (Yarnell *et al*., 2014).

The tunnel is typically formed from lightweight, corrugated plastic (such as Correx), which is folded to create a triangular tunnel containing a detachable, sliding tracking plate. This tracking plate is equipped with two sheets of A4 paper, four strips of masking tape coated in charcoal ink (a mixture of charcoal powder and vegetable oil), and a small pile of bait (dried cat food). As the target species walks through the tunnel towards the bait, their feet are coated in the charcoal ink. Once they egress, their footprints are captured onto the paper for later analysis. The tunnels are checked every day, at approximately the same time, and when necessary, the paper, ink and bait are replenished. Table 2 outlines the daily logistics of undertaking this footprint survey.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Prepare equipment and set tunnel	Check results and reset tunnel if needed	Check results and reset tunnel if needed	Check results and reset tunnel if needed	Check results and reset tunnel if needed	Final check and collect tunnels
Night 1	Night 2	Night 3	Night 4	Night 5	

Table 2: Logistical timeline of footprint tunnel survey and actions to be complete on each survey day.

Due to the length of the towpath, it was impractical to simultaneously survey the entire park. As a result, the data collection was spread over five weeks; with 10-15 tunnels being surveyed at any one time, as summarised by table 3. The division of sites was often determined due to their accessibility, as the footprint tunnels were difficult to transport, distribute, and required daily repeated maintenance. The survey was scheduled for the months of May and June to coincide with peak mammal activity levels.

Tunnel No.	**Approximate location**	**Dates surveyed**
1-15	Stranmillis to Gilchrist	13th-18th May
16--29	Gilchrist to Drumbridge	19th - 24th May
30-39	Drumbridge to McIlroy Park	25th - 30th May
40-52	McIlroy Park to Civic Centre	31st May - 6th June

53-63	Civic Centre to Union Locks	7th - 12th June

Table 3: Breakdown of the survey schedule; including the survey date and the approximate location of the tunnels surveyed.

On the sixth day of each respected surveying effort, all of the tunnels were collected and removed from the site. In an attempt to prevent the artificial transference of scents that may affect the results, (as prey species may be discouraged to enter if the tunnel has a strong predator scent (Brinkerhoff, Haddad and Orrock, 2005)), the tunnels were washed off using non-fragranced soap and warm water. Additionally, any tunnels that were destroyed, damaged or purposefully vandalised were removed and replaced as and when was deemed necessary. On these occasions, the data was recorded as completely negative for any footprints.

2.3 DISTINGUISHING SPECIES FROM THEIR FOOTPRINTS

One of the complications of studying small mammal footprints arises from the similarities between species. Many species produce similar footprints that can often be misinterpreted if not carefully examined. Individual results were measured and inspected for specific characteristics to ensure the correct species were identified and recorded. Examples of such distinct features include number of toes, shape of footprint palm and toe pad, and the overall symmetry of the footprint (as seen in figure 5).

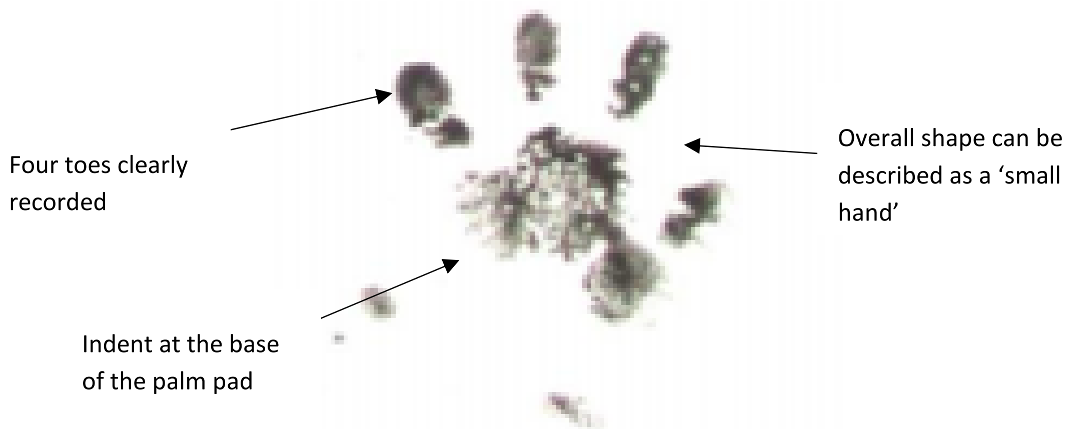


Fig. 5: Example of a hedgehog footprint collected using a mammal footprint tunnel, showing the distinct features which aid in identification.

2.4 STATISTICAL ANALYSIS

Following the completion of the data collection, the results were subjected to statistical analysis (as detailed in section 4). As the data contained a large proportion of negative results, variations in daily detections rates were analysed using a chi-sqaured test in order to determine the preverlance of each species within the park. Additionally, interspecies detection trends were also studied, using a spearman's rank correlation test, to identify any potential relationships between the small mammals. Furthermore, the overarching hypotheses were tested by developing a binary, logistic, generalised linear model. This model helped highlight environmental factors that had any significant impact on species detection. These factors were then finally anaylised against species richness at an overall site level using a Kruskal-Wallis test.

3 RESULTS

3.1 DIVERSITY OF DETECTIONS

Overall, a total of 244 positive detections were recorded throughout the duration of the survey. From these detections, a total of 10 different mammal species were identified. The footprint for each species identified have been described below (corresponding images can be seen in Appendix A-H).

3.1.1 CAT

Whilst highly variable in size depending on the breed, cat footprints are typically small and delicate. The forefoot and hindfoot are identical and can be identified by two indentations at the base of the palm pad. The four short toe pads are often clearly represented, and as cats walk with their claws retracted, the claws are not observed. Within footprint tunnels, evidence of a dragging tail is also often recorded.

3.1.2 DOG

Like cats, dog footprints are often highly variable in size depending on the breed of dog. The overall shape of the entire print can often be described as square and symmetrical. The triangular palm print is much larger than the toe pads, with one large indentation positioned in the middle of the base of the palm print. These prints, unlike cat prints, can usually be observed with additional claw marks at the top of the toe pads.

3.1.3 FOX

Fox prints are typified by a triangular palm pad which is often fairly similar in size to the toe pads. The palm and toe pads are separated by a large space, where hair is often visible within the ink. When identifying a fox print, the observer should be able to imagine a cross drawn through the centre of the print whereby the lines of the cross do not intercept the print at any point. The prints are long and narrow; typically measuring 50mm in length by 35mm in width (for adult foxes). Fox prints and tracks can occasionally be confused with that of a dog; however, fox prints are characteristically much smaller in overall size and the tracks are much straighter and more purposeful than the erratic tracks of a dog.

3.1.4 HEDGEHOG

Both the forefoot and the hindfoot of a hedgehog have five toes; however due to the natural gait of a hedgehog, the fifth digit ('thumb print') is rarely observed. The forefoot is notably wider than the hindfoot and is usually described as 'small hands'. The toe prints on the forefoot are widely spread out and elongated with claw marks. In comparison, the hindfoot is longer and the toes are forward facing, as well as sitting closer together.

3.1.5 MOUSE

The forefoot and the hindfoot of mice vary significantly. The forefoot is approximately 10mm in length with four clear toepads. In comparison, the hindfoot is much longer, approximately 20mm in length, with five clear toepads. Overall, mice prints are fairly delicate, however they can often be misidentified as vole. Unfortunately, it is not possible to distinguish between mouse species simply by analysising the footprints alone.

3.1.6 OTTER

Otter prints are rarely preserved unless within soft substrate (or in the case of this project, within footprint tunnels). The forefoot and hindfoot significantly differ from one another; in both size and shape. The forefoot is often rounder in overall shape (60mm width x 65mm length), whereas the hindfoot is more elongated and thinner (60mm width x up to 90mm length); this is also observed in the general shape of the palm pad. A key feature of otter prints is the clearly distinguishable webbing between the small, oval shaped toe pads. Additionally, there are often clear signs of tail dragging.

3.1.7 RAT

Like mice prints, the forefoot and the hindfoot of rats also differ greatly. The forefoot has four toes, of which, the first and fourth digit can splay if the substrate is particularly soft, potentially leading to misidentification. In comparison, the hindfoot is significantly longer than the forefoot (up to 45mm in length) and has five elongated toes. Whilst to unexperienced surveyors, rat footprints can be misidentified as water vole footprints, a key feature of the rat footprint is that the first and fifth toe on the hindfoot is at a gentle angle to the central three toes. Additionally, larger adult rats tend to leave deeper impressions and clearer footprints than other rodent species.

3.1.8 SHREW

Shrew footprints are particularly minute, typically measuring less than 10mm in length and width. Both the forefoot and the hindfoot have five toes, however, they are not always observed; this can often lead to confusion between shrew and juvenile mice footprints. Often, shrew footprints are also observed with fine, tail drags.

3.1.9 SQUIRREL

The forefoot and hindfoot of squirrels vary in size, shape and number of toes. The forefoot has four toes and measures 25mm in width x 35mm in length. There are two clear heel pads, and three palm pads, which can appear to form one large pad. Comparatively, the hindfoot is much longer, measuring 35mm in width x 45mm in length. There are five narrow, long toes on the hind foot, of which the middle three toes are of equal length. Occasionally, the four palm pads can be observed, however the heel pads are not seen. Like mice, it is impossible to distinguish between grey squirrel and red squirrel simply from footprints alone.

3.1.10 STOAT

Stoats produce very small, delicate footprints, measuring up to 20mm in width and 22m in length. The five toe pads often produce a sharp, star shape, however the fifth digit is not always preserved, which can lead to misidentification. The palm pad is often described as heart-shaped, with three noticeable indentations (two at the top and one at the base). It is this significant feature that makes to stoat print distinguishable from other members of the weasel family.

3.2 FREQUENCY OF DETECTIONS

As displayed in table 4, the most frequently detected species were mice; forming over 58% of the total number of positive results at 142 detections. In comparison, the second most common species appearance was that of dog, which formed just 13.5% of the total record at 33 detections. Whilst not strictly a small mammal, or a mammal of conservation importance, for the purpose of this study, dog detections (as well as cat and fox detections) shall be analysed and discussed, as their notable presence within the park may be observed to significantly impact the appearance of other noteworthy small mammals. Contrastingly, hedgehogs were only detected twice during one survey night. However, other species of conservation importance were notably detected, including one positive detection of otter, and four detections of stoat at three different sites.

	Night					
Species	**1**	**2**	**3**	**4**	**5**	**Grand Total**
Cat	2	1	1	1	1	6
Dog	5	7	6	5	10	33
Fox	1	0	2	2	1	6
Hedgehog	2	0	0	0	0	2
Mouse	21	25	28	32	36	142
Otter	0	1	0	0	0	1
Pygmy Shrew	1	5	5	8	4	23
Rat	2	6	2	6	7	23
Squirrel	1	0	1	1	1	4
Stoat	0	0	1	1	2	4
Grand Total	**35**	**45**	**46**	**56**	**62**	**244**

Table 4: Total number of positive detections collected throughout the survey, as well as the cumulative total of species detection each survey night.

3.3 LOCATION OF DETECTIONS

As demonstrated by table 5, the abundance and diversity of species detected varied between sites. Within the final set of sites (tunnel numbers 53-63 between Civic Centre and Union Locks), each tunnel produced at least one positive detection, with a total of 6 different species being detected. This was the most productive of all the site sets surveyed. In comparison, tunnel numbers 30-39 (situated between Drumbridge and McIlroy Park) only yielded 4 different species detections. Additionally, out of these sites surveyed, 4 tunnels did not record any footprints across all five nights. In total, throughout the 25 consecutive survey nights, only 15 sites yielded completely negative results for each night. In total, 1/3 of the sites produced positive results for each of the nights surveyed and over 76% of the sites surveyed yielded at least one positive detection.

Tunnel No.	Approximate Location	No. of Positive Detections	No. of Species Detected
1-15	Stranmillis - Gilchrist	41	7
16-29	Gilchrist - Drumbridge	44	6
30-39	Drumbridge - McIlroy Park	21	4
40-52	McIlroy Park - Civic Centre	26	6
53-63	Civic Centre - Union Locks	45	6

Table 5: Breakdown of site specific footprint productivity throughout the survey.

In addition to these figures, figure 6 also depicts the exact location of each of the positive species detections throughout the park, highlighting particular areas of significance for each species.

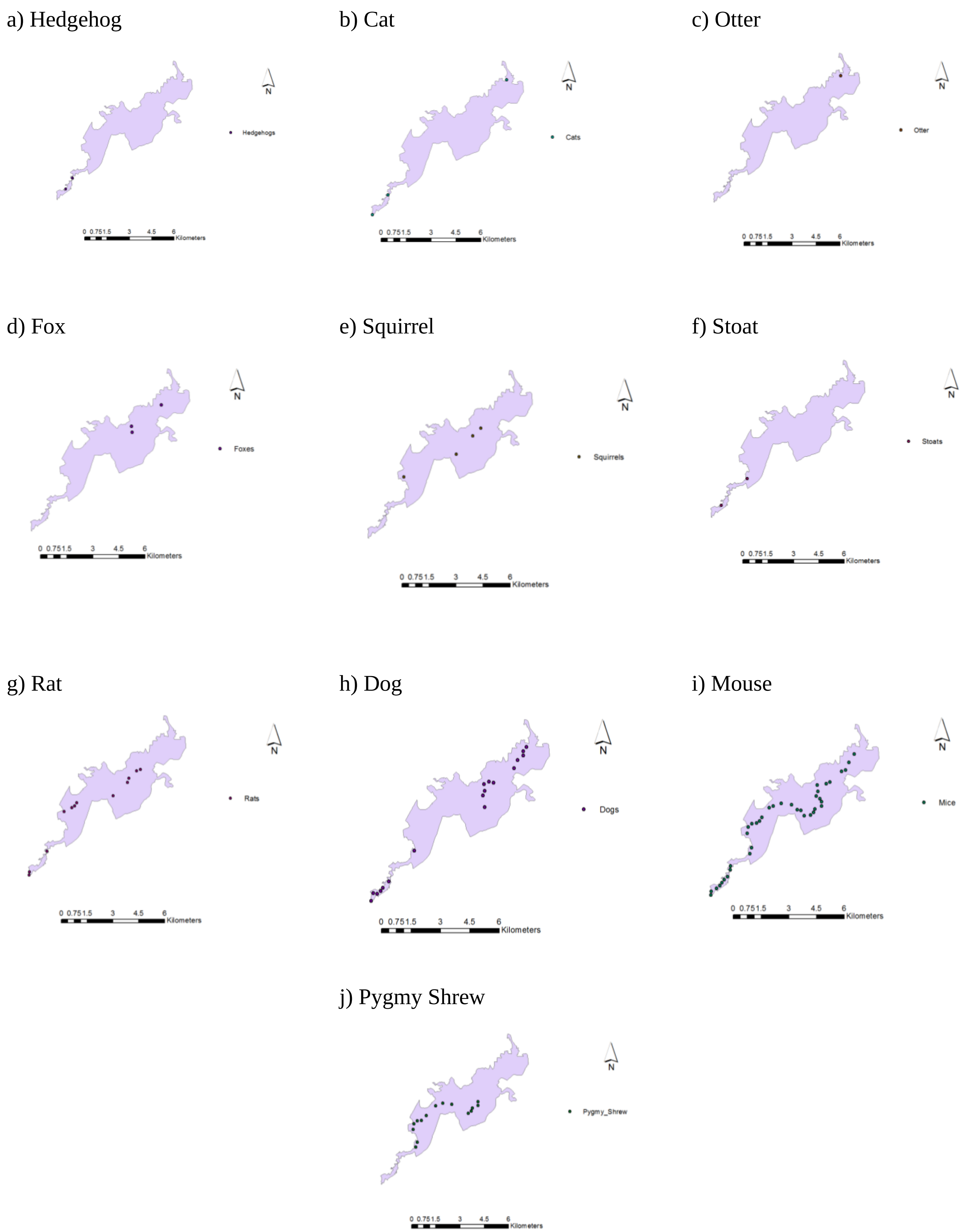


Fig. 6: Detection locations for each species (ordered by statistical significance - see section 4.1) observed through positive results collected from footprint tunnels throughout Lagan Valley Regional Park, Belfast.

3.2.1 HEDGEHOG

Hedgehogs were only detected at two sites along the entire of the towpath. Both sets of prints were found very close together (site 54 and site 58) on the same survey night (night 1) in the south-west of the park, towards the Lisburn area.

3.2.2 CAT

Cat footprints were constantly found at one site throughout the entire survey. Positive results were collected 4 out of 5 nights at site 2; situated near Belfast Boat Club as well as the Lisburn area. On each occurrence, cats were detected in close proximity to heavily populated, residential areas.

3.3.3 OTTER

An otter footprint was only recorded in one location throughout the entire survey. Detected on survey night 2, the print was found at site 4, which is located off of the main footpath, in a relatively quiet, undisturbed area towards the Belfast Boat Club.

3.3.4 FOX

Fox footprints were found relatively consistently within the north-eastern section of the park. Prints were particularly concentrated towards Shaw's Bridge, Barnett Demesne and Minnowburn with detections occuring on 6 separate occasions at 3 different sites.

3.3.5 SQUIRREL

Squirrel prints were infrequently detected throughout the entire survey. A relatively high frequency of squirrel footprints were detected towards the middle of the section, specifically towards Drumbeg, there was also a clear singular squirrel print found in the south-western area of the park, towards Lambeg.

3.3.6 STOAT

Stoat footprints were not detected until the later stages of the survey effort. Positive detections of stoat prints were restricted between Lambeg and Union Locks, towards the Lisburn area of the park. In total, there were 4 positive appearances of stoat prints found.

3.3.7 RAT

Detection rates of rat footprints increased fairly steadily throughout the survey. In total, rat footprints were identified on 23 occasions across each of the survey nights. Detections appeared to occur within population hotspots throughout the park; with more detections occurring towards the Lisburn area of the park than the Belfast area.

3.3.8 DOG

Dog detections were fairly consistent throughout the entire survey; however, there was an area between Drumbeg and Lambeg where there appears to be significantly less detections than elsewhere in the park. Overall, dog footprints were identified 33 times across each survey night.

3.3.9 MOUSE

As previously mentioned, mouse detections dominated the majority of the survey. Out of 63 sites surveyed, 39 sites produced positive mouse detections. Whilst detections appeared to be spread fairly evenly throughout the park, there were significantly less detections towards Stranmillis than any other area. Mouse prints did not start to appear until the sites in close proximity to Lagan Meadows. Comparitively, mouse prints were consistently detected towards the very end of the towpath at Union Locks.

3.3.10 PYGMY SHREW

Interestingly, pygmy shrew footprints also appeared to be concentrated within the mid-section of the park. These footprints were detected on 23 separate occasions between Drumbeg and Lambeg. However, elsewhere in the park, there was no other shrew footprints discovered.

4 DISCUSSION

4.1 TESTING THE SIGNIFICANCE OF DETECTION RATES

By analysing the number of observed detections against the number of expected results, using a chi-squared test, the statistical significance of detection rates across each of the survey nights can be observed. Table 6 displays the results of the performed chi-squared test, in ascending order of significance (descending order of '*p*'-value). The chi-squared test displays actual data (both positive and negative detections of each species at each site), and then calculates what would have been observed if detections were uniform across the nights, and whether the observed data differs from the expected data. As the data consists largely of negative results, more sophisticated statistical analysis cannot be completed, however the chi squared test does show that there is a significant difference in detection rates across the nights thus implying that the detections are not occurring by chance. Hence, the results suggest that the species with the highest *p*-values, such as hedgehog, cat and otter, were detected moreso by chance. These species are uncommon throughout the park; therefore, the sample size of their detection is extremely small in comparison with the negative results. Hence, there is no statistical robustness within their data. Conversely, species with the lowest *p*-values, such as dog, mouse and shrew, reveals that there was a significant difference between the detection rates across the nights.

Species	χ^2	df	*p*
Hedgehog	*0*	4	1
Cat	*0.299*	4	0.99
Otter	*1.01*	4	0.908
Fox	*2.26*	4	0.688
Squirrel	*3.2*	4	0.524
Stoat	*3.55*	4	0.471
Rat	*8.31*	4	0.081
Dog	*9.64*	4	**0.047**
Mouse	*12.7*	4	**0.013**
Pygmy Shrew	*17.8*	4	**0.001**

Table 6: Chi-squared test of association between species occurrence (number of presences vs absences) across five trap nights (2x5 contingency table). *P*-values highlighted in bold

represent the most statistically significant difference in detection rates across the five nights.

4.2 VARIATION IN DETECTION RATES ACROSS EACH SURVEY NIGHT

As previously observed, mouse footprints dominated the overall number of positive detections collected throughout the survey. However, by analysing the cumulative species occurrence across each relative survey night, it is possible to observe the proportional presence of each species, as shown in figure 7. Rarely detected species (in particular hedgehog, cat, and otter) display a very gradual, yet consistent, increase in cumulative detections across each survey night. By the fifth night, only approximately 10% of all sites surveyed recorded positive results for these species. Comparatively, more frequently detected species (such as fox, squirrel and stoat) present a similar trend in cumulative occurrence in the early stages of the survey. However, detection rates appear to spike around day 3 of the surveying effort. For example, overall squirrel detections double in frequency between the night 2 and night 3 from 5% to 10%. Consequently, on average approximately 17% of the sites surveyed recorded positive results for these species. More regularly detected species (such as rats, dogs and pygmy shrews) present a more rapid increase in cumulative detections. By just survey night 3, over 20% of all sites surveyed tested positive for these species. For dog and pygmy shrew, this percentage doubles to 40% by the fifth night, showing a rapid increase in detection rates towards the latter half of the survey. For each of these species, detection rates continue to increase until the end of the fifth survey night. This could suggest that the true number of individuals has not yet been reached, therefore with continued surveying efforts, more detections of these species could be expected. However, as previously mentioned, mouse footprints appeared to dominate the detections observed. By the first survey night, nearly 40% of all sites surveyed had already observed the presence of mice; equalling the highest number of detections by any other species throughout the survey. By the end of the fifth survey night, a total of 75% of sites are positive for mouse detections, however it does appear that detection rates begin to plataeu. This implies that the results collected are trending closer to the true number of individuals within the proximity of the towpath.

Interestingly, most species detections increase gradually throughout the entire survey. With the exception of dogs, whose detection significance is debatable due to the large quantity of dog walkers that frequent the area, and small rodent species, (i.e. rat, pygmy shrew and mouse) whereby detection rates demonstrates a rapid increase between each night, all other species are detected at a fairly consistent rate. This is likely caused by species population finding the tunnels and returning to them each night once they have become comfortable with their presence and aware of the regular source of food. Whereas the less frequently observed species, such as hedgehogs, otters and squirrels, are renowned for their ability to disperse across vast distances in a short space of time (Wolff, 1994; Bowman, Jaeger and Fahrig, 2002) which could account for their infrequent detections.

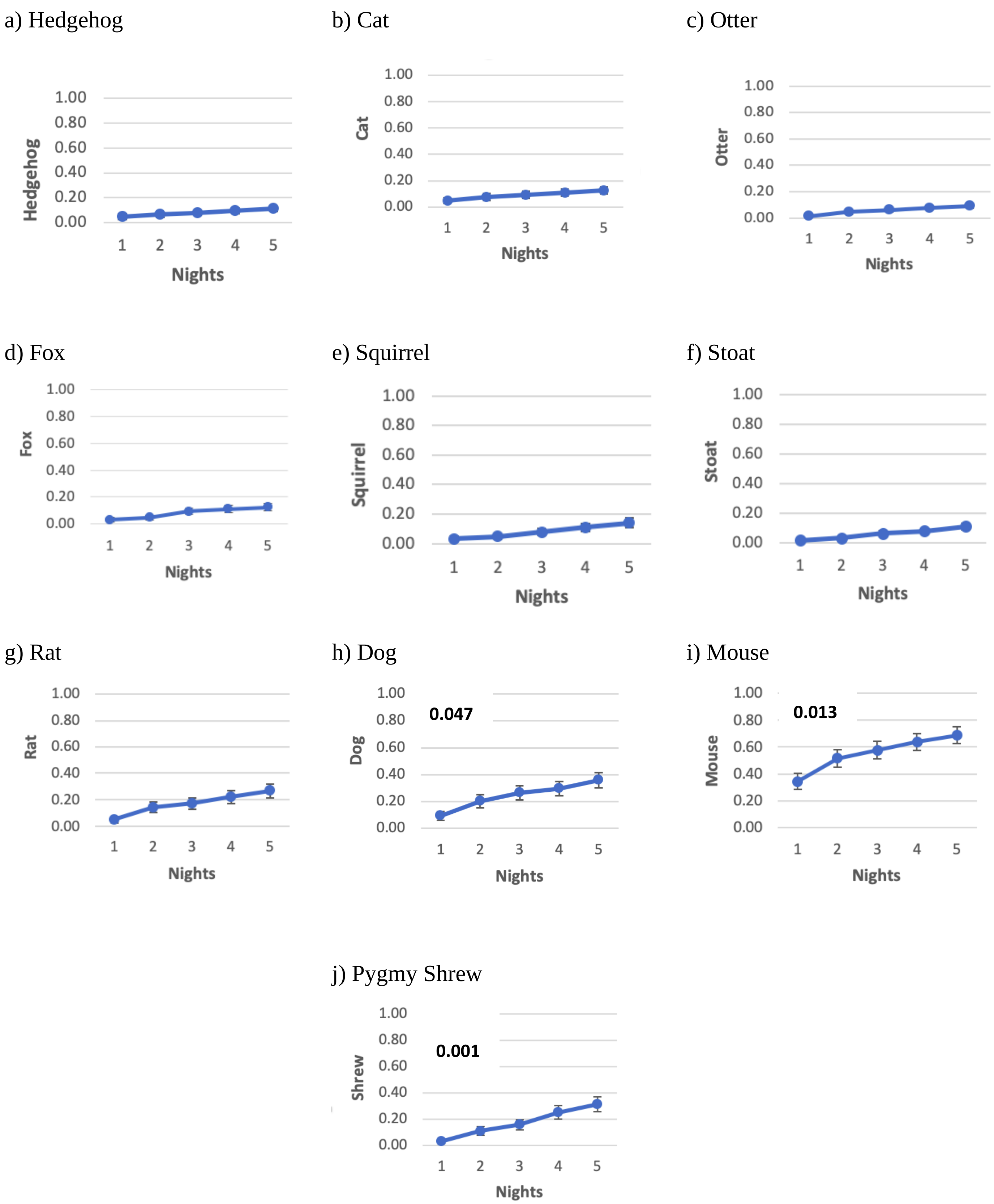


Fig. 7: Cumulative species occurrence (proportion of sites surveyed) ± SE across five survey nights using footprint tunnels for each species detected in Lagan Valley Regional Park, Belfast. For the purposes of comparison, the same scale was used to display proportional presence

across the entire survey. For dog, mouse and pygmy shrew, the relevant *p*-value from the chi-squared test is also displayed.

4.3 INTERSPECIES CORRELATION

A spearman's rank correlation analysis was also performed in order to determine any significant correlation between interspecies detection (table 7). The outcome of this analysis highlighted several significant relationships between species; both positively and negatively correlated. Interestingly, the correlation analysis highlighted a greater number of positive relationships compared to negative relationships. Understanding these interspecies relationships could be particularly beneficial when implimenting conservation strategies.

	Cat	Dog	Fox	Hedgehog	Mouse	Otter	Rat	Pygmy Shrew	Squirrel	Stoat
Cat	1.000	-0.005	-0.050	-0.040	-0.171	-0.028	0.087	-0.124	-0.058	-0.040
Dog	X	1.000	**.370****	0.100	0.122	0.154	0.026	**-.265***	0.164	0.104
Fox	X	X	1.000	-0.040	0.066	-0.028	0.063	-0.124	0.247	-0.040
Hedgehog	X	X	X	1.000	0.191	-0.023	0.178	-0.100	-0.047	**.492****
Mouse	X	X	X	X	1.000	-0.141	**.372****	**.399****	**.290***	0.151
Otter	X	X	X	X	X	1.000	-0.061	-0.070	-0.033	-0.023
Rat	X	X	X	X	X	X	1.000	-0.021	**.356****	-0.087
Shrew	X	X	X	X	X	X	X	1.000	-0.005	0.091
Squirrel	X	X	X	X	X	X	X	X	1.000	-0.047
Stoat	X	X	X	X	X	X	X	X	X	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

X = repeated results

Table 7: Results of Spearman's Rank correlation between interspecies detection rates

4.3.1 FOX AND DOG

LVRP is a particular popular location for dogwalkers. Consequently, dogs are often allowed to roam off of leads; enabling them to freely track scents located off of the towpath. As dogs are instinctively attracted to the scent of foxes, it is probable that the correlation between the detection of these two species is indicative of predator-prey stalking behaviour (Banks, Daly and Bytheway, 2016).

4.3.2 STOAT AND HEDGEHOG

Similar to the correlation between fox and dogs, there appears to be a significant correlation between stoat and hedgehog detections. Whilst stoats have been recorded harming or even predating on juvenile hedgehogs (King and Moody, 1982), it is more likely that this is correlation is unreliable and lacks statistical significance as positive detections for both species were extremely limited.

4.3.3 MOUSE AND RAT

The data collected suggests that these two species have relatively large populations throughout the park. As both species thrive in similar environments, it is likely that these population densities typically overlap; potentially resulting in a competition for resources. Likewise, rats will also predate on mice if needed (O'Boyle, 1974), therefore the correlation could also be described once again as predator-prey interaction.

4.3.4 MOUSE AND SHREW

Similar to the mice and rat correlation, shrews and mice are noted to populate similar habitats. However, unlike rats, shrews and mice have been recorded to cohabit peacefully, despite limited competition between these two species (Adler, 1985; Eckrich, Flaherty and Ben-David, 2018). Therefore it can be suggested that habitats between Drumbridge and Lambeg are particularly important to the two species; providing ideal habitat.

4.3.5 SQUIRREL AND MICE AND RATS

Whilst there appears to be significant correlations recorded between squirrel detections and mice and rat detections, this could be explained by the large activity range of squirrels. It is more likely that simultaneous detections between squirrels and other species is by chance, however low detection rates of squirrels throughout the survey has generated an unreliable correlation; similar to stoat and hedgehogs.

4.3.6 DOGS AND SHREW

Interestingly, the relationship between dogs and shrew was the only significant negative correlation detected throughout the survey. As in all shrews, pygmy shrews have a well-developed sense of smell. It is likely that shrews actively avoid areas of high dog walking activity to avoid mortality. Experiments by Apfelbach *et al.*, (2005) support this as it was found that prey species typically avoided predator-derived odours. Specific adaptations were made in behaviour such as foraging and feeding activity whenever sources of predator odor were released.

4.4 SPECIES-SPECIFIC HYPOTHESES TESTING

In order to test the three original hypotheses, a binary, logistic, generalised linear model was created. This highlights the presence of any significant trends between species detection (where the reference category = 0 or negative detections) and environmental factors such as dominating habitat type, nightly conditions (such as moon illumination, precipitation and cloud cover) and the positioning of the tunnel in relation to the Lagan Towpath. The results of this model are summarised in the table 8 below.

SPECIES / Influencing factor	**Wald Chi-Square**	**β ± se**	**df**	**Sig.**
CAT				
Night	0.004	Factorial	4	1.000
Habitat primary	0.002	Factorial	2	0.999
Habitat secondary	0.001	Factorial	2	0.999
Moon illumination	0.004	-34.35 ± 575.86	1	0.952

Precipitation	0.004	20.89 ± 348.99	1	0.952
Cloud cover	0.003	-11.67 ± 200.48	1	0.954
Towpath distance	0.268	-0.24 ± 0.45	1	0.605
Moon * Cloud	0.004	0.48 ± 8.08	1	0.952
DOG				
Night	2.843	Factorial	4	0.584
Habitat primary	0.836	Factorial	2	0.658
Habitat secondary	0.277	Factorial	2	0.870
Moon illumination	0.598	-0.03 ± 0.04	1	0.440
Precipitation	2.733	0.08 ± 0.05	1	**0.098**
Cloud cover	1.151	-0.04 ± 0.04	1	0.283
Towpath distance	1.191	-0.16 ± 0.15	1	0.275
Moon * Cloud	1.728	<0.001 ± 0.001	1	0.189
FOX				
Night	0.118	Factorial	4	0.998
Habitat primary	1.213	Factorial	2	0.545

Habitat secondary	2.280	Factorial	2	0.320
Moon illumination	0.054	-0.096 ± 0.41	1	0.817
Precipitation	0.361	-0.35 ± 0.59	1	0.548
Cloud cover	0.090	-0.137 ± 0.45	1	0.764
Towpath distance	1.337	-0.56 ± 0.48	1	0.248
Moon * Cloud	0.251	0.003 ± 0.01	1	0.616
HEDGEHOG				
Night	0.000	Factorial	4	1.000
Habitat primary	0.000	Factorial	2	1.000
Habitat secondary	0.000	Factorial	2	1.000
Moon illumination	0.000	3.87 ± 938.6	1	0.997
Precipitation	0.000	-8.68 ± 2398.61	1	0.997
Cloud cover	0.000	6.27 ± 786.41	1	0.994
Towpath distance	0.000	2.51 ± 3268.42	1	0.999
Moon * Cloud	0.000	-0.06 ± 12.18	1	0.995

MOUSE				
Night	13.296	Factorial	4	**0.010**
Habitat primary	1.557	Factorial	2	0.459
Habitat secondary	7.648	Factorial	2	**0.022**
Moon illumination	0.116	0.006 ± 0.019	1	0.733
Precipitation	7.809	-0.096 ± 0.034	1	**0.005**
Cloud cover	0.135	-0.007 ± 0.020	1	0.714
Towpath distance	4.244	0.191 ± 0.093	1	0.039
Moon * Cloud	0.097	<0.001 ± 0.003	1	0.756
OTTER				
Night	0.000	Factorial	4	1.000
Habitat primary	0.000	Factorial	2	1.000
Habitat secondary	0.000	Factorial	2	1.000
Moon illumination	0.000	0.006 ± 801.15	1	1.000
Precipitation	0.000	-0.1 ± 972.67	1	1.000
Cloud cover	0.000	-0.01 ± 718.08	1	1.000

Towpath distance	0.040	0.19 ± 0.79	1	0.841
Moon * Cloud	0.000	>-0.001 ± 9.98	1	1.000
PYGMY SHREW				
Night	8.320	Factorial	4	0.081
Habitat primary	0.190	Factorial	2	0.909
Habitat secondary	0.566	Factorial	2	0.753
Moon illumination	0.312	0.01 ± 0.04	1	0.576
Precipitation	1.956	-0.24 ± 0.09	1	0.162
Cloud cover	0.290	0.3 ± 0.04	1	0.590
Towpath distance	0.522	0.16 ± 0.19	1	0.470
Moon * Cloud	0.922	<0.001 ± 0.0006	1	0.337
RAT				
Night	5.661	Factorial	4	0.226
Habitat primary	8.604	Factorial	2	**0.014**
Habitat secondary	2.550	Factorial	2	0.279
Moon illumination	0.779	0.02 ± 0.05	1	0.377

Precipitation	1.783	-0.13 ± 0.1	1	0.182
Cloud cover	1.339	-0.02 ± 0.1	1	0.247
Towpath distance	0.156	0.14 ± 0.2	1	0.693
Moon * Cloud	0.994	>-0.001 ± 0.0007	1	0.319
SQUIRREL				
Night	1.838	Factorial	4	0.766
Habitat primary	1.666	Factorial	2	0.435
Habitat secondary	1.354	Factorial	2	0.508
Moon illumination	0.770	-0.04 ± 0.23	1	0.380
Precipitation	1.110	-0.13 ± 0.5	1	0.292
Cloud cover	1.440	-0.06 ± 0.41	1	0.230
Towpath distance	0.806	0.08 ± 0.42	1	0.369
Moon * Cloud	0.897	<0.001 ± 0.003	1	0.344
STOAT				
Night	0.000	Factorial	4	1.000
Habitat primary	0.000	Factorial	2	1.000

Habitat secondary	0.000	Factorial	2	1.000
Moon illumination	0.000	-0.2 ± 2192.37	1	0.999
Precipitation	0.000	0.52 ± 1239.97	1	0.996
Cloud cover	0.000	-0.5 ± 1150.65	1	0.999
Towpath distance	0.000	0.38 ± 1316.16	1	0.991
Moon * Cloud	0.000	0.003 ± 28	1	0.999

Table 8: Results of binary, logistic, generalised linear model, examining the significance between species detection and external factors, with the most significant results being highlighted in bold.

* = interaction factor between moon illumination and cloud cover

As displayed, there were no significant trends detected in cat, dog, fox, hedgehog, otter, pygmy shrew, squirrel or stoat. Therefore, it can be concluded that the testing hypotheses do not have any significant influence on the detectable presence of these species. However, the results for mice and rat appear to show that several factors do appear to have a significant impact on their detection. There was a significant difference in detection rates across survey nights, as supported by the previous chi-squared tests, for mice as well as an apparent significance between prominate secondary habitat types and levels of precipitation. Likewise, the model also suggests that primary habitat type had a significant influence on the detection of rats.

4.4.1 MOUSE

HABITAT SIGNIFICANCE

According to the model produced, mice detections were more prevalent in areas where the secondary habitat was dominated by scrub (to a significance of 0.022). As illustrated in figure 8, detection levels would dramatically decrease in areas where woodland was the dominate secondary habitat. This finding is particularly interesting as, in comparison, the primary habitat type appeared to have no significance on detection rates. However, similar work into the preferential habitats of small mammals (in particular focusing on rodents) conducted by Dickman and Doncaster (1987) highlighted that, on average, mice species tend to favour dense, vegetative habitats (predominately scrub) over low level grasses and high growing treelines. Whilst these results only allude to a significance in secondary habitat type, the findings do still support a species preference towards areas dominated (at least to some extent) by scrub.

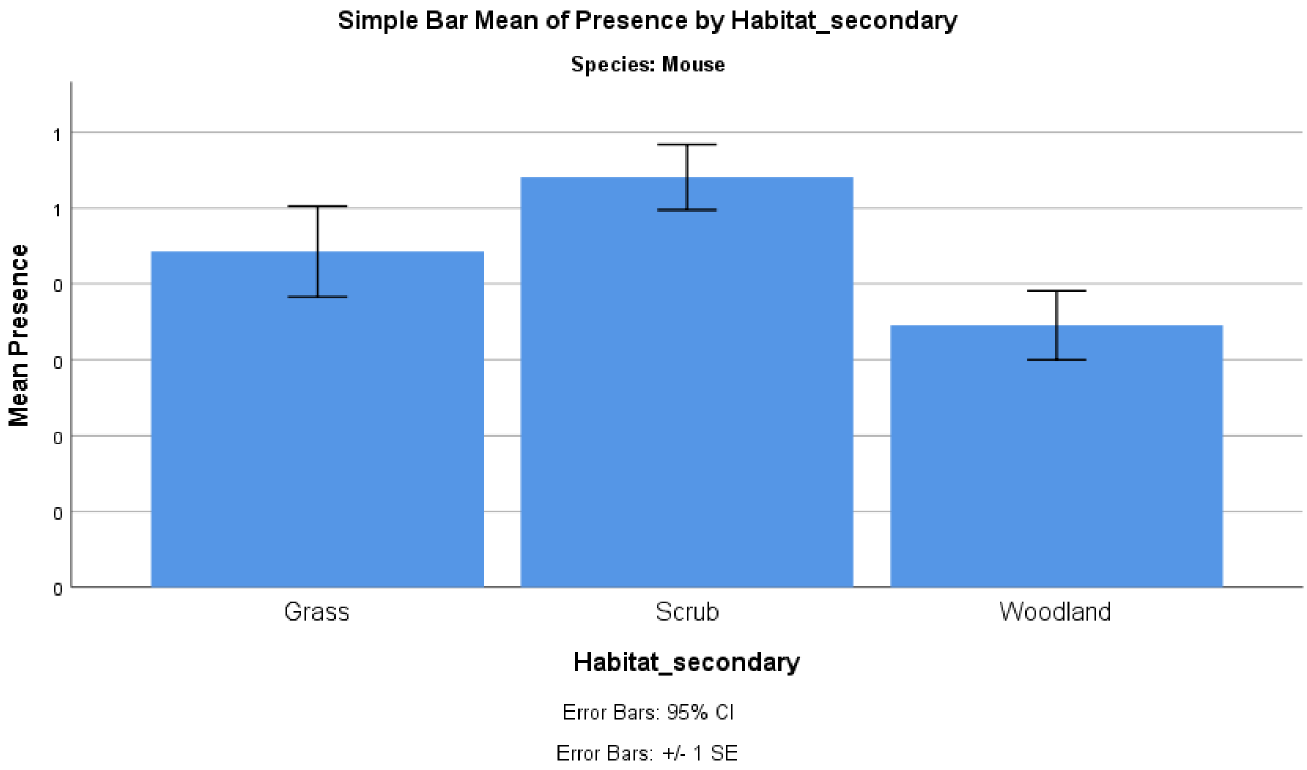


Fig. 8: Graphical representation in the variation of significance between secondary habitat type and the detection of mice.

PRECIPITATION SIGNIFICANCE

Throughout the duration of the survey, rainfall appears to have had a significant influence in the detection of mice. As observed in figure 9, on average, positive mouse detections were 50% more likely over the days that experienced <2.5mm of rainfall, compared to days that experienced >5mm of rainfall. This finding supports the original hypothesis suggesting that external environmental factors (in particular precipitation levels) have an adverse effect on mice detection rates. Similarly work by Wróbel and Bogdziewicz (2015) supports these findings. This study highlights the need for small rodents to balance foraging activity whilst avoiding increasing risks of mortality (in this case adverse weather conditions).

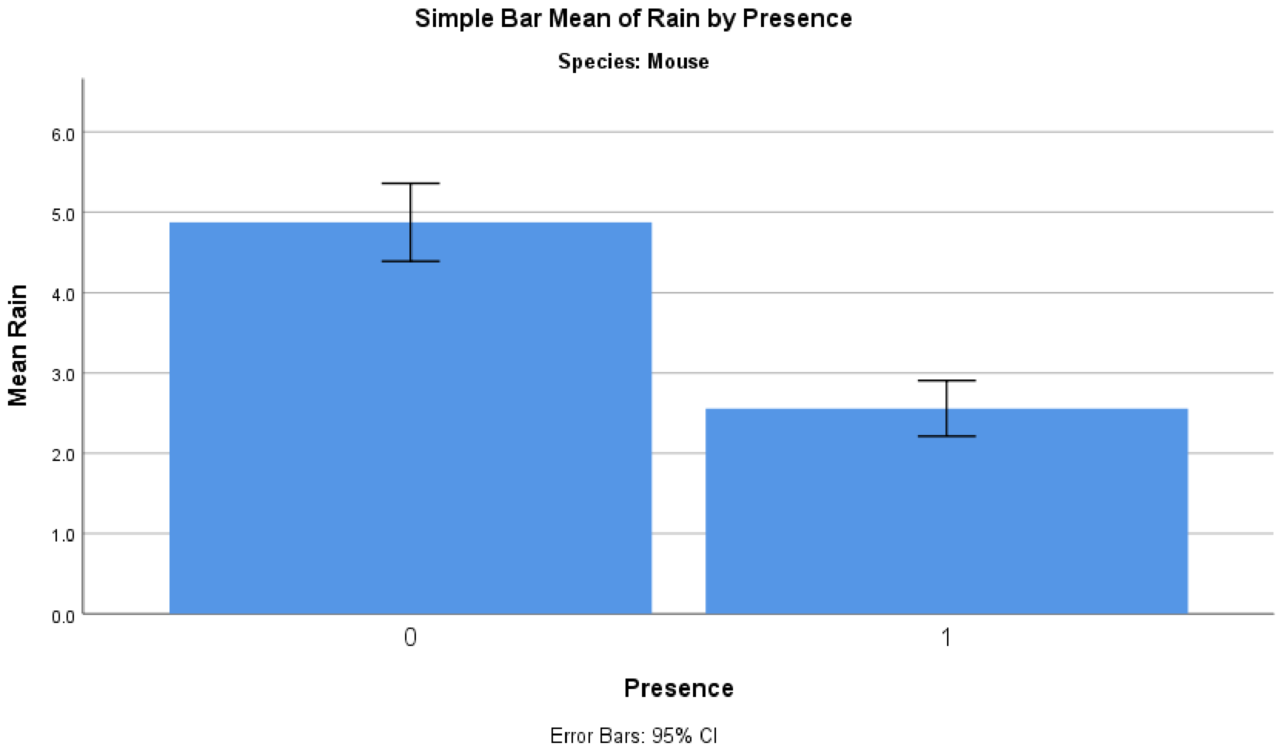


Fig. 9: Graphical representation of the relationship between mouse detections and precipitation levels.

4.4.2 RAT

Similar to mice detections, rat detections were significantly influenced by habitat type. However, and as to be expected, in the case of rats, the primary habitat had a much greater impact of positive detections. Figure 10 clearly shows that grasslands are more conducive to rat detections. In comparison to scrub and woodland, grassland was almost 3 times more likely to support rat populations; directly contradicting the theory whereby detections would be significanly lower in areas dominated by grassland.

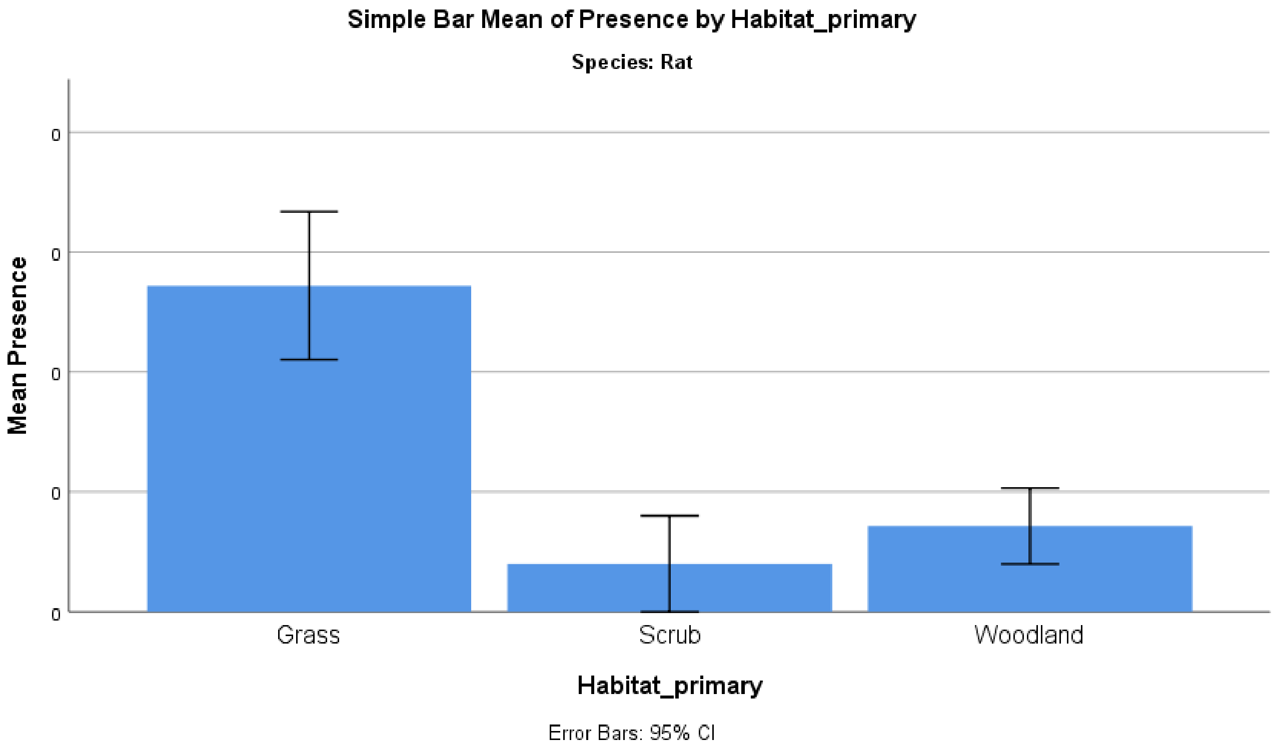
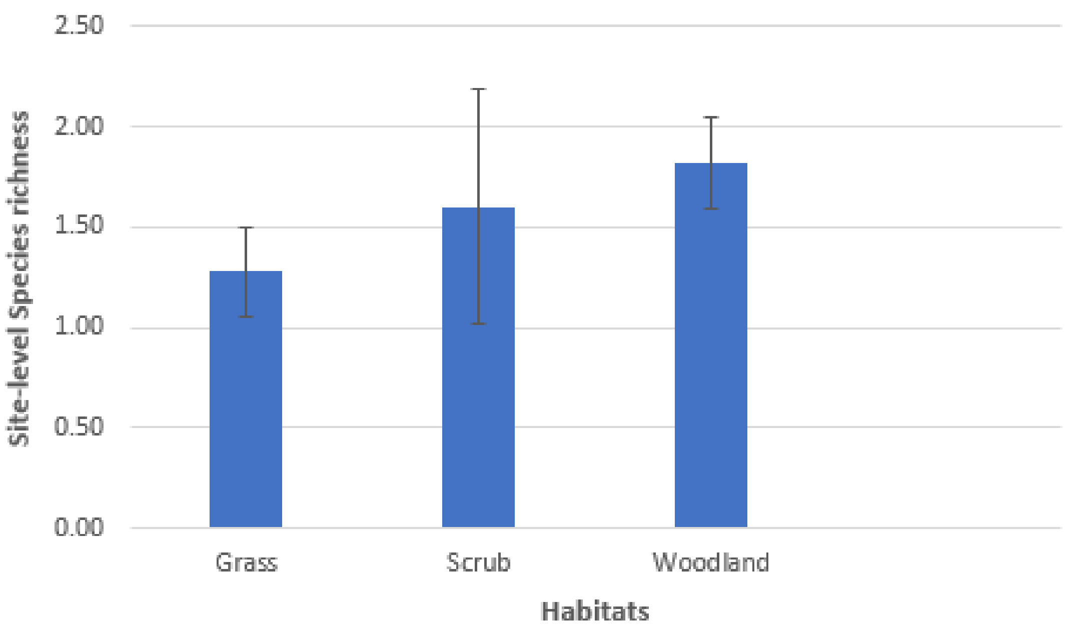


Fig. 10: Graphical representation of rat detections against primary habitat type.

4.5 OVERALL HYPOTHESES TESTING

Expanding further on the Chi Square test and the generalised linear model, a Kruskal Wallis test was also performed on the data to analysis the overall influence of primary habitat type (hypothesis 1) and distance from the towpath had on the detected species richness (hypothesis 3). Whilst numerically, sites dominated by woodland habitats supported the greatest species richness, the Kruskal Wallis test shows there was no significant difference in species richness between primary habitat categories i.e. grassland, scrub or woodland (Kruskal Wallis H = 2.529, df=2, p=0.282; Fig. 11a). Similarly, there was no significant difference between species richness and recorded categories of distance from the towpath i.e. <1m, 1m, 1-3m, 3-5m or >5m (Kruskal Wallis H = 0.342, df=4, p=0.987, Fig. 11b).



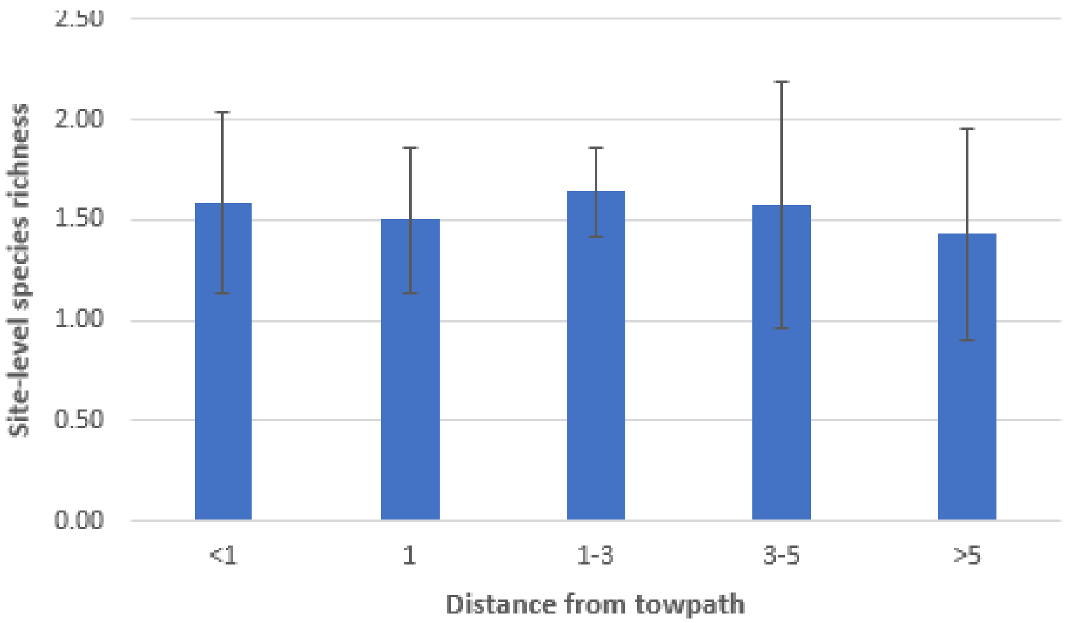


Fig. 11: Results of the Kruskal-Wallis testing site-level species richness against: a) primary habitat type and b) distance of tunnel position from the towpath.

4.6 CONSERVATION RECOMMENDATIONS

Despite these queries surrounding the significance of the results, what cannot be dispute is the significance of LVRP for small mammal populations. The park supports a variety of small mammals, including those of highlighted significant conservation importance. It is clear from the results that LVRP provides a wide range of suitable habitats to support a variety of small mammal species. To continue providing such an important environment for small mammals, it is the recommendation of this project to implement specific species-focused conservation strategies.

4.6.1 HEDGEHOG

Hedgehog populations thrive in interconnected environments which support a wide zone of roaming with a high abundance of invertebrates. Whilst populations are scarce in woodland areas, hedgehog abundance is relatively high within parklands and amenity land (Young *et al*., 2006; Parrott *et al*., 2014; Trewby *et al*., 2014). The continued work utilising traditional hedgerow management strategies, such as coppicing and natural laying (Mills and Billings, 2011) is recommended to promote healthy hedgerow quality. By doing so, this shall provide a source of food, shelter and areas for nesting sites; creating an ideal habitat for hedgehogs. Further monitoring of hedgehog populations could also be considered, continuing survey efforts using footprints tunnels and undertaking night-time torch lit surveys

4.6.2 OTTER

One of the largest threats that otter populations are presently facing is the rapid loss of viable habitats (White *et al*., 1997). In order to maintain and expand current populations, the growth of bankside vegetation should be encouraged; providing breeding and resting areas (JNCC, 1996). LVRP is an ideal habitat for otters due to the vast expansion of wetlands. However, water pollution also poses a great threat to otters. Careful water management is recommended to allow a clean home range and ideal conditions for prey species for the otters at LVRP, including the continued work already being undertaken at LVRP such as the removal of litter within the River Lagan and the monitoring of water quality in the river and surrounding water bodies.

4.6.3 STOAT

Whilst often described as opportunistic feeders, the population density of Irish stoats depends considerably on the distribution of healthy rabbit populations (McDonald, Webbon and Harris, 2000). Although they do also predate on birds, eggs and rodents, the spread of diseases such as myxomatosis throughout rabbit populations can be particularly detrimental for the Irish stoats, removing up to 50% of their diet (Croose and Carter, 2019). By continuing to support a healthy population of prey species, the stoat population should increase. Additionally, by providing ideal habitats with secure cover in a dry and warm environment (such as tree hollows, rock crevices and den boxes), stoats will be encouraged to establish home ranges and territories which support feeding and breeding habits (Sainsbury *et al*., 2019).

5 CONCLUSION

5.1 SUMMARY

In conclusion, the data collection from Lagan Valley Regional Park yielded some interesting results which not only illuminated the status of small mammals throughout the park, it also highlighted some fascinating trends of species behaviour regarding external influences and correlating species detections. It is clear from the results that LVRP supports a large variety of small mammal species. With continued, species-focused conservation efforts, Lagan Valley Regional Park could easily become one of the most significant and influential sanctuaries for small mammal populations in the entire of Northern Ireland.

To summarise overall detection, rodent species appeared to dominate small mammal populations throughout the park; most notably mouse footprints were frequently identified during the entire survey. Species of notable conservation status, such as hedgehog, otter and stoat were also discovered, albeit less frequently than other more prominent species.

Regarding the original project hypotheses under test, the statistical analysis generally suggests that there was no significant variation in species detection between habitat types at a site level. However, as hypothesized, woodland habitats did support the highest number of detections, followed closely by scrub, with grassland habitats supporting the lowest number of detections. Overall, species detectability showed no relation to environmental conditions during the survey. Likewise, on average there was no significant variation in occurrence relative to moon illumination, precipitation levels or cloud cover. However, at species level, there was a significant relationship between mouse detection and precipitation levels. Finally, there was very little variation between species occurrence and the distance of the footprint tunnel from the towpath. Interestingly, the raw data observed a higher number of detections from tunnels positioned less than a metre from the towpath, than those placed at a distance greater than 5 metres. However, these results are extremely tentative, as the room for error may have significantly influenced these findings.

Finally, it should be noted that Lagan Valley Regional Park is a particularly successful site for small mammal populations. The results of this project highlight the healthy abundance and distribution of small mammal populations throughout the entire park. By continuing the current work of the LVRP management team and focusing on species-specific conservation management plans, these populations can continue to thrive and succeed for future generations.

5.2 PROJECT LIMITATIONS

As with all projects, some limitations were encountered throughout the project. These limitations should be acknowledged whilst considering the data collected and the subsequent analysis. As the data was gathered in stages, there is the possibility of repeat counts due to the roaming nature of the species observed. For example, an individual squirrel may be recorded during the early stages of the survey, and then reappear in a different location at a later stage. Additionally, the footprint tunnel can be considered as a relatively restricted surveying technique, as only species that enter the tunnel and pass through the ink are recorded. Consequently, there is no way to determine repeat appearances or absolute abundance. The tunnels also proved ineffective in adverse weather conditions. Tunnels would often become flooded during times of high precipitation; distorting and in some cases destroying any useable results. Likewise the effectiveness of footprint tunnels is also limited by the influence of human error. Whilst the accessibility of the park was a substantial benefit regarding the logistics of the project, it did allow for possibilty of significant human interference, potentially distorting the results. As the project itself was restricted to the towpath, many of the tunnels were positioned in places that were easily accessible to the general public. As a result, a number of tunnels were damaged, destroyed and even vandalised. Interestingly, whilst the interfered tunnels were repaired or replaced according, they would often show very little sign of mammal activity following the disturbance. Additionally, human error may also lead to the misidentification of footprints. As outlined in the methodology, some species produce very similar footprints (particularly in the rodent family). Misidentification could easily occur depending on how well the footprints were recorded. For example, a small juvenile mouse print could easily be misidentified as a shrew print where the fifth digit has not been captured.

5.3 FUTURE PROJECTS CONSIDERATIONS

Future projects may want to utilise more manpower to survey the entire park in one simultaneous event. By doing so, this could produce a more accurate representation of small mammal populations within the park at any one point, as well as improving the statistical significance of the data collected. Alternatively, future projects may want to employ the utilisation of multiple surveying techniques such as hair sampling and camera traps in addition to the footprint tunnels in order to create a more in-depth picture of population size and density across the park. Finally, it is recommended that future projects explore surveying the wider area of Lagan Valley Regional Park. There is a vast area of potential habitats that were not explored in the duration of this project due to a limited number of surveyors, challenges obtaining landowner permission, and a restricted timeframe. By eliminating the listed limitations, future projects would be extremely beneficial for the park. Focused conservation strategies could be developed, and by using this project as a baseline in which to compare the results, the effectiveness of small mammal management within the park could become much more efficient.

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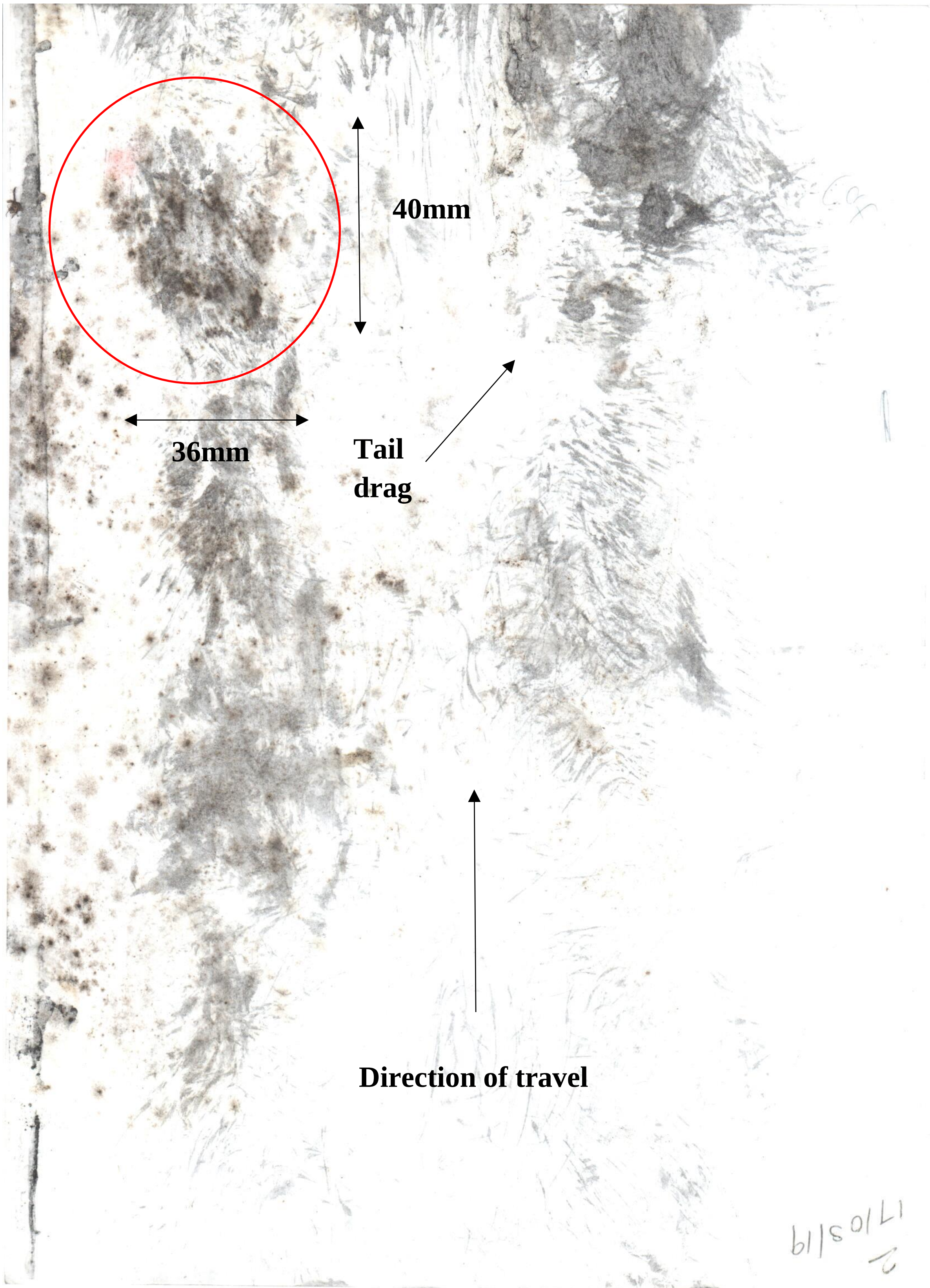
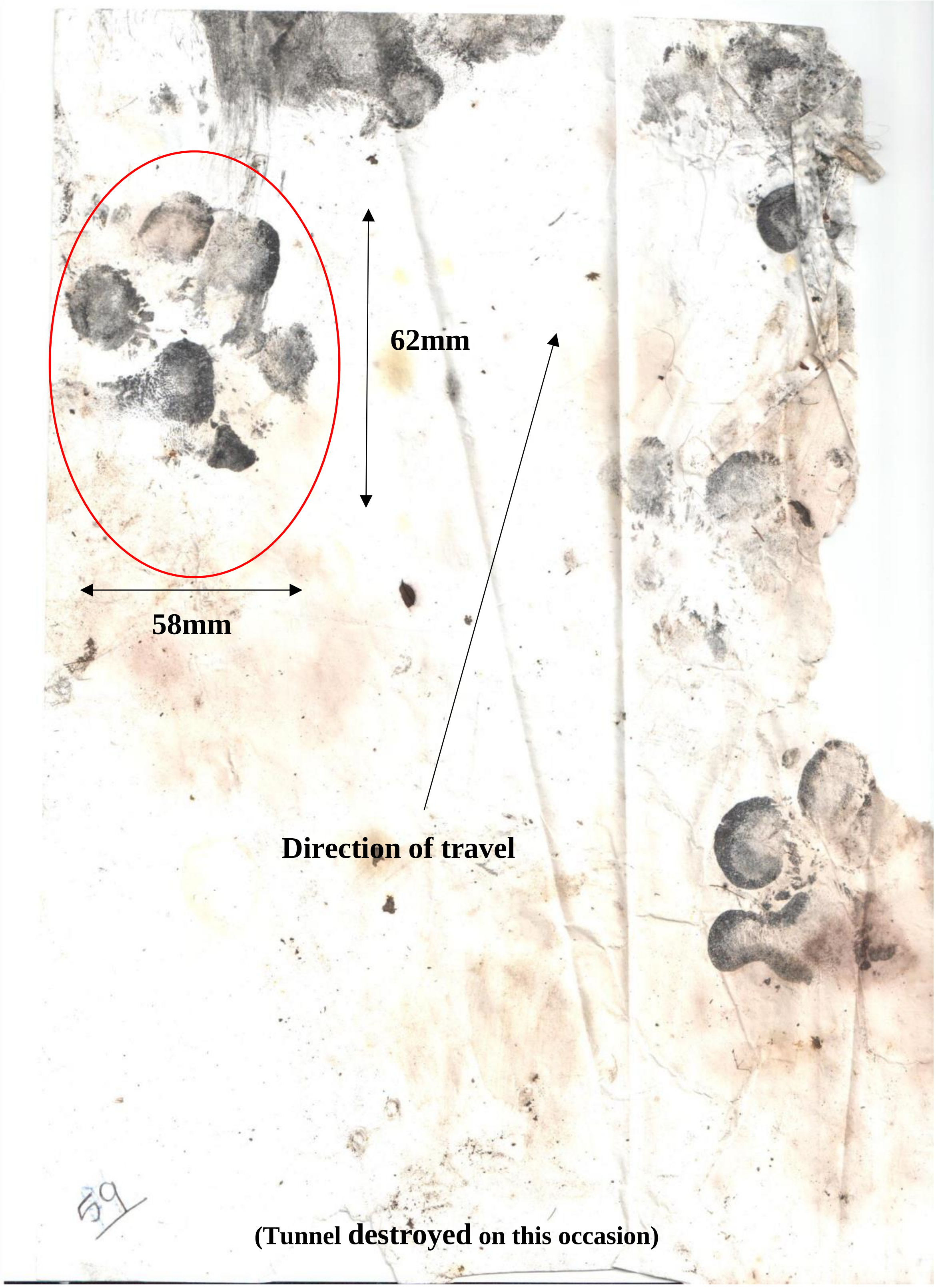
8 APPENDIX

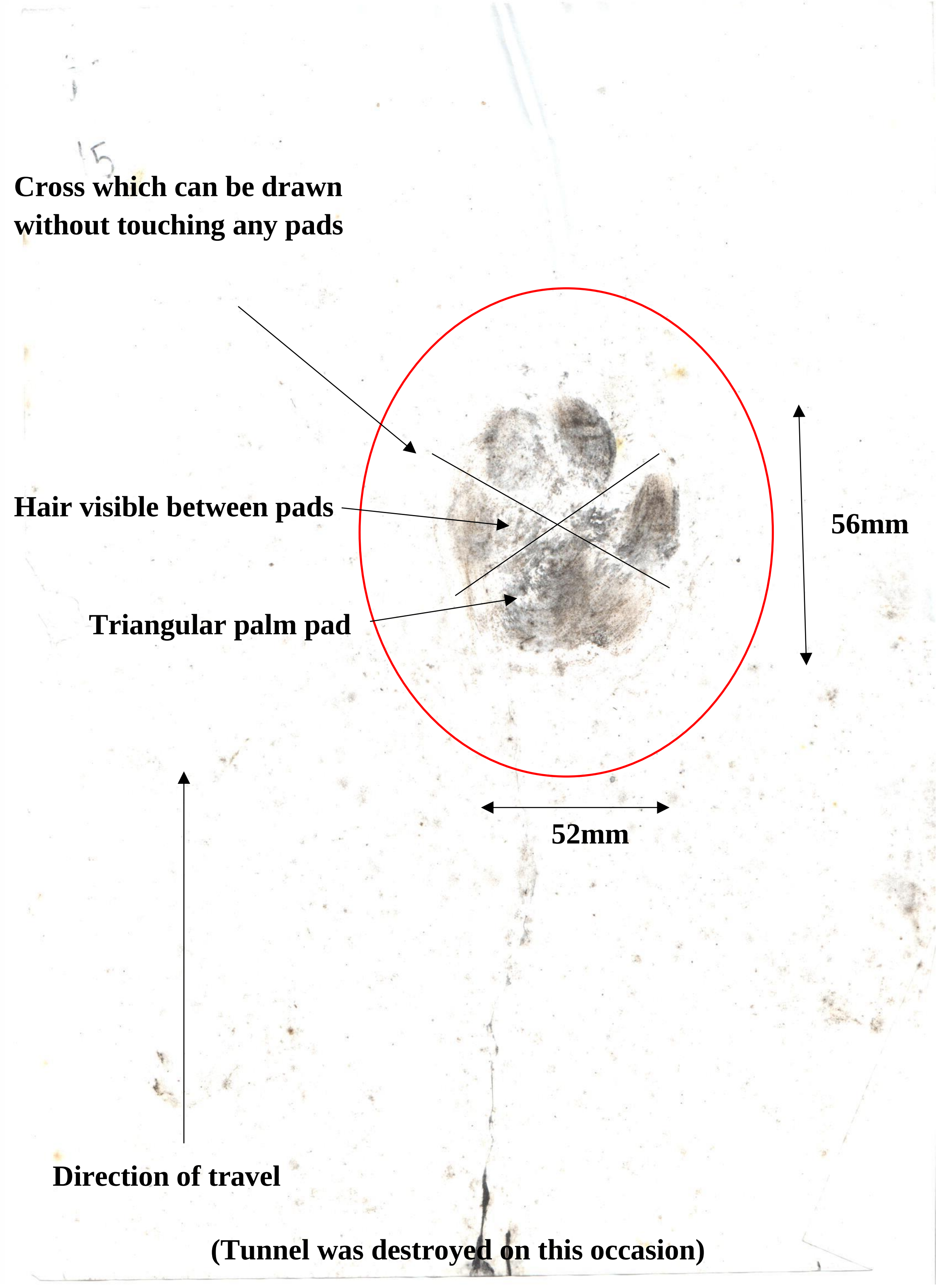
A) CAT FOOTPRINT



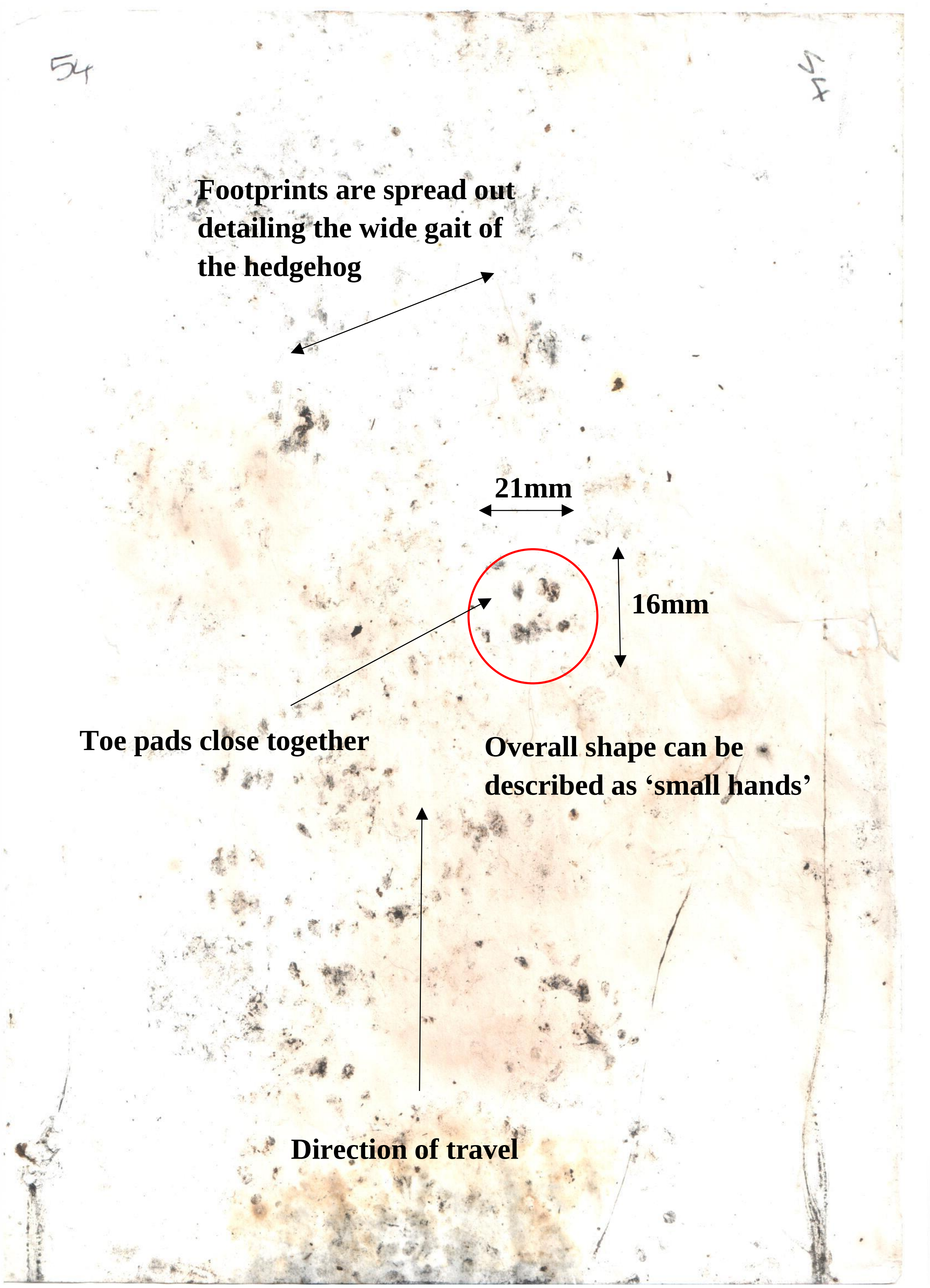
B) DOG FOOTPRINT



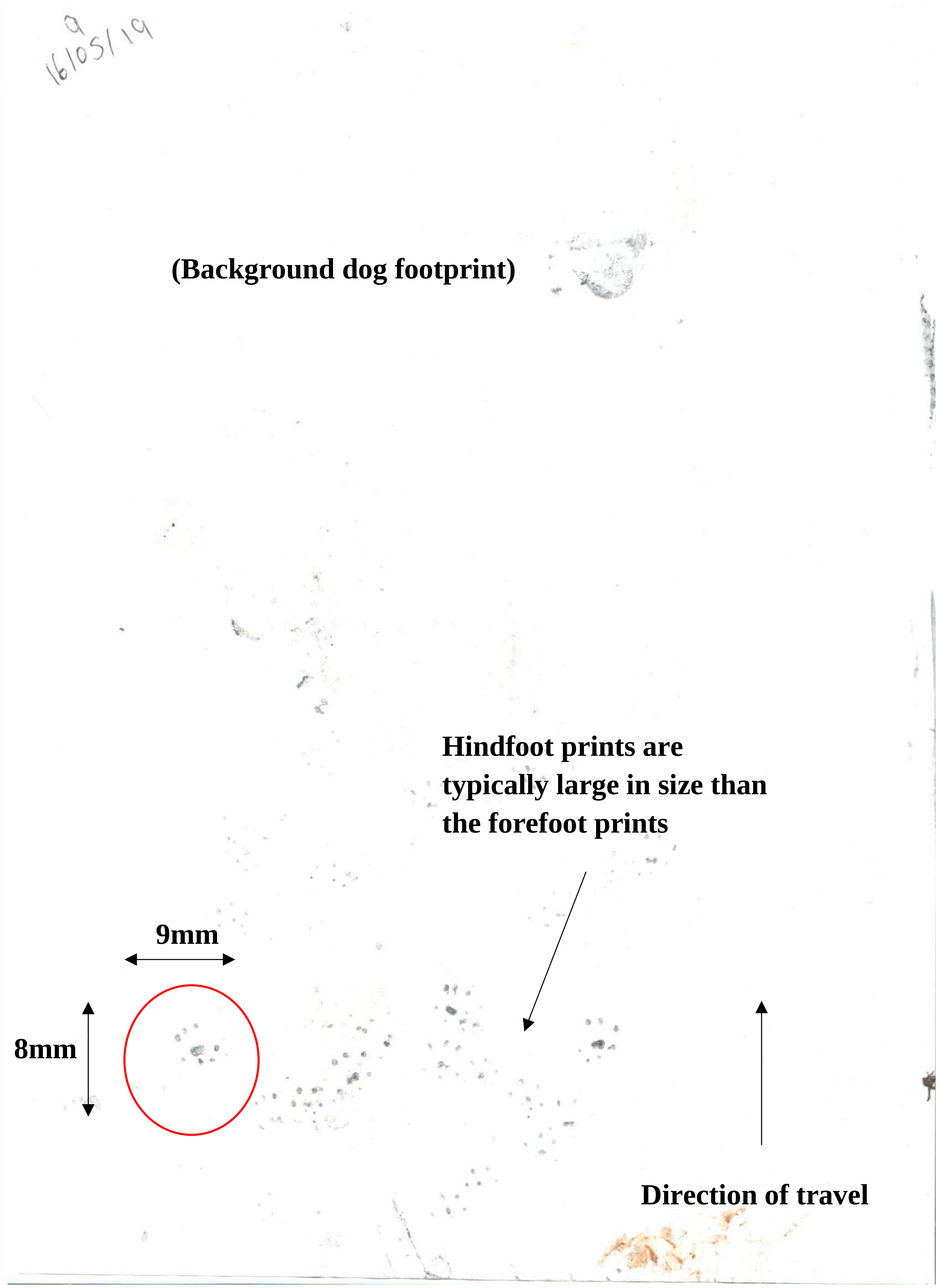
C) FOX FOOTPRINT



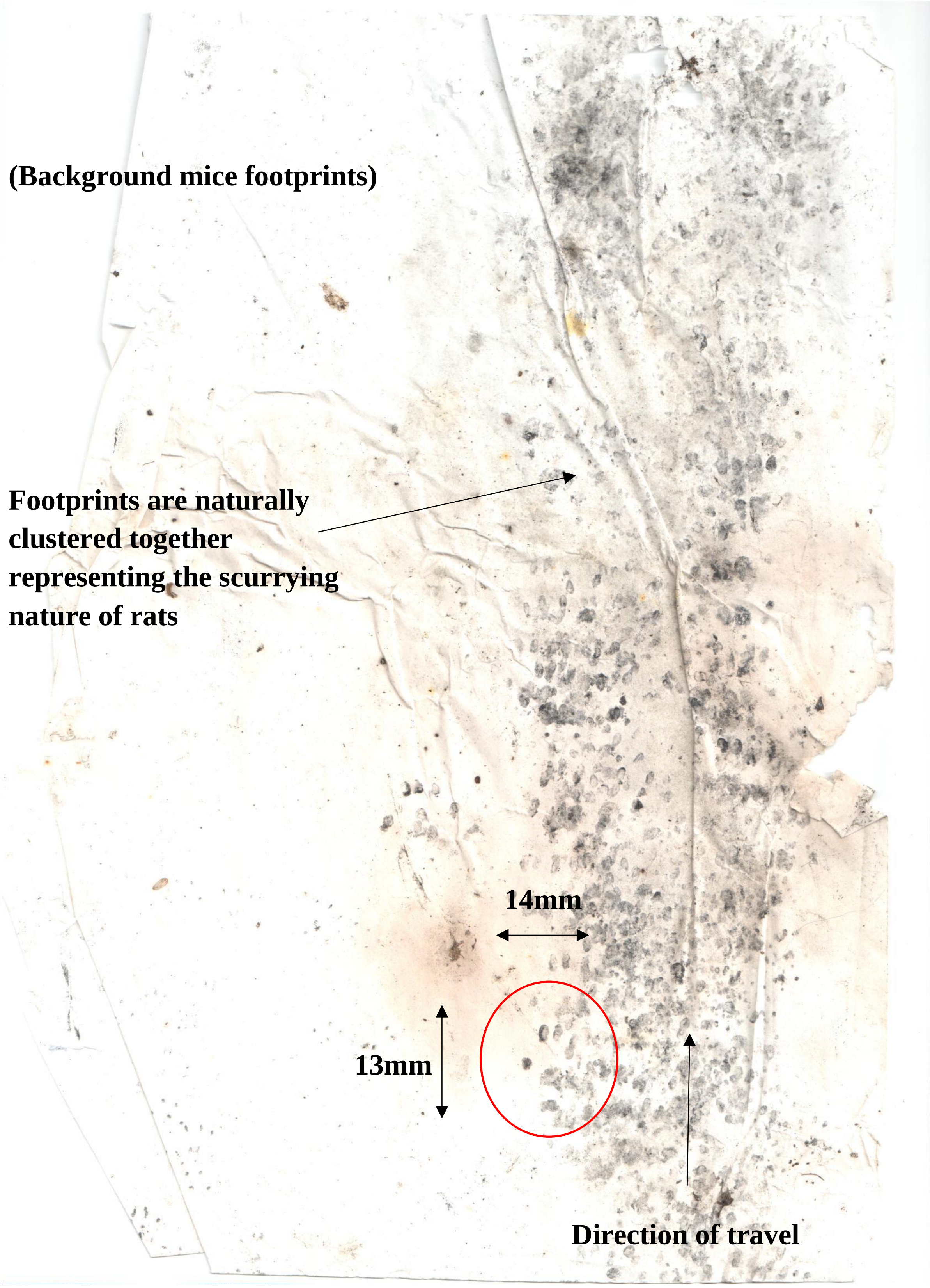
D) HEDGEHOG FOOTPRINT



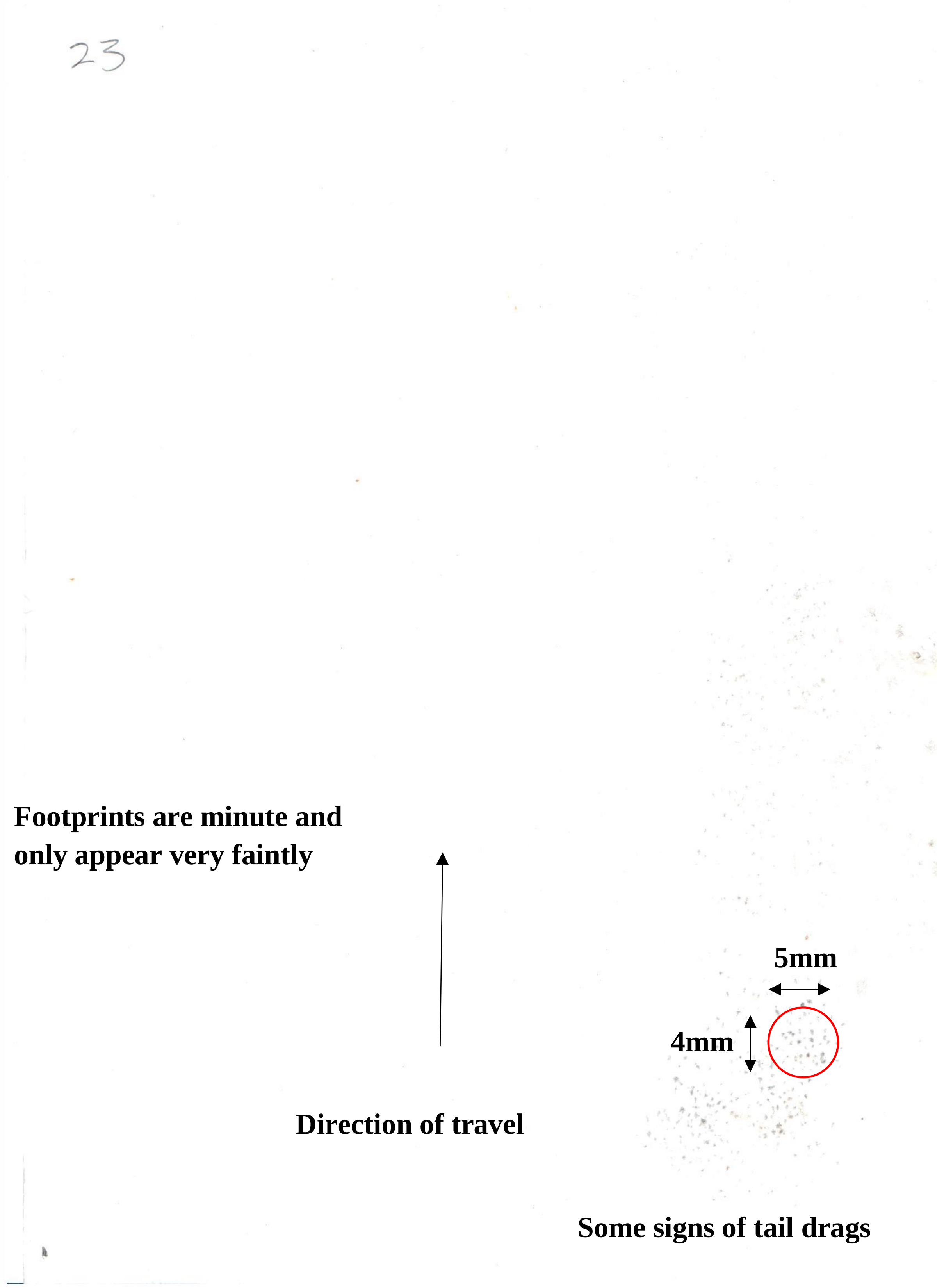
E) MICE FOOTPRINTS



F) RAT FOOTPRINTS



G) SHREW FOOTPRINTS



H) STOAT FOOTPRINTS