

# **Trooper's Hill Local Nature Reserve Small Mammals Survey**

Ivan Packer

31 July 2008

Certificate in Wildlife Biology Final Year Project

## ABSTRACT

The purpose of this project was to identify the small mammals, resident or otherwise, on the site of the Trooper's Hill Local Nature Reserve (LNR) in Bristol, UK. The site is a mixture of grassland, heathland and woodland habitats established on sandstone.

Previous studies of nesting birds, fungi and insect life on the site has assisted in the careful management of the site and contributed to it winning the Green Flag Award for 2007/8 & for 2008/9.

The aim of this project was to provide the managers of the site with sufficient quality data of any small mammal population that would further assist this management. Equal numbers of Longworth live mammal traps were distributed across the heathland and the woodland on 2 consecutive nights during January 2008 and the contents of each trap was analysed early on both mornings. The animals captured were identified for species allocation, then weighed and sexed before having the fur on the right hip clipped and were then released. The fur clipping allowed the identification of animals captured the previous night and allowed for accurate population size calculations.

Three species were found; Wood mouse (*Apodemus sylvaticus*), Pygmy shrew (*Sorex minutus*) and Bank vole (*Clethrionomys glareolus*). Only 1 pygmy shrew was captured, on the heath, but had to be released before it could be weighed and sexed. 1 bank vole was captured on the heath, the same animal on both nights, and 2 bank voles were captured in the woods. The wood mouse was captured in larger numbers in both habitats.

The results were clear. Twice as many animals, i.e. wood mouse and bank vole, were captured in the woods as on the heath. This shows a preference for the woodland habitat and the associated shelter, nesting opportunities and prey items.

Total project word count = 8975

## **DECLARATION**

I declare that the work in this dissertation was carried out in accordance with the Regulations of the University of Bristol. The work is original except where indicated by special reference in the text. Any views expressed in the dissertation are those of the author and in no way represent those of the University of Bristol. The dissertation has not been presented to any other University for examination either in the UK or overseas.

## **ACKNOWLEDGEMENTS**

I would like to thank the following for their help and guidance during this project:

Karen Hunneyball

Dr Emma Smith, University of Bristol Lecturer

Dr Michael Pocock, University of Bristol Research Associate

The Friends of Trooper's Hill conservation group

Sally Oldfield, Bristol City Council Local Nature Reserves Officer

Dr Andrew Kennedy, Certificate in Wildlife Biology Course Director

Professor Stephen Harris, University of Bristol Professor

# TABLE OF CONTENTS

<b>1. INTRODUCTION.....</b>	<b>6</b>
1.1. AIMS OF THE INVESTIGATION .....	6
1.2. HYPOTHESIS TESTED.....	6
1.3. SITE DETAILS AND DESCRIPTION .....	6
1.4. BACKGROUND RESEARCH .....	8
1.5. LITERATURE REVIEW .....	14
<b>2. METHODS.....</b>	<b>17</b>
2.1. EXPERIMENTAL METHODOLOGY .....	17
2.2. SITE SELECTION CRITERIA .....	17
<b>3. RESULTS.....</b>	<b>24</b>
3.1. SUMMARY OF PROCESSED RESULTS .....	24
3.2. OUTCOME OF STATISTICAL RESULTS.....	26
3.3. TRENDS IN DATA .....	26
<b>4. DISCUSSION.....</b>	<b>28</b>
4.1. BIOLOGICAL SIGNIFICANCE IN RESULTS .....	28
4.2. SUPPORTING RESEARCH/SECONDARY DATA .....	28
4.3. EVALUATION OF METHODOLOGY .....	28
4.4. LIMITATIONS OF THE INVESTIGATION .....	29
4.5. FURTHER WORK.....	29
<b>5. CONCLUSION .....</b>	<b>31</b>
5.1. SUMMARY OF FINDINGS .....	31
<b>6. REFERENCES .....</b>	<b>32</b>
6.1. BIBLIOGRAPHY .....	32
6.2. WEBSITES .....	32
<b>7. APPENDICES.....</b>	<b>33</b>

## LIST OF FIGURES

FIGURE 1.1	AERIAL MAP OF TROOPER’S HILL LOCAL NATURE RESERVE (LNR).....	7
FIGURE 1.2	BANK VOLE ( <i>CLETHRIONOMYS GLAREOLUS</i> ) .....	10
FIGURE 1.3	WOOD MOUSE ( <i>APODEMUS SYLVATICUS</i> ).....	10
FIGURE 1.4	PYGMY SHREW ( <i>SOREX MINUTUS</i> ).....	10
FIGURE 1.5	PREPARED TRAPS IN CARRYING CASE .....	13
FIGURE 2.1	THE HEATHLAND FACING NORTH TOWARDS THE CHIMNEY .....	18
FIGURE 2.2	TRAPS BEING LAID ON STEEP SLOPE NEXT TO WOODLAND PATH .....	20
FIGURE 2.3	WEIGHING ANIMALS IN THE WOODS .....	22

## LIST OF TABLES

TABLE 2.1	SPECIES CAPTURED ON SATURDAY ON THE HEATH.....	21
TABLE 2.2	SPECIES CAPTURED ON SATURDAY IN THE WOODS .....	22
TABLE 2.3	SPECIES CAPTURED ON SUNDAY ON THE HEATH.....	23
TABLE 2.4	SPECIES CAPTURED ON SUNDAY IN THE WOODS .....	23
TABLE 3.1	DATA FOR POPULATION SIZE ESTIMATE USING THE LINCOLN MODEL .....	25
TABLE 3.2	DATA FOR POPULATION SIZE ESTIMATE USING THE PETERSEN MODEL.....	26
TABLE 3.3	SEX RATIOS, EXCLUDING RECAPTURES .....	27
TABLE 3.4	SEX RATIOS EXPRESSED AS PERCENTAGES, EXCLUDING RECAPTURES .....	27

# **1. INTRODUCTION**

## **1.1. Aims of the investigation**

The aims of this investigation were to ascertain how the management of the Trooper's Hill Local Nature Reserve (LNR) in Bristol was affecting the numbers of small mammals on the site, and also to determine how the current and future management of the site could benefit those populations.

“The free living small rodents and insectivores are groups of mammals of interest to many professional and amateur biologists. Not only are they interesting little animals in their own right, but by virtue of their abundance and wide range of ecological adaptations they are also important components of almost every existing terrestrial ecosystem” (Delaney, 1974).

## **1.2. Hypothesis tested**

The site is made up of three different habitats, namely grassland, heathland and woodland. In the past and in the current management plan the woodland is being cut back and this study was to analyse what affect this would have on the numbers of small mammals and whether they preferred the heathland or woodland habitat. The most obvious way to do this would be to compare the population numbers in the woodland to the population numbers on the heathland. In order to do this baited live traps would have to be laid, such as Longworth traps, possibly borrowed from the Biological Sciences Department of the University of Bristol, which could be checked for occupancy then an estimation of the populations in both locations could be made.

## **1.3. Site details and description**

Site Grid Reference: ST628731 (see Figure 1.1)

Extract from the Friends of Trooper's Hill website: “Troopers Hill in St George, East Bristol, is on a hillside overlooking the River Avon that has been quarried and mined in the past. The hill contains a fascinating mix of history, wild plants and animals. With heather and broom, rocky crags, spoil heaps and gullies, stunning views and two listed chimneys, Troopers Hill is one of the most spectacular wildlife spots in the city.

Troopers Hill's geology is unusual in Bristol. Most of the city lies on carboniferous limestone, but Troopers Hill is dominated by pennant sandstone. In places, the sandstone can be seen on the surface, both as natural outcrops and old quarry faces. The

sandstone has resulted in acid soils, which are rare in Bristol. This has encouraged a wealth of plants to flourish, that are found nowhere else in the City”.

“The site supports the only substantial area of acidic grasslands and heath in Bristol and the best developed surviving example in the former County of Avon. Since acidic soils are uncommon in the area, 25 of the plant species recorded here are included in the list of Notable Plant Species in the former County of Avon” (Bristol Parks Management Plan, 2007). Further details of other plant species on the site is detailed on pages 20 and 21 of the Management Plan (see Appendix C).

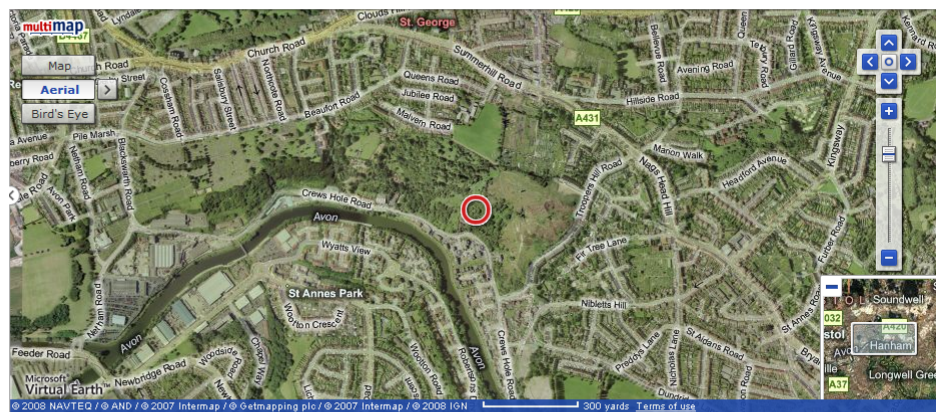


Figure 1.1 Aerial map of Trooper’s Hill Local Nature Reserve (LNR)

The total area of the site, which is roughly triangular in shape, is 8.4 Hectares (21 acres) to which there are 7 entrance gates, 2 of these (both in the north of the site) are maintenance gates and the remaining 5 are kissing gates used by members of the public for access as it is a popular spot for recreational activities such as dog-walking and there are a number of public rights of way (see Appendix E - Public Rights of Way Map 2 from 2007 Management Plan). The south western border is made up on the Crew’s Hole Road, and the south eastern border is made up of Trooper’s Hill Road. To the west is Crew’s Hole Woodland and in the north is “The Farm” which a series of allotments managed by the Bristol East Allotments Association (see Appendix F – Site Features map 3 from the 2007 Management Plan).

On a map of Kingswood dated 1610 it is named Harris Hill and local tradition has it that during the civil war the Parliamentary army, under the command of Sir Thomas Fairfax, camped on it prior to the siege of Bristol in 1645 and the name was changed to Trooper’s Hill. The copper smelting industry was established in the area in the eighteenth century when the copper ore was brought by boat, mainly from Cornwall and North Devon, and was used in the manufacture of brass. The most obvious feature is the

Grade 2 listed chimney at the top of the hill which may date from as early as 1698. There was some quarrying of the sandstone during this period, but the most significant development was the opening of Troopers Hill Pit. The second chimney, which still stands at the junction of Troopers Hill Road and Crews Hole Road in the south eastern corner of the site, was at the corner of the engine house and is all that remains of this colliery. On 21 December 1956 the area was purchased by Bristol City Council for use as a refuse tip. There is a story that one of the trucks working on the tip over-turned, rolled down the bank and is now buried. The site was declared as a Local Nature Reserve (LNR) on 22nd June 1995 run in partnership with the Friends of Trooper's Hill.

#### **1.4. Background research**

When considering a project subject the initial consideration was that of the European otter (*Lutra lutra*) because 2 had been seen on the River Avon – one close to St Anne's Park in Bristol and the other close to the Valentine's Bridge in the city of Bristol. A brief discussion with the Certificate in Wildlife Biology course director, Dr Andrew Kennedy, identified that finding these shy and elusive mammals would be extremely difficult and therefore obtaining sufficient data for the project would also be extremely difficult. The red fox (*Vulpes vulpes*) was then considered as the subject for the project following a long term interest in their social structure. Professor Stephen Harris at the University of Bristol was contacted who advised that it would be possible to use the red fox as the subject for the project, but although it was possible to join his team and to help in their data collection and/or provide additional data, he warned that the majority of the work that him and his research team did was at night, generally from 8pm until 4am which is when the foxes are at their most active in the city. This would not be feasible due to full time employment commitments so another option had to be considered.

It was then that the local community was considered and realised that just across the river from St Anne's Park was the Trooper's Hill Local Nature Reserve (LNR). Before the project was started a brief search on the internet revealed that the site was owned and managed by the Bristol City Council in partnership with The Friends of Trooper's Hill. A phone call was made to them asking if a small mammal survey had ever been done on the site. Rob Acton-Campbell who, along with his wife Susan, runs the Friends advised that although a number of mice and shrews had been seen by its members and there had been reports of them by members of the public, and other surveys had been done on the site, namely a nesting birds survey, insect survey, and a fungi survey a



small mammal survey had never been done. There is also a known population of badgers (*Meles meles*) on the site. Rob advised that a small mammal survey would be warmly welcomed and an invitation to their next meeting was extended. He advised that they held meetings every six weeks or so at the Wesley Memorial Church Hall in Bryant's Hill to discuss ideas for events and works to be done on the hill and to pass on any news or information. He said that although they generally had an agenda that their meetings were very informal and light hearted.

A meeting was attended on Tuesday 2<sup>nd</sup> October 2007 (see agenda on Appendix G) and introductions were made to Rob & Susan along with other members of the group. A place in the agenda was provided to introduce the fact that it would be beneficial to do a small mammal survey on the Trooper's Hill LNR with a view to using the data to assist the council, in partnership with the group, in having information available that would help them in the management of the site. The suggestion was welcomed by all members of the group and assistance from 2 people was offered. It was advised that it was intended that two surveys were done, one in winter and one in spring, but both of these would depend on weather conditions, the availability of the traps and the data collected. Rob advised that the contact at the Bristol Council was Sally Oldfield, the Local Nature Reserves Officer.

Sally Oldfield at the Bristol City Council was contacted by telephone, and she was advised of the plan and permission was requested to access rights to the site. Sally was happy to provide permission and that formal written notice was not necessary. Nevertheless a written brief of the project was sent to Sally. The project proposal form (see Appendix A) was completed and handed in to Andrew Kennedy on Wednesday 24<sup>th</sup> October 2007. A risk assessment form (see Appendix B) was also completed and sent to Emma Smith on Wednesday 27<sup>th</sup> November 2007.

#### **1.4.1. Anticipated species**

A consideration had to be made of the animals that were most likely to be found on the site and Dr Michael Pocock, a research associate specialising in small mammals at the University of Bristol, was approached. He advised that in both the heathland and woodland it was likely that the Wood mouse (*Apodemus sylvaticus*), Common shrew (*Sorex araneus*), Pygmy shrew (*Sorex minutus*) and Bank vole (*Clethrionomys glareolus*) would be found, possibly a Yellow necked mouse (*Apodemus flavicollis*) although they were less likely. This is confirmed in Nigel Webb's book *Heathlands: A*

*natural history of Britain's lowland heaths* published in 1986. “The Pygmy shrew is expected, but the Common shrew is less common on heathland. The Wood mouse is expected although the Bank vole and the Short-tailed vole (*Microtus agrestis*), which is also known as the Field vole, are much less common”.

Dr Pocock advised that if the yellow-necked mouse was found in the wood, and that it was possible to trap one, it would have to be handled with care as they are agile and ferocious when caught and will squeal and bite in order to escape. This is backed up by Paul Sterry's book *Complete British Animals*, published in 2005, which quotes “they are remarkably agile and ferocious in the hand, and will bite, squeal and wriggle with alarming vigour”. With this all of this new information in mind the habitats, diet and predator information for the wood mouse, shrew species and the bank vole were considered.



Figure 1.2 Bank vole  
(*Clethrionomys glareolus*)



Figure 1.3 Wood mouse  
(*Apodemus sylvaticus*)



Figure 1.4 Pygmy shrew  
(*Sorex minutus*)

#### 1.4.2. Distribution and habitats

The bank vole is known to inhabit a wide range of wooded and scrub habitats. It makes a nest, usually underground, from plant material from which it will venture out from shallow burrows and surface tunnels to forage (Sterry, 2005). It is usually active throughout the 24-hour period and its diet is almost exclusively vegetarian with grass roots being the most important component. Having said this they generally prefer deciduous woods, the fringes of woods, hedges and bushes, i.e. ground covered with scrub or herbage and mainly in dry and warm places (Van Den Brink, 1967).

As its name suggests the wood mouse is mainly found in woodland, but also in hedgerows and scrub. Early writings suggested it lived mainly in open country and was rarely found in woods within the range of the yellow-necked mouse (Van Den Brink, 1967). It is mainly nocturnal and digs burrows, often with 1 chamber for the nest and another for storing food. It suffers high mortality in spring and its normal lifespan is

only about 18 months (Hart-Davis, 2002). When it does leave its burrows it will forage on the woodland floor.

Shrews are robust and hardy and have evolved to stand a wide range of temperatures as can be seen by the geographical distribution – the different species can be found on most continents and the common shrew has been caught amongst scree on a Scottish mountainside at 1,000 metre elevation (Churchfield, 1990). Although shrews mostly occupy moist, terrestrial environments where there is an abundance of vegetation cover and a wealth of invertebrate prey, they are extremely widespread in many different habitats. They are found in woodlands, forests, grasslands and scrublands and habitually live around human dwellings, however they generally live on the ground surface amongst vegetation, hiding up in nests in grass tussocks or under logs.

### **1.4.3. Diet**

The bank vole diet includes plant shoots and leaves, as well as berries, nuts and fungi when in season (Hart-Davis, 2002) so my initial thought was that they were more likely to be found in the woodland than on the heath. Knowing this, and also having an understanding of the dietary requirements of the other species that were likely to be found in the woods and on the heath would help in identifying signs of their existence. Items to look for would be seeds and small cones stripped of scales as well as hazelnuts with a neat round hole and no teeth marks outside the opening.

The wood mouse is an opportunistic feeder and its diet includes insects & other invertebrates as well as seeds, nuts and fungi when in season (Hart-Davis, 2002), much like the Bank vole. The average weight of the wood mouse is 15-30g and the yellow-necked mouse can grow to almost twice that size. Their diet, much like the wood mouse, is varied and will include invertebrates as well as seasonal nuts, fruits, berries and fungi.

Dr Pocock advised that because it was likely that shrews would be caught a licence from English Nature (now called Natural England) to trap them would have to be obtained as they are protected by the Wildlife & Countryside Act 1981. This was done by accessing the English Nature website and downloading the licence form (see Appendix D). It was also known that pygmy shrews, being particularly small, lose body heat extremely quickly because the ratio between surface area and volume is greater in small objects than in big ones. Shrews, like humans, keep their body temperature at

around 37°C. They are insulated by a coat of fine, dense fur, but even this is not enough to keep them warm. To compensate for this they have to eat every few hours, consuming up to three times their body weight per day (Attenborough, 2002). Because of this it was important to ensure that each tray would have to contain enough hay for them to make a warm bed and that there should be sufficient food for them to survive in the trap for up to 12 hours. Both species are widespread across Britain and are both found in a wide variety of habitats including woodland, heathland and moors. They are active both day and night, and throughout the year in the quest to find food. Their diet consists of a number of different insects and other invertebrates such as slugs, snails, spiders, woodlice and insect larvae.

#### **1.4.4. Breeding habits**

A further consideration that had to be made was that of the breeding habits of the mammals. The shrew species in Britain have a breeding season extending from April to September, although most young are born between June and early September (Churchfield, 1990). The breeding season of the bank vole extends from early spring to late autumn and females have the potential to produce up to 5 litters a year, each with an average of 3-5 young (Sterry, 2005). The breeding season of the wood mouse and the yellow-necked mouse are very similar to that of the bank vole. Based on this research there was confidence that none of the species that were likely to be encountered would be carrying young or have a brood back in their nests that they would have to return to to feed.

The intention would be to lay a number of Longworth live traps borrowed from the University in the evenings of a Friday and Saturday over a weekend, collecting them up early the next morning. Dr Pocock had advised that a minimum of 40 traps would be needed and it was useful that the traps came in large carrying containers that each held 48 traps. This meant that it would be possible to lay 24 traps per night in each of the 2 habitats to provide an accurate comparison of numbers. It was intended that this be done sometime between Christmas 2007 and the early May bank holiday 2008 depending on the availability of the traps as they are used by students at the University throughout the year. This would hopefully give a broad range of quality data in the two different habitats across the reserve and allow a comparison and contrast to be made of the species/population size, etc which would hopefully provide information on how the management of the vegetation on the reserve could/can affect/benefit the existing and future population.



Figure 1.5 Prepared traps in carrying case

#### 1.4.5. Precautions against trap mortalities

There were a number of other factors that had to be considered and possibly the most important is the welfare of the subjects trapped. A consideration had to be made that the animals would be in the traps overnight so it was important to ensure that the traps were laid when the weather was mild, and that the traps were stable & sloped so that rain water did not collect in them, and that all traps would contain sufficient food and bedding. The traps would be laid one evening then collected early the next morning and the contents examined. The reasons for this were fourfold: they would only be down overnight; any animal trapped would be captive for as little a period as possible; the traps wouldn't be left in a public place in daylight and finally camouflage netting was considered that could be used to hide them. This would be done for 2-3 consecutive nights during the periods mentioned above. Harvest mice may be difficult to trap..., the other species are easily trapped. Voles are easily trapped” (Corbet, 1989).

Because some of the animals are vegetarian and some insectivorous a mixture of food types had to be provided. Dr Pocock suggested a handful of oats, a slice of carrot and a handful of casters (blowfly larvae). Gurnell and Flowerdew’s book *Live Trapping Small Mammals*, published in 2006, confirms this: “To standardise trapping methodology, it is a good idea to stick to one type of bedding and food and bait throughout a study. It’s convenient to use the same substance for baiting the traps and provisioning them, although this is not essential. Many things have been used as food/bait in small mammal studies. Whole oats, wheat, crushed oats, cut wheat or other cereals are acceptable for trapping rodents and a small piece of fresh apple or carrot is a useful addition and provides a source of moisture to trapped rodents”. This information provided a useful

guide and confirmed that providing oats and a slice of fresh carrot would be sufficient for the rodents.

Knowing that shrews are insectivores meant providing appropriate insects in the trap. It was advised that the best food to provide would be blowfly larvae (known as casters) and were readily available from angling shops. S Veals & Son angling store on Old Market in Bristol was contacted and they advised that it was possible to supply both fresh and frozen casters. Dr Pocock had suggested obtaining frozen casters as they were not only cheaper, but also kept for longer. A large bag was ordered to be collected on the first day of trapping. Good quality hay was going to be ordered from an equestrian store, but Dr Pocock had some that could be used instead. This was going to be used in the traps for the bedding.

#### **1.4.6. Signs of small mammals**

A visit was made to the site in an attempt to find and identify the species resident there. Signs being looked for were footprints, droppings, discarded food and/or food stores, runs, burrows and nests. There were a number of burrows evident on the heath and some droppings were found near the burrows. Based on the size of the droppings - 4mm - it was thought that they might be from wood mice (the droppings of the bank vole is 50% larger at 6mm and the droppings of the 2 shrew species are smaller at 2 and 3mm) (Yewlett, 1975).

A number of runs were also identified amongst the heather so it was clear that there was a population of small mammals. As it was raining heavily it was not possible to find any footprints or any discarded food or nests. When searching the woods it was not possible to find any footprints, nests or discarded food, but it was possible to find more droppings, again possibly from wood mice, and a number of burrows. A search was also made under logs and other debris lying on the ground.

#### **1.5. Literature review**

In order to more accurately establish what small mammals might be on the site there had to be knowledge of what habitats there were and also what plans the council and the Friends had for the site. A copy of the 2007 Management Plan for Troopers Hill Nature Reserve (see Appendix C) was provided. This not only provided vital information about the habitats that made up the site, but also additional information such as details of the plant species, maps showing the layout of the site, a short history of the site, and the

aims for the site. It states that the Trooper's Hill LNR "supports the only significant area of Lowland Heathland and Lowland Acidic Grassland in the Bristol area. Both of these habitats are identified under the UK Biodiversity Action Plan (<http://www.ukbap.org.uk>) as UK Priority Habitats.

According to the Habitat Action Plan "Lowland acid grassland typically occurs on nutrient-poor, generally free-draining soils with pH ranging from 4 to 5.5 overlying acid rocks or superficial deposits such as sands and gravels". This is confirmed by the 2 species of heather that were identified on an early visit to the site. Ling Heather (*Calluna vulgaris*) with its pinky-purple flowers, and the Bell heather (*Erica cinerea*) with its crimson-purple flowers are both very common on the British Isles and are locally dominant on heaths and moors on acid soils (Rose, 2006). Both of these species are members of the Heath Family (*Ericaceae*) and are described as "shrubs with simple, narrow, leathery, mostly evergreen leaves without stipules". Trooper's Hill LNR is an ideal location for both species. For example Bell heather grows in free-draining soils of disturbed ground and along the edges of tracks (Webb, 1986). Iron is toxic to Bell heather and plants growing in dried (well drained) soils take up less iron.

As well as a consideration being made of what species were on the heath another had to be made of the tree and plant species of the woodland. The woodland is in records dating back at least as far as the nineteenth century. The trees present in the woods include hawthorn (*Crataegus monogyna*), silver birch (*Betula pendula*), and oak (*Quercus robur/petrea*) of which the hawthorn and the oak are native British trees. The oak is our most common broadleaved tree and the two British species are closely related and can hybridise (Thompson, 2005). The hawthorn is also one of the most common British trees. It is a quick-growing hedge plant, yet growing slowly into a tree; its tangled crown makes a favourite habitat for many nesting birds, its sharp thorns offering excellent protection.

A wood will nearly always contain more than just the tree species as part of a diverse ecosystem. There are a number of different layers of vegetation in a wood so if the vegetation was thick then it was possible that it may be difficult to move through. Again, being winter it was less likely as the leaves on trees usually come out around May. When there is hawthorn present in a wood there are a number of other plant species in the field layer and the ground layer such as Dog's mercury, common cleavers,

nettles and herb robert (Read, 1999). Woods help to protect soils, retain moisture and store & recycle nutrients.

### 1.5.1. Predators

Woodlands will have a population of many different species of mammals and they will have an affect on it in one way or another. One is to attract predators. Small mammals have a number of predators, one of which is the adder (*Vipera berus*) although they do not inhabit heathlands so this was only appropriate for the woodland. These were of no concern during the laying of the traps in January as they hibernate from October to March (Sterry, 2005). Another small mammal predator is the red fox (*Vulpes vulpes*), but it was not expected that they would be seen on the day of laying or collecting the traps because although they are generally nocturnal animals they will venture out during daylight hours if they know that they are unlikely to be disturbed, people clambering around in the woods would be sure to scare them off. Another predator is the Tawny owl (*Strix aluco*) which, also nocturnal, nests in tree holes and prefers old broadleaf trees such as oaks (Svensson, 1999). These birds had been heard hooting at night so it was known that if they were present then there would probably be a population of small mammals. The yellow-necked mouse's vivid colouring has a disadvantage of attracting predators.

The age of a wood will also have an affect on the relative abundance of different species of small mammals with the greatest abundance being in woods of 30 years or more in age (Read, 1999). It was also known that the animals were preyed on by weasels (*Mustela nivalis*) which are exclusively carnivorous - bank voles specifically are heavily preyed upon by owls, foxes and weasels - but as they favour a wide variety of habitats such as hedgerows, farmland and moors as well as woodland it was uncertain that they would be present.



## **2. METHODS**

### **2.1. Experimental methodology**

It was not possible to experiment with any usage methods as the Longworth traps would be difficult to obtain at short notice. A consideration was made that it was possible that should they be used by other students or that the University would, for whatever reasons, not allow them to be used, that they may not be available at all. With this in mind alternative methods of identifying the small mammals present on the site was considered. In an early lecture Dr Pocock had shown 'hair tubes' that he had made and successfully used on a number of projects. They were lengths of plastic tubes of approximately 6-8 inches in length and of three different diameters. They were taped together so that they formed what looked like a mouth organ. The different diameters meant that only certain size animals could pass through them when they were placed on a known run. Double sided tape was then placed halfway over the entrance to the tubes so that the hairs of any animal passing through them would be caught and could then be analysed. A second, less preferable, option would be to simply look for signs of the animals such as entrances to burrows, droppings and discarded food remains. Fortunately these concerns were unfounded as the traps were available and permission to use them had been granted.

### **2.2. Site selection criteria**

#### **2.2.1. Safety precautions**

The Live Trapping Small Mammals book by Gurnell & Flowerdew was referred to and it was known that there were a number of safety precautions that one has to take when handling wild animals. Firstly up-to-date tetanus vaccinations had to be confirmed. It was also necessary to ensure that those involved knew how to extract the animals from the traps and how to handle them in a manner that was not only as stress free as possible for them, but also safe for the handler. In order to maintain hygiene standards a pair of domestic rubber gloves for handling the animals had to be provided. A first aid kit was also taken in the event that someone was hurt during the day or bitten by one of the animals. A mobile phone for emergency use was also taken and hand washing facilities were provided for once the handling of the animals had been completed.

When laying the traps for the first time in January 2008 it was clear that it was not going to be an easy task. It was a cold day and there was persistent heavy rain all day as well as persistent rain forecast by the Met Office. The site visit and study area selection started with the heath. There was little vegetation in the north of the site near the chimney as it is mainly grassland that is kept short as it is frequented by families visiting to enjoy the commanding views over east Bristol. The area around the gully was also unsuitable for the sighting of the traps due to the lack of foliage and the steepness of the banks. The southern part of the site was the best as it provided enough plant cover for the traps although it was much lower than it is in spring and summer. “Sometimes in winter, reddening and death of *Calluna* foliage occurs” (Webb, 1986). It was possible that this was a cause of the reduced amount of foliage showing.



Figure 2.1 The heathland facing north towards the chimney

The traps were in a carry case of 48 so 24 would be used for each of the 2 habitats. A transect was identified that would allow the placement of traps at 5 metre intervals on the heath. The exact location of each trap, and therefore the spacing between each trap, was going to be dictated by the available foliage. The area identified as being suitable for laying the traps was measured and was 50 metres in length. It was clear that if the traps were to be placed at the recommended 5 metre intervals then they would have to be in 10 pairs. This appeared to be possible as the available foliage allowed it and the traps in each pair could be placed at least 1 metre from the other

A visit to the woodland showed a different situation. There was sufficient suitable foliage but the only level area was that of the main path that ran into the middle of the wood from Crew’s Hole Road. The rest of the woodland was on a steep slope. Due to the small size of the wood it was clear that it would be possible to place the traps at the

recommended 10 metre intervals approximately 2-3 metres from the path. Again they would have to be placed in pairs with the traps in each pair at least 1 metre from the other. This was possible because the path 'meandered' through the wood and the traps could not be placed in a straight line.

### **2.2.2. Preparing and laying the traps**

On the day of the project, Friday 18<sup>th</sup> January 2008, a 1Kg bag of rolled oats and a number of fresh carrots were purchased. S Veal & Son angling store was visited and a 1Kg bag of frozen casters was purchased that had been reserved the week before. The University of Bristol was visited and the 48 traps were collected in the carry case from Dr Pocock. Each trap was already numbered, the first pair being 55A & 55B and the last being 75A & 75B. Upon arriving at home each trap was filled with a handful of hay, a handful of oats, a handful of casters and a slice of fresh carrot. Dr Emma Smith who had volunteered to assist me in the laying of the trays and also in their collection on the Saturday morning was met at the site.

Twenty four traps (12 pairs of 2), numbered 64A to 75B, were placed in the wood first whilst there was still enough light to do so. This was done on the evening of Friday 18<sup>th</sup> January 2008. The first pair was placed, approximately 1 metre apart, at the start of the path. Although the trays were laid they were not set. This was due to the fact that the traps that were to be laid on the heath would be collected first and therefore they would be set first. This would ensure that no animal caught early on the Friday evening in the woods would be in the trap for longer than was necessary. The remaining 24 traps, numbered 52A to 63B, were then placed on the heath and then revisited them to set them. This had a second purpose, that of ensuring that it was known where they were and that they could easily be found and retrieved on Saturday morning. Once the traps on the heath were laid and set the traps in the woods were revisited and also set.



Figure 2.2 Traps being laid on steep slope next to woodland path

On the morning of Saturday 19<sup>th</sup> January 2008, Ivan Packer and Karen Hunneyball met Dr Emma Smith and Dr Michael Pocock at 7.45am on Crew's Hole Road and proceeded on to the heath and started inspecting the traps. The first trap that was inspected had been sprung and Dr Pocock showed how to place it in a clear polythene bag and how to open the trap & empty the contents into the bag. The occupant was a wood mouse. Dr Pocock demonstrated how to coax it into the corner of the bag then how to hold it by the scruff of the neck (much like adults do with their young) and how to sex the animal. Generally it is easier to sex a rodent during the breeding season when the sex organs are enlarged, but in mid winter (and in immature and non-breeding adult males) it is more difficult because the testes are very small and held inside the abdomen. In immature females the vagina may be covered with a membrane and will not be obvious (Gurnell, 2006). "The vagina may close up temporarily during the non-breeding season but the skin over the vagina is rough scar tissue".

Despite this it was possible to identify that the first wood mouse was a male, and it weighed 27 grams. The fur on the right hip on all of the animals was clipped using a sharp pair of scissors. This would ensure animals that were recaptured on the Sunday morning could be identified. The fur regrows in a few days or weeks so has not detrimental affect on the animal. It is ideal for short-term work, but not for long-term work. For long-term work tattooing can be done on the inside of the ear lobe, but is

difficult in small mammals, and applying PIT (passive integrated transponder) tags requires a Home Office Licence (Gurnell, 2006).

A total of eight (8) animals were caught in the 24 traps on the heath - 6 wood mice (5 males and 1 female) as well as a female bank vole and a pygmy shrew (see data in Table 2.1). It was not possible to sex or weigh the shrew as due to the heavy rain it became wet whilst handling it so it was decided to release the animal for its own wellbeing. Starting at 8am, it took a total of one hour and fifteen minutes to inspect all 24 traps on the heath. Once all of the traps on the heath had been inspected and collected the traps in the woods were visited.

**Saturday**

<b>Heathland (24 traps)</b>		
	<b>male</b>	<b>female</b>
Wood mouse	5	1
Pygmy shrew	0.5	0.5
Bank vole	0	1
	5.5	2.5
	<b>8</b>	

Table 2.1 Species captured on Saturday on the heath

Moving into the woods the 24 traps were inspected. The first trap contained a female wood mouse and it was larger and a lot more aggressive than the mice had been on the heath. This was due to the fact that generally woodland is a preferred habitat so the competition for territory is fierce. Animals that are not successful in establishing a territory are forced to move out of the woods, either on to the heath or elsewhere. On average most of the animals caught in the woods were larger and more aggressive than those caught on the heath. After 4-5 animals had been removed, weighed and sexed Dr Pocock felt that Ivan had sufficient knowledge and confidence to continue on his own, with Karen making notes and Emma assisting with the trap inspections (as well as taking photographs), and Dr Pocock made his way home.

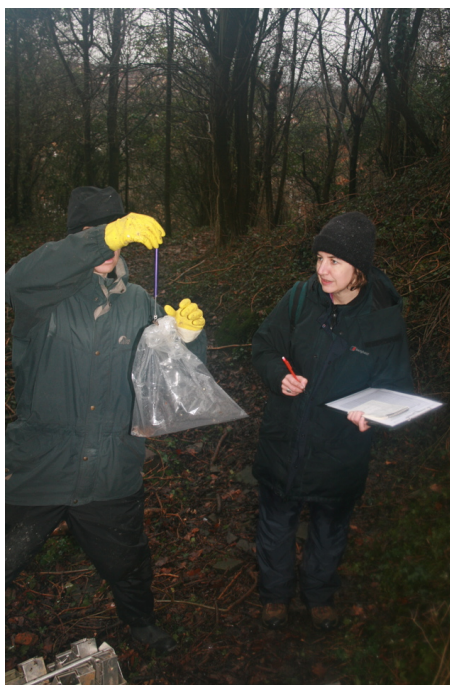


Figure 2.3 Weighing animals in the woods

A total of ten (10) animals were caught in the 24 traps in the wood – all of which were wood mice; 5 males and 3 females (see data in Table 2.2) and all but 2 were sexed and weighed. The 2 that were not sexed or weighed were released when they became too difficult to handle due to their ferocious biting and it was decided that they should not be exposed to anymore stress than was necessary. Starting at 9.30am, it also took a total of one hour and fifteen minutes to inspect all 24 traps in the wood, and all traps were inspected and collected. There was evidence of badger movements in the night as a number of the traps had been moved as if rolled with a paw. All of which were sprung, but empty indicating that possibly the badgers had reached the traps before the small mammals had. It is unclear why a badger would attempt to attack a trap, unless it was out of curiosity, as their diet consists mainly of earthworms as well as fruit, nuts, beetles, even baby rabbits and small hedgehogs (Hart-Davis, 2002), but it was not possible to find any recorded evidence of badgers eating mice, shrews or voles.

<b>Saturday</b>		
<b>Woodland (24 traps)</b>		
	<b>male</b>	<b>female</b>
Wood mouse	5	3
Pygmy shrew	0	0
Bank vole	0	0
<b>Total</b>	<b>5</b>	<b>3</b>
	<b>10</b>	

Table 2.2 Species captured on Saturday in the woods

The traps were cleaned and refilled with fresh hay, oats, casters and carrots in the afternoon of the Saturday. Karen and Ivan then returned to the wood late in evening as the light was fading and laid, but did not set, the 24 traps in the wood. The 24 traps were then laid and set on the heath, and then the traps in the woods were revisited and set.

The heath was returned to by Karen and Ivan on Sunday morning and the first trap was inspected at 8am. Only 6 of the traps were occupied; 5 were wood mice (2 male and 3 female) and of those 4 were recaptures from Saturday (see data in Table 2.3). The sixth trap was occupied by the same female bank vole that had been caught the previous day, identified by the fur clip on the right hip.

**Sunday**

<b>Heathland (24 traps)</b>				
	<b>male</b>	<b>female</b>	<b>recaptures</b>	<b>new</b>
Wood mouse	2	3	4	1
Pygmy shrew	0	0	0	0
Bank vole	0	1	1	0
<b>Totals</b>	<b>2</b>	<b>4</b>	<b>5</b>	<b>1</b>
	<b>6</b>		<b>83.3%</b>	

Table 2.3 Species captured on Sunday on the heath

After inspecting and collecting all of the traps on the heath, the traps in the woods were inspected and it was found that 16 of the traps were occupied. They consisted of 14 wood mice (8 males and 6 females), of which 7 were recaptures from Saturday, and 2 bank voles (1 male and 1 female) neither of which were recaptures (see data in Table 2.4).

**Sunday**

<b>Woodland (24 traps)</b>				
	<b>male</b>	<b>female</b>	<b>recaptures</b>	<b>new</b>
Wood mouse	8	6	7	7
Pygmy shrew	0	0	0	0
Bank vole	1	1	0	2
<b>Totals</b>	<b>9</b>	<b>7</b>	<b>7</b>	<b>9</b>
	<b>16</b>		<b>43.8%</b>	

Table 2.4 Species captured on Sunday in the woods

### **3. RESULTS**

#### **3.1. Summary of processed results**

In total 8 animals were caught on the heath on the Saturday and 6 on the Sunday making a total of 14 over the 2 days of trapping; but of the 6 caught on the Sunday 5 were recaptures – 83.3%. This is compared to 10 animals caught in the wood on the Saturday and 16 on the Sunday making a total of 26 over the 2 days of trapping, but of the 16 caught on Sunday 7 were recaptures – 43.8%. Both Dr Pocock and Dr Smith advised that because of the relatively large number of animals captured over the 2 days of trapping that this level of data was sufficient for this study and there was little need for a second trap laying study later in the year.

##### **3.1.1. Home range**

With the site being 8.4 hectares, the wood takes up approximately 2.0 hectares of the overall site. The home range of the bank vole is 0.20 hectares for the male and 0.14 for the female. For the pygmy shrew it is 0.05-0.19 hectares and for the common shrew it is 0.02-0.08 hectares. The male wood mouse has a home range of 0.23 hectares and the female 0.18 hectares (Delaney, 1982). A home range is best described as “the area over which an animal travels in pursuit of its routine activities” compared to a territory which is described as “any defended area” (Delaney, 1974). The home ranges of small mammals are usually measured by the capture, mark and recapture method. Ideally one needs at least fifteen records from one animal or else the size of its range is only an estimate. Based on this, and the fact that one capture-mark-recapture exercise was done on the site it was not possible to establish the accurate home range of each individual.

##### **3.1.2. Estimation of population size**

Estimating the size of a population of any animals can be very complicated and there are many different models that have been introduced, however there are 2 main models used to establish population size. The first was advocated by C G J Petersen in 1896 when researching the yearly immigration of young plaice into Limfjord from the German Sea (Begon, 1979). This would generally be used to estimate the size of a population where there is neither birth nor immigration (such as a short-term study). There are many other issues to take into account. Using the capture-mark-recapture method is one that has been used in many studies. “The simplest Petersen estimate rests on the assumption that the marks released on the first occasion represent the sum total of marks available for recapture on the second. All alternative methods modify this



assumption to some extent” (Begon, 1979). Capture-recapture methods do not distinguish between death and emigration, nor do they distinguish between birth and immigration.

The Petersen model was used and simplified by F C Lincoln in 1930 to estimate the size of the North American duck population, and it is often called the Lincoln Index (Delaney, 1974). The Lincoln Index can be expressed in this form:

$$N = x_1x_2/y$$

Where  $N$  is the total population within an area,  $x_1$  the number caught marked and released at the first sampling,  $x_2$  the total number caught at the second sampling and  $y$  the number of the  $x_2$  animals that had been marked at the first sampling.

Therefore the data for the heath shows                      And the data for the woods show

$N = 8 \times 6 / 5$	$N = 10 \times 16 / 7$
So $N = 9.6$	So $N = 22.8$

Table 3.1 Data for population size estimate using the Lincoln model

Using the Petersen model the population can be estimated with some confidence in accuracy. During a first visit a random sample of individuals is caught – known as  $r$ . These are marked and released and then mix in with the rest of the population. During a second visit another random sample of individuals is caught: total size  $n$ , of which  $m$  individuals are marked (Begon, 1979). If the size of the population before the visit was  $N$ , then the following equation is true:

$$\frac{m}{n} = \frac{r}{N}$$

i.e. the marked proportion has remained the same, and our random sample of a mixed population reflects this. We can now estimate  $N$ . The symbol  $\hat{N}$  (N-hat) denotes an estimate of  $N$ , and therefore

$$\hat{N} = \frac{rn}{m}$$

Therefore the data for the heath shows

And the data for the woods show

$\frac{5}{6} = \frac{8}{N}$ <p>So <math>N = 9.6</math></p>	$\frac{7}{16} = \frac{10}{N}$ <p>So <math>N = 22.8</math></p>
--	---

Table 3.2 Data for population size estimate using the Petersen model

Using both the Petersen and Lincoln models the population estimate for the heath is **10** (rounded up from 9.6 to the 1<sup>st</sup> whole number) and for the wood is **23** (rounded up from 22.8 to the 1<sup>st</sup> whole number). It should be noted that this population size is based on the animals caught in the traps available that were laid out in an accessible area. It does not take into account any additional animals outside of the trapping area. It also should be noted that the population size is generally at it's lowest in mid-winter and could be more than 5 times higher in late spring or early summer during the breeding season.

### 3.2. Outcome of statistical results

The outcome of the statistical results clearly shows that the population in the wood is 2 times higher than the population on the heath. When looking at the raw data the ratio of the wood mouse population between the wood and the heath is 2 to 1 and this applies to both the total number caught as well as the total number caught less the recaptures. This could be for a number of reasons. Firstly there is more shelter from the elements, from predators and more shelter from humans. Secondly there is potentially more food in the woods as trees produce more fruit, seeds and berries than the heather or bracken on the heath which the small mammals feed on. This is supported by the literature stating that the wood is the preferred habitat for all species as.

### 3.3. Trends in data

The main trend that is evident in the data is that of the difference in the population sizes between the wood and the heath. The other significant data is that of the male and female ratio caught in both habitats as well as the difference in the numbers in the sexes caught on the 2 days. The number of males caught on the heath on the Saturday was 500% higher than females. If the recaptures on the heath on the Sunday are excluded then the numbers were even. This is in comparison with the wood. The number of males caught in the wood on the Saturday was 167% higher than females. If the recaptures in

the wood on the Sunday are excluded then the numbers show that there were 25% fewer males than females.

<b>Sex ratios (male/female)</b>	<b>Heathland</b>	<b>Woodland</b>
Wood mouse	6/2	8/7
Pygmy shrew	0/0	0/0
Bank vole	0/1	1/1

Table 3.3 Sex ratios, excluding recaptures

In basic terms this trend shows that overall there were more males than females caught on the Saturday, but more females than males caught on the Sunday.

<b>Sex ratios (% male/female)</b>	<b>Heathland</b>	<b>Woodland</b>
Wood mouse	75/25	53/47
pygmy shrew	0/0	0/0
bank vole	0/100	50/50

Table 3.4 Sex ratios expressed as percentages, excluding recaptures

## **4. DISCUSSION**

### **4.1. Biological significance in results**

The clear difference in the wood mouse and bank vole population of the wood being twice that of the heath is significant for a number of reasons. Firstly as mentioned above it displays a clear preference for the woodland habitat. It is known that small mammals, like most other wildlife species, will exploit a habitat and the resources it provides. It is also known that it may be that the vegetation diversity and make-up or lack thereof would not encourage a large number of species to utilise it (Delaney, 1974). All three species found on the site maintain a territory so their spatial distribution would appear to be even, however this is complicated by the knowledge that the wood mouse, being partially subterranean as a result of its nest and burrows, generally prefers open areas whereas the bank vole prefers habitats with more ground cover. But there are obviously many woods where both can be found.

### **4.2. Supporting research/secondary data**

Rodents, in particular, will maximise their fitness by optimally regulating both emigration of offspring and immigration of other conspecifics (Anderson, 1989).

“Parents might benefit through dispersal of their offspring if the latter become established in more than one habitat patch. This could help avoid lineage extinction and permit the testing of variable offspring in different environments. The higher the risk of local extinction, the more young should be exported if the benefit is to be achieved”.

### **4.3. Evaluation of methodology**

The use of the Longworth traps has long been considered the most effective way of capturing small mammals for a study of this type. The shelter and relative safety that they provide means that the survival rate of a captured animal is high, indeed no animals perished during this study. It is felt that they were the right method of capture for this study and provided a good amount of quality data from the animals that were encouraged into them by the promise of food, warmth and shelter. The limitations of the investigation stated below meant that simply using signs of the animals was never going to be sufficient to obtain accurate data on the species resident on the site let alone their numbers. Nor would the use of the hair tubes have provided the same level of information about the sex and weight of the individuals, possibly only their species.

#### **4.4. Limitations of the investigation**

There were a number of limitations of the investigation for this study. The first study had to be done in the winter and this presented an issue in that the population numbers would mostly likely be at their lowest as it was at the end of the breeding season i.e. before the start of the new breeding season. Another issue was the weather. It was cold and rainy on the days of the trapping and for a number of days prior to the trapping. This could have a positive as well as a negative affect. The positive being that it would mean that the animals could be more easy to trap as they would have a limited time to forage (however the long nights could contradict this) and the negative being that it could mean that more animals had perished from the elements and lack of available food prior to the study so there would be fewer to trap. The dates that the trapping could be done was limited due to personal and employment restrictions, and was limited by the availability of the traps being borrowed from the University.

The site was also a limiting factor. The mixture of plant species across the site provided a difficult trap laying foundation. The grassland in the northernmost section of the site was unsuitable for laying traps which left the heath and the woods. As this was the intention of the study it was expected. However, the lack of vegetation on the heath meant there were limited places to locate each of the traps in a manner that would optimise the likelihood of encouraging and capturing the animals, but also so that they would be concealed or at least camouflaged from members of the public and their inquisitive dogs. The contour of the land within the woods also provided limitations in the availability of suitable trap laying locations. As previously stated the steep banks on either side of the relatively level main path through the woods caused some problems and meant that there was a restriction to placing the traps closer to the path than was hoped. Knowing that the path was rarely used, especially in winter, and especially with the rain as heavy and persistent as it was meant that it was unlikely that a member of the public would venture into the woods, but it was ensured that they were carefully concealed nevertheless.

#### **4.5. Further work**

Although Michael Pocock and Emma Smith advised that the data from the captured animals was sufficient for this study it would be beneficial to do another trapping study later in the year, or perhaps at the same time a year later, to be able to compare the 2 studies and any differences in the population numbers and species distribution. This

would be even more appropriate if the vegetation on the site had changed between the 2 study periods, whether by the actions of the site management or any other factor.

## **5. CONCLUSION**

### **5.1. Summary of findings**

It was found that the site is separated into three distinct habitats; grassland, heathland and woodland. Without any scientific knowledge it is clear to see that the data shows an obvious difference in the population size of small mammals in the woodland compared to the heathland and this is probably for the reasons stated. It is therefore recommended that the site is managed sympathetically in order to maximise the diversity of plant and insect species as well as small mammal species. This will in turn increase the diversity in terms of the other species to be found and improve the overall ecology of the site.

## 6. REFERENCES

### 6.1. Bibliography

- Anderson, P K. 1989. *Dispersal in Rodents: A Resident Fitness Hypothesis*. The American Society of Mammalogists
- Attenborough, D. 2002. *The Life of Mammals*. BBC Books.
- Begon, M. 1979. *Investigating Animal Abundance; capture recapture for biologists*. Edward Arnold (Publishers) Limited.
- Churchfield, S. 1990. *The Natural History of Shrews*. Christopher Helm (Publishers) Ltd
- Corbet, G. 1989. *Finding and identifying mammals in Britain*. British Museum (Natural History).
- Delaney, M J. 1974. *The Ecology of Small Mammals*. Edward Arnold (Publishers) Ltd.
- Delaney, M J. 1982. *Mammal Ecology*. Blackie & Son.
- Gurnell, J & Flowerdew, J. 2006. *Live trapping small mammals*. The Mammal Society.
- Hart-Davis, D. 2002. *Fauna Britannica*. Weidenfeld & Nicolson.
- Read, H J & Frater, M. 1999. *Woodland Habitats*. Routledge.
- Rose, F. 2006. *The Wild Flower Key*. The Penguin Group.
- Sterry, P. 2005. *Complete British Animals*. Harper Collins.
- Svensson, L. Grant, P. 1999. *Bird Guide*. HarperCollins
- Thompson, A. 2005. *Native British Trees*. Wooden Books Ltd.
- Van Den Brink, F H. 1967. *A Field Guide to the Mammals of Britain and Europe*. Collins.
- Webb, N. 1986. *Heathlands: A natural history of Britain's lowland heaths*. William Collins Sons & Co Ltd.
- Yewlett, G. 1975. *Wildlife Tracks*. Jogger.

### 6.2. Websites

- [http://www.english-nature.org.uk/science/licensing/pdf/shrew\\_general\\_licence.pdf](http://www.english-nature.org.uk/science/licensing/pdf/shrew_general_licence.pdf). Accessed 11 October 2007
- <http://www.naturephoto-cz.com/>. Last accessed 23 July 2008.
- <http://www.troopers-hill.org.uk/index.htm>. Last accessed 29 June 2008.
- <http://www.ukbap.org.uk/UKPlans.aspx?ID=14>. Last accessed 29 June 2008.



## 7. APPENDICES

Project Proposal Form .....	Appendix A
Risk Assessment Form .....	Appendix B
Trooper's Hill 2007 Management Plan .....	Appendix C
Natural England Licence to take Shrews (Soricidae).....	Appendix D
Trooper's Hill Public Rights of Way Map .....	Appendix E
Trooper's Hill Site Features Map.....	Appendix F
Friends of Trooper's Hill Meeting Agenda .....	Appendix G
Raw data of animal species captured .....	Appendix H