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A study of a translocated population of *Anguis Fragilis* in Cornwall, UK

Casey Fuke

Project Advisor: Roy Lowry, School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA

Abstract

A population of slow-worms were monitored throughout August and September 2010 at a roadside location near Dobwalls, Cornwall. The population was released onto the site in 2009 and one of the aims of the study was to determine if the population was surviving in their new habitat. Follow up work post-translocation is rarely done in the UK.

The vegetation was predominantly saplings, young shrubs and rough grassland and black roof felt was used as refugia to attract the slow-worms. The site was visited two to three times a week and the temperature, weather, invertebrates present, sex or age and location of the slow-worms were recorded.

The results found that the site was abundant in invertebrate species that slow-worms could feed on and it was unlikely their distribution was determined by the food source alone. It was also apparent that the site contained smaller microhabitats of damp, sunny and overgrown areas that influenced the slow-worms' location.

It is possible that some individuals had migrated up to 267m from the release point in the one year of being on site. It is a complex combination of many environmental factors that determine where the slow-worms are on site.

The weather conditions including the temperature are very important factors in observing the slow-worms under the refuges. The optimum conditions were 15°C with at least 40% cloud cover and a moderate breeze. When it was too cold or hot very few were recorded.

The distribution of the population in terms of gender and age was heavily weighted towards females and juveniles. This could be due to the fact that they tend to bask and utilise the refuges more or because there were more females in the population but probably due to both.

A number of recommendations have been made including an extended monitoring area and a more detailed food source survey.

Acknowledgements

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Aim
To conduct a reptile survey, using artificial refugia, of the species *Anguis fragilis* for a period of six weeks during their most active time of year in order to establish their success in breeding, their population division in terms of age and gender and any other influencing factors that will affect their distribution on the ground. No previous study has been conducted here before.

Hypothesis
There will be slow-worms on site and the chances of them utilising the refuges will be high due to the density laid out. The population structure will be strongly influenced by the population structure of the original population translocated to Dobwalls. The slow-worms will mostly be found within 100m of the release point.

Introduction

Background
An abandoned site at Doublebois found *Anguis fragilis* (slow-worm) on the area. The site was to be developed and therefore translocation (capture and relocation) was recommended by Green Ecology, an ecological consultancy. Doublebois is situated approximately 5 kilometres west of the village of Dobwalls in Cornwall.

The A38 road used to pass through the village of Dobwalls but the A38 bypass gained approval in the summer of 2006 and it was completed in December 2008 (Highways Agency, 2011). The proposals were for a new 4km stretch of dual carriageway running east/west including a 2km stretch of new road to bypass the village of Dobwalls to the north (Whalley, 2007) as shown in figures 1 and 2.

It was decided that the slow-worm population from Doublebois could be relocated to the roadside of the new A38 bypass at Dobwalls and this was carried out during 2009 from May to August.

All modern developments, particularly large ones such as a road construction will include a detailed ecological survey and action plan. It enforces the law by protecting the listed species, and in most cases it safeguards the environmental integrity of the area.

All species of reptile and amphibian are protected by the UK Wildlife and Countryside Act (1981), under Schedule 5, against intentional killing, injuring or selling (Natural England, 2009). The slow-worm is also BAP (Biodiversity Action Plan) priority species (Natural England, 2011).

During and after development the roadsides also become the responsibility of the Highways Agency and a comprehensive planting scheme was developed.

Expensive bat bridges were also erected over the roads as part of the mitigation plan laid out by their ecological consultant. Compliance with the consultants conditions is mandatory and ecology is now a significant portion of the cost of development.

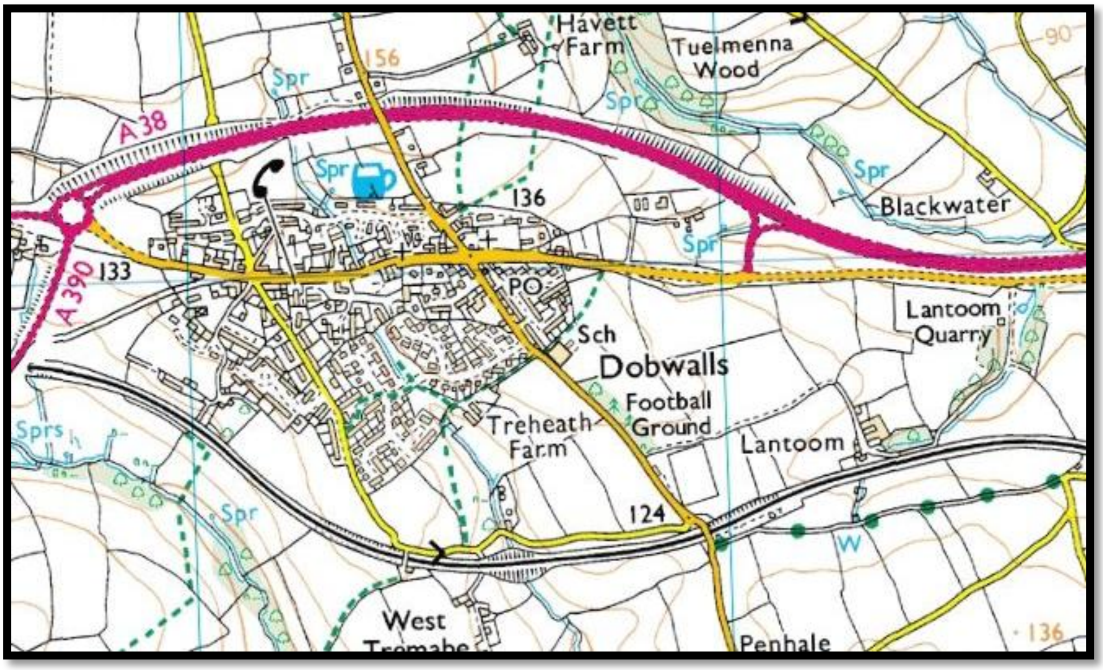

Figure 1: Ordnance map of Dobwalls showing the new route of the A38. (Bing Maps, 2011)

Figure 2: An aerial view of the new site at Dobwalls with the A38 bypass proposal overlaid. N.B. The road has now been built so this is not an accurate representation of the site (Google Maps, 2011).

Literature Review

There are six native reptile species in the UK and all are listed as a UK BAP species (Wright and Baker, 2011). There has not been a great deal of study on the reptile species *Anguis fragilis,* probably owing to the fact that they are a secretive animal (Hubble & Hurst, 2006). The people that are probably most familiar with them today are developers and ecologists who are likely to come across them and must protect them under UK legislation. Urban development poses a large threat to slow-worms particularly because they inhabit brownfield sites that are increasingly being redeveloped (Hubble & Hurst, 2006).

The Highways Agency is aware that it needs to take responsibility for the populations of reptiles in the UK. The construction of many miles of new road every year increases habitat loss, fragmentation and incidental mortality during construction for all six native reptile species. However a new favoured habitat for the *Anguis fragilis* is alongside road embankments therefore post-construction management is also implemented to create suitable new habitats (Highways Agency, n.d).

The best time of year to survey for reptiles is from March to October, but in particular April, May and September. The range of optimum air temperatures for finding reptiles is between 9°C and 20°C where ranges of (10°C to 17°C), (12°C to 20°C) and (9°C to 18°C) have all been noted (Froglife, 1999), (Griffiths and Inns, 2003). The best time of the day is either morning, between 8.30am and 11.00am, and in the late afternoon between 4.30pm and 6.00pm (Froglife, 1999).

Description

Commonly mistaken for a snake the slow-worm does move like and superficially look like a small snake growing up to 50cm in length (Beebee & Griffiths, 2000), but it is in fact a legless lizard from the *Anguidae* family and the *Anguinae* subfamily (Pough et al,. 2004). It is sometimes referred to by the name of 'blind-worm' because they have eyelids and snakes do not. Snakes just have large unblinking eyes and this is a primary identification feature between slow-worms and snakes (Beebee & Griffiths, 2000).

The *Anguis fragilis* has 26 rows of smooth scales (Beebee & Griffiths, 2000). The scales are very small, giving a shiny, smooth, silky texture (Froglife, n.d.). The females have different markings to males. The males are generally uniform in colour but their colours can vary from grey, brown and copper variations. They will sometimes have dark markings on the sides of their bodies which can lead to some confusion in identification as this is a female trait (Beebee & Griffiths, 2000). The females often have a dark stripe running down their back, but not always. The belly usually remains black (Smith, 1969), with dark markings on the side of their bodies too. Sometimes these are longitudinal lines or they can be broken into spots or dashes (Beebee & Griffiths, 2000). Juveniles have a very distinct black vertebral line that starts as a black spot on their head and extends to their tail, they are all a light gold, silver or copper colour, and also have a jet black belly. The young measure between 65 to 90mm but it is rare to be less than 75mm (Smith, 1969). It is impossible to distinguish the sexes in the newborns because their markings are universal (Beebee & Griffiths, 2000). The sub-adults will still have some of these juvenile markings until they become distinguishable by the end of their fourth year (Smith, 1969).

Males also have a larger and broader head than females which enables them to be identified easily in the field (Beebee & Griffiths, 2000).

There is a subspecies of slow-worm that bears blue spots and is called *Anguis fragilis colchica.* However some *Anguis fragilis* can also have blue spots but this is not frequent and are mainly only prevalent in the males (Beebee & Griffiths, 2000).

Location

The *Anguis fragilis* can be found in almost all European countries and extends eastwards through the Balkans, the Caucasus and into Southwest Asia and into western Siberia (Beebee & Griffiths, 2000). It is not found in southern Spain and Portugal, nor in southern Greece or many Mediterranean islands or Ireland (Arnold, 2002) although there is an introduced population in the latter country (Beebee & Griffiths, 2000). The slow-worm is also absent from the extreme north of the European continent (Arnold, 2002). England is not the slow-worm's northern boundary as some have been recorded in Scotland (Reading, 1996). The limiting factor at the northern boundary of its territory is the low temperatures that can affect hibernation, and in the south it is the lack of precipitation (Beebee & Griffiths, 2000). In southern regions the slow-worm can be found up to 2,000m and up to 2,400m in the Alps (Arnold, 2002). In the UK in the 1960's it was particularly abundant in the South-west (Smith, 1969).

Habitat

The slow-worm can be found in a number of habitats, all of which tend not to be too boggy or marshy, although the animals do like slightly damp conditions. In the same respect they do not like very dry or arid habitats (Beebee & Griffiths, 2000). The common habitats that slow-worms will be found in are scrub-land, "rough grassland, hedgerows, heathland, woodland edges, downs and moorland" (Beebee & Griffiths, 2000).

They often occur near to man-made habitats such as road and railway embankments, allotments, gardens, churchyards and parks. Any place that provides dense vegetation as well as basking areas are ideal (Beebee & Griffiths, 2000). The *Anguis fragilis* is secretive and spends a lot of its time below the surface in the roots of dense vegetation or loose soil (Arnold, 2002). In a study conducted into the population structure and translocation of the slow-worm "only 3 of 577 slow-worms captured were found moving or basking on the surface" (Hubble & Hurst, 2006).

Often they are found near ants' nests, probably because it utilises the loose soil to manoeuvre and not because it is a feeding source (Beebee & Griffiths, 2000), (Smith, 1969). In grassland areas they also utilise the thatch and litter layer (Wright and Baker, 2011) which is formed when the long grass (knee high) collapses in the autumn and the new blades will grow through the dead layer in the next spring. Other small mammals and animals also use this as their habitat; field voles will build a network of tunnels and latrines in the thatch (Barn Owl Trust, 2006) that slow-worms could utilise. Compost bins also provide a good habitat for the slow-worm to burrow in and provides warmth which aids thermoregulation (Beebee & Griffiths, 2000). Slow-worms also utilise stone walls and piles of rocks or debris and discarded sheets of tin or rubber mats to secretly bask under (Arnold, 2002). The use of artificial refuges such as corrugated iron is an efficient way of finding slow-worms and snakes, but not for detecting sand lizards or common lizards (English Nature, 2005).

Population

Figures of population densities can range from 600-2,000 per hectare (Arnold, 2002). Slow-worm populations are poorly understood and so accurate population sizes and distributions are not known. In the past reptiles in temperate zones have often been neglected in zoological studies (Webb et al, 1978). However by using a capture-mark-recapture method one can at least estimate a population size (Spellerberg, 1982).

Some studies carried out have shown a sex dominance but this has not been consistent with either male or females being the dominant. One translocation by Hubble and Hurst saw twice as many adult females as adult males but other similar observations have been put down to gravid females basking more and are therefore easier to capture (Hubble & Hurst, 2006).

NARRS (National Amphibian and Reptile Recording Scheme) set up survey squares around the UK that were visited in 2007-2009 and the results showed that slow-worms occupied 22% of the squares compared with 32% by the common lizard *(Zootoca vivipara)*, 13% by great crested newts *(Triturus cristatus)* and 19% by the grass snake *(Natrix natrix)*. The slow-worm was in the middle of the data showing it was not the most common but not the most threatened reptile species (Reynolds, 2011). However according to Baker, Lucy and Howard in 2009 the slow-worm is the most likely reptile to be seen in the garden.

Diet

Anguis fragilis feed on a variety of invertebrates such as earthworms, slugs, snails, pill millipedes (*Glomeris marginata*), and lepidoptera larvae (Jensen et al, 2009). The preferred food source are small white slugs (*Agriolimax agrestis)* (Smith, 1969) but spiders and other insects have been known to be consumed, but in captive animals nearly 70% of the slow-worms stomachs contained molluscs and earthworms (Beebee & Griffiths, 2000).

“Step (1921) records that an adult male slow-worm in his possession once devoured 17 slugs in succession” (Smith, 1969).

Predators

The slow-worm has many predators; the juveniles even more so because they are sometimes mistaken for earthworms, because they are the same size, and eaten by some animals including frogs and toads. The list of predators to slow-worms includes the smooth snake, hedgehogs, vipers, badgers, foxes, rats, fowl, some birds of prey such as the kestrel, other birds (Smith, 1969) and the domestic cat (Baker and Carey, 2004).

Breeding

Males and females mate between May and June and the males will fight between each other during this period. The fights are often witnessed in the open but copulation between the males and females mainly occurs in seclusion (Smith, 1969). Females start reproducing from the age of four years (Smith, 1969) and will give birth from late August through September (Beebee & Griffiths, 2000). The female gives birth to live young (ovoviviparous birth) (BBC, 2010) and the litter size is usually between 6 and 12 but can range from 3 to 26 (Arnold, 2002).

“Females are able to breed once they achieve a total length of 280mm, but the majority do not produce young every year. A biennial breeding cycle is the norm in Britain, although this does depend upon size and environmental conditions.” (Beebee & Griffiths, 2000).

Some reptiles have evolved temperature-dependant sex determination (TSD) as well as the genotypic sex determination (GSD) method shared with humans. Neither form of sex determination conforms to a single pattern. For example in turtles low temperatures produce males but in some lizards the converse is thought. It is not stated how the slow-worm in particular exhibits this trait (Mattison, 2008).

Behaviour and characteristics

In the wild there are records of slow-worms living for 27, 30, 32 and 33 years (Smith, 1969) although 10 to 15 years might be a better average life expectancy (Arnold, 2002). There are many recordings of the individual that lived in captivity for as long as 54 years; the age of the animal on arrival was unknown (Smith, 1969).

The slow-worm is found active between April and October (WSBRC, n.d) and hibernates during the winter. Places that are used for hibernation include holes in hedgerows or banks, underneath piles of leaves or stones (Smith, 1969) that act like a hibernacula. They can hibernate in groups or singly and are one of the first reptiles to emerge in the spring in March (Smith, 1969).

It is semi-fossorial (burrowing) which means it spends a lot of it’s time underground and underneath objects (BBC, 2010). It is thought that if the environment provides a good food source, sufficient cover and the temperature remains constant then the slow-worm is not inclined to move any great distance and can remain in a small area of 1 to $2m^2$ for long periods of time (Hubble & Hurst, 2006).

An unusual behaviour observed in the *Anguis fragilis* was of a juvenile found in a puddle, then after 5 minutes of laying on the ground was seen diving back into the puddle, either as an escape or to find prey (Gollmann & Gollmann 2008). Smith (1969) reports that slow-worms do not freely enter water but if thrown in they can swim well, but will not stay in the water long or they will drown.

The slow-worm as a lizard has the ability to lose its tail by consciously breaking its tail vertebrae that has a fracture plane, a process known as autotomy. It can only do this once and a new tail will grow back but it will be significantly shorter than the original. This function is to allow it to escape predation but involves costs in reduced movement and agility as well as metabolic resources. It is thought that animals that have undergone autotomy are less successful at reproduction and are more likely to spend time closer to hiding places. Another anatomical feature that lizards have is the ability to move their upper jaws as well as their lower jaws (Beebee & Griffiths, 2000).

The slow-worm often lies still and moves slowly but if it is disturbed or frightened has the ability to move very quickly (Smith, 1969). Lizards shed their skin and the slow-worm is no different (Smith, 1969).

Thermoregulation

Slow-worms are cold-blooded or *poikilothermic* and are *ectotherms,* meaning they do not generate their heat internally but source it from the external environment. This is also sometimes referred to as *behavioural thermoregulation* because it requires the animal to move according to whether they need to heat up (in warm areas) or cool down (in shaded areas) (Avery, 1979).

Protection

Reptiles such as adder, common lizard, slow-worm and grass snake are protected against intentional killing, injuring or selling, and the smooth newt, palmate newt, common frog and common toad are protected only against sale. Species such as the smooth snake, sand lizard and great crested newt are also protected by European legislation (Natural England, 2009).

Slow-worms are protected under the UK legislation below and a £5,000 fine could be incurred (English Nature, 2005):

- Bern Convention 1979: Appendix III
- Wildlife & Countryside Act (as Amended) 1981: Schedule 5
- Countryside Rights of Way Act 2000

Mitigation and translocation

Translocation is “the intentional release of individuals to establish or enlarge the population of a target species” (Vitt & Caldwell, 2009). Repatriation, a form of translocation, is the release of individuals of a species into a locality from which the species was extirpated. Translocation is only considered as a last resort because this method is not always successful and is costly in both time and money (JPR Environmental, 2010). An ecological consultants’ suggestion of another way of protecting slow-worms from harm during development is to use reptile fencing (Green, 2010)

Vitt and Caldwell believe that largely translocations fail. One example is in south-east England when a population was translocated to an ecologically similar site, but it failed. This failure is probably because the individuals were not as robust as neighbouring populations. Translocations enable the public and developers to put their minds at rest by believing natural populations have been conserved however this is not always the case. Few translocations include follow-up monitoring but one study found out of the hundreds of gopher tortoise *(Gopherus polyphemus)* translocations, at least 50% of the relocated individuals are gone within 2 years. Relocation can also introduce disease into healthy populations (Vitt & Caldwell, 2009).

If translocation is the best option then "structures known as hibernacula can be constructed to greatly improve conditions for slow-worms. Hibernacula provide hibernating habitats giving protection from even the most severe frosts and when scrub vegetation has grown on top of the structure they can also provide foraging and basking habitats" (JPR Environmental, 2010). In addition to a hibernacula a scrub management plan and south-facing slopes are required when introducing slow-worms to new habitat (Taylor, 2008).

Due to the fact that translocations are becoming a common method of mitigation in the UK, this investigation of a post-translocated population is important because currently there are few national monitoring schemes to evaluate population trends or the success/ failure of mitigation methods already carried out (Baker and Carey, 2004).

Surveying
Due to the fact that reptiles need to bask because they are cold-blooded provides an easy way to survey for slow-worms. The method is to lay out artificial refuges such as dark roof felt or corrugated iron sheets that the animals will utilise. Transect walks can also be used to record reptiles and this means that there is no human influence on the habitat but produces fewer sightings. Sand lizards are the only reptile species that will not be found easier by using refuges because they tend not to utilise them (Reading, 1996). The best months to survey are May, June and September and the worst are March, July and August (Reading, 1996) shown in figure 3, not including the months of hibernation. The refuges will require a settling in period of a few days (Hubble & Hurst, 2006) but some leave it longer. For example Green Ecology are ecologists that leave them for a week and this enables the reptiles to find them.

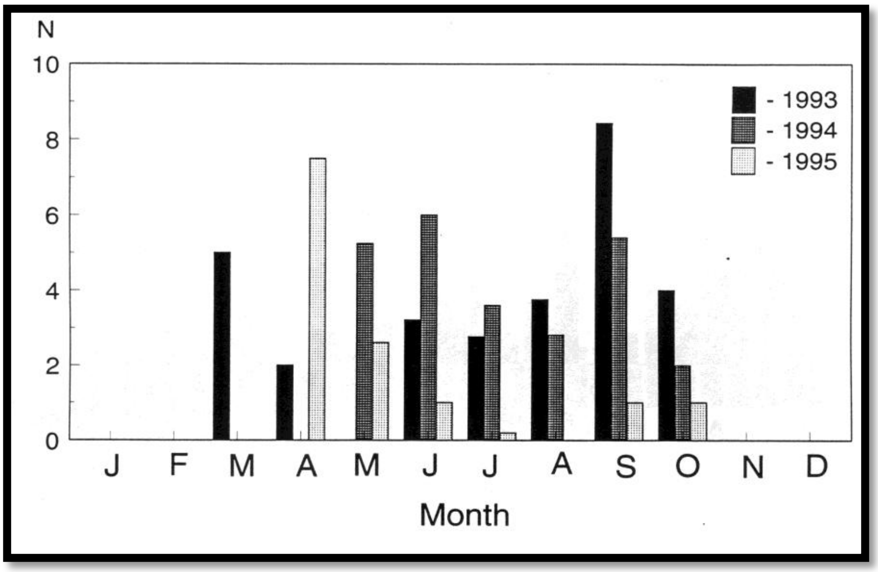

Figure 3: This graph shows the average number of slow-worms captured (by English Nature in their study) per visit per month for three different years 1993, 1994 and 1995 on the same site (Reading, 1996).

A study conducted by English Nature sought to identify an effective, systematic and standardised way of arranging the refuges on a site to make it possible to:

- compare sites,
- determine presence/absence and
- determine population size (Reading, 1996).

The best standardised method that enables ecologists to compare sites is to have a hexagonal array of 37 refuges laid 10m apart, at a density of 127/ha (Reading, 1996). A different translocation exercise undertaken by Hubble and Hurst used a density of 1170/ha and it was found the capture rate increased as refuge density increased and this did not lead to a tail-off at high densities (Hubble & Hurst, 2006). For translocation it might be necessary to increase the density to make certain all the animals are captured. The captured population at the site investigated by Hubble and Hurst was also a lot larger than was originally estimated (Hubble & Hurst, 2006).

"Each array should be visited/searched 15-20 times throughout the period April to October" (Reading, 1996).

When determining the presence or absence of a species on a site the arrangement of the refuges is less important than the time of year of the visit (Reading, 1996) and the weather conditions will also affect whether or not the slow-worms will be basking under the mats. If it is too hot or raining too heavily then they are unlikely to be out (Hubble & Hurst, 2006). It is important to record the weather conditions when making a site visit as well as temperature because the results as discussed will be affected greatly by this.

Determining the population size on a site involves using as large an area as possible including all the places they are suspected to be. Individuals can be painted or dyed, or identified by their markings (Baker and Gent, 2003) which is more time consuming but less expensive. Lizards can have their nails clipped in various patterns to determine individual from individual (Reading, 1996). There is however no recognised standard way of surveying for and the translocating of slow-worms; only guidelines are offered by the Herpetofauna Groups of Britain and Ireland (Hubble & Hurst, 2006).

Site Description

The site is approximately 1 hectare in size (10,000m^2) and is the buffer zone between the new A38 bypass and private land. The site consists of a bank that runs parallel to the road and drops down quite steeply to the south particularly as the bank gets closer to the slip road. The site also includes a privately owned field that is triangular in shape. The access to the field was via the southern point.

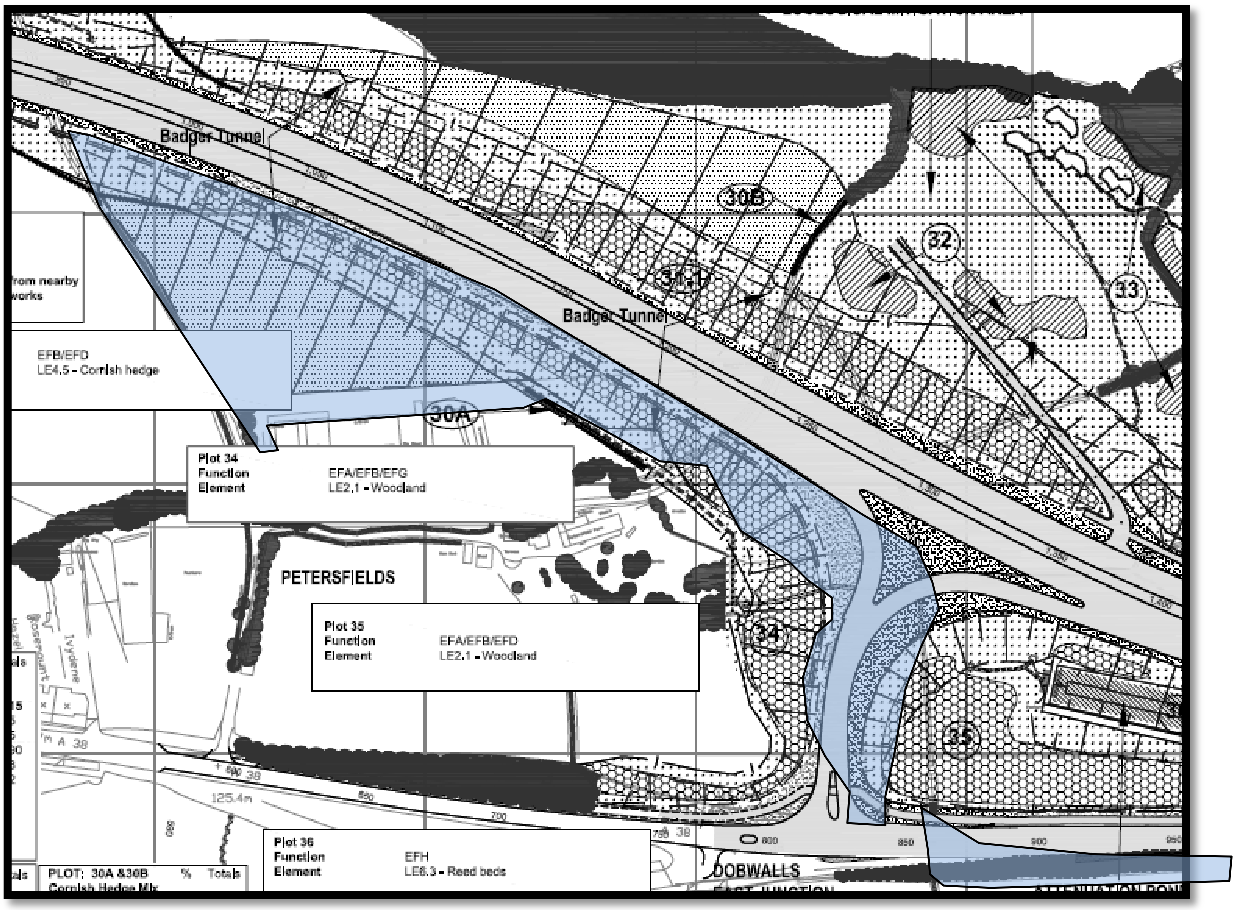

Figure 4: A portion of the planting map showing the area monitored in blue. (Produced for the Highways Agency, 2006). N.B The larger version is in Appendix C.

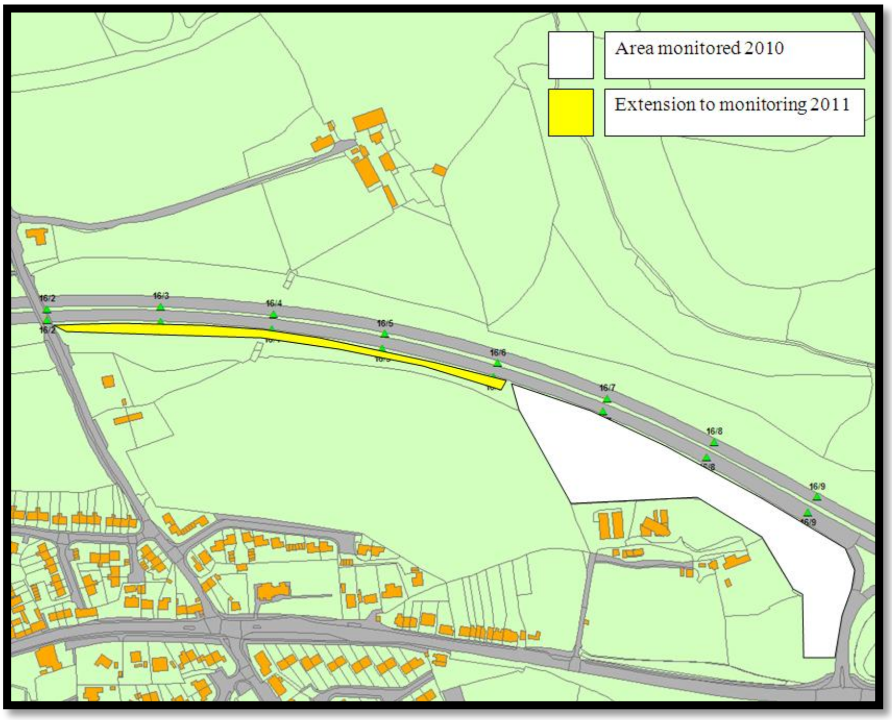

Figure 5: The site in general. The area for extended monitoring is shown in yellow.

Plate 1: A view of the eastern end of the site and the slip road.

Plate 2: A view of the western end of the site. The dark green hedge line represents the boundary of the site.

The slope is south facing and there is a gully that runs along the boundary with the private land at the bottom of the slope. It is about 40cm deep and 50cm wide.

A hibernacula was created when the slow-worms were released. The translocated slow-worms were released from here and this is known as the release point. Mat 11 is situated on the hibernacula and is at the location that the photographs shown in plate 1 and 2 were taken from.

A control, of 5 mats, was set up on the other side of the slip road in a sectioned off area used as an oil interceptor where slow-worms had not been released into (plate 3). The same planting scheme was used in the control area as the main site.

The ground was newly planted with a considered species planting arrangement. At the time of survey the vegetation was short. The vegetation and ground cover was not uniform over the site. The bank and lower fence line was planted with grass species listed in table 2. The middle section was planted as woodland with tree saplings species such as Sessile Oak *(Quercus petraea)*, Common Ash *(Fraxinus excelsior)*, Common Beech *(Fagus sylvatica)*, Alder *(Alnus glutinosa)* and Field Maple *(Acer campestre)*, shown in table 1.

The private field was overgrown and can be seen in the left edge of plate 2. It consists mainly of tall broad leaved dock (*Rumex obtusifolius)* and grass species and was unmanaged, but the landowner planned to graze sheep here after the experiment was collapsed.

Table 1: Planting plan for plots 34 and 35 on the planting scheme map (Appendix C). The main investigation site and the control site respectively.

Species common name	Latin name	Percentage
Sessile Oak	*Quercus petraea*	5
Common Ash	*Fraxinus excelsior*	20
Common Beech	*Fagus sylvatica*	20
Alder	*Alnus glutinosa*	5
Field Maple	*Acer campestre*	5
Common Hazel	*Corylus avellana*	20
Goat Willow	*Salix caprea*	5
Grey Willow	*Salix cinerea*	5
Common Hawthorn	*Crataegus monogyna*	5
Blackthorn	*Prunus spinosa*	5
Holly	*Ilex aquifolium*	5

Table 2: Planting plan for grassland areas on the planting scheme map (Appendix C). This is the perimeter of the site shown by dots in figure 4.

Species common name	Latin name	Percentage
Strong creeping red fescue	*Festuca rubra*	35
Slender creeping red fescue	*Festuca rubra*	10
Hard fescue	*Festuca longifolia*	25
Brown top bent	*Agrostis capillaris*	10
Smooth stalked meadow grass	*Poa pratensis*	20

The site was bordered by the A38 to the north and the slip road to the east that slow-worms were unlikely to cross. On the western side was a large hedge approximately 7m tall with open playing fields the other side. The private land to the south describing from west to east was a mixture of overgrown vegetation and abandoned rubble, maintained lawns and gardens, a couple of large fir trees with occupied horse stables and a grazed field holding sheep.

Plate 3: The control site situated on the other side of the slip road.

Method

Preliminaries

A preliminary site survey was conducted on 29/08/2010. On arriving on the site for the first time a risk assessment was carried out (Appendix A). It was also clear that the large fenced off area within the translocation site was unlikely to belong to Enterprise Mouchel, an agency contracted by the Highways agency. The fenced grassland area was also more overgrown than was expected. Slow-worms utilise the sunlight so vegetation that is too tall is not ideal as the sun gets blocked. The landowner was very unwilling for the experiment to take place due to his prior dislike for the Highways agency. This was understandable considering his property now sits approximately 65metres from the newly built A38 dual carriageway. After assurance that we had no affiliation to the Highways agency he agreed to the placement of the refuges.

It was originally thought that the new site did not contain any slow-worms before releasing the new population. To an extent this is true because the site was cleared of reptiles before development. However the land owner had sighted them on and around his property, particularly on the stone walls that surround his house and garden. This means that any observations during the experiment cannot positively be identified as the translocated population as individuals could have migrated from the privately owned area of land.

Setting Up

Black roof felt cut into 50x50cm squares were used as the refuges and are referred to in this report as refuges or mats (shown in figure 6). Two people laid them in the transect arrangement shown in figure 7 at 11 pace intervals following research conducted by English Nature;

“the best method for surveying sites for reptiles was the use of artificial refuges laid out in a basic array of 37 refuges spaced 10m apart (Reading, 1996).

11 paces equates to approximately 10 metres. An accurate measurement of the distance of each mat from the release point was taken at the end of the experiment but due to mat movement and suitable placement the tiles were not all precisely 10 metres apart. A suitable position is not a bias towards the experiment but for example if at 11 paces there was a bush or tall broad leaved dock the mat was laid next to it and not under or on it as this would almost certainly not attract any slow-worms. Also as the grass became yellow under the mats they were moved slightly to uncover part of it.

Figure 6: Black roof felt used as refuges.

The recommended density of refuges by C J Reading is 127/ha based on the hexagonal array structure. This structure has not been adopted at the Dobwalls site due to the linear shape of the site however the density was used. There were 3 transects running parallel with the A38. The first passed through the release site along the highest bank (transect 1), the other followed along the fence line boundary between the site and the neighbouring private land (transect 2) and transect 3 ran between transects 1 and 2 as the fence and road become further apart as shown in figure 7.

Site investigations carried out by many ecologists using refuges such as these are normally used to determine whether or not the area is inhabited by reptiles. They place them in likely favourable areas or “hotspots” to increase their chance of finding them, however it does not give a detailed picture of their distribution but this is not what they require. One of the aims of the survey was to determine the distribution of reptiles over the site. Therefore placing the mats at equal intervals covering the whole area would determine this. Placing the mats purely in favourable areas would be biased towards finding them and would not show an overall distribution although it might have increased the numbers found.

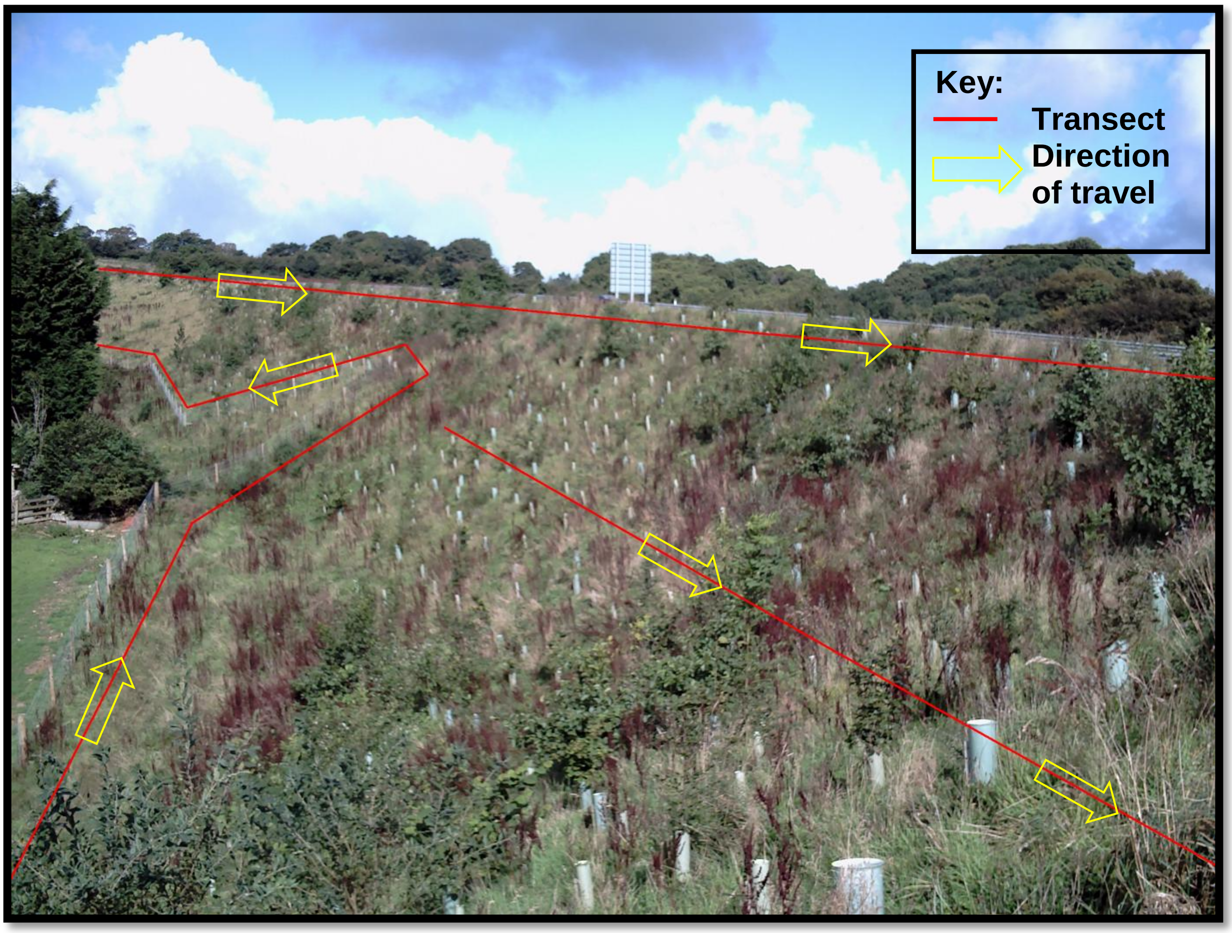

Plate 4: A view of the centre of site taken from the eastern end near mat 43. The red lines indicate the transect of tiles and the yellow arrows the direction of travel along the transect.

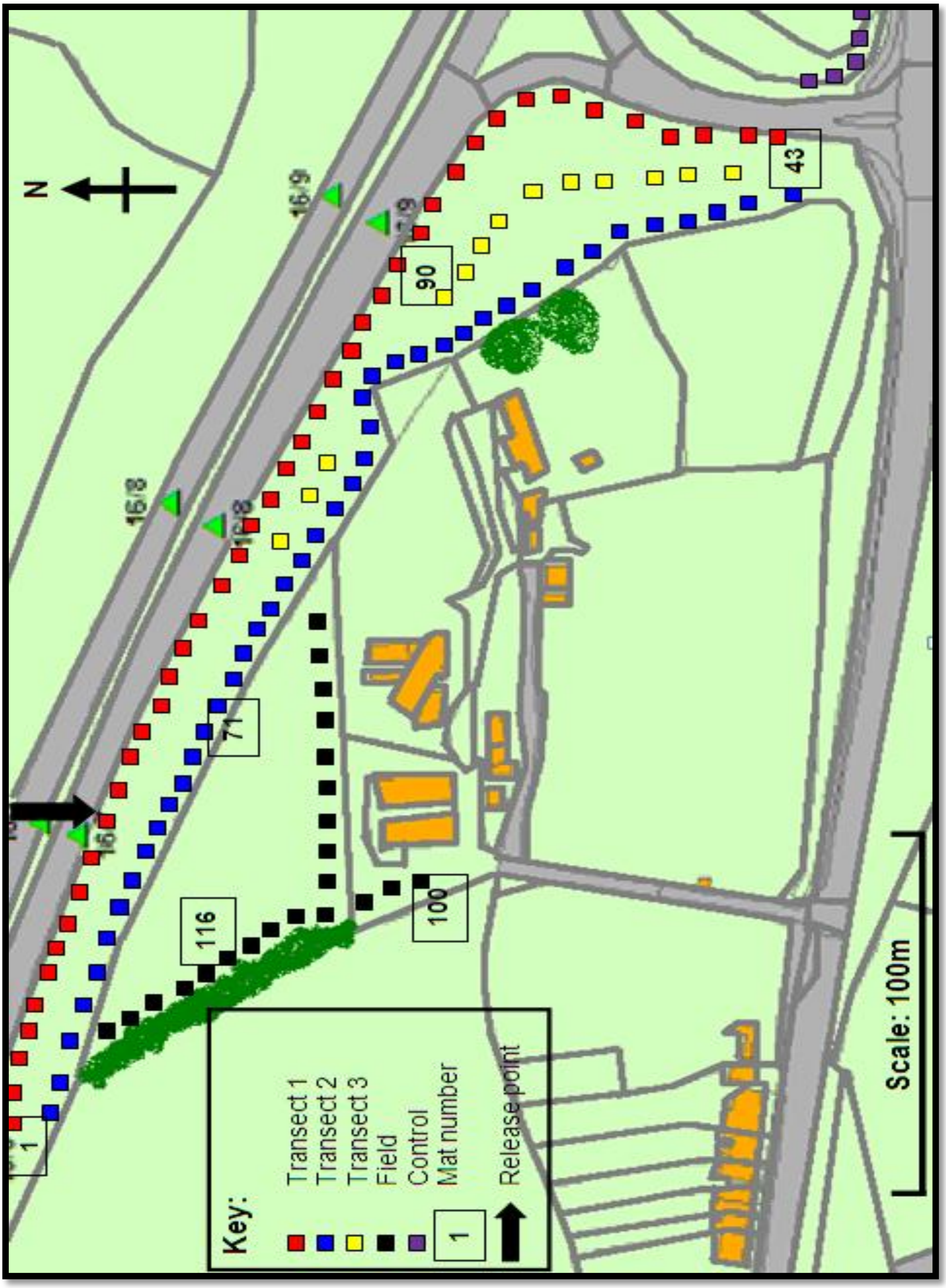

Figure 7: A diagram of the area surveyed showing the arrangement of tiles, the location of the hibernacula and the release point.

Survey Method

The site was sometimes visited in the morning and sometimes in the afternoon bur never twice in one day. This was to get a variety of results and weather conditions. The site was monitored 2-3 times a week depending on the weather. If it was raining heavily then no monitoring took place as it would be a poor use of time to drive to the site and not record the maximum number of slow-worms possible.

On arrival at the site the Network Control Centre was phoned to alert them of our presence along the roadside. High visibility trousers and a full length sleeved top must also be worn due to the proximity of some of the mats to the road. A mental risk assessment must be carried out at the start of each visit to ensure there are no new hazards or risks. The weather and temperature were then recorded. The thermometer was placed under the car so it was out of direct sunlight and left for 5-10 minutes before reading the temperature.

A set route was walked every visit. The tiles were numbered in the order of the route and started at the north western corner of the northern transect. The route followed along the northern transect (transect 1 in figure 7) to mat 43. Mat 44 was at the bottom of the slope at the eastern end and the route continued along the bottom transect back to the western boundary shown by transect 2 in figure 7. The middle transect was then walked from west to east. This is shown in plate 4 and figure 7. The access to the field was from a track from the south and was checked after the main site. The three tiles outside of the field were checked then the lower transect running from west to east and finally after cutting back to the corner of the field the vertical transect was checked.

Each mat was lifted in order and the number of slow-worms found and the sex and/ or age (juvenile, sub- adult or adult) noted on the slow-worm recording form (Appendix B). During the first four visits the number and species of invertebrate present under each mat that were edible to slow-worms was recorded. Once the survey was complete the Network Control Centre must be informed that the person is leaving the site.

Each visit took approximately 2 hours for the first few visits when invertebrates were also being recorded and by the end of the six weeks it took around 1.5 hours as the identification became easier and the route was well trodden.

Identification

The juveniles are the easiest to identify because they are smaller (about 7cm in length) and have a very distinct pattern. There is a black stripe running down their back and they also have very dark sides as shown in plate 5. The sub-adults are bigger versions of the juveniles and they share the same pattern but it is not as distinct in some of them. The sub-adults were approximately 12cm in length but distinctly wider than the juveniles

.

Plate 5: A juvenile slow-worm with its markings clearly shown.

The female adults were again larger but still retained the juvenile features of a vertebral stripe but it is less dark and not continuous in many of the females. Female slow-worms also retain the dark sides. The males in comparison are very uniform in colour and lose their juvenile markings. They also have a larger head and by using these features this species is quite simple to identify in the field.

Plate 6: A gravid female slow-worm. She still retains her dark sides and dorsal stripe

Results

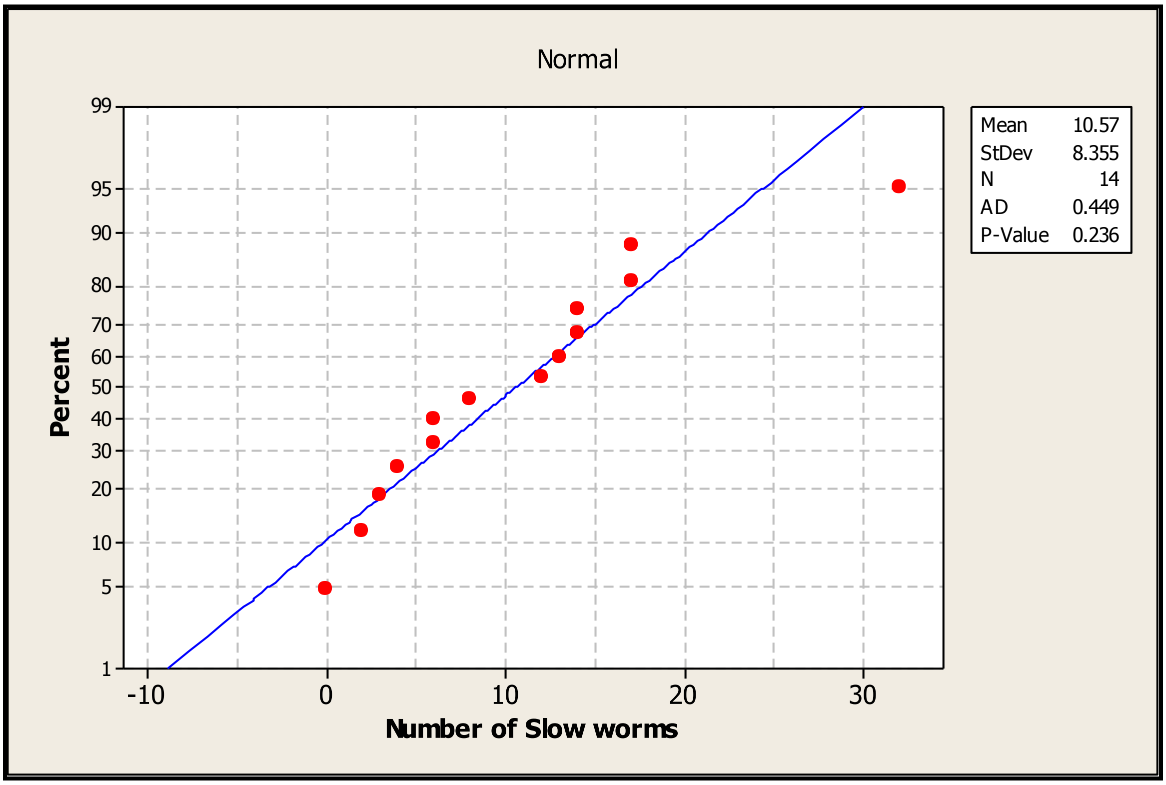

Figure 8: Normal probability plot of the number of slow-worms recorded at varying temperatures.

The red data points in figure 8 sit close to the blue line and the p-value is greater than 0.05 which means the data comes from an underlying normal distribution. This is useful because other statistical analysis rely on this assumption.

Table 3: Basic statistical calculations.

Number of visits/ data sets	Mean number of Slow-worms observed per visit	Standard deviation	Minimum number observed	Maximum number observed	Median
14	10.57	8.35	0	32	10

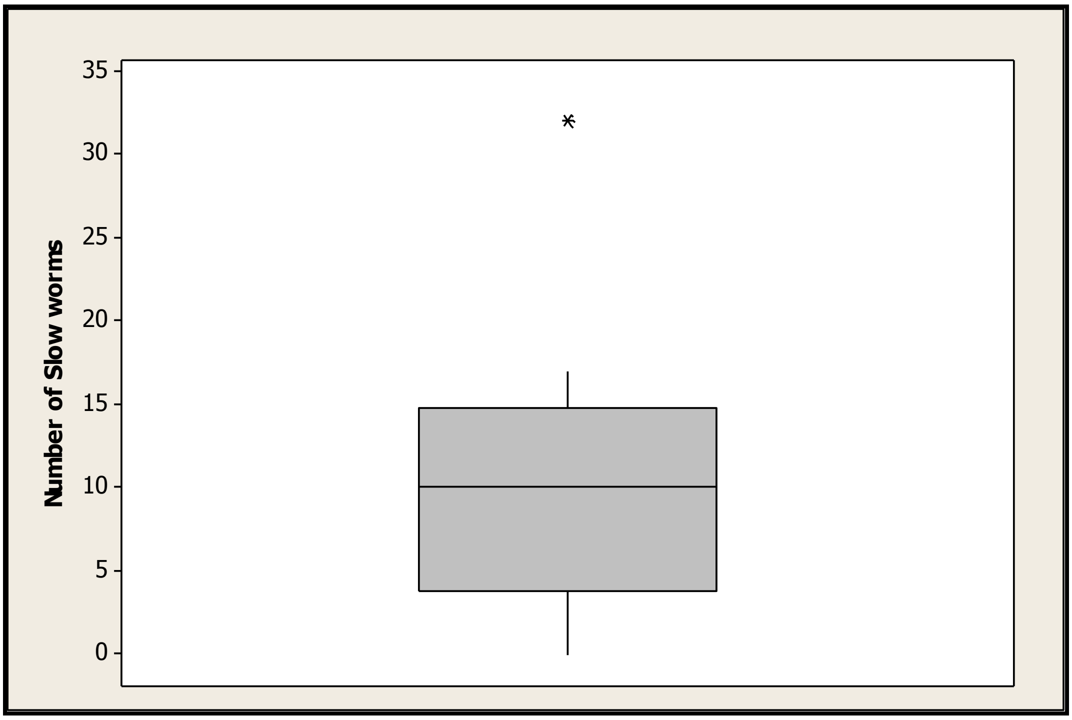

Figure 9: A box-plot to show the total number of slow-worms observed on each visit.

The anomaly shown by the asterix in the box-plot in figure 9 has increased the mean and standard deviation value for the data sets. The anomaly is the 32 slow-worms recorded on 10/09/10. If this figure is taken out of the data then the new mean is 8.92 and the standard deviation is 5.87, compared with those in table 3. The lower the standard deviation is the less variation there is in a data set, so a high value shows a larger spread in data. It is better to have a smaller standard deviation, however this anomaly is an integral part of the results as it indicates the potential size of the population. All results are valid in this type of experiment.

Observations

No slow-worms were recorded in the open, they were only observed under the mats. During the first few visits the number of slow-worms recorded was low and this is most likely to be because the tiles had not yet been located.

Other species such as field vole *(Microtus agrestis)*, common toad *(Bufo bufo)*, a large number of a spider species likely to be the garden spider *(Araneus diadematus)*, a number of ants nests under the mats and a large moth species were also recorded on the site. Another reptile study at RAF Fylingdales also recorded ants nests and the common toad under their refuges (Rowe, 2004) showing that they like the same type of habitat.

There were approximately three occupied field vole nests underneath the mats laid out for the investigation that contained young (plate 7). There were also many tunnels and signs of field vole activity under other mats as shown in plate 8. This is relevant because the tunnels and aerated thatch could also be used by the slow-worms.

The common toad was recorded under mat 109 on five occasions. Mat 109 was situated in the triangular private field along the transect running east to west. These other species present on site will help to further indicate the conditions of the habitat or microhabitats that exist on site and influence where the slow-worms are situated.

Plate 7: Newborn field voles underneath mat 6 on 09/09/10.

Plate 8: Evidence of field voles building nests and tunnels all over the site.

Food

During the first few visits the invertebrates present under each tile was recorded. The species that were found on site that would act as a food source included woodlouse (the most common species are *Porcellio scaber*, *Armadillidium vulgare, Philoscia muscorum*, *Oniscus asellus* and *Trichoniscus pusillus* (Imperial College, 2000)). As well as earthworms and slugs of which there are many species. When the vegetation and ground was dry there were many flying insects and woodlice present. During wet periods there were many slugs present and this is the slow-worms preferred food (Baker et al, 2009).

Table 4 shows the species recorded under three mats chosen at random on the first three visits. The first three visits were used because they have a varied temperature range.

Table 4: The food species present under mats 1, 30 and 92 on three separate days.

Mat number	**Distance from release point (m)**	**Date: 3/8 Temperature (°C): 13**		**Date: 9/8 Temperature (°C): 11**		**Date: 12/8 Temperature (°C): 16**	
		Species Present	**Quantity**	**Species Present**	**Quantity**	**Species Present**	**Quantity**
1	100	Slug	3	Wood louse	>10	Slug	1
30	140	Slug	>10	Small Slug	>5	Wood louse	>10
92	215	Slug	>10	Slug	>10	Worm	>5

Weather

Table 5: The temperature and weather conditions recorded on each visit, the time of day and the number of slow-worms observed.

Date	Weather	Morning/ Afternoon	Temperature (°C)	Number of Slow-worms recorded
3/8	50% White cloud Slight Breeze Sunny Ground damp	**M**	**13**	**2**
9/8	100% overcast No breeze Spots of drizzle	**M**	**11**	**3**
12/8	90% Grey cloud Breeze Sunny Intervals	**A**	**16**	**14**

	Ground dry			
16/8	Clear blue sky Warm Very slight breeze	**M**	**17**	**4**
17/8	90% Grey cloud. Breeze Spots of Drizzle Been a warm muggy day	**A**	**21**	**6**
19/8	100% grey cloud Intermittent breeze and showers	**M**	**16**	**13**
23/8	0920: 100% grey cloud and rain 0935: 90% grey cloud Patches of sunshine and breezy	**M**	**14**	**8**
27/8	20% white cloud Blue sky and sunny Strong breeze	**A**	**20**	**6**
31/8	5% White Cloud Blue sky Light breeze Damp grass and cold the previous night	**M**	**16**	**14**
1/9	70% cloudy haze Sunny Moderate breeze	**M**	**15**	**12**
2/9	60% White Cloud Warm sunshine Dry Ground	**A**	**20**	**0**
7/9	50% Grey Cloud No breeze	**A**	**15**	**17**
9/9	Blue Sky 40% white Cloud Moderate breeze	**M**	**15**	**17**
10/9	100% Grey Cloud Mist Moderate breeze	**A**	**15**	**32**

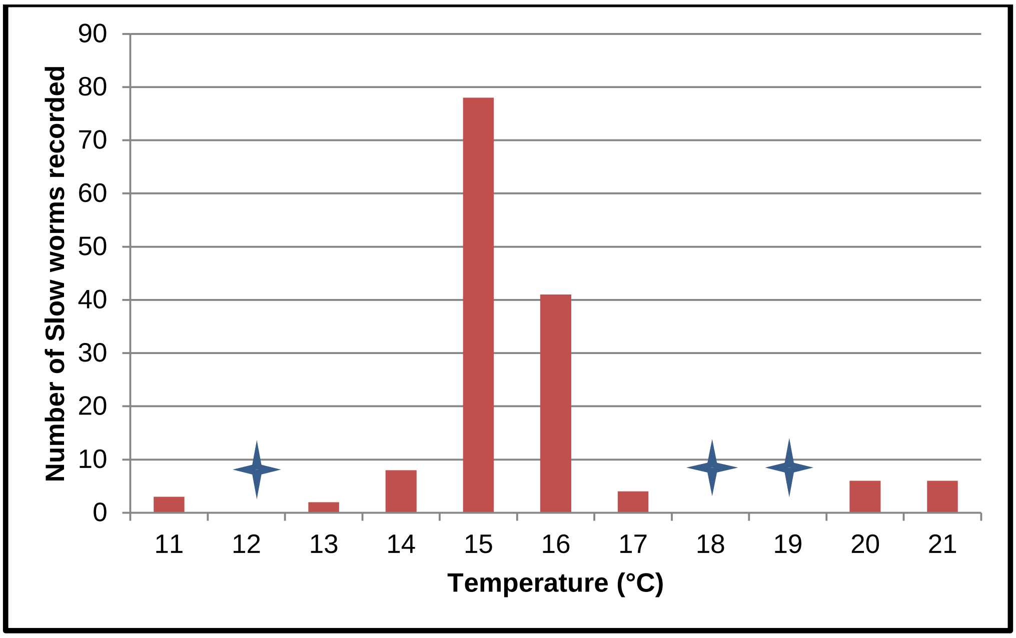

Figure 10: The number of Slow-worms recorded at different temperatures,

 denotes no data collected at this temperature.

Table 5 and figure 10 both show the number of slow-worms recorded under the mats at different temperatures. It is clear that the largest number of slow-worms were recorded at 15°C, and the next largest number at 16°C.

It illustrates that 15°C is the optimum temperature but this does not take into consideration other weather conditions and the data range for all the different temperatures is quite limited.

Population Structure

29 slow-worms were released onto the site from the release point in 2009. This 29 was made up of 10 females, 6 males, 8 sub-adults and 5 juveniles shown in figure 11.

The highest number of slow-worms recorded in one single day during the investigation was 32; out of this 20 were juveniles, 9 were female, 2 were male and one was sub-adult (figure 12).

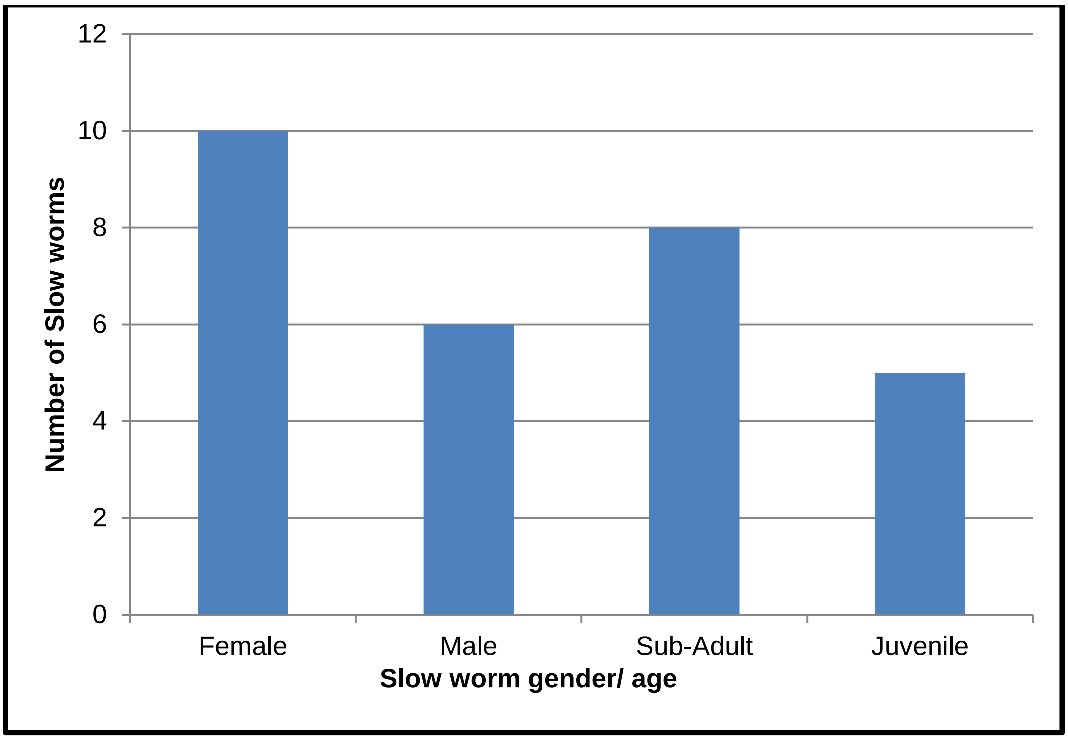

Figure 11: The structure of the population of slow-worms translocated to Dobwalls throughout 2009.

The original population is to a certain extent evenly spread in terms of gender and age but there are a higher number of females and sub-adults, than males and juveniles (figure 11). The number of females recorded on the 10/09/10 was 9 and the highest number recorded in a single visit was 12 (on the 12/08/10). Both of these values are similar to the original number of 10 females that were translocated from Doublebois.

The maximum number of males recorded in one visit was only 3. It is not expected that all the males that exist on site would be observed in one visit, however the number of slow-worms observed will reflect the number in the population. The number of females recorded stayed quite consistent but for the males it has decreased to half; 6 were translocated but only 3 or less observed. This could be for a number of reasons and is considered in the discussion.

Similarly the number of sub-adults recorded during the six weeks was never more than 1 and the number translocated was 8. This is even less than the male decline and again is discussed below. The number of juveniles recorded at Dobwalls was high which indicates successful breeding has taken place since translocation. Figure 12 compares the different population structures visually.

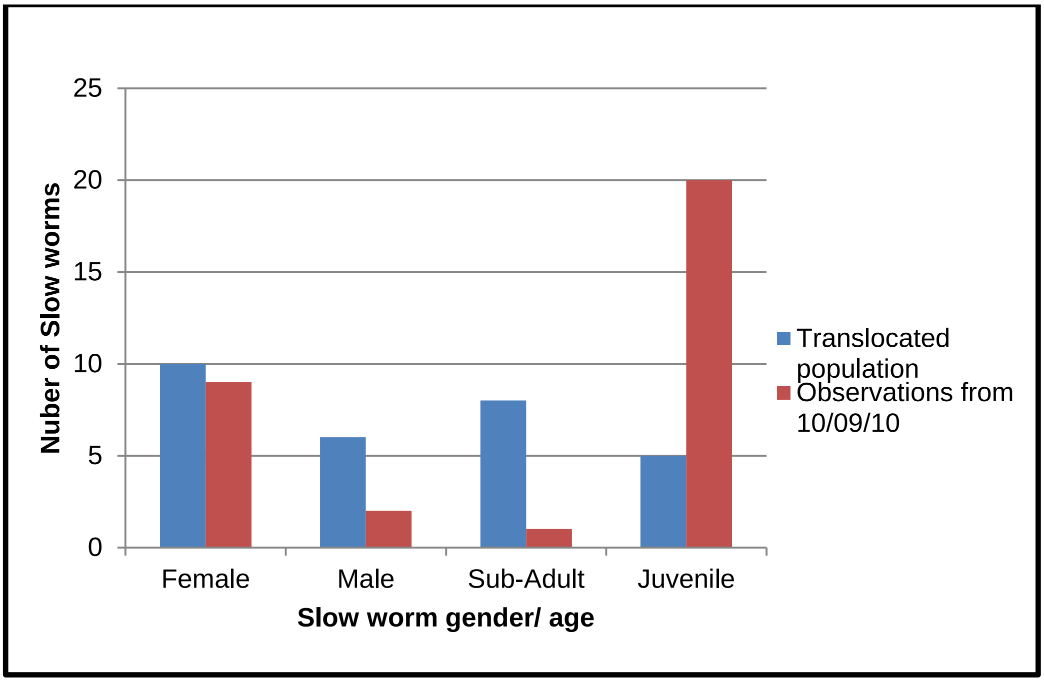

Figure 12: The structure of the original population translocated to Dobwalls and the structure of the slow-worms recorded on the single day of the 10/09/10. This was the final visit and the day that recorded the largest number of individuals.

Figure 13 shows all the observations made over six weeks. The number of female observations made was 67 and the male observations only 12. These observations are frequently multiple sightings of the same individual over six weeks, i.e. not 67 different female individuals, but it does strongly indicate that there are more female slow-worms present than male despite known habits of basking.

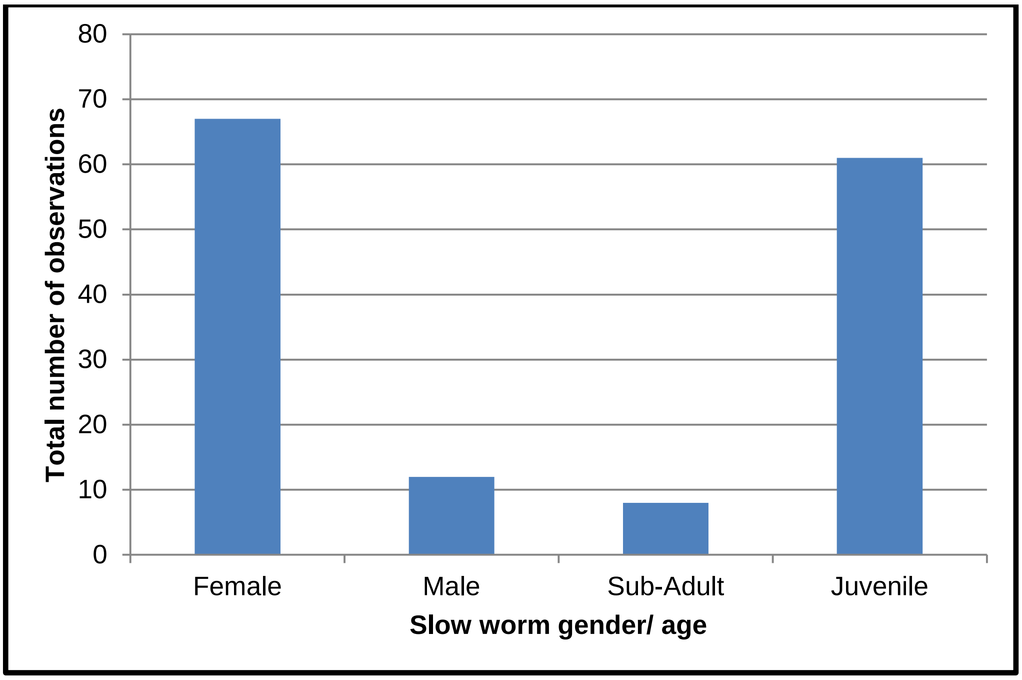

Figure 13: The classification of all the slow-worms recorded over six weeks.

Control
There were no slow-worms recorded at the control site.

Migration
Figure 14 shows the total number of slow-worms observed at distances from the release site. The set of results include multiple observations of a single slow-worm perhaps remaining under the same mat for several visits.

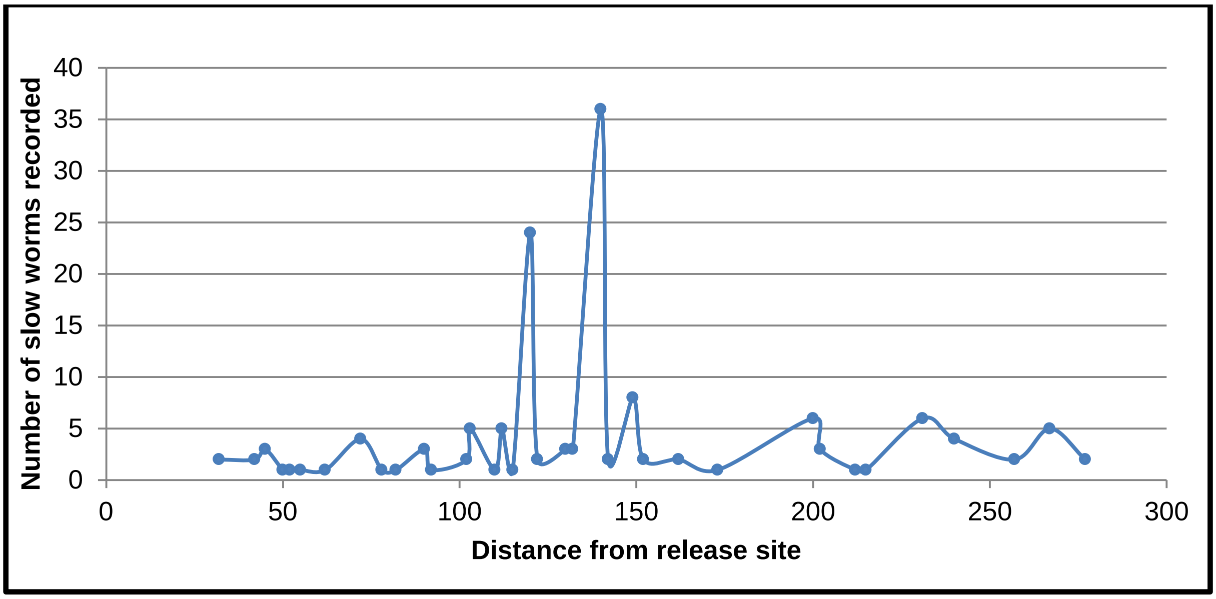

Figure 14: The total number of slow-worms recorded at distances from the release point in the six week period.

A chi square table was produced (table 6) to gauge if the gender or age of the slow-worm had an effect on how far it might have travelled from the release site (providing it is one of the translocated slow-worms). However because it contains five values of zero the test is not valid but the table demonstrates a few connections. The females and juveniles mostly remained in the area 101-150m. The juveniles have not travelled far after being born. Very few were found closer to the release point than 101m but fewer females were found here also.

No juveniles were found over 200m although female slow-worm presence was recorded 23 times. Over 200m is where the males were mostly found so it could be possible that the females do not give birth near them. Another explanation is that the habitat was not as suitable to give birth to young compared with 101-150m.

Table 6: Chi square.

Distance from release point (m)						
Gender/ age of Slow-worm		0-50	51-100	101-150	151-200	Over 200
	Male	**2**	**3**	**2**	**0**	**5**
	Female	**5**	**5**	**31**	**3**	**23**
	Sub-adult	**0**	**3**	**3**	**0**	**2**
	Juvenile	**1**	**2**	**56**	**2**	**0**

Microhabitat

A microhabitat is a smaller habitat with varying conditions within a larger one. Figure 15 was composed using the information gathered over the six weeks and presents an attempt of loosely categorising the areas within the site.

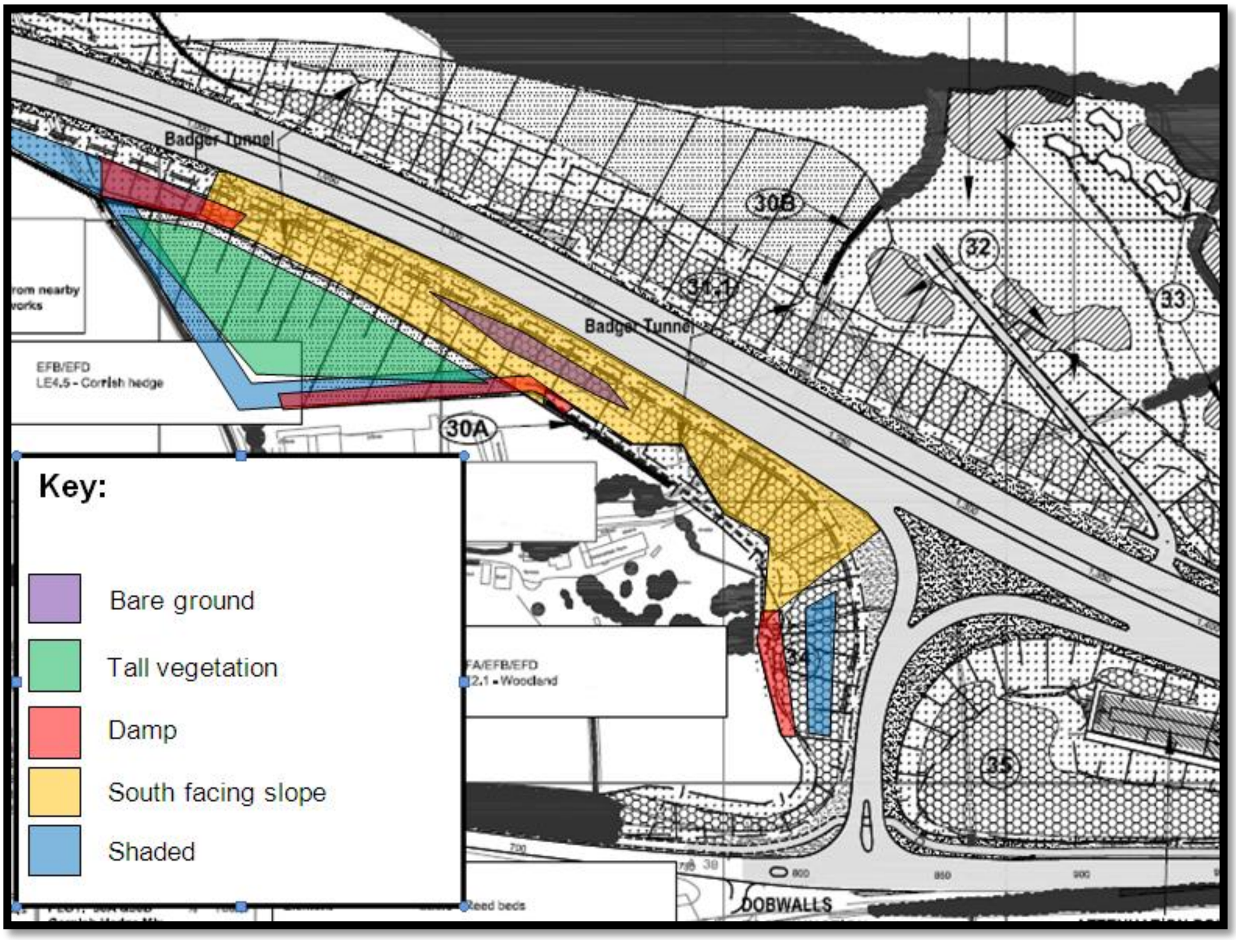

Figure 15: A map of the site showing different microhabitat conditions.

Even minor habitat differences over the site could contribute to the slow-worms distribution. There can be very subtle differences between habitats and microhabitats that species adapt to and when they are moved they can struggle to survive due to the changed conditions (Vitt & Caldwell, 2009).

The large presence of slugs such as under mats 80 to 86 could indicate a damp area. The location of the resident common toad could also indicate a damp area because being amphibian they live near water bodies. There was no specific water body nearby but there is a gully running along the boundary of the site.

Table 7: The number of slow-worms recorded in each section of the site with the varying vegetation cover.

	Vegetation cover				
	Little to bare	Medium, <25cm	Medium, >25cm	Overgrown, <25cm	Overgrown, >25cm
Mats	87-89	All others including control	37-41 97-99	100-105	106-121
Approximate Area (m^2)	60	9295	65	80	500
Number of Slow-worms	**0**	**145**	**1**	**1**	**1**

Due to recent planting and only young saplings being present the majority of the site fell into the category 'medium vegetation cover less than 25cm in height'. This categorisation therefore is ineffective at determining the most favoured vegetative cover on site because there is little variety available. Unless slow-worms had congregated into the smaller areas with different vegetation coverage it cannot be shown that they are more favourable.

Table 7 does help towards building the microhabitat map shown in figure 15 that shows a number of habitat variables important to slow-worms. Vegetation cover for example will affect the quantity of light and soil temperatures.

Discussion

Observations

Just because there were no slow-worms observed in the open does not prove that they never move around in the open. However the literature does state it is unusual for them to do so. Slow-worms could have utilised the field vole labyrinths and although none were found near the ants nests these could also have been used for mobility underground.

During the experiment it was apparent that an individual would stay under one tile for many days even weeks but some were also observed utilising many. In particular one gravid female was continuously recorded under mats 56, 57, 58, 59 and 60 on multiple occasions. There was no tag to scientifically prove this was the same individual however from observations of its pattern and size and appearance of being pregnant it is more than certain she was the same individual. This is an example of movement in the area of at least 40m in the six weeks (the distance between mats 56 and 60) as well as static behaviour for a few days.

The hotspot for females and juveniles was between mats 28-31 which was 101-150m from the release point. Many of the slow-worms here would not have moved as far as 40m. This is because there were slow-worms continuously observed under these mats and it is unlikely different individuals kept appearing, although not impossible. Hubble and Hurst point out that if conditions are satisfactory then they can remain in an area 1 to $2m^2$. Mats 28 -31 were situated on top of the bank approximately in the middle of the transect. The conditions that made this location popular was firstly the vegetation was well established with a thatch layer. The vegetation was an integration between two planting plots. Plot 34 as described in the site description and a grassland species mix (table 2) aimed to be infrequently cut and was a maximum of 25cm in height. A large portion of the site had these characteristics but this particular part of the bank is also south facing with adequate drainage either side of the bank. It is continuously noted by studies such as that at RAF Fylingdales that slow-worms are found on steeply sloping banks with a southerly aspect (Rowe, 2004). The food was also abundant. There is other areas on site alongside mats 28-31 that also had these conditions but the slow-worms particularly favoured here.

The juveniles were predominantly recorded under mats 28, 30 and 31 in the latter half of the investigation when it was the usual time for young to be born (Beebee & Griffiths, 2000). Previous to their presence there were females, some of which appeared gravid, recorded under or near to these mats (numbers 19, 27, 29, 30). The majority of the juveniles then remained under these tiles for around two weeks until the investigation was collapsed.

Some mats were occupied by a lone slow-worm but others had multiple slow-worms underneath, particularly the juveniles. It is possible the juveniles stayed together for thermoregulation purposes and shared body heat because they were observed with their bodies entwined with each other or on top of each other in piles. Up to 11 juveniles were recorded together under mat 30. Juveniles were recorded in increasing numbers under mats 28 and 30 as more were born, but both mats also had a decline in the number occupying them before increasing again during this period. For example mat 30 recorded 4 individuals then only 1, then 8, 6, and finally 11. This shows that juveniles do move around to a degree; perhaps underground or to neighbouring mats. Interestingly research by the MOD noted that juveniles were particularly difficult to observe, even more so than adults (Rowe, 2004) but this did not stand for this investigation when the juveniles were the most frequently recorded. Also other studies show that almost a quarter of slow-worm populations were estimated to contain fewer than 10 adults (Baker and Carey, 2004). This proves that slow-worms are still not a well studied species.

Food

The abundance of food source indicates that the lizards distribution is not based on the need to search for food. If food was only available in particular areas then slow-worms might congregate where the supply is, but this was not the case.

On some occasions crickets and grasshoppers were noted. Some mats had an abundance of food such as mat 66. Slugs, worms and wood louse were all recorded under it on the single day of the 31/08/10. Mats 80 to 86 always had a noticeably larger number of slugs under them but the slow-worms were not found in this area. It is common knowledge that slugs can indicate damp conditions so it is likely this area was too damp. A large hedge is nearby and therefore the area is quite shaded too.

When it became clear that the site in general was extremely abundant in the quantity and variety of edible species the continuation to record them was abandoned because it was not an efficient use of time. The invertebrate species present could help to indicate the type of microhabitats that exist such as the slugs indicating dampness. A variety of food sources might also be sought for a range of nutrients which could influence movement. Hotspots could also be present in relation to microhabitats and these have not been identified because over the entire site this would have taken a much longer time to investigate.

The abundance of food sources available across the site indicates that the lizards distribution is not directly based on **locating** food but it could be based on the slow-worm's preference of invertebrate or food source hotspots that require further investigation.

Weather

The temperature alone is not enough to indicate whether slow-worms are likely to be using the refuges because the other weather conditions are also important. The optimum range to see slow-worms basking under the artificial refuges is 9°C - 20°C (Froglife, 1999). This is a broad range but is consistent with the results in figure 9.

On the 2/09/10 there were no observations of slow-worms at 20°C but the other days that had a temperature of 20°C and 21°C six animals were observed on both days. The weather on the 2/09/10 was sunshine and there were no clouds, so the direct sunlight would have heated the mats. On this day the mats felt very hot to handle and even became sticky. The reptiles would have found the environment under the mats too warm so would have sought a cooler location and this is the reason that none were observed. Compare this to the 27/08/10 (20°C) where there was 20% white cloud and a strong breeze recorded and the 17/08/10 (21°C) when there was 90% grey cloud, a breeze and spots of drizzle that would have kept the temperature of the mats down.

Due to thermoregulation requirements the slow-worms behaviour is heavily influenced by the temperature but other weather conditions are also important in influencing the temperature felt. The wind for example can make it feel colder and cool the mats down by drawing the heat away, as does the rain and damp conditions. The cloud cover dictates how much direct sunlight is being absorbed by the mats which would speed up their warming such as on the day of the 02/09/10.

There were no visits when the temperature was 12°C, 18°C or 19°C so it is not possible to know if more or less slow-worms would have been found. There were multiple visits when the temperature was 15°C and 16°C which means there is more chance of recording slow-worms at these temperatures so in that respect the results are biased towards this being the favoured temperature.

The lack of slow-worms at 13°C was due to the fact this was the first visit and the mats had only been laid out a week and probably not yet located.

The dates when the weather was 15°C are all in September and this is the time when the young are being born. A number of females inhabited the mats and then gave birth to their young under and around some of the artificial refuges. This increased the chance of observing them compared to them choosing another location to give birth. The fact there is this increased number of slow-worms in September also gives the temperature 15°C another bias.

The weather and temperature results can be compared to the weather conditions and number of captured slow-worms recorded by Green Ecology at Doublebois throughout 2009. The largest number captured was 4 and the weather that day was 14°C, 80% grey cloud with an intermittent breeze. The weather conditions on some of the days that recorded zero captures were between 15°C and 18°C and all had a cloud cover of at least 50% showing that this temperature is not alone optimum as figure 9 suggests. In fact all the visits to Doublebois had ideal weather conditions. However the more slow-worms that had been captured the less there were left on site and the harder it becomes to observe and capture them. In comparison to Dobwalls the longer the mats are in place the more likely they are to be utilised. However if this was not the case then disturbance by lifting the mats continuously should be taken into account.

The best weather conditions from the results were therefore 15°C with at least 40% cloud cover and a moderate breeze.

Population Structure

The density of slow-worms found on the site was small. Arnold suggested population sizes of between 600-2,000 in a hectare. Although the exact population number at Dobwalls is not known, including the 29 that were released, the possible migration of individuals from the private land and breeding taken into consideration it is still probably not close to 600. Without a tagging technique it is impossible to gauge an accurate population size. The very nature of slow-worms secretive behaviour and time spent underground (BBC, 2010) means there is likely to be more in existence than are observed using refuges. Hubble and Hurst mention that if the conditions are good and there is an adequate food source the individual will not be inclined to move. Therefore there could be a number of slow-worms that never moved near to the refuges laid out.

In the literature it is thought that females, particularly gravid females, tend to require more heat for thermoregulation and will therefore bask more and hence are more likely to be seen utilising refuges. The total number of females recorded in one visit was 12 on the 12/08/10 and the total number of males was 3 on the 01/09/10.

There could be a temperature gradient that juveniles and females prefer to bask in that is different to males.

The original population that was released onto this site consisted of 10 females which is an increase of at least two. Assuming not all the slow-worms inhabiting the site were observed on that day means there is a very high chance of there being more than 12. The increased number of females could have come from the sub-adults maturing from the original population or migration from the private land.

The male number was low in comparison. Possible reasons are because a lot of the juveniles and sub-adults that were translocated were female, or because females are reported to bask more (Hubble & Hurst, 2006). This investigation would certainly conclude that females either bask more or this population has a female sex dominance due to the large difference in the number recorded; 67 female to 12 male. Sex dominances of both genders have been known (Hubble & Hurst, 2006) but it makes ecological sense to have more females to produce more young.

The number of sub-adults was also very low; only 8 were recorded over the six week period. A reason for this low number could be due to the sub-adults habits in using the refuges, however it is hard to judge because slow-worm behaviour is poorly studied. Sub-adulthood is a dynamic phase of development and the lack of observations could be because a lot of the sub-adults were already at a mature stage and were observed in 2010 as adults. Or the sub-adults and juveniles may have found surviving after translocation more difficult and so it is possible that the juveniles that were translocated never made it to sub-adulthood and the sub-adults also died.

Litter sizes can vary, usually between 6 and 12 but can also range from 3 to 26 (Arnold, 2002). This broad range makes it hard to predict an accurate number of juveniles that are likely to have been born on site from the number of gravid females present. At least three different gravid females were observed and at least 20 juveniles were observed in a single day. If these were the only slow-worms on site this would be a mean litter size of 6.7. However there could be, and it is probable that there are more.

Control

Although the habitat at the control site was very similar to the main site there were zero observations of slow-worms. The differences between the two was that the density of mats was significantly higher at the main site and the slope was north facing (but the mats were placed at the top of the hill). The lack of slow-worms indicates that they do not cross large open spaces such as a road. It is known for a fact that they were not released into this area and it is otherwise isolated by surrounding roads.

Migration

As mentioned the slow-worms have been recorded moving up to 40m and as little as between a few mats. It is interesting that no juveniles were found over 200m. One idea is that this area is still relatively unexplored and therefore it would be a risk to give birth here. A large number of females were observed here as well as the largest number of males so perhaps it is not so uncharted. Perhaps it is the males presence that prevents them but this is just an idea as there is no literature to support this. Unfortunately due to the lack of study on slow-worms as a species, particularly in the UK there is little evidence to back this up.

The slow-worms were released in 2009. Within a year at least 3 slow-worms have travelled up to 267m providing they did not move there from the private land. It is possible the slow-worms are from the private land because mat 45 (267m from the release point) is along the bottom transect closest to the boundary with the private land). Unfortunately with no method of identification used when they were released there is no way of knowing. The number of slow-worms recorded over 200m from the release point is 30 and some of these are very likely to be from the translocated population. This demonstrates a large amount of movement and supports the need to extend the monitoring area further west along the A38. The favoured area that was occupied by the largest number of slow-worms was 101-150m from release point. Interestingly no slow-worms were found closer than 32m from the hibernacula and release point; it would have been useful to monitor if they had used the hibernacula during the winter and if any slow-worms or other species will use it this winter.

Microhabitats

One of the most important factors in the distribution of the slow-worms was the presence of microhabitats. Areas that are too damp such as those mentioned in the results are not suitable for slow-worms (Beebee & Griffiths, 2000). The tall vegetation in the field was also unsuitable since it kept the soil cooler because it did not allow enough sunlight to penetrate. During the setting up phase it was predicted that the number of slow-worms found in that environment would be minimal if any. During the experiment one individual was found under mat 103 in the southern corner of the field where the vegetation was still not very tall; ~25cm in height. One other individual was found under mat 119 on the western transect running north to south along the hedge boundary. This is surprising because the vegetation was tall and it was near a large hedge that created shade. However the refuge must have provided the right temperature for that basking individual on one of the warmer days (16°C on the 12/08/10).

The planting scheme of plot 34 that covers the majority of the site is woodland. At present the vegetation on site is suitable but as the saplings mature they will shade the ground and this will no longer be suitable for slow-worms and they could be forced to migrate.

Conclusion

The slow-worm as a species is still not very well studied, and therefore mitigation programmes that are in place have yet to improve alongside our knowledge of the species behaviour and habitats. More post-mitigation studies are required to achieve this.

In the investigation there were a large number of juveniles found which means that there has been successful breeding and this indicates a healthy population. There is plenty of space and food for the small population to expand. However due to the type of planting in place the population could run out of suitable area as the trees get taller and block out the sun.

This investigation would certainly conclude that females either bask more or this population has a female sex dominance because of the large difference in numbers observed.

The distance they had travelled over the course of the year 2009-2010 was further than expected as they reached the furthest limit of the transects. Therefore there is great potential for slow-worms to be further than 267m from the release point in all directions.

As prior advice indicated the fickle nature of the slow-worm is very dependent on the temperature of the soil and air, which in turn is dependant not only on the weather at the time of survey but potentially on the previous night, i.e. if the ground is damp or dry etc. On some visits there were very few slow-worms recorded after having recorded up to 14 the previous visit showing they only utilised the refuges some of the time.

Recommendations

The planting scheme for the area is designed to grow a woodland within a few years time with grassland around the perimeter as shown on the planting scheme map in Appendix C. The motives for a woodland could have been to provide a natural screen from the road for the residents however this contradicts with releasing slow-worms onto the site. As discussed slow-worms do not like heavily shaded areas that a woodland would create meaning that in the future they might be forced out of this new habitat in search of sunlight.

A cutting regime to prevent succession of woody species and therefore shading vegetation would be needed to maintain the integrity of the site, however this does contradict the planting scheme. A cutting regime can also have adverse effects:

- Immediate- killing or injuring,
- Short-term- removal of cover from predators,
- Long-term- removal of key elements of habitat such as grass tussocks, ant-hills or vegetation structure (Edgar et al, 2010).

“Areas subject to routine swathe cuts, should be mown only annually (minimum height of 15 cm), during winter, hence providing cover for reptiles and their prey during the active season” (Edgar et al, 2010).

Due to the fact that the slow-worms have migrated up to 267m, and at least 200m, means the monitoring area should be extended. There could have been individuals further away than this that have already been missed in this year’s study. The area should be extended east and west to identify the maximum distances slow-worms will travel.

The food source investigation undertaken was very basic but still very time consuming, hence it was abandoned. A further study into the relationship between food source and slow-worm distribution is recommended, however it would be challenging on a site as large as this. A smaller site with uniform habitat conditions could be tailored by artificially creating hotspots of different invertebrate species to see how slow-worms react. How often and how much they can survive on and require is still not very clear so this could be incorporated into the investigation. It is known that most lizard species always have food in their stomach. Nocturnal lizards or species of lizard that sit-and-wait for their prey are more likely to be found running on empty (Huey et al, 2001). This shows that slow-worms must eat quite regularly and will therefore look for food regularly.

The best method to aid the recommendations above is to incorporate tagging of individual slow-worms to gain a true scientific population picture. This would ensure the slow-worm was from the population released, it would make it possible to determine how far they travel and no slow-worm would be recorded twice when trying to find the population size. Slow-worms feeding habitats could also be tracked in relation to the investigation proposal because the number of times a slow-worm goes to the feeding site or remains there could be monitored.

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