The Adders of Marley Common

By Lucy Struthers

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Preface

Haslemere Natural History Society, in furtherance of its aims to promote appreciation and conservation of the wildlife in the Haslemere area, organised a field meeting in 2013 with Matt Bramich to search for and learn more about reptiles. Matt Bramich (then Area Ranger for Black Down Estate of the National Trust) had a particular interest in adders. From their Clare Britton Bequest the Society agreed to provide equipment to enable Matt to undertake a study of the adder population on Marley Common near Haslemere, Surrey and at Weavers Down, near Rake, Hampshire, in 2014.

The equipment needed for this project included ten radio transmitters and a radio receiver. Given leave of absence for three months by the National Trust, Matt established the adder presence on both sites, recorded the vegetation within a square metre of an adder's capture and studied the post-breeding dispersal. He described his findings in a presentation at the Society's Annual General Meeting in April 2015.

Matt felt it would be beneficial for his findings to be confirmed with further surveying and tracking. Therefore, on the website of Amphibian and Reptile Conservation Trust, an internship was advertised for a Radio Telemetry Study of Adders and Lucy Struthers was successful in filling this role. She was funded by Haslemere Natural History Society to undertake this project from 8th June to 8th September 2015, working on Marley Common, and then to write a report on her findings.

On 23rd January 2018 at Haslemere Museum, Lucy gave a presentation of her findings to the Committee of Haslemere Natural History Society together with Matt Bramich and other staff of the local National Trust. Subsequently she submitted a full report on her findings, and the Society's Committee thought this to be of such a quality that it could, with minor modification, be published as part of the Society's series of Science Papers. The current paper is the outcome.

Margaret Hibbard
Judith Kusel
April 2020

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The Natural History of the Adder

The adder has the widest distribution of any terrestrial snake species in the world, ranging from the British Isles in the west, eastwards to Russia, western Mongolia and north-east China, and the Sakhalin island (Crnobrnja-Isailović et al. 2011; Cui et al. 2016; Prestt, 1971; Strugariu & Zamfirescu, 2011; Ursenbacher et al. 2006; IUCN 2018). The Balkan Peninsula represents the southern-most boundary of the adder's range, whilst to the north, the adder's range extends to Fennoscandia. The adder is the only terrestrial snake that occurs north of the Arctic circle (Prestt, 1971; Andersson, 2003).

Despite the adder's wide distribution, populations remain fragmented throughout much of its range (Andersson 2003; Crnobrnja-Isailović et al. 2011). The adder inhabits a diverse array of habitats, from lowland heathland in the south of England (250m) to mountain slopes up to 2600m, in the Swiss Alps (Andersson, 2003; Carlsson, 2003; Crnobrnja-Isailović et al. 2011; Luiselli & Anibaldi, 1991).

Three sub-species are recognized: *Vipera berus bosniensis* (Boettger, cited in Ursenbacher et al. 2006), restricted to the Balkan Peninsula; *Vipera berus sachalinensis* (Zarevsky, cited in Ursenbacher et al. 2006), restricted to Sakhalin Island and Russia's Pacific coast; and *Vipera berus berus* (IUCN, 2018), the most genetically diverse sub-specie, found throughout the remainder of the adder's range.

Genetic analysis reveals three major clades (Figs. 1-2) that reflect historic isolation and re-colonisation events which occurred during the glacial cycles of the lower Pleistocene (Carlsson 2003; Ursenbacher et al. 2006). The Italian clade represents a refuge in the southern Alps and includes adders from northern Italy, Austria, northern Slovenia and south-east Switzerland; the Balkan clade represents a refuge in the Balkan peninsula and comprises the distribution of the sub-species *Vipera b. bosniensis*; the genetically diverse Northern clade represents a refuge near the Carpathian Mountains and includes adders from the British Isles, north, east and central Europe, Asia and Russia. In contrast to the Northern clade, the Italian and Balkan

clades represent genetically divergent, endemic populations which have remained geographically isolated from their northern conspecifics (Carlsson, 2003).

Following division of the major clades, further isolation events and divisions occurred (Carlsson, 2003; Ursenbacher et al. 2006). The northern clade can be divided into four sub-clades that emerged during the last glacial events of the Late Pleistocene (Figs. 1-2). The basal (ancestral) 'Carpathian Subclade' represents the source of the Northern clade and includes populations from Romania, eastern Slovakia and southern Poland. The 'Eastern Subclades' include populations from eastern Europe, Finland, Asia and Russia; the western subclade represents a refugial population from central France and includes populations from France, Switzerland and western Austria; the central European subclade originates north of the Alps (possibly Hungary) and went on to colonise the British Isles, Central Europe and Scandinavia.
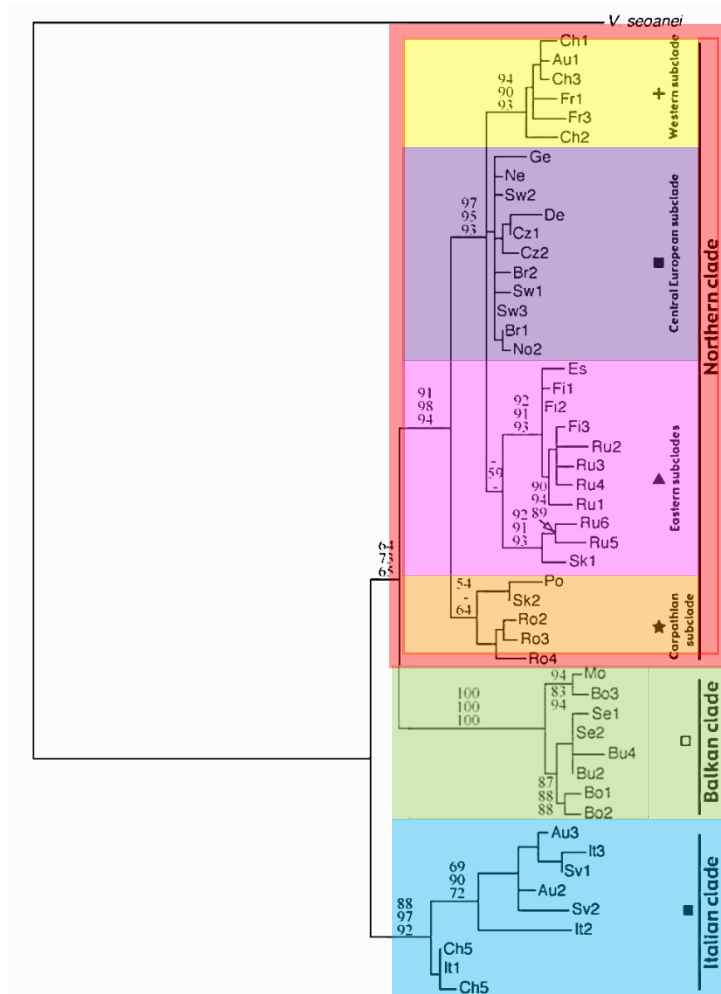

Figure 1. Cladogram showing the three major clades that emerged during the lower Pleistocene. The Northern Clade (Red) can be divided into a further four sub-clades. Image source: Ursenbacher et al. (2006).
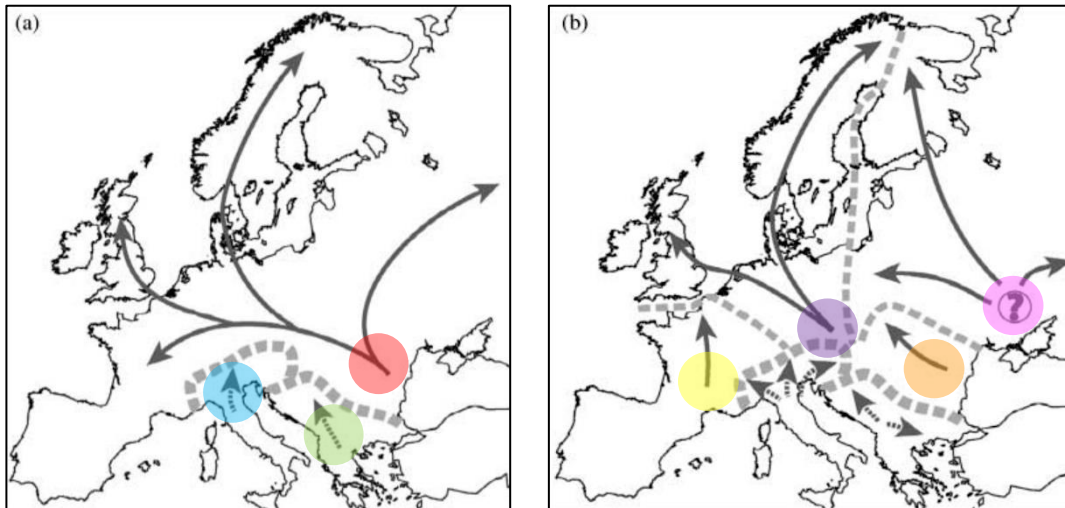
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Figure 2. Recolonization routes following the first isolation event (a) and second isolation event (b). The Northern clade (red) originating from a refuge near the Carpathian Mountains, colonises the British Isles, Europe, Russia and Asia. By comparison, the Italian Clade (blue) and Balkan Clade (green) undergo little expansion of their range. The basal Carpathian subclade (orange) colonised Romania, Slovakia and Poland. The western subclade (yellow), from a refuge in central France, colonised western Austria and France. The Central European subclade (purple), which originated north of the Alps, colonised Scandinavia and the British Isles. The Eastern subclade (Pink) colonized Finland, eastern Europe, Asia and Russia. Image source: Ursenbacher et al. (2006).

The Distribution of Adders in Britain

The adder has a widespread but patchy distribution across England, Wales and Scotland, and exhibits considerable regional variation in abundance. Current models of the adder's distribution in England indicate that the adder is most prevalent along coastal regions, particularly in the south of England (Fig. 3) (Gleed-Owen & Langham, 2012). There are also localised populations in East Yorkshire, Cumbria and Northumberland and Suffolk. The adder is sparsely distributed throughout the remainder of England and is thought to be absent from Hertfordshire, Huntingdonshire and Nottinghamshire; and exceedingly rare in Cambridgeshire, Greater London, Lancashire and Oxfordshire (Atkins, 2005; Gleed-Owen & Langham, 2012). The earliest grid-based map of adder populations across Britain (Fig. 4) suggests that populations in England have long been scarce in the east midlands (Warwickshire, West Yorkshire) and the north west (Arnold 1995; Swan & Oldham, 1993).

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Questionnaire surveys carried out across Scotland in the early 90's reveal that adders are most commonly found in the south west (Dumfries & Galloway and Argyll), the Grampians and Highlands but become increasingly scarce towards the central belt – the most densely populated region of Scotland (Reading et al. 1996).

Figure 3. Known distribution of the adder based on data collated from 2006-2011 mapped at a resolution of 1Km^2. Image Source: Gleed-Owen & Langham (2012).
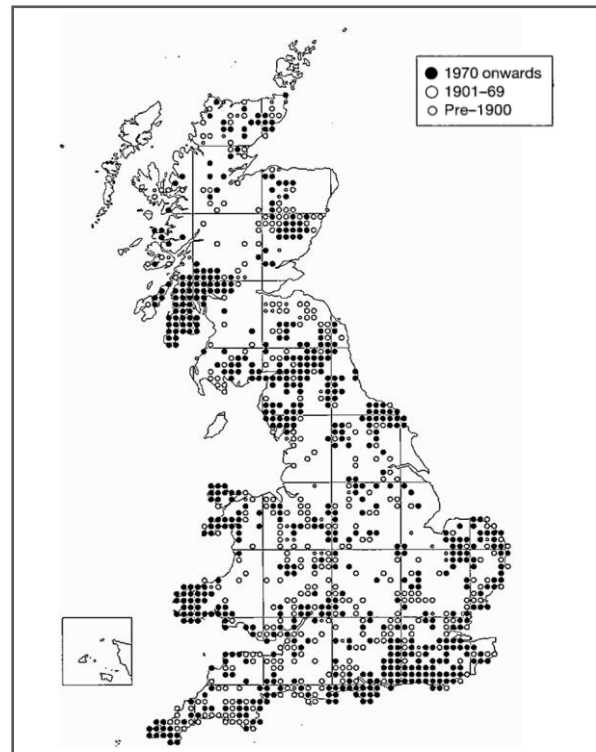
Figure 4. Map showing the distribution of the adder in the UK at a resolution of 10km^2. Data from 1901-1969 (open circles) suggest losses in south-east England, the Midlands and the Grampians. The map indicates that adders have long been scarce in some regions of the UK. Image Source: Arnold (1995).

Knowledge of the adder's distribution is likely to reflect survey bias towards human population centres and areas where adders are known to exist, such as nature reserves (Baker et al. 2004; Gleed-Owen & Langham, 2012). Remote regions and wider agricultural landscapes are relatively inaccessible to surveyors and tend to be overlooked. Thus, spatial resolution and coverage of remote regions is often poor. For example, regions of apparent adder scarcity in

northern England (e.g. The Pennines) and mountainous regions of Wales and Scotland may in fact reflect inadequate surveying as opposed to the absence of adders from these regions. A concerted and coordinated effort is needed to determine the presence or absence of adders in these regions. Renewed efforts such as the National Amphibian and Reptile Survey (NAARS) have sought to reduce such knowledge gaps.

With the use of GPS, data resolution and reliability has improved significantly. Figures 5 and 6 illustrate how at a resolution of 1km^2, adder populations appear fragmented and isolated. A closer look reveals the extent to which land-use change has shaped the landscape, resulting in the loss and fragmentation of key reptile habitat.
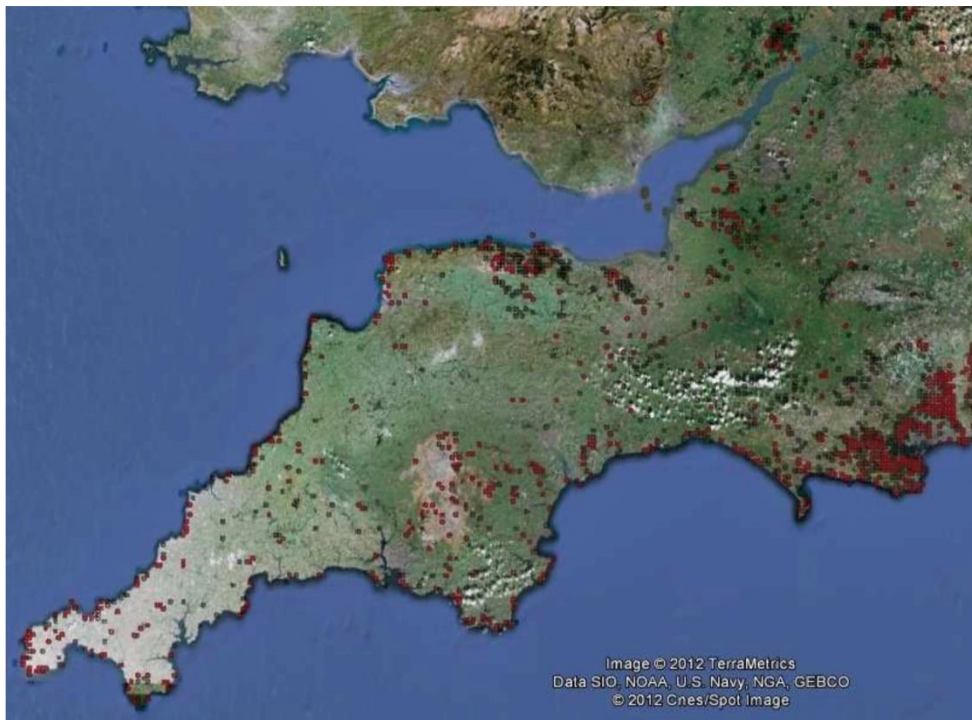

Figure 5. Map of Current (2006-2011) and historic (Pre-2006) adder distribution in South East England. Red squares represent current data and black squares represent historic data. Image source: Gleed-Owen & Langham (2012).

Figure 6. Current adder distribution in Haslemere, Surrey, and surrounding areas (2001-2016 Data). Anthropogenic landscape changes are evident (e.g. roads, agriculture/pasture, urban). Each red square represents 1km^2. Image source: https://records.nbnatlas.org

The Conservation Status of the Adder in Britain

Despite the adder's widespread distribution, there are growing concerns about the status of the adder in the UK. Reports of country-wide declines and county level extinctions paint a worrying picture (Baker et al. 2004; Baker 2016; Cooke & Scorgie, 1983; Gleed-Owen & Langham, 2012; Hilton-Brown & Oldham, 1991; Sheldon, 2011).

Arnold's 1995 atlas of reptiles (Fig. 4) suggests that the adder has undergone losses over the last century, especially across the Midlands as well as south west England, Hertfordshire, Bedfordshire and parts of East Anglia. The atlas also points towards a decline in records in north east Scotland and the Scottish Borders.

This trend is supported by questionnaire surveys carried out in the early 80's (Cooke & Scorgie, 1983) and early 90's (Hilton-Brown & Oldham, 1991). Although such surveys are subjective by nature and lack systematic data, respondents reported declines in the adder's status in the

south of England, the West Midlands and East Anglia during the 70's; and declines in all regions of England except the west Midlands and north west during the 80's (Table. 1).

Region	n 1980	n 1990	Regional Status Index 1980	Regional Status Index 1990	Change in Status Index 1970's	Change in Status Index 1980's
ENGLAND						
South West	6	8	0.50	0.94	0.14	-0.08
South	9	8	0.59	0.63	-0.28	-0.27
South East	10	13	0.65	0.56	-0.18	-0.26
West Midlands	21	21	0.62	0.57	-0.36	-0.04
East Midlands	12	13	0.72	0.32	0.00	-0.35
East Anglia	10	5	0.73	0.46	-0.40	-0.57
North West	14	10	0.41	0.41	-0.20	-0.25
North East	10	6	0.48	0.60	-0.15	-0.26
Total	92	83	0.58	0.55	-0.20	-0.24
SCOTLAND						
South West	12	12	0.73	0.63	0.00	-0.08
South East	8	12	0.67	0.56	0.00	-0.07
North	15	17	0.46	0.41	-0.16	0.00
Total	35	41	0.62	0.54	-0.05	0.05
WALES	13	16	0.66	0.56	0.08	-0.09

0 to 0.25	Absent/Rare
0.26 to 0.50	Scarce
0.51 to 0.75	Widespread but not common
0.76 to 1.00	Common

-1 to -0.61	Severe Decrease
-0.60 to -0.21	Decrease
-0.20 to 0.20	Little or no change
0.21 to 0.60	Increase

Table 1. Comparison of questionnaire survey results from Cooke and Scorgie (1983) and Hilton-Brown and Oldham (1991). Respondents reported a decrease in the adder's population status in 6 regions during the 1980's compared to 3 regions during the 1970's.

Historic losses are the result of a decline in traditional practices that maintained open heath (Marrs et al. 1986; Rose et al. 2000; Webb, 1990; Webb & Haskins, 1980), followed by agricultural expansion, urbanization and afforestation (Cooke & Scorgie, 1983; Hooftman & Bullock, 2012; Webb & Haskins, 1980). 80% of lowland heathland, a key habitat for reptiles, has been lost since the beginning of the 19th century (Hayhow et al. 2016; The UK BAP, 1995) and what remains is greatly fragmented (Edgar et al. 2010; Hayhow et al. 2016; Hooftman & Bullock, 2012; Rose et al. 2000). Such landscape changes have left many areas of suitable habitat isolated, making dispersal between sites impossible. This increases the risk of local extinctions as a result of fires, succession and inbreeding depression (Offer et al. 2003).

Today population declines are attributed to a variety of factors (Fig. 7), including adverse management practices, inadequate mitigation and habitat degradation due to neglect and disturbance (Baker et al. 2004; Edgar et al. 2010; Gleed-Owen & Langham, 2012). Of particular concern is damage to hibernacula and excessive scrub clearance (Gleed-Owen & Langham, 2012; Sheldon, 2011; Phelps, 2004), although the impacts of such practices often go unmonitored.
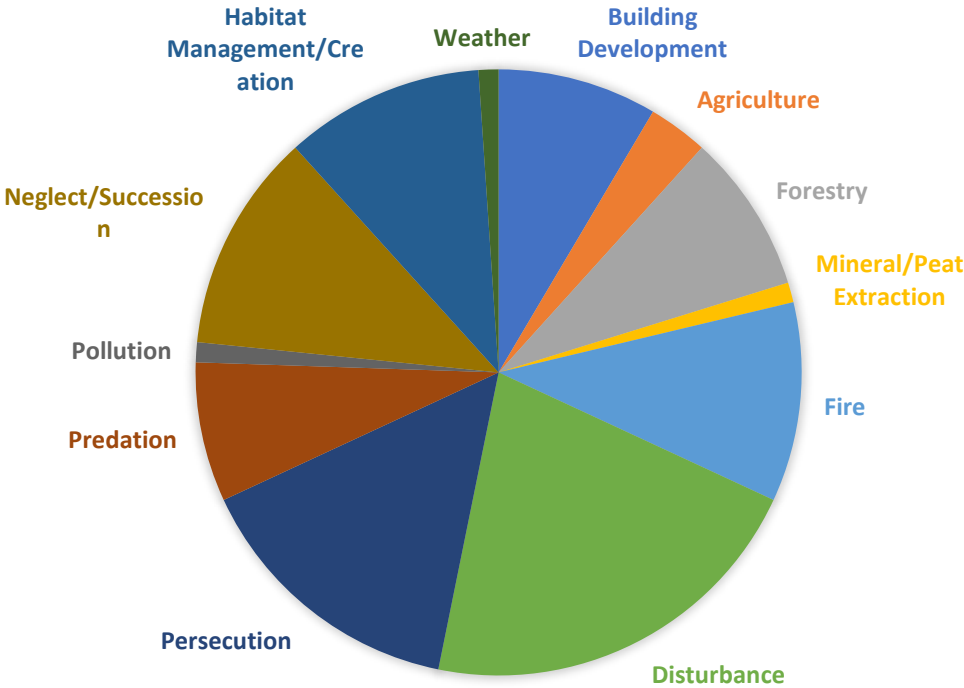

Figure 7. Factors attributed to adder declines. Data from Baker et al. (2004).

The inadequacy of current conservation policy remains a primary concern. Adders are protected from intentional killing, injuring and sale under Schedule 5 of the Wildlife and Countryside Act (1981) and are listed as a priority species for conservation action under section 41 of the Natural Environment and Rural Communities Act (2006) (JNCC 2016a). However, adders are not afforded the highest levels of protection given to nationally rare species such as the sand lizard (*Lacerta agilis*) and smooth snake (*Coronella austriaca*). As a consequence, adder habitat may not receive strict protection unless the presence of European

Protected Species are noted (Baker, 2016). As such, the specific requirements of adders are not often incorporated into habitat management plans (Edgar 2016; Gleed-Owen & Langham, 2012).

More recent assessments of the adder's status provide evidence of continued widespread declines into the 21st century (Baker et al. 2004; Baker 2016). Research on the status of adders in England has revealed population declines on 35% of sites for which population estimates were available (Baker et al. 2004). This increased to 44% when subjective estimates were included. Despite the presence of increasing and stable populations in most regions, the disproportionate number of population decreases to population increases indicates a declining national trend (Fig. 8).
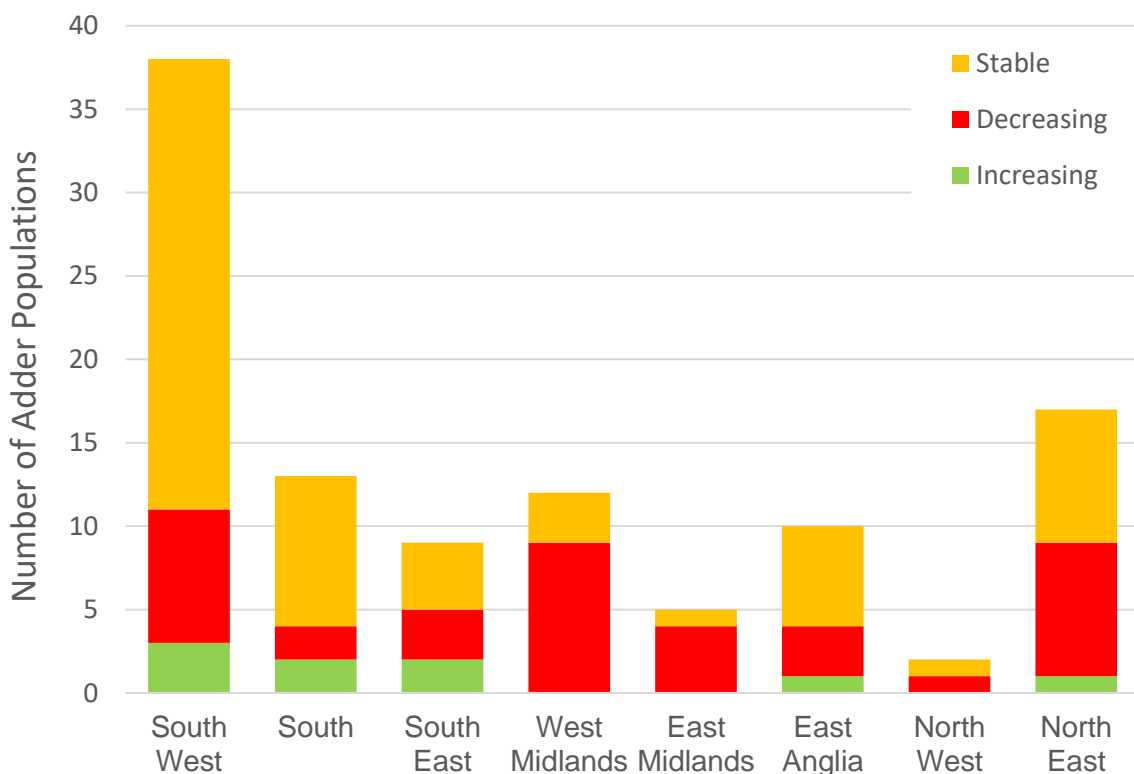

Figure 8. Population trends for adder populations by region. Data is based on 106 sites across England. The Midlands and north had the greatest proportion of population decreases. Data source: Baker et al. (2004).

Worryingly, a third of the populations were reported to have fewer than 10 adults. Furthermore, the data reveal that unstable and decreasing populations occur more frequently on smaller, more isolated sites compared to larger, well-connected sites. Thus, adder populations are especially vulnerable to extinction on these sites. This is particularly concerning given that a third of adder sites in this study were less than 6 ha.

Although the study includes a greater amount of systematic data compared to previous assessments, samples are heavily biased towards protected sites or nature reserves where habitat is perhaps most favourable. Therefore, the data may under-estimate the current conservation status of adders in England.

The most current assessment of the adder's conservation status in England has sought to account for uneven survey coverage and poor spatial resolution. The adder status project (Gleed-Owen & Langham, 2012) represents the first attempt to map the adder's distribution at a resolution of 1km, providing 100 times greater resolution than previously attempted. The project uses an empirically-derived occupancy-based model to generate maps of known and predicted adder occupancy (presence) in England. The model predicted adder occupancy by identifying statistically significant associations between land cover (habitat types, geological features etc.) and collated adder records. The model was used to determine changes to adder occupancy across space and time.

Results suggest staggering under-occupancy: adders are currently estimated to occupy just 29% of suitable habitat and just 7% of 1km squares nationally (Fig. 9). Furthermore, the model estimated a 39% decrease in predicted occupancy over recent decades. All counties have undergone a pronounced decrease in occupancy however the magnitude of the loss varies locally within each region (Fig. 10).
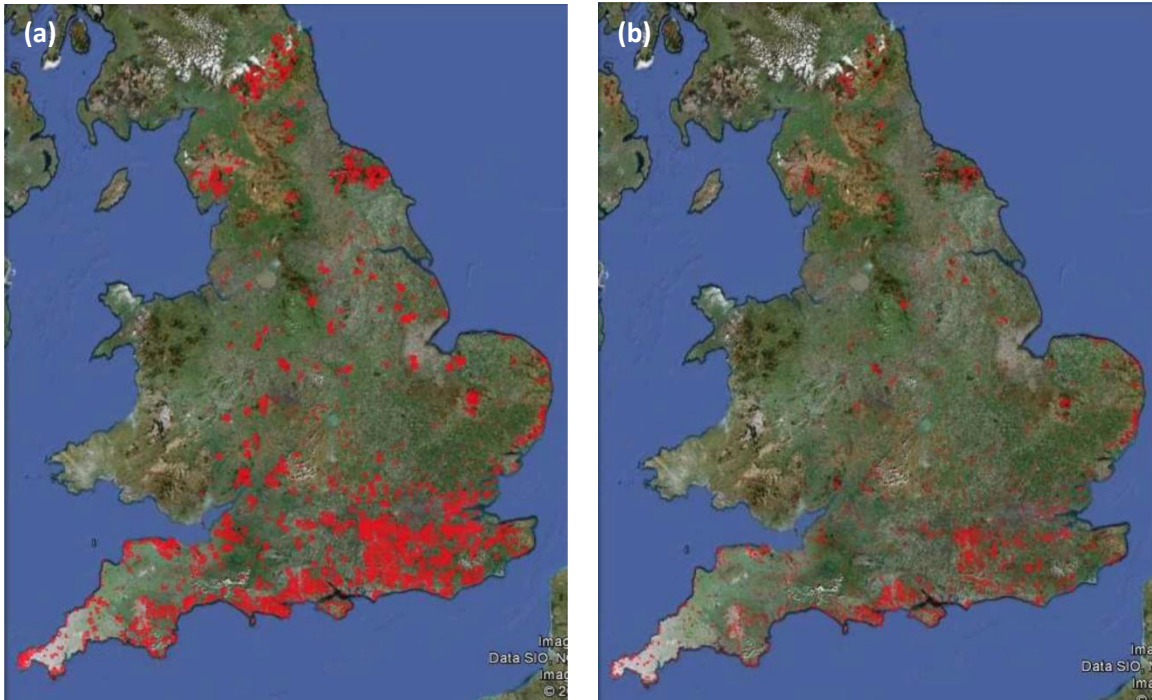
Figure 9. Distribution maps showing under-occupancy. Predicted adder distribution generated by model (a) compared to the known adder distribution (b). Image Source: Gleed-Owen & Langham (2012).
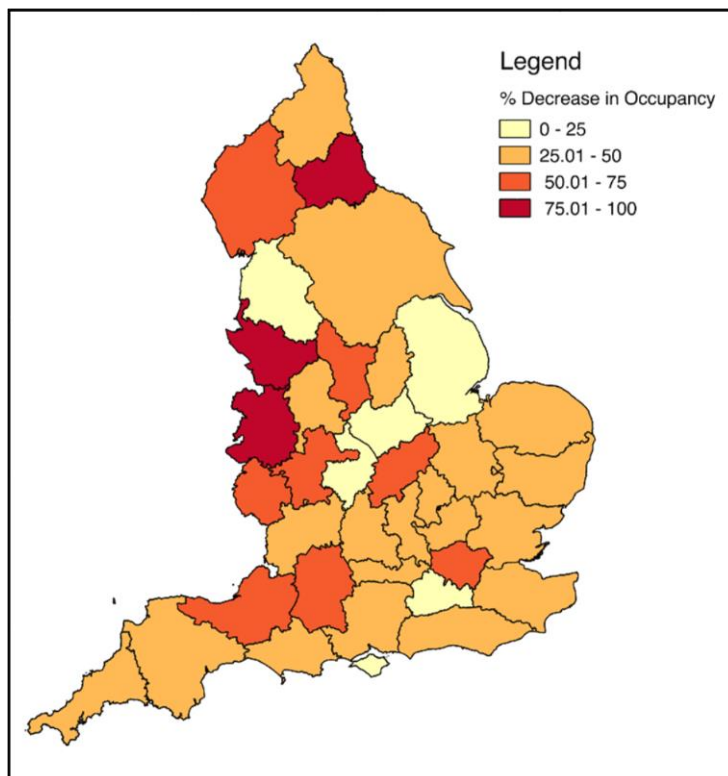

Figure 10. Variation in loss of occupancy across England. Data source: Gleed-Owen & Langham (2012). Map created using QGIS version 2.8.4 and Ordnance Survey Boundary-Line open source data.

Ecology of the Adder

In Britain the adder inhabits a range of habitats including rough grassland, heathland, scrub, woodland and moorland (Baker et al. 2004; Swan & Oldham, 1993). They may reach an age in excess of 20 years (Forsman & Lindell, 1991; Phelps, 2004, 2007) in the wild and reach sexual maturity at 3 or 4 years of age (Madsen 1988; Prestt, 1971).

The adder spends the winter months in a state of torpor, hibernating, often communally, within roots, rocky crevices, disused burrows or dense scrub (McInerny, 2014; Prestt, 1971). Hibernacula are typically located on well-drained, south-facing slopes, optimally positioned for the spring-time sun (Andrén, 1982; Beebee & Griffiths, 2000; Gleed-Owen & Langham, 2012; McInerny, 2014; Prestt, 1971). Emergence from hibernation is temperature dependent and the exact timing may vary between years depending on prevailing conditions (Prestt, 1971; Viitanen, 1967).

Males typically emerge from hibernation to commence basking in late February/early march (Fig. 11) (Andrén, 1982; Beebee & Griffiths, 2000; Phelps, 2004; Prestt, 1971). It is during this time that male adders undergo rapid testes growth and peak testosterone production (Prestt, 1971). Early emergence of males is thought to have a selective advantage as it allows optimal spermiogenesis, enhancing male fitness and enabling greater acquisition of mates during the breeding period (Herczeg et al. 2007).

Females emerge 3-4 weeks later, typically in late March/early April (Andrén, 1982; Madsen et al. 1993; Phelps, 2004, 2008; Prestt, 1971). During the ensuing weeks, both males and females disperse locally and establish dens (retreats) in association with favourable basking spots (Phelps, 2004, Prestt, 1971). Non-breeding females and immature adders migrate to feeding areas and begin foraging in April (Andrén, 1982; Phelps, 2007; Viitanen, 1967).

Figure 11. Male adders basking in late March. Photo by Matt Bramich.

In the first weeks of April, adult males undergo their first exuviation of the year (shedding of skin) after which they exhibit a dramatic change in behaviour, marking the beginning of the mating period (Phelps, 2004; Prestt, 1971). Adult males become highly active, roaming large distances in search of females. Larger males may contest for access to females by engaging in vigorous combats (Andrén, 1982, 1986).

It is not uncommon for females to mate with multiple males within a season and give birth to clutches of mixed paternity (Höggren & Tegelström, 1995, 2002; Madsen et al. 1993; Ursenbacher et al. 2006). Female adders do not exhibit sexual selection however mating with more than one male may enable other, potentially better-quality males to contribute to her fitness (Höggren & Tegelström, 2002).

After mating, some males guard the female for several days (Fig. 12) (Andrén, 1986; Phelps, 2004). Such mate-guarding behaviour is believed to promote male fitness by excluding other males from siring offspring (Phelps 2007). Genetic evidence of first-male mating advantage supports this theory (Höggren & Tegelström, 2002).

Figure 12. A male mate-guarding a melanistic female. Photo by Matt Bramich

A single adder population is made up of distinct, reproductively-autonomous clans that occupy specific mating areas (Langham, S. 2017.pers.comm, 15th May; Luiselli, 1993; Phelps, 2004, 2007). Adders exhibit pronounced attachment to their respective mating areas – i.e. the same adders re-occupy the same mating areas (Madsen et al. 1993; Phelps, 2004, 2007). Genetic interchange occurs via dispersal of juveniles and immature adders to new areas (Phelps, 2004; Prestt, 1971).

The mating period lasts 3-4 weeks, peaking in early May (Phelps, 2004; Prestt, 1971), after which time, the males disperse to summer feeding areas. Summer feeding areas are usually wetter areas such as wet heath, valleys and marshland; and may be several hundred metres from hibernacula (Andersson, 2003; Andrén, 1982; McInerny 2014; Phelps, 2004; Prestt, 1971; Viitanen, 1967). Prey species typically comprise small mammals such as mice, voles and shrew; nestlings, slow worms and common lizards (Prestt, 1971). Juvenile and immature adders feed more commonly on nestling mammals and lizards (Luiselli et al. 1995; Prestt, 1971).

The adder is ovoviviparous, which means the female retains the eggs within the oviduct and the developing young are nourished by the egg yolk (Beebee & Griffiths 2000). By retaining the young within the oviduct, the female can regulate the incubation temperature and thus optimize the development of her young (Gregory et al. 1999; Qualls & Andrews 1999). By contrast, oviparous species that lay eggs, such as grass snakes (*Natrix helvetica*), rely on the availability of thermally stable nesting sites (Shine 2005). Incubation temperature influences the mass, growth rate and survival of offspring; and so viviparity has a clear selective advantage in cooler, more variable climates (Gregory et al 1999; Qualls & Andrews 1999).

Figure 13. Adult female. Adders exhibit sexual dimorphism. Females typically have brown dorsal markings whereas males have black. Photo by David Struthers

The female adder (Fig. 13) is a capital breeder - she relies on accumulated energy stores for reproduction. Capital breeding ensures optimal reproductive success in reptiles that live at high latitudes where the active season is short (Gregory, 2006). Females must obtain a critical mass in order for vitellogenesis (yolk development) to proceed (Naulleau & Bonnet, 1996). Females typically breed biennially as they are unable to accrue enough mass each season to breed annually (Forsman & Lindell, 1991; Madsen & Shine, 1993; Prestt, 1971; Viitanen, 1967). Gravid females do not feed and thus remain relatively sedentary, close to their hibernacula

(Phelps, 2004, 2007; Viitanen, 1967). Development of the young is therefore not dependent on the feeding rate during gestation but on energy stores prior to vitellogenesis and thermoregulation during incubation (Doughty & Shine 1998; Gregory 2006; Naulleau & Bonnet, 1996; Shine 2005).

Throughout pregnancy, female energy reserves become impoverished, leaving them extremely emaciated after birth (Gregory et al. 1999; Madsen & Shine, 1993; Naulleau & Bonnet, 1996; Shine, 2005). In late August/early September, females give birth to 3-14 offspring and immediately begin foraging within their wintering quarters (Andrén, 1982; Madsen, 1988; Phelps, 2007; Prestt, 1971; Viitanen, 1967). Neonates are fully venomous and live off fat reserves during their first winter (Prestt, 1971).

Adders return to their hibernacula in the late summer where they bask before hibernation begins at the end of October/early November (McInerny, 2014; Prestt ,1971). Adders are highly philopatric, often returning to the same hibernaculum every year throughout adulthood (Gleed-Owen & Langham, 2012; Phelps, 2004; Prestt ,1971; Viitanen, 1967).

Marley Common

Marley Common is an area of relict heathland and secondary woodland situated less than a mile south of the county border between surrey and West Sussex (N51° 04.397' W0° 44.085'). The common overlies the sandstone Hythe Formation of the early Cretaceous (British Geological Survey 2007) and is characterised by sandy, well-drained, acidic soils (Lister & Alexander 2000). The habitat underwent large scale clearance of secondary woodland in 2005/2006 to restore former heathland (M. Bramich 2017, pers. comm., 12 April). Four Belted Galloway cattle were introduced to the site in 2010 for the purpose of scrub management and maintaining structural diversity.

The study area covers approximately 13 ha, excluding wooded regions on the eastern and northern margins (Figs. 14 & 15). A road running adjacent to Marley's western margin

intersects a narrow corridor of woodland that connects Marley Common to Linchmere Common on its north-eastern edge. Marley and Linchmere Common form part of the South Downs Serpent Trail.

Marley Common is characterised by a matrix of scrub, heath and woodland. The existing heath most closely represents a H2 *Calluna vulgaris-Ulex minor* community (Lister & Alexander 2000). Figures 15a to 15e give examples of the variation in structural complexity between different areas of the common. Marley predominantly comprises dwarf shrubs and scrub, notably, heather (*Calluna vulgaris*), bilberry (*Vaccinium myrtillus*), gorse (*Ulex europaeus*) and birch (*Betula spp.*). Bracken (*Pteridium aquilinum)* and bramble (*Rubus fruticosus*) also occur widely. Bell heather (*Erica cinerea*) and cross-leaved heath (*Erica tetralix*) occur sporadically and are much less abundant.
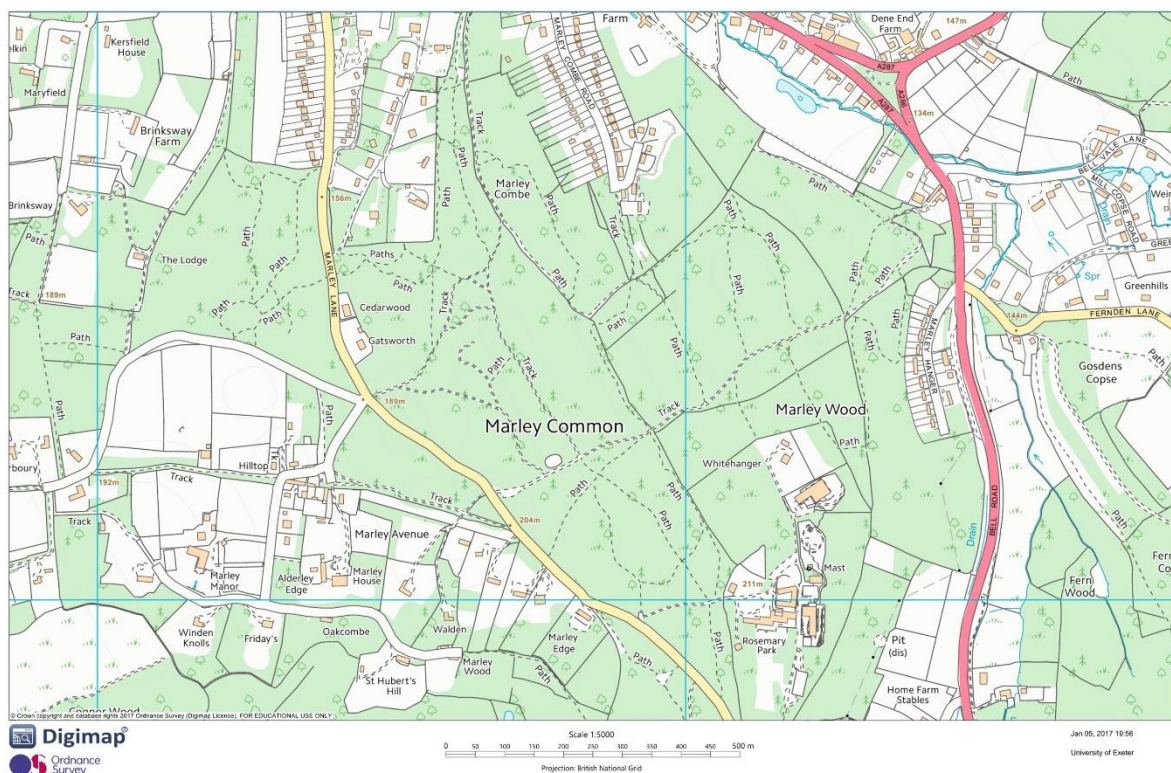

Figure 14. Ordnance Survey map of Marley Common. Image Source: http://digimap.edina.ac.uk/roam/os.
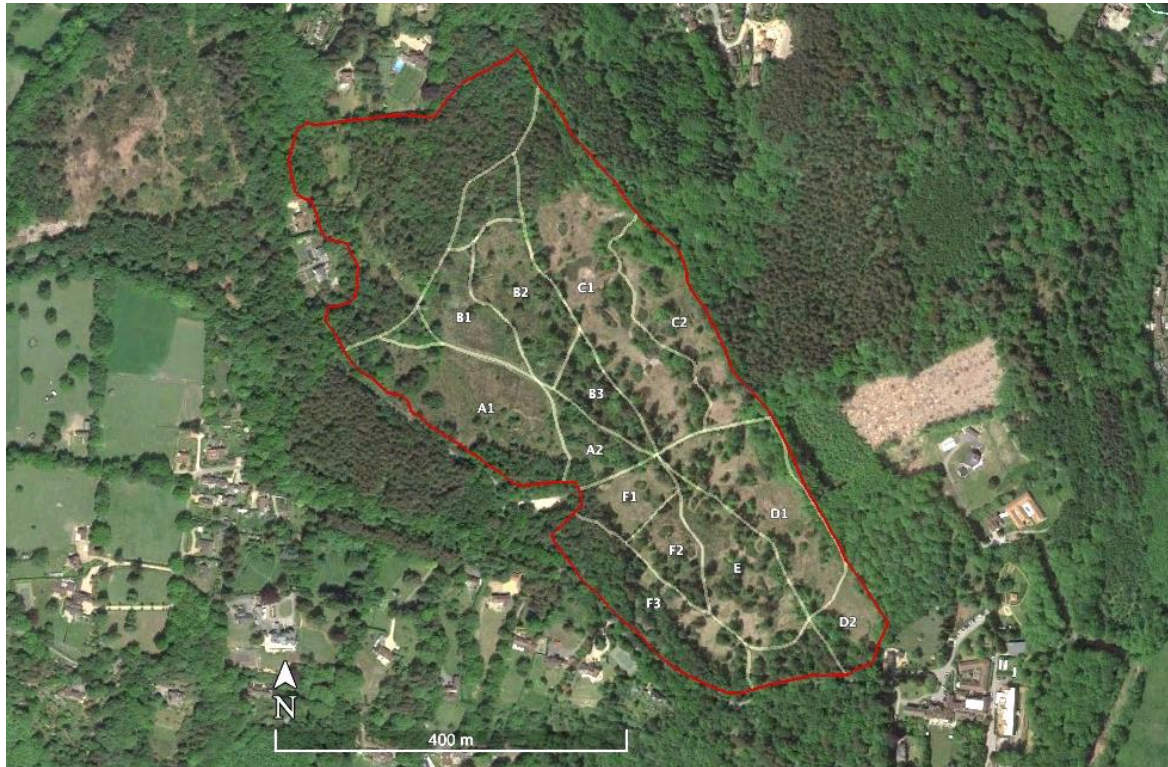
Figure 15. Satellite map of Marley Common showing survey areas (Labelled A1-F3). Satellite imagery sourced from Google Earth Pro 7.1.8.3036.

The common lizard (*Lacerta vivipara*) is abundant across Marley Common. Slow worms (*Anguis fragilis*) are also frequently encountered beneath artificial refugia. Several grass snakes (*Natrix helviticus*) have also been recorded and appear to be widely distributed. Small mammals have also been noted, including shrew (*Sorrex spp.*) and field voles (*Microtus agrestis*).

Among more widespread species, a variety of invertebrates characteristic of lowland heathland have been recorded in Marley's past, such as the horse chestnut moth (*Pachycnemia hippocastanaria)*, the heather leafhopper (*Ulopa reticulata)* and various wasps and bees including the spider hunting wasp *Arachnosplia anceps* and the mining bee, *Colletes succinctus*.

Clouded buff moth (*Diascrisia sannio*) at Marley Common.

The common formerly supported woodlarks (*Lullula arborea*) and nightjars (*Caprimulgus europaeus)* however disturbance has probably prevented these from breeding successfully in recent decades (Lister & Alexander 2000; M. Bramich 2018, pers. comm., 26 July). Heathland restoration will provide larger areas of core habitat buffered from disturbance, which may benefit ground nesting birds in the future.

Figure 16a. Area A1 is a small area of remnant heath and is the only area not to have undergone large scale woodland clearance. Mature heather and moss form a sparse mosaic of islands and mounds, providing ideal opportunities for basking and refuge.

Figure 16b. Area B2 is structurally diverse matrix of birch re-growth, gorse, bilberry and mature heather, with scattered trees. The dense vegetation offers refuge and small pockets offer secluded basking spots.

Figure 16c. Area C1 is a large open area comprising acid grassland and low-level scrub re-growth, including birch, bramble and gorse. Pioneer heather becomes more common towards the is north west. Large, poorly connected thickets of mature gorse and birch provide edge habitat for basking.

Figure 16d. Area F1 looking south-east to Area F2. An open area with sparse gorse regrowth and widespread pioneer heather. Large birch thickets may serve as hibernacula.

Figure 16e. D1 is a densely vegetated area, dominated by gorse and birch. A mosaic of mature heather and bilberry can be found beneath the canopy of birch.

Methodology and Objectives

The project was carried out in two phases. The first phase was conducted in the Spring of 2014 by Matt Bramich (Senior Ranger of the South Downs National Trust) and aimed to understand more about the movements of male adders during the mating period. The second phase of the project took place in the summer of 2015 and aimed to understand male foraging behaviour.

Adders are most easily located in the morning, when they are likely to bask in the open or along the edges of vegetation, with their bodies fully exposed to the sun. This behaviour maximises exposure to solar radiation and enhances the rate at which the adder achieves an optimum body temperature. In 2014, adders were located on visual surveys, conducted between 10:00 and 16:00, from the 3rd of March to the 12th of May. In the Summer 2015, hot weather restricted surveys to 9:00-11:30 in the morning, however, the site was often re-visited in the late afternoon, between 3:30-19:00. Surveying in 2015 was conducted from 8th of June to the 23rd of July, after which, short, informal surveys were undertaken weekly.

During the surveys, adders were captured, photographed, weighed (using a Pesola LightLine 10500 Spring Scale, measuring to the nearest 5g), measured (using a flexible measuring tape to the nearest mm) and marked (to avoid further disturbance). The aim of this work was to create a photo log of each specimen in order to facilitate future monitoring of the population. Adders were differentiated from one another by examining scale and colour patterns on their heads (Fig.17). Each adder has a unique number and arrangement of head scales (Benson 1999) which typically remain the same throughout their life, (however see Hodges & Seabrook , 2014), allowing re-identification in the future. The apex and inverted Y shaped markings on the head are other distinguishing features (Sheldon & Bradley 1989).

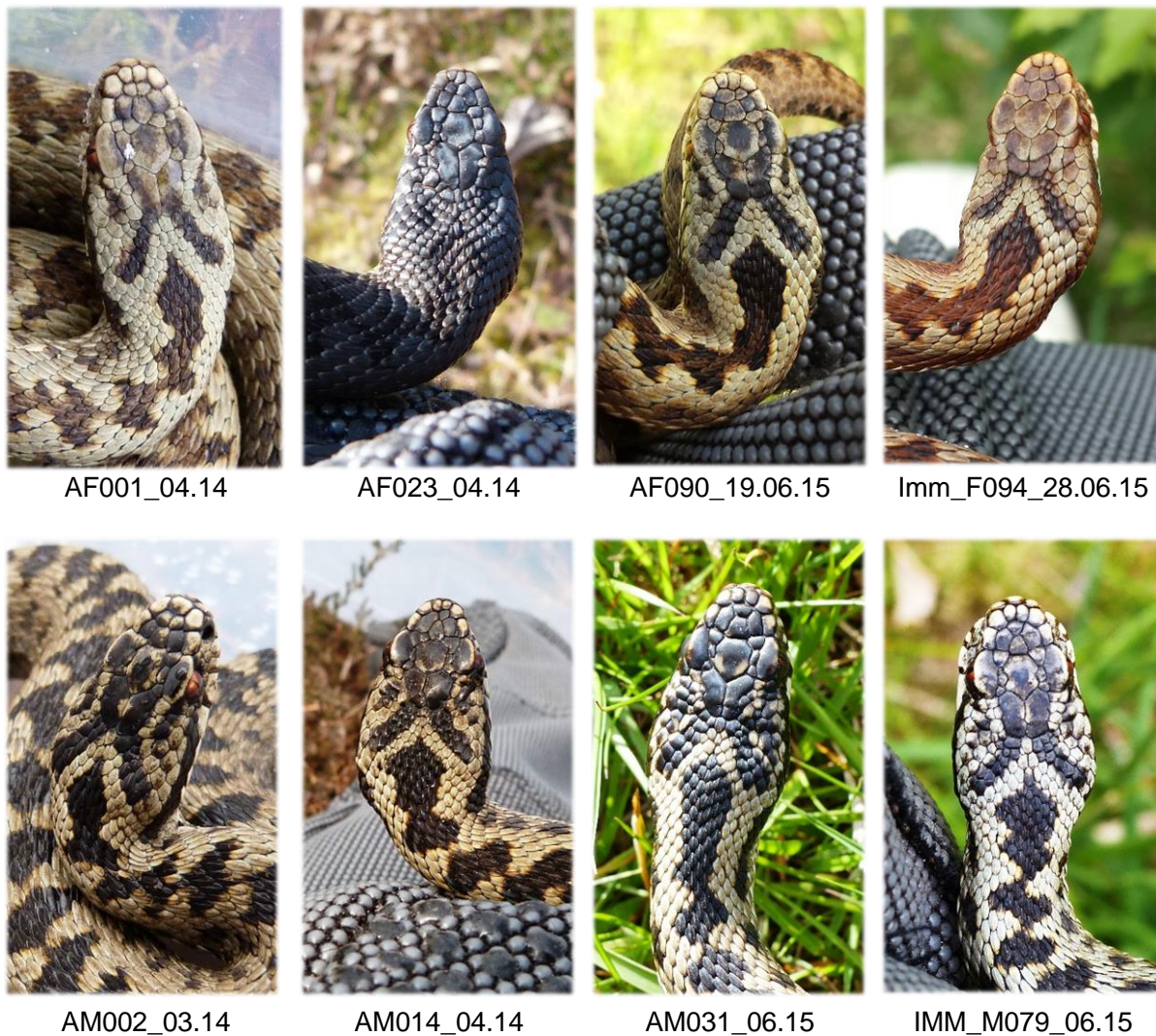| AF001_04.14 | AF023_04.14 | AF090_19.06.15 | Imm_F094_28.06.15 |
| AM002_03.14 | AM014_04.14 | AM031_06.15 | IMM_M079_06.15 |

Figure 17. An example of photos from the adder ID log, used to identify individuals. The top row are females, the bottom row are males.

The common was surveyed for an average of 4 hours a day, both in 2014 and 2015. PicoPip AG392 radio-transmitters (by Biotrack) were secured externally to adders using clear 'Tagaderm' medical tape wrapped around the body of the snake, above the cloaca (Fig. 18). The tags weigh 1.1g and have a battery life of 59 days, allowing 2 months of data collection. Adders were tracked on a daily basis using the Biotrack SIKA radio tracking receiver and flexible Yagi antenna. Adder positions were recorded using a Garmin e-trex 20 handheld GPS device. In some cases, adders that were particularly active were located twice in the same day. Eight adult males and two adult females were tracked in 2014. Eight of these tags were re-covered and reconditioned for use in 2015.

Figure 18. A male adder fitted with the PicoPip radio-transmitting tag.

In spring 2014, only movements of 5 or more metres were recorded due to limited GPS accuracy. In 2015, the GPS position of the adder was recorded on every occasion. GPS accuracy is limited to 3-4 metres and so GPS data representing the same location may vary. Using field notes, it was possible to determine which GPS data should be averaged to give a single point.

Outcomes and Findings

Spring 2014 Telemetry

A total of 10 adders were tagged in 2014 - 8 males and 2 females (Table. 2). Figures 18.1-18.8 illustrate the track-log for each adder. The track-log for AM016 is not described as it contained just two GPS points, the data is instead included in Appendix 1.1.

Adder ID	Name	Sex	Age	Total Length (cm)	Relative Body Mass (mass/length)	Start Date	End Date	Duration (days)	Total Distance (m)	m/day
AM003	Jellybean	M	Ad	53	0.85	16-Apr	02-Jun	48	291	6.2
AM064	Dr Livingstone	M	Ad	55	1.09	16-Apr	01-Jun	47	718	15.3
AM004	Slough Daddy	M	Ad	57	1.32	15-Apr	31-May	46	413	9.2
AM014	Litmus	M	Ad	48	1.22	15-Apr	31-May	46	1393	34
AM038	Edmund	M	Ad	44	0.91	17-Apr	01-Jun	46	387	8.6
AF023	Ebony Nightshade	F	Ad	55	1.65	18-Apr	01-Jun	45	227	6
AM013	Norman	M	Ad	49	1.02	20-Apr	29-May	39	222	6.2
AM016	AM016	M	Ad	49	1.02	24-Apr	29-May	35	7	0.2
AM043	Tyson	M	Ad	53	1.79	06-May	01-Jun	26	592	22
AF018	Judith	F	Ad	67	1.87	26-Apr	06-May	10	20	2

Table 2. A summary of adders tracked in 2014. Refer to Appendix 1.1-1.10

Explanation of Figures

All maps were created using Google Earth Pro 7.1.8.3036. Faded lines indicate trajectories between points recorded from visual encounters (without telemetry). Bold lines represent displacement between consecutive points recorded during tracking with telemetry. It is important to remember that lines between points do not represent the actual path or distance

travelled by the adders but represents the trajectory or straight-line distance between consecutive points.

Blue shaded areas indicate possible hibernacula. Pink-shaded areas indicate mating areas. Red-shaded areas indicate areas that were re-visited by adders. Numbers denote the number of days an adder stayed at the same location. Refer to legends for an explanation of icons. Inflated icons represent locations where adders remained for consecutive days.

Litmus (AM014)

Litmus (Fig 18.1) was first encountered on 10th March at the edge of a wooded margin in area C1. It is likely that a hibernaculum is located nearby, especially as two other males (AM016 and AM031) were seen in this area from early to mid-March. On the 15th April Litmus was encountered again, approximately 116m south-west, in a small glade, in area A2.

It is possible that Litmus contacted two adult females here: Alice (AF001) and AF054. Alice was encountered in area A2 between 3rd March and 8th April and left the area by the 12th April. AF054 was encountered in the area on 29th April, however, it is possible that she arrived earlier as her movements are unknown after the 10th April, when she was encountered in area F1.

On average, Litmus travelled 34m a day (*n*=41; *range* = 4-211m; appendix 1.2), more than any other male tracked during spring 2014. The total distance of his track-log is almost 1400 metres. Litmus exhibited large daily movements, pausing only occasionally, and frequently returned to previously visited areas (clusters of points shaded red and blue). In particular, Litmus visited a wooded margin in area D1 (shaded blue) on the 17th March and returned on the 26th April, where he remained for 4 days. Interestingly, this area could be close to a hibernaculum as another adult male (AM004) was encountered here early in the season, on the 4th March.

Figure 18.1. Track-log for Litmus (AM014). Other adders encountered (visually) during the course of telemetry are also shown.

Litmus also re-visited his own hibernaculum on the 30th April before returning to the edge of a previously visited thicket in area C2. He then completed a large loop and re-visited an area in Area D1 (shaded red). Numerous females were encountered in this area in summer, 2015. The track-log shows that Litmus was often located on the edge of scrubby thickets or wooded margins and it is possible that such features are used as stepping stones or corridors.

Norman (AM013)

Two other adult males were also encountered in area A2 – Norman (Fig 14.2) and Tyson (AM043, Fig 14.3). Data and behavioural observations suggest that A2 is an important mating area.

Norman was present in area A2 between the 10th March and 5th May. On the 8th of April he was observed mate-guarding Alice. Norman was tagged on the 20th April and was located to the same position from the 24th April to the 5th of May (12 Days), during which time he was seen close to AF054 (29th April). It is therefore possible that Norman mated with AF054 as well

as Alice. Norman left the mating area on the 6th May and was located to a birch tree in area A1 on the 9th of May, where he remained for 7 days. Norman's average daily distance of 6.16m (*n*=39, *range* = 2-59m; appendix 1.3) a day is much smaller than that of Litmus. This may reflect differences in mating strategies between the two individuals, although both males had a similar body condition and size.
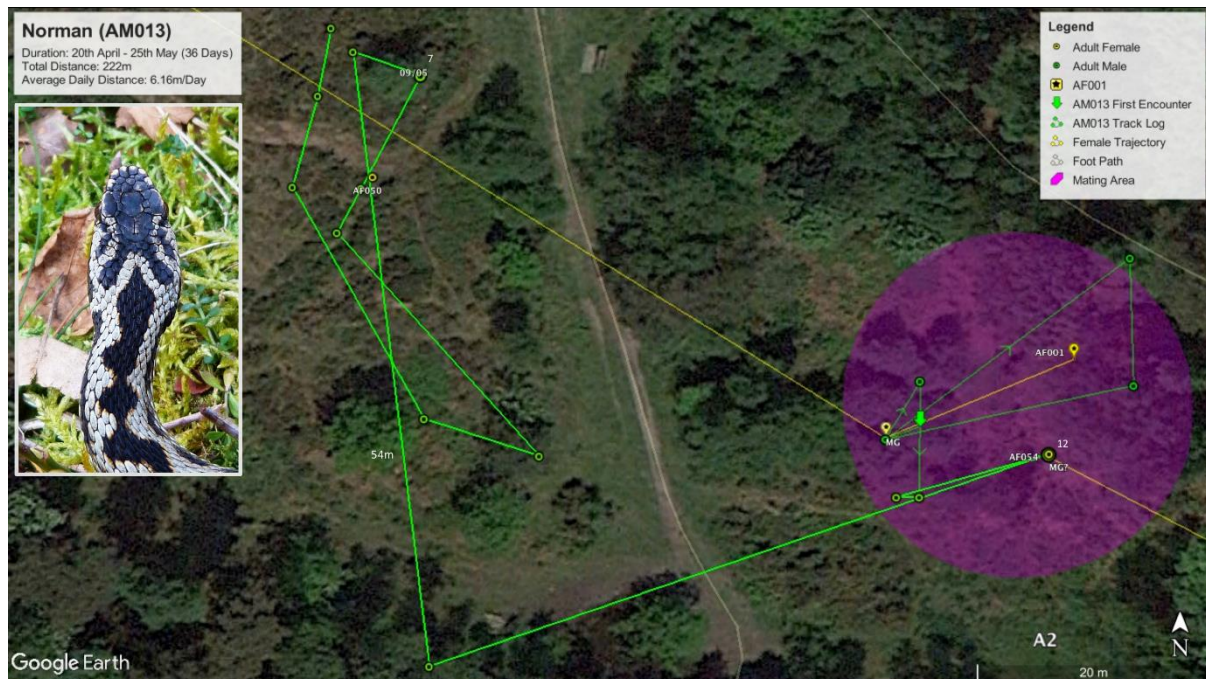

Figure 18.2. The track-log for Norman (AM013) highlighting activity in the mating area (shaded pink). *MG* denotes mate-guarding behaviour.

Tyson (AM043)

Tyson was first recorded in Area A1 on the 26th March (Fig. 18.3). On the 14th April, he was encountered, 137m ESE, in area A2. Tyson's movements are unknown for the next 40 days and it is possible he contacted Alice and AF054 during this time.

Tyson was fitted with a transmitter on the 6th May, approximately 116m away from his previous sighting in the mating area. Tyson's average daily distance was 22m (*n*=27, *range* = 6-89m; appendix 1.4) and like Litmus, Tyson returned to previous locations. Between the 20th and 30th May, Tyson was repeatedly located to a thicket in area A1 where he may have courted

a female although no mate-guarding behaviour was recorded.

Figure 18.3. Track-log for Tyson (AM043). Direction of travel is shown for adult female AF018 and adult female AF001 (yellow).

Edmund (AM038)

Both Litmus and Tyson exhibited large, daily movements however other males exhibited much smaller daily movements with frequent pauses lasting 4 days or more. Edmund (Fig 18.4) was first encountered on the 22nd of March in area A1 and was subsequently observed mate guarding AF055 on the 10th April. On the 17th April, Edmund was tagged and tracked for a period of 45 days, during which he travelled approximately 390m. On average, Edmund travelled a distance of 8.6m per day (*n*=45, *range* = 7-79m; appendix 1.5). Edmund paused on numerous occasions, for 5-7 days, using mounds and thickets for refuge. Edmund was not observed with any females during tracking but was frequently observed basking in the late morning and afternoon. This behaviour may indicate that Edmund had started to hunt, since basking is necessary to optimize digestion of food.
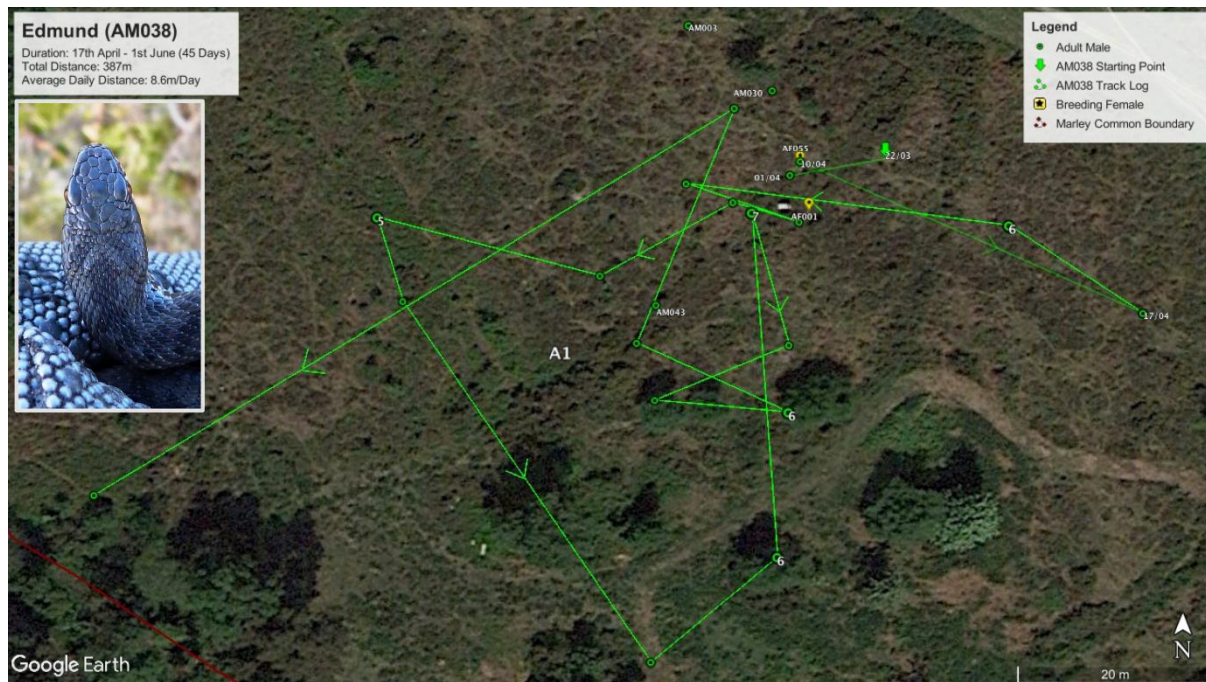
Figure 18.4. Track-log for Edmund (AM038). Other adders present during the tracking period are shown – refer to legend.

Slough Daddy (AM004)

Slough Daddy (Fig. 18.5) was first recorded on the 4th March on the edge of a wooded margin, in area D1. He was recorded here again on the 10th of March and 1st April. By the 3rd of April, he had travelled 130m south-south west to a mating area/hibernaculum in area E. This behaviour reflects the immediate increase in activity following the first exuviation, as described by Prestt (1971).

A number of females were recorded nearby during the first half of April – AF049 on the 1st, AF061 on the 12th and AF023 on the 14th April. Although Slough Daddy was not observed with any females, the data suggest that it is likely he came into contact with AF061. On the 15th April, Slough Daddy was recorded in the same location that AF061 occupied three days earlier. He remained in the vicinity for 19 days, during which he remained relatively sedentary, moving an average 3.1m per day (n= 46, *range* = 5-119m; appendix 1.6).

Figure 18.5. Track log showing movements of Slough Daddy (AM004). Other adders present during the tracking period are shown – refer to legend.

Comparison of the body condition of AF061 to that of other females suggests that she may well have been in breeding condition. Her body condition was similar to that of Ebony Nightshade (AF023), a large melanistic female that was mated by Dr Livingstone (AM064) in the same year.

In first week of May, Slough Daddy travelled approximately 120m north to area D1, where he was subsequently located to the same thicket for a period of 13 days. Adult female, AF073, was recorded just 49m away from this thicket on the 2nd May therefore it is possible that Slough Daddy contacted or mated with this female sometime in mid-May. By the 19th of May, Slough Daddy had returned back to area E, close to his previous location.

Dr Livingstone (AM064) & Ebony Nightshade (AF023)

Figures 18.6 and 18.7 show the track logs for Dr Livingstone and Ebony Nightshade. Ebony Nightshade was encountered, visually, on the 14th of March in area E, close to the aforementioned hibernaculum. Dr Livingstone was encountered nearby and tagged on the

16th. On the 18th of April, Dr Livingstone was observed mate-guarding Ebony Nightshade on the edge of a wooded margin in area F3. The GPS data reveal that Dr Livingstone followed the same trajectory as Ebony Nightshade and appears to have followed her movements closely.
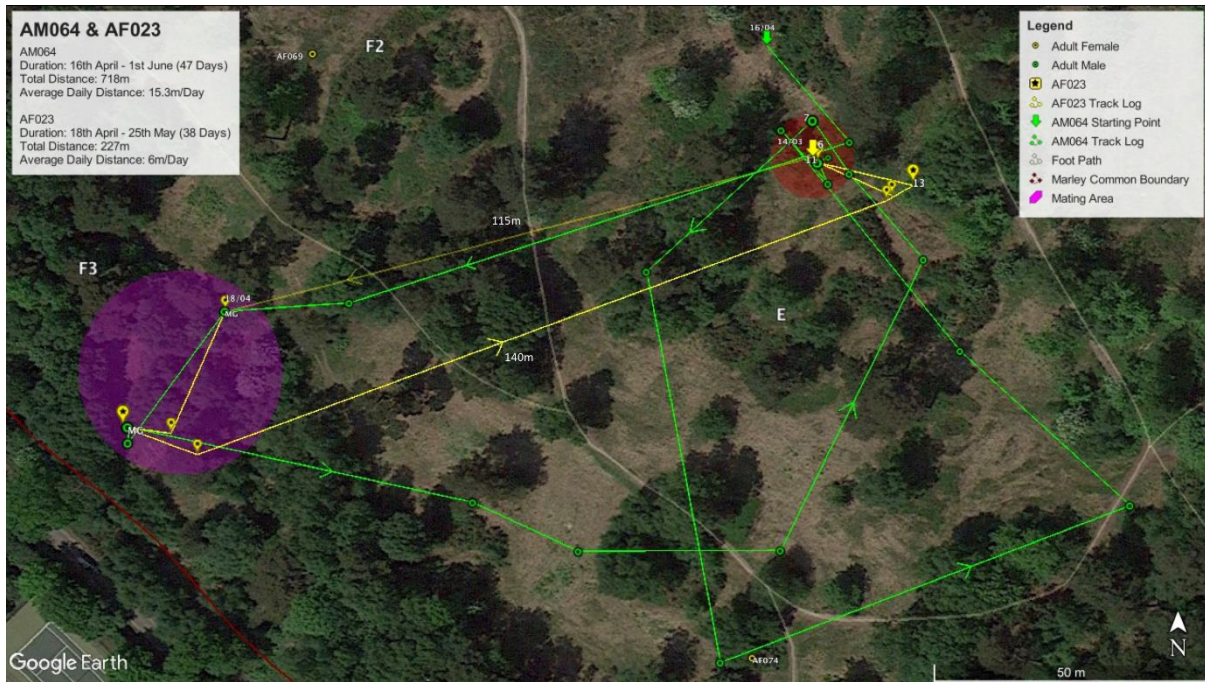

Figure 18.6. Map showing the movements of AM064 (green) and AF023 (yellow).

After being fitted with a radio transmitter, Ebony Nightshade moved further into cover. Dr Livingstone followed her movements and the pair remained together until the 29th of April, at which time Dr Livingstone began to circle back towards area E, pausing shortly at thickets along the way. Ebony Nightshade remained in the mating area until the 4th May. Within a day, she had travelled 140 metres back to her presumed wintering quarters in area E. Over the next 20 days, Ebony Nightshade became very sedentary and was frequently observed basking.

The track-log shows that Dr Livingstone undertakes two large circular movements in which he returns to a previous position (red shaded circle), where he remains for a number of days. This 'looping' behaviour is evident on other track logs and suggests that adders have a high tendency to return to features, besides hibernaculum and mating areas.

On average, Dr Livingstone travelled 15.23m per day (n=47, *range* = 3-99m; appendix 1.7). Ebony Nightshade travelled an average 5.18m per day (*n*=45, *range* = 13-125m; appendix 1.8).
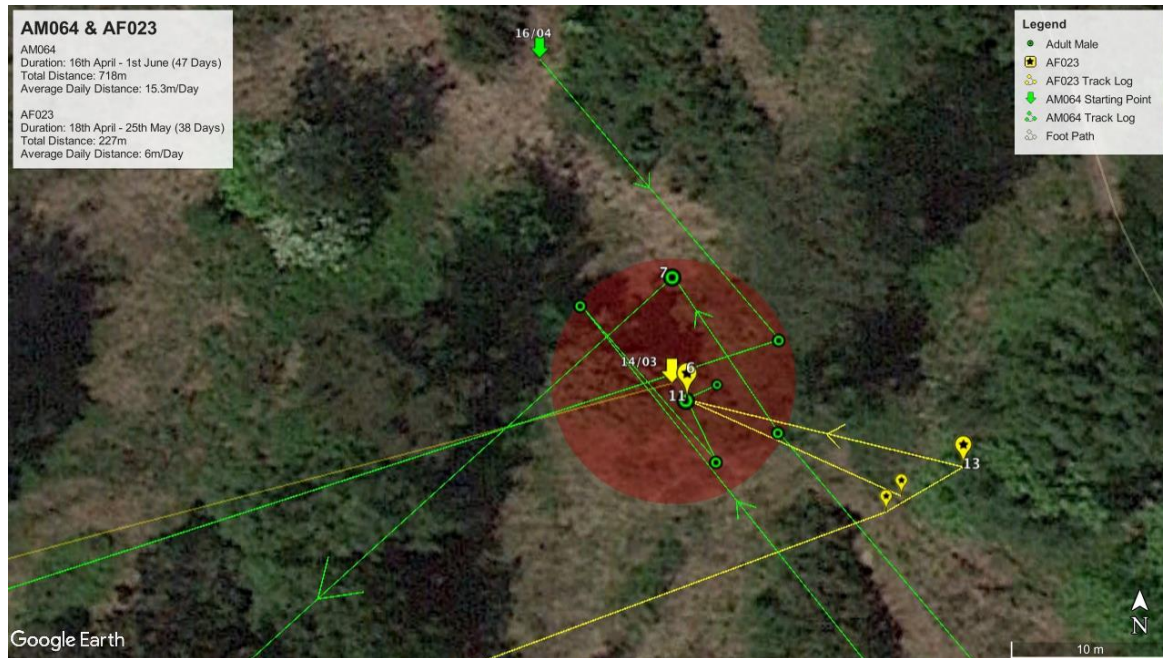

Figure 18.7. Magnified view of AM064 and AF023 in area E.

Jellybean (AM003) & Judith (AF018)

Judith was not tracked for just three days due to a transmitter failure. She was first encountered on the edge of woodland in area C2, on the 12th March. This is likely to be close to her hibernaculum. She was next encountered on the edge of a wooded margin in Area C1 on the 1st April. When tagged on the 26th of April, Judith was 212m, south-west, in area A1. Judith's relative mass at the beginning of march (1.87g/cm) was higher than that of other females, known to have mated - Ebony Nightshade (1.65g/cm) and Alice (1.07g/cm). This may indicate that Judith was in breeding condition in 2014. Judith travelled an average 2m per day (*n*=20, *range* = 0-10m; appendix 1.10)

Jellybean, like Norman had a small average daily distance (*M*=6.19m, *range* = 0-57m; appendix 1.9) and total distance (291m). His movements were much shorter and less frequent than his male conspecifics (Fig. 18.8). On the 29th April, adult female AF073 was seen less than a metre away from Jellybean and so it is possible that he mated with her, especially as he remains here

for a further 3 days. Jellybean then travelled a further 57 metres before becoming very sedentary, travelling just 10 metres in 26 days. For 18 days, Jellybean is tracked to the same artificial refugia (corrugated metal used for surveying reptiles). It is possible that towards the end of April/early June, Jellybean was in ecdysis (shedding of skin), explaining his sedentary behaviour.

Figure 18.8. Track-logs for Judith (AF018) and Jellybean (AM003). MG? denotes possible mate-guarding behaviour.

Spring 2014 Survey Data

Visual encounter data from spring 2014 surveys is available in appendix 2. Figures 19.1 and 19.2 show the distribution of adders encountered on visual surveys between the 1st March and the 7th May 2014. These data were used to determine the most likely locations of hibernacula on Marley Common (Fig. 21). Adult males encountered in the first two weeks of March are likely to be close to their hibernacula whereas males recorded in late March are more likely to have undergone local dispersion. Similarly, encounters of females in March and early April are likely to occur close to hibernacula whereas females recorded in late April are more likely to have undergone local dispersion.
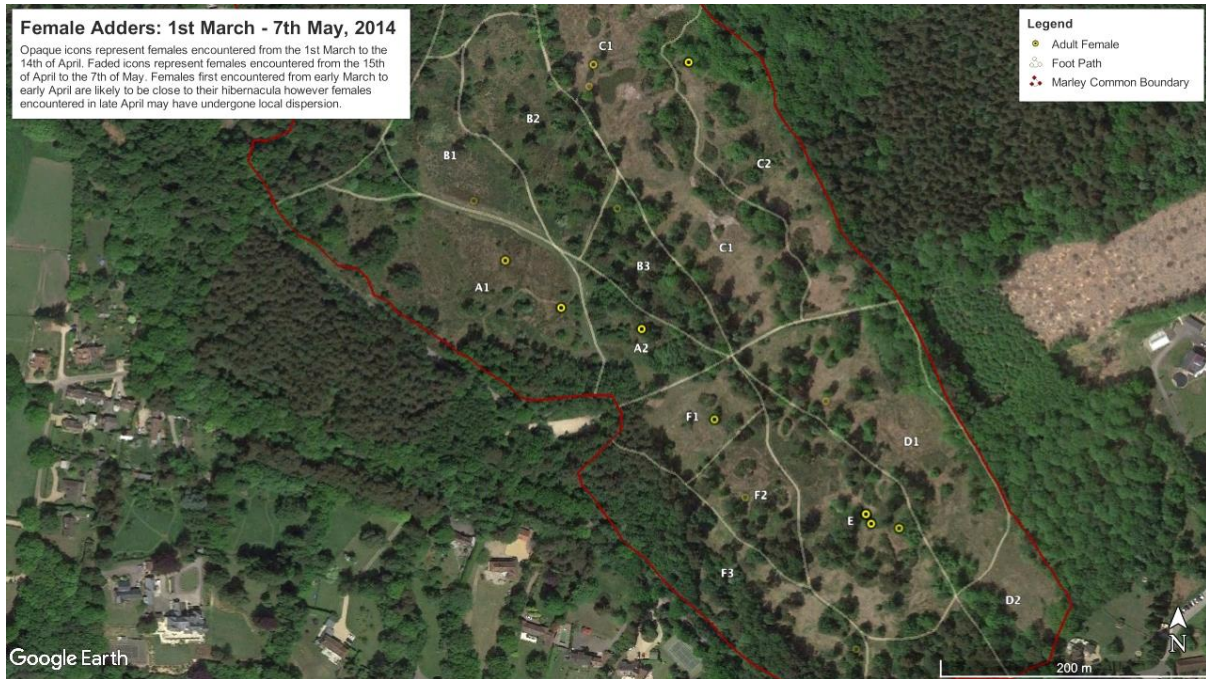
Figure 19.1. The distribution of first-time encounters of adult females between 1st March and 7th May 2014. Successive encounters of the same individual are omitted therefore the data show the encounters of new individuals only. Opaque (bold) icons represent females encountered from the 1st March to the 14th April. Transparent (faded) icons represent females encountered from the 15th April to the 7th May.

Figure 19.2. The distribution of first-time encounters of males during the 1st March to the 21st April 2014. Successive encounters of the same individual are omitted therefore the data show encounters of new individuals only. Opaque (bold) icons represent males encountered from the 1st to the 14th March. Transparent (faded) icons represent males encountered from the 15th March to the 21st April.

Figure 21 shows the most likely locations of hibernacula based on spring visual encounter data. The data reveal that the majority of the hibernacula are associated with wooded margins and scrubby thickets, highlighting the importance of retaining such features in the habitat.

Figure 21. Map of hibernacula (blue) and mating areas (pink). Such data can be incorporated into management plans for Marley Common.

Figure 22 shows the number of first-time encounters from the beginning of March to the first week of May. The data indicate that male emergence peaks in the second week of April, whilst female emergence is much more protracted, peaking in late April. Emergence of immature and juvenile adders is also protracted, peaking in the 3rd week of April. The data generally support the sequence and timing of emergence recorded by other observers (Andrén, 1982; Andersson, 2003; Prestt, 1971; Viitanen, 1967). Notable examples include AF001 (Alice) and AF023 (Ebony Nightshade), which were first encountered on the 3rd and 12th of March respectively. This may be considered particularly early for a female; especially as female emergence is widely considered to occur several weeks later than males. The majority of female records occurred in April, with just 4 records of new individuals in March, compared to 11 in April (Fig. 22).

It is important to exercise caution when interpreting visual encounter data. Visual encounter data are influenced by survey bias, weather conditions and imperfect detectability and so may not reflect true emergence patterns and abundance. The number of hours spent surveying in 2014 varied between 6 and 14 hours each week (M=10, SD=2.47), possibly accounting for differences in the number of encounters between weeks. Furthermore, adder activity is influenced by abiotic factors such as temperature and solar radiation which varies day to day. Thus, it may not always be possible to survey under optimal conditions on each visit. In addition, not all adders present in a particular location may be detectable during the short period that the surveyor spends at that location.
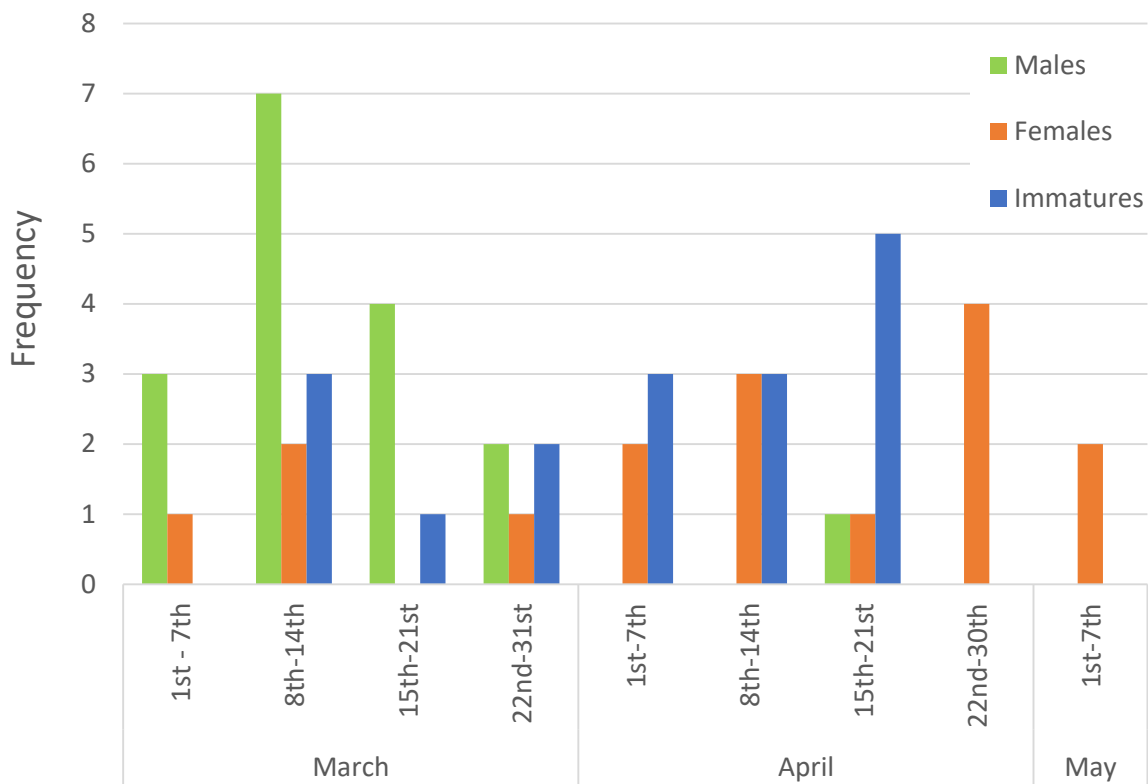

Figure 22. The frequency of new encounters from 1st March and 7th May, showing a peak in new adult males (Green) during the second week of March and the more protracted emergence of adult females (Orange). The number of new Immature individuals encountered are shown in blue, peaking in the 3rd week of April.

Analysis of visual encounter data reveals movements by both males and females towards other hibernacula to form mating aggregations (Figs 23.1 & 23.2). At least 3 males (AM004, AM016 and AM034) are known to have migrated to area E during the mating period. Similarly, at least 2 males are known to have migrated to area A2 (Fig 23.1). There is also evidence of females migrating to mating areas (AF023 and AF054).

The visual encounter data also provides an example of a female migrating away from the mating area after mating. AF001 (Alice) exhibits similar behaviour to Ebony Nightshade (AF023), migrating away from area A2, after mating with Norman (Fig 23.2). On the 29th of April, Alice was encountered close to a possible hibernaculum in area B2, 154m from her mating area. Her whereabouts after this date remains unknown.

Interestingly, mating areas (shaded pink) are associated with trees and are characterized by small glades, with scrub providing refuge. This highlights the importance of maintaining woodland features within the habitat matrix.

Figure 23.1. Visual encounter records for Spring 2014, showing migration towards mating areas (pink). The blue dashed line represents the displacement between the AF054's location on the 8th and 29th April. Distances between consecutive encounters are shown.
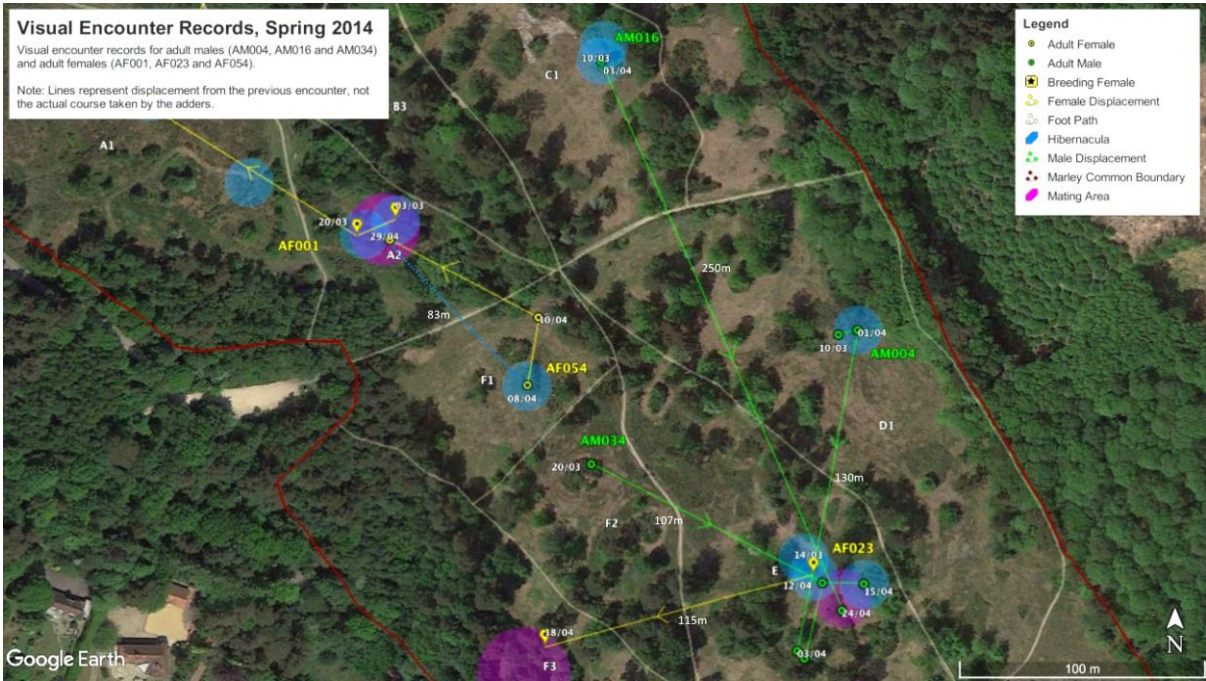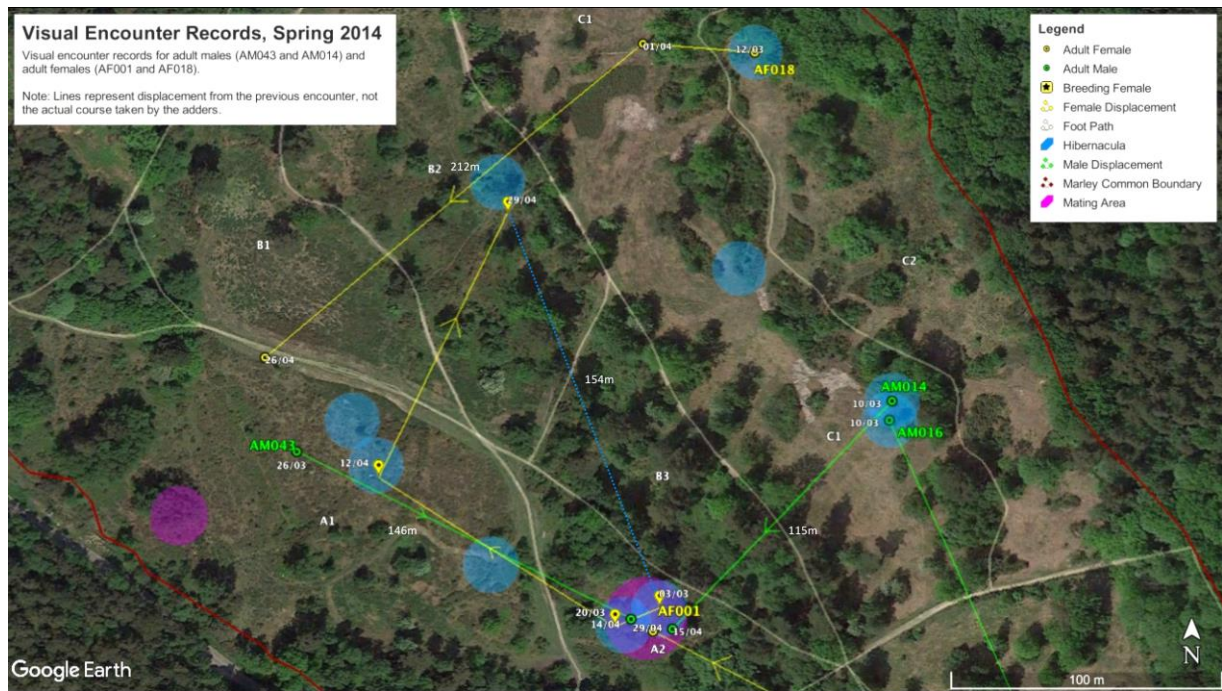
Figure 23.2. Visual encounter records for Spring 2014, showing migration towards mating area in A2. The blue dashed line represents the displacement between AF001's location on the 3rd of March and her location on the 29th April. Distances between consecutive encounters are shown.

Summer 2015 Survey Data

A total of 93 individuals were captured and assigned ID's during the course of the project (Table 3; appendix 3). 43 individuals were recorded in 2015 (see appendix 4), 12 of which were recaptured from spring 2014. 2015 survey data are biased towards females due to the increased detectability of gravid females during the summer (Figs 24 & 25). The encounter rate of females during the summer 2015, was almost three times that of adult males (Fig. 25). Gravid females remain relatively sedentary until parturition and could frequently be found basking at the same location. By contrast, adult males were rarely found at the same location. This was most likely due to increased frequency of movement and time spent in dense vegetation.

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	Spring 2014	Summer 2015	TOTAL	No. of new Records	No. of individuals captured in 2014 & 2015
Adult Females	15 (30)	23 (53.5)	38 (40.9)	17	6
Immature Females	4 (8)	3 (7)	7 (7.5)	2	1
Adult Males	17 (34)	8 (18.6)	25 (26.9)	3	5
Immature Males	2 (4)	5 (11.6)	7 (7.5)	5	0
Juveniles	12 (24)	4 (9.3)	16 (17.2)	4	0
TOTAL	50	43	93	31	12

Table 3. Summary of records for individuals that were assigned an ID. Percentages of the proportion of individuals for each category are shown in brackets for each column.
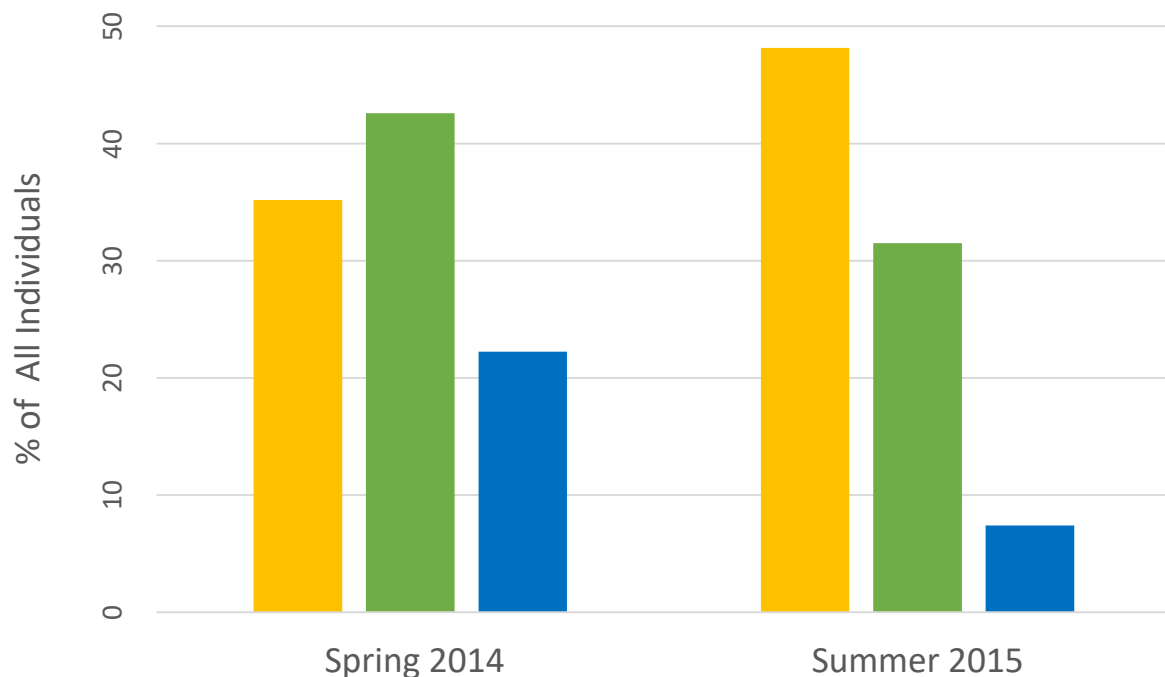

Figure 24. % of males (green), females (yellow) and juveniles (Blue) captured and identified in spring 2014 compared to summer 2015. There was an increased proportion of females and a decreased proportion of males captured and identified during the summer 2015.

Fewer adult males were identified in summer 2015 compared to 2014 (8 and 17 respectively; Fig. 24). Furthermore, fewer adult males were re-encountered within the same year during summer 2015 (37.5%) compared with spring 2014 (52.9%). Just 5 adult males identified in 2014 were recaptured again in 2015, leaving the whereabouts of 12 adult males unknown. It is unlikely that these 12 adult males died during the interval between surveys. Therefore, it may be by chance that these males were not encountered in 2015, especially given the elusive behaviour of adult males during the summer. Alternatively, it is possible that adult males migrate to feeding areas outside the survey area.

It is not possible to reliably determine adder foraging areas from 2015 visual encounter data due to the lack of male encounters and bias towards females. Although a number of adult females would not have been in breeding condition in 2015, it was difficult to distinguish between individuals that were gravid (not feeding) and those that were feeding, unless an obvious food bolus in the upper digestive tract was visible.
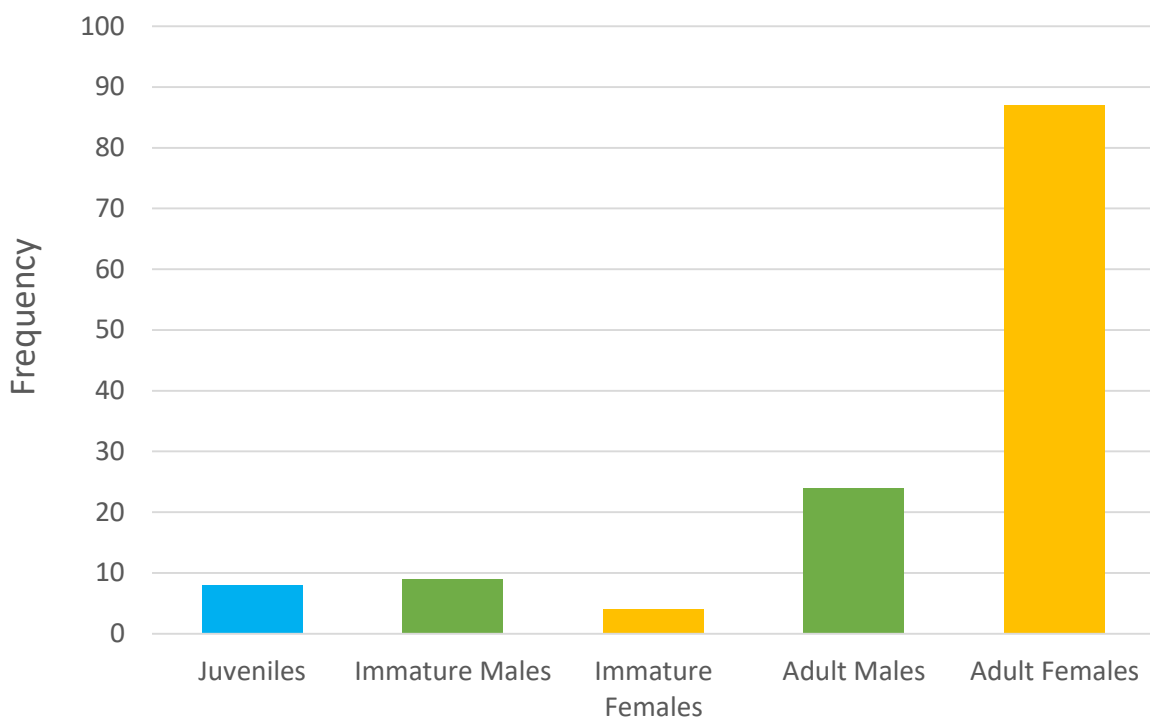

Figure 25. Total number of visual encounters during Summer 2015, including individuals that were not caught and identified. Adult females were encountered almost three times as often as adult males.
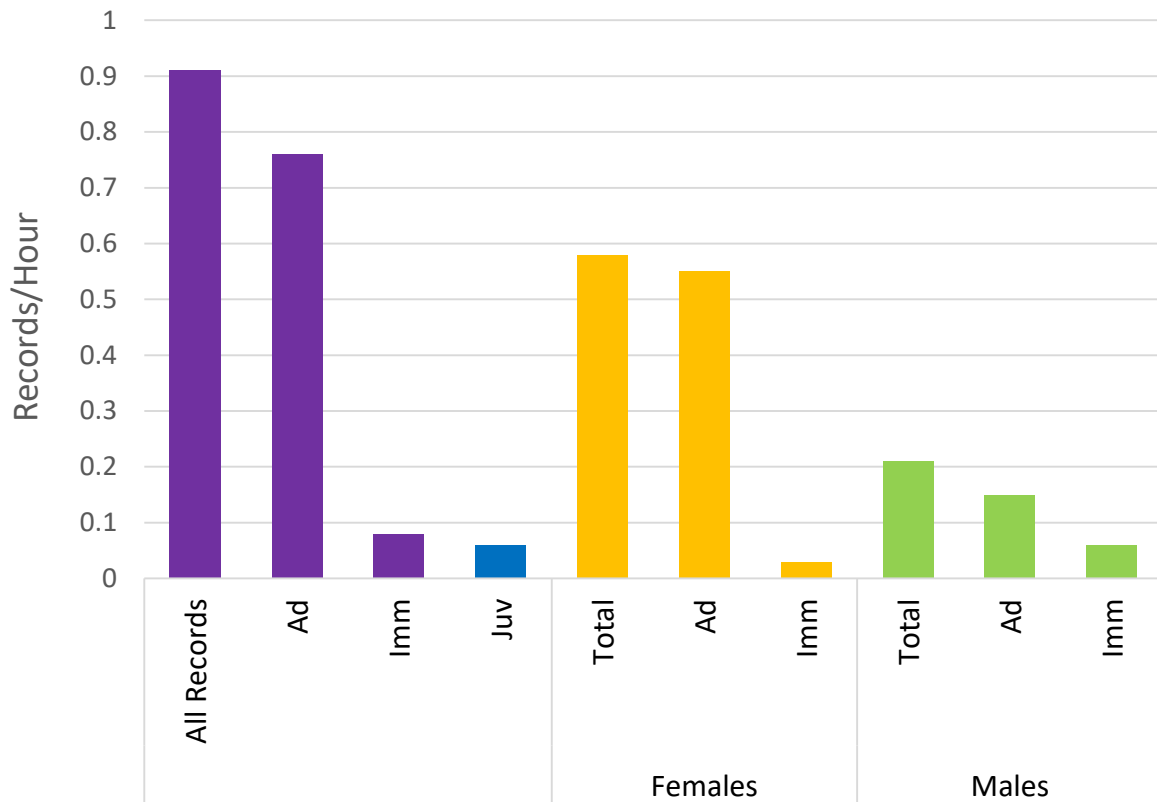
Figure 26. Encounter rates for summer 2015 visual surveys, reflecting relative detectability. Data all records for which sex and age was determined, including individuals that were not caught.

Comparison of visual encounter data shows that fewer adders were encountered in areas A2 and E, where adders had previously aggregated in spring 2014 (Figs 27 a and b). There were also fewer encounters along the wooded margins of areas C1 and D1. This suggests that adders vacate hibernacula and mating areas during the summer and disperse to other areas.

A greater number of adders were encountered in areas A1, B2, F1, F2 and D1 compared to spring 2014, however encounters are heavily biased towards adult females (Figs. 28 & 29). By contrast, more adders were encountered in area A2 and E during Spring 2014, which may indicate a shift in habitat use between seasons or a change in distribution over time. It was not possible to confidently identify the reproductive status of adult females however several females (e.g. AF101 in D1, AF081 in A1 and AF054 in F1) could be predictably located to the same basking spots. This raises the possibility that these locations may be nursery areas,

where gravid females give birth. Two neonates were found in late August/early September (Fig. 27), however, the common was not surveyed purposely at this time for new-born adders.
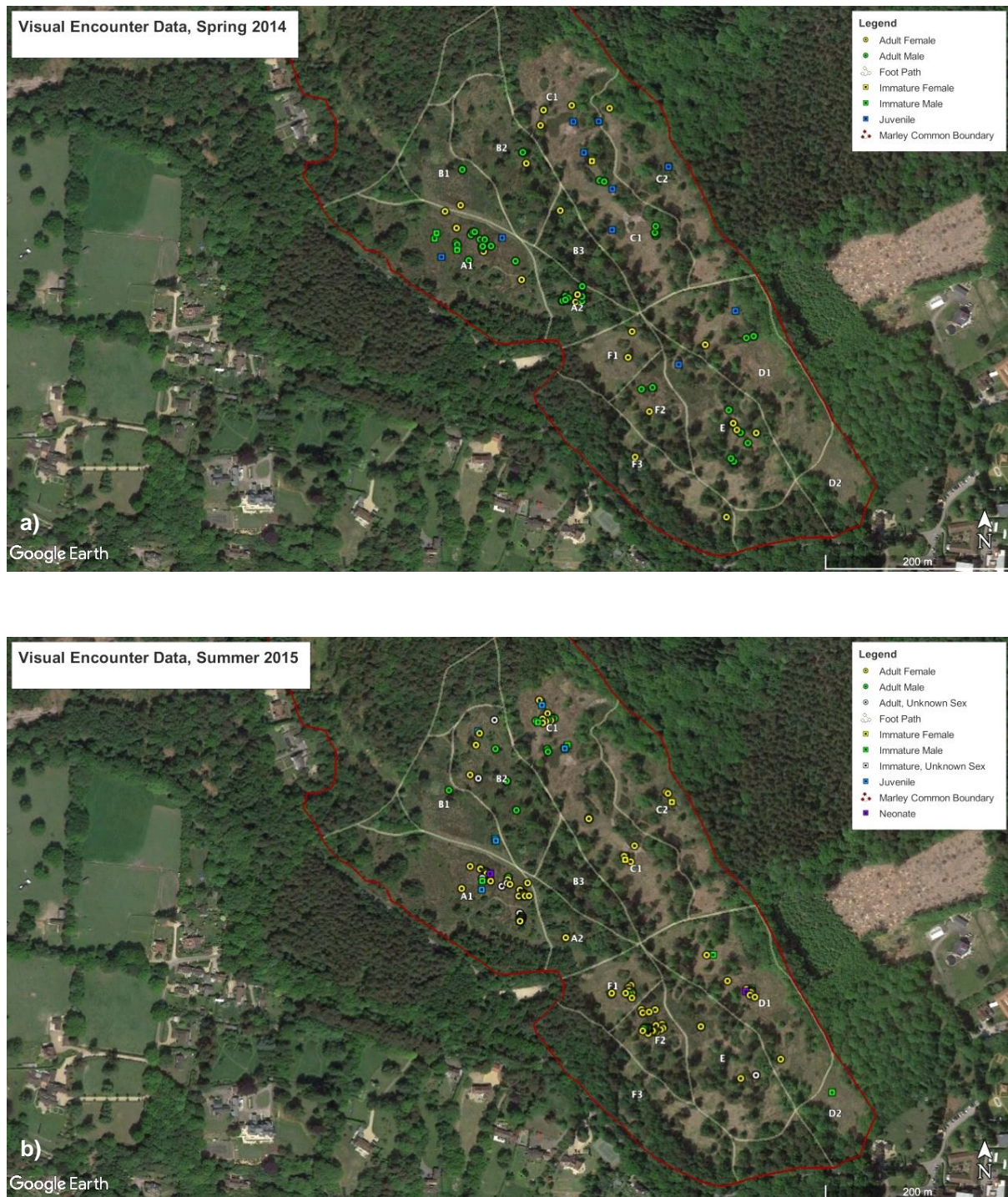
Figure 27. Comparison of the distribution of adder visual encounters from **a)** spring 2014 (top) and **b)** summer 2015 (bottom). Spring 2014 visual encounter data is available in appendix 2. Summer 2015 visual encounter data is available in Appendix 4.
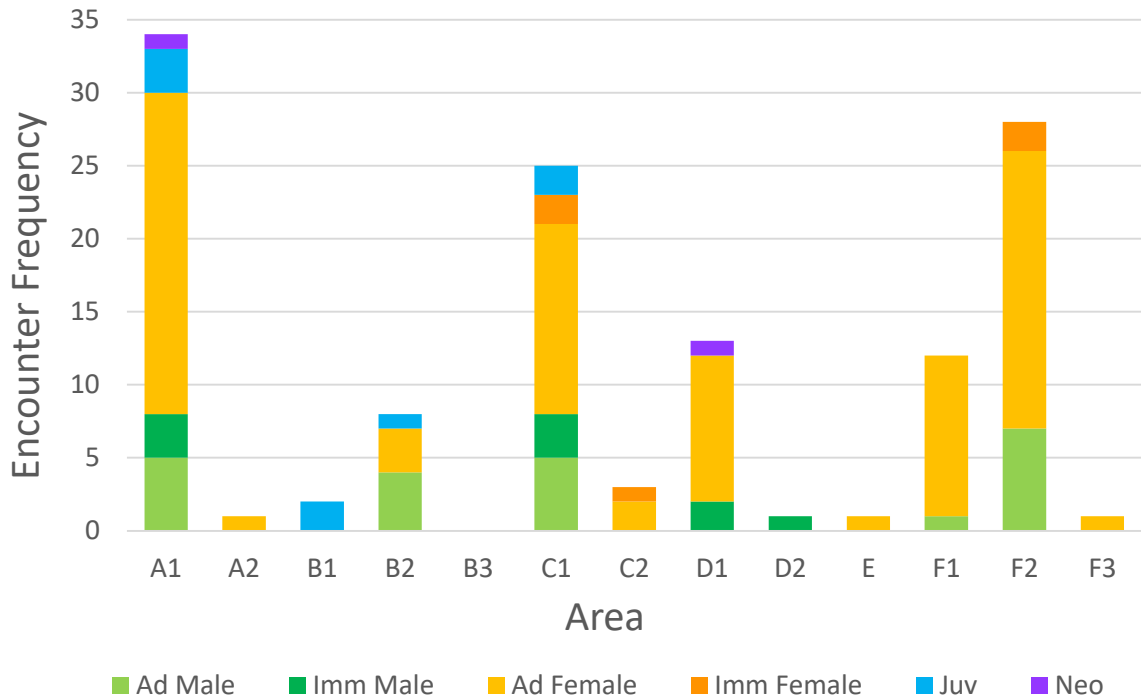
Figure 28. Comparison of the frequency of adder encounters across different areas of Marley Common in Summer 2015.
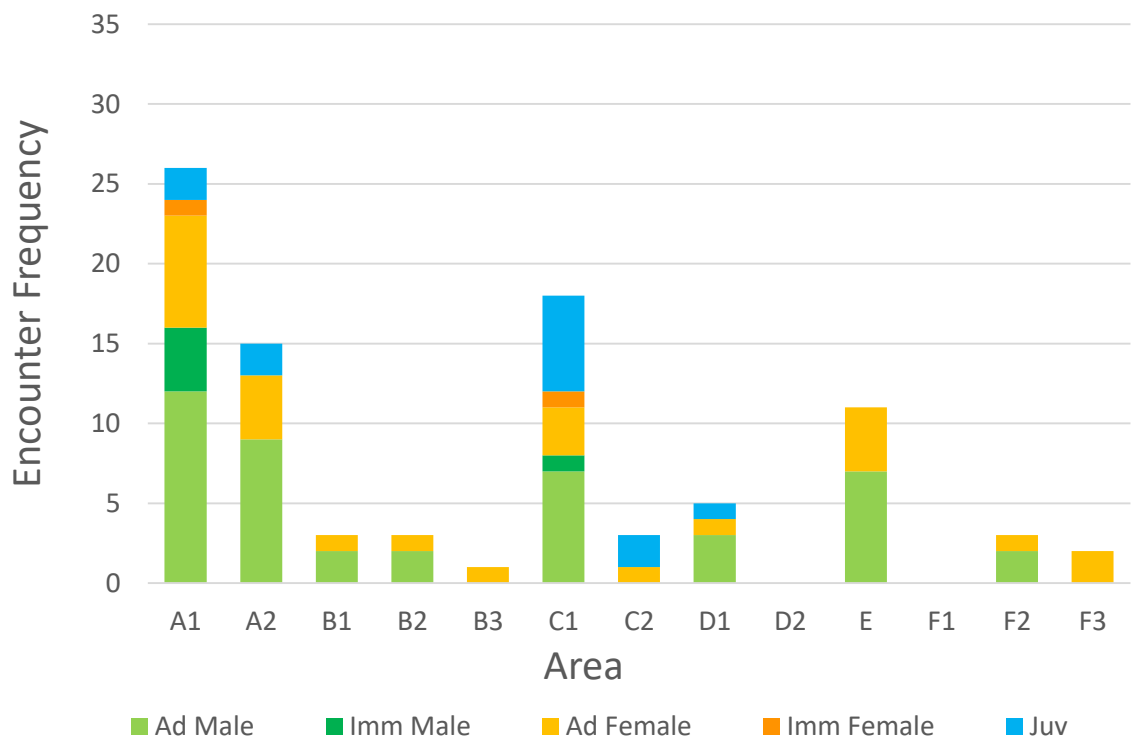
Figure 29. Comparison of the frequency of adder encounters across different areas of Marley Common in Spring 2014.

Visual comparison of the distribution individuals captured in both years reveals that adult females reoccupied similar areas in both summer 2015 to and spring 2014 (Fig. 30). By contrast, male distribution was more varied between years, with some males occupying different areas to those in which they were encountered in spring 2014 (Fig. 31).
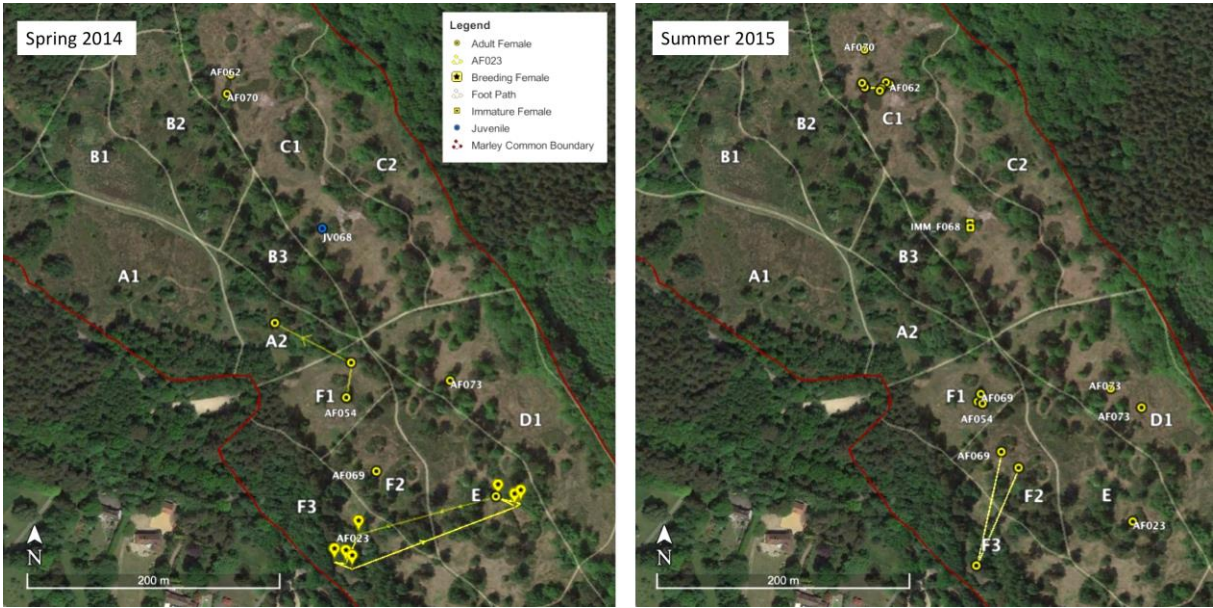
Figure 30. Comparison of the distribution of adult females encountered in both Spring 2014 and Summer 2015 shows that similar areas of the common were used.

Figure 31. Comparison of the distribution of adult males encountered in both Spring 2014 and Summer 2015 shows that areas used varied between years/seasons.

It is important to remember that encounter data is influenced by survey bias as the surveys were not designed to determine demographics but sought to locate adult males for the purpose of tracking. It is likely that there is a bias towards areas where adult males had previously been seen, resulting in some areas being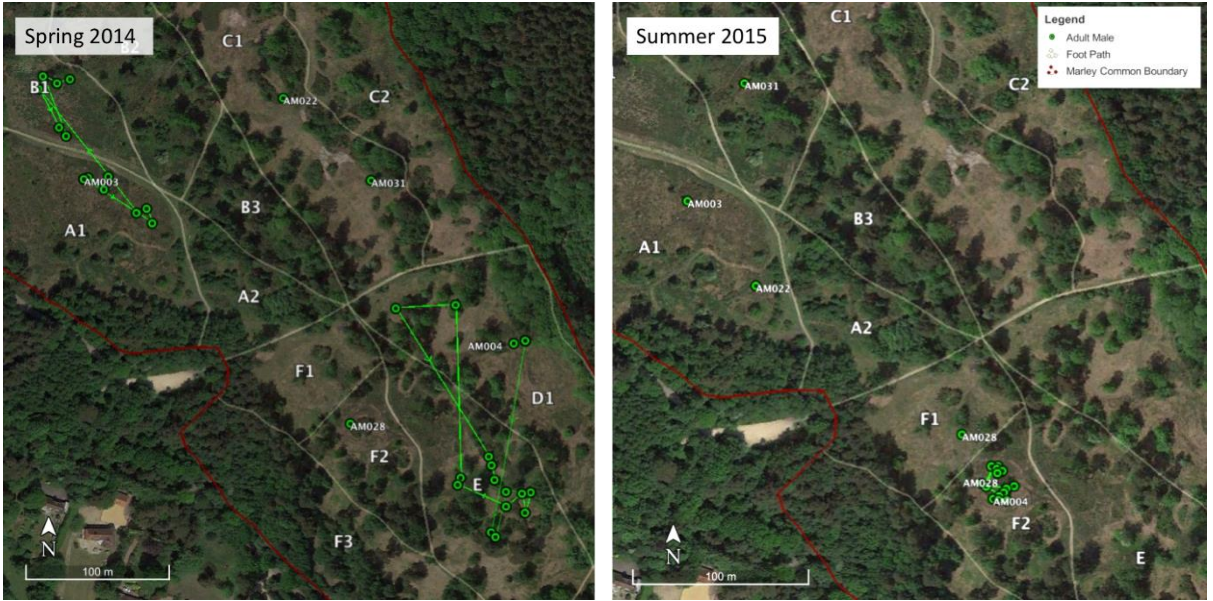 visited more than others. Records of survey hours for 2014 are incomplete therefore it is not possible to compare survey effort between years. Surveyor experience also varied between the two years, possibly resulting in fewer captures in 2015. Data will also reflect differences in detectability across the site, with adders being more visible in areas that are less densely vegetation (e.g. A1).

In 2015, many adders were encountered in association with thickets such as those in area C1 and F2 (Figs. 32.1, 32.2 & 33.1). Basking spots were typically small open pockets (Fig 33.3) or edge structures associated with dense vegetation or a natural refuge (Figs. 34.1 & 34.2). For example, in area F1, female adders were encountered at the edge of a birch thicket and upon disturbance, retreated into cavities at the base of the birch trees (Fig. 33.1 & 33.2). Adders were also observed using crevices within rotted tree stumps (Figs 35.1 & 35.2).

Surface dens included mossy mounds, such as those in area A1 (Figs 36.1 & 36.2) and small scrubby thickets (36.3). Adders were observed basking on top of mounds and would retreat inside the mound or into dense vegetation upon disturbance. Scrub appeared to be an important feature to adders. Young birch may provide cover from avian predators whilst allowing exposure to the sun at ground level. European and dwarf gorse also provides protection from predators. Basking substrate often comprised moss, dead gorse and dead bracken (Figs. 37a & b).

Figure 32.1. Satellite view of the northern portion of area C1 showing the distribution of adder encounters associated with a large thicket (pictured below).

Figure 32.2. An example of a mixed thicket used by adders during the summer 2015. Adders would often bask along the edge of the thicket and retreat into the thicket upon disturbance.
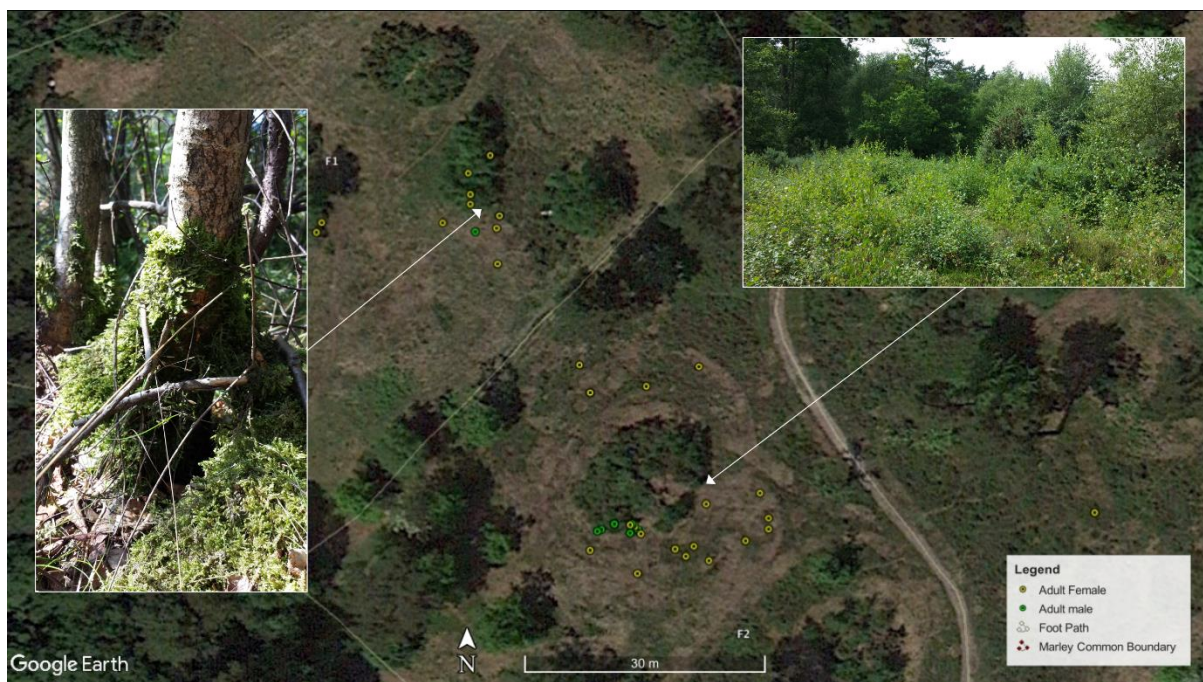
Figure 33.1. Satellite image of areas F1 and F2, showing the distribution of adder encounters concentrated around large thickets.

Figure 33.2. (left) An example of a root cavity used as a den in area F1.

Figure 33.3. (Right) An example of a small open pocket with moss substrate, adjacent to dense vegetation, used as a basking spot in area F2.

Figure 34.1. Distribution of adder encounters in area D1.

Figure 34.2. An example of an edge structure used by several females for basking in area D1.

Fig 35.1. Satellite image of the southern portion of area C1 showing adder encounters along the edge of thickets.

Fig 35.2. This tree stump was frequently occupied by adders in the late afternoon/evening during July and August. Well insulated and suitably positioned to catch the evening rays, often two adders were found coiled inside crevices of the stump. This photo shows two immature adders, IMM_M102 (foreground) and IMM_F068. This stump was frequently used by at least three different adders.
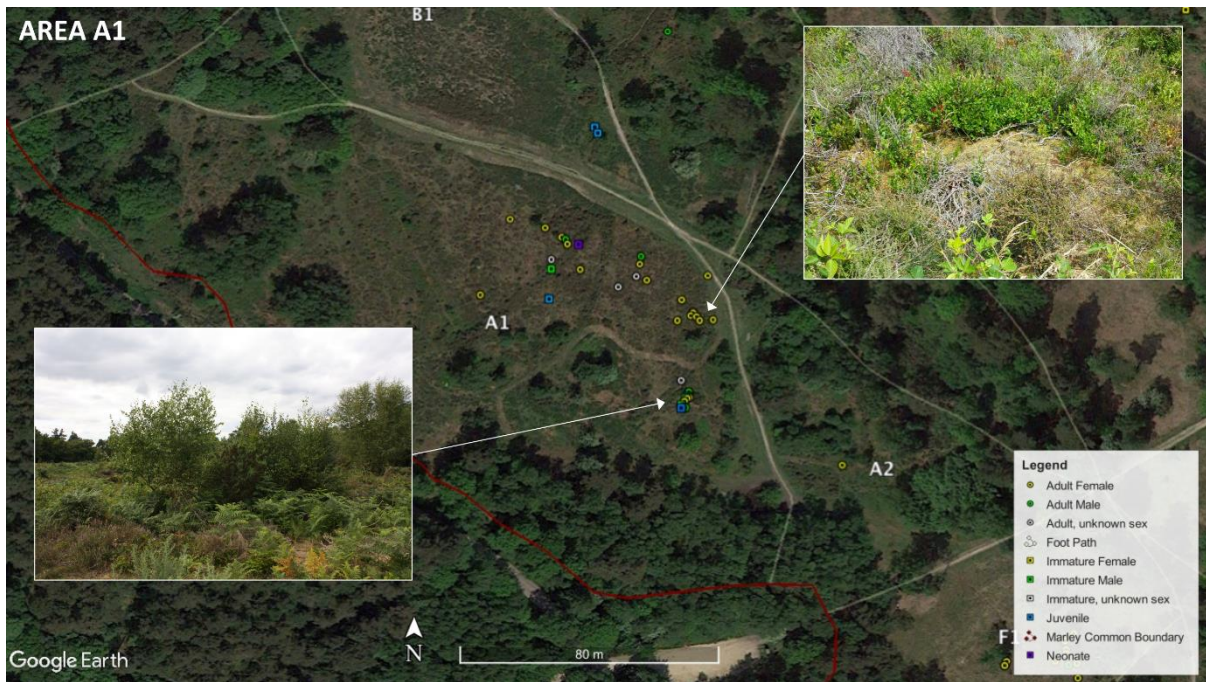
Figure 36.1. Satellite view of area A1 showing distribution of adder encounters.

Figure 36.2. An example of a mossy mound used by AF097 in area A1.

Figure 36.3. An example of a small scrubby thicket in area A1. An artificial refuge is placed at the edge of this thicket and was a popular refuge and basking hide for adders and grass snakes.

Figure 37. Examples of basking substrate comprising moss and dead gorse a) (left) an open pocket in area A1, used by a juvenile adder (JV096), adjacent to dense heather. b) (right) a small pocket on the edge of a large thicket in area C1, used by an unidentified juvenile.

Summer 2015 Telemetry

Table 4 shows a summary of adders tracked using radio telemetry in 2015. Track logs for all tagged adders are shown in appendices 5.1 to 5.11. Several adult males were located on the edge of thickets and beneath artificial refugia in early June (see appendix 4). All adult males captured between the 8th and 10th June exhibited opaque subcaudal scales and clouded spectacles (eye caps), indicating that they would soon shed their skin. After shedding, adult males quickly disperse to foraging areas and were difficult to re-locate, leaving a small window in which to attach the transmitters. From mid-June, it became increasingly difficult to find adult males, as reflected by encounter data in Figures 25 and 26. In the absence of males, female and immature individuals were tagged instead.

Adder ID	Sex	Age	Tracking Start Date	Tracking End Date	Duration (Days)	Total Distance	m/Day
IMM_M079	M	Imm	10th June	8th July	29	135	4.66
AF069	F	Ad	12th June	13th June	2	84	42
AM063	M	Ad	21st June	22nd June	2	7	3.5
IMM_M085	M	Imm	15th June	2nd July	18	94	5.22
AF087	F	Ad	16th June	28th July	43	238	5.53
AM086	M	Ad	15th June	25th June	11	157	14.27
IMM_F101	F	Imm	21st July	18th August	23*	73	2.52
AM004	M	Ad	16th June	19th June	4	10	2.5
AF062	F	Ad	16th June	24th June	9	33	3.67
AF091	F	Ad	19th June	7th August	50	111	2.22
AM028	M	Ad	27th June	7th July	11	63	5.73

* 7 days missed due to broken receiver

Table 4. Summary of adders tracked via radio telemetry in the summer, 2015.

A number of challenges were experienced during radio telemetry in 2015, including transmitter failures and tag-detachment (see appendix 5). Just three of eleven adders fitted with transmitters were tracked for a duration of at least 4 weeks. Four adult males were tagged between the 15th and 27th June, however due to difficulties described in Table 4, no adult males were tracked for a period lasting more than 11 days. As a result, there is insufficient data to determine foraging areas used by adult males during the summer.

Two adult females and one immature male were tracked for a period exceeding 4 weeks. In contrast to the large roaming movements of male adders during the spring 2014, adders successfully tracked in the summer remained within a relatively small area. Due to variation in the accuracy of GPS, consecutive data points less than 2m apart have been averaged (appendices 7.1-7.4).

IMM_M079

IMM_M079 was located to an area with a radius of approximately 10m for a period of 29 days (Fig. 38). He was often observed basking along the edge of the thicket, positioning himself with respect to the sun. In the evening IMM_M079 moved deeper into the thicket and was located to a den at the base of an oak tree (see appendix 6.1). IMM_M079 was very sedentary, travelling an average 4.66m per day (n= 29, $range$= 0-10m; appendix 6.1)

Figure 38. Track log for IMM_M079. White icons represent points that have been averaged. At such a small scale, the error in GPS accuracy becomes more apparent. GPS points have been averaged for consecutive records at the exact same location (determined from field notes).

IMM_M085

IMM_M085 (Fig.39) had a similar average daily distance to IMM_M079 (M=5.4m per day, n= 29, range= 0-44). IMM_M085 was initially captured and tagged in area D1 on the 15th June and subsequently travelled approximately 78m (M= 15.6m per day, n= 4, *range*= 5-44m; appendix 6.2) before exhibiting much reduced movements (red circle). From the 18th June to the 2nd July (15 days), the total distance between subsequent records was 19.6m, averaging 1.3m per day. Data points recorded within this time lie within an area with a radius of just 4.5m. IMM-M085 was often observed basking along the edge of mature gorse or was hidden in dense vegetation. Track logs for both IMM_M079 and IMM_M085 raise the possibility that immature males remain within a relatively small area, at least short term. Unfortunately, IMM_M085 shed his transmitter and so it was not possible to record his movements for long enough to detect patterns in behaviour. Similarly, there are insufficient data to compare the behaviour of adult males with that of immature males.

Figure 39. Track log for IMM_M085. White icons represent points that have been averaged. GPS Data have been averaged for consecutive records at the exact same location (determined from field notes). Numbers denote the number of days the individual remained at the same location. The red circle represents an area with a radius of approximately 4.5m.

AF087

AF087 (Fig.30) also remained within a relatively small area, traveling an average 5.5m per day (*n*= 43, *Range*= 0.85-34m). All GPS points recorded for AF087 lie within an area with a radius of approximately 20 metres. This sedentary behaviour may indicate that she was gravid however due to tag-detachment, it was not possible to recapture AF087 to determine her breeding condition. AF087 was frequently observed basking along the edge of dense vegetation, sometimes under partial cover and at other times fully exposed to the sun (see appendix 6.4). On a number of occasions, she was also observed in the rain.

Figure 40. Track log for AF087. White icons represent points that have been averaged. GPS Data have been averaged for consecutive records taken at the exact same location (determined from field notes). Numbers denote the number of days the individual remained at the same location.

AF091

AF091 exhibited the most sedentary behaviour of adult females monitored during the summer, travelling an average 2.22m per day (*n*= 50, *Range*= 0-20m). GPS data recorded for AF091 lie within an area with a radius of approximately 15 metres (Fig.41). Furthermore,

AF091 was located to the same 4m^2 area for 33 days and it is likely she used the same surface den (Fig. 42) for up to 41 days (see appendix 6.5). Despite her sedentary behaviour, when re-captured on the 7th August, AF091 had recently eaten, indicating that she was not gravid. When re-weighed her mass was 102g, compared to 105g on the 19th June, suggesting her mass had decreased between 19th June and 7th August (a period of 50 Days).
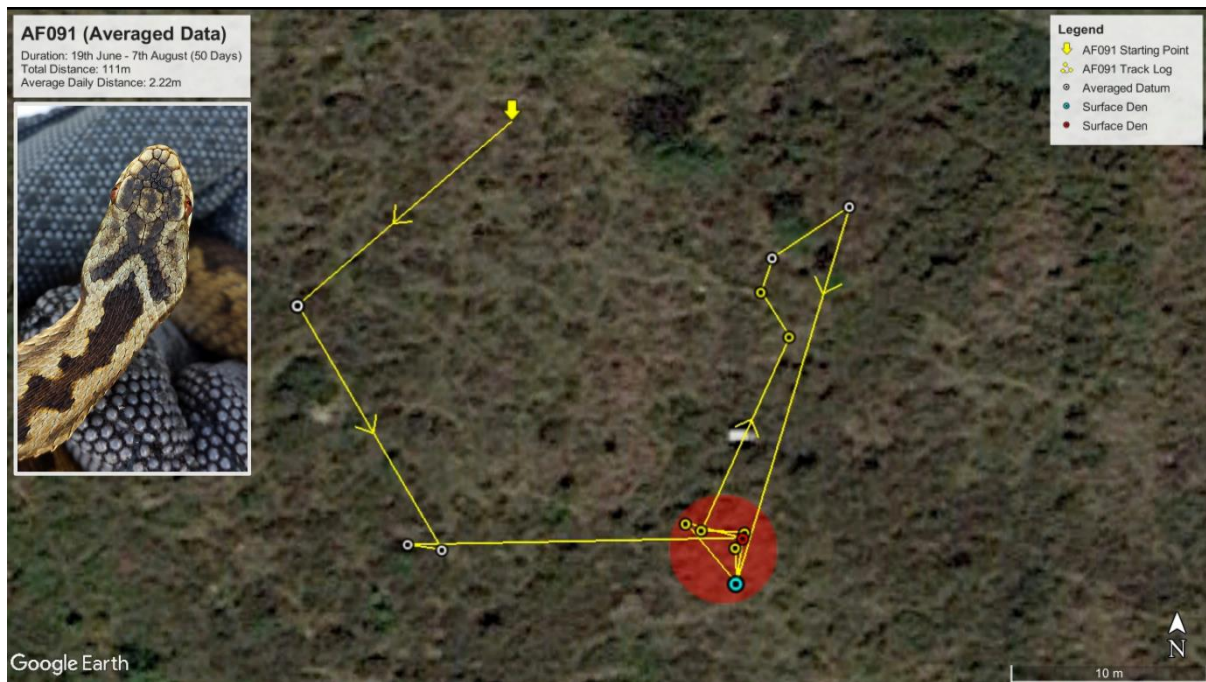

Figure 41. Track log for AF091. White icons represent points that have been averaged. GPS Data have been averaged for successive records at the exact same location (determined from field notes). The red and blue icons were created from averaged data and represent two dens in close proximity to one another (1.5m). The red circle represents an area with a radius of approximately 2.5m and is the area where AF091 was located to for 33 consecutive days.

Estimating yearly prey consumption per adder is difficult. Feeding rates are likely to vary between individuals and across time and space. Andrén (1982) estimated a yearly consumption of 9 field voles per adder - an average consumption of 1 field vole every 2 to 3 weeks. Assuming a similar feeding rate among adders at Marley Common, AF091 would have been expected to gain mass between June and August however, growth rates and changes in relative mass are dependent on ingestion rates and assimilation efficiency, which in turn are influenced by prey density and distribution (Andrén, 1982, Andrén & Nilson, 1983; Forsman 1997; Forsman and Lindell, 1991, 1996, 1997) as well as intraspecific competition (Lindell & Forsman, 1996), morphological variation (Forsman & Lindell, 1993) and weather conditions

(Lindell, 1997).

Figure 42. The surface den used by AF091 for more than a month, comprising moss cavities, dead bracken, degenerate heather and dwarf gorse.

Trade-offs between growth and energy storage has been shown for *male* adders subject to fluctuations in prey availability (Forsman & Lindell, 1991); however, further studies are needed to understand the relationship between growth and energy storage in *female* adders. Investment in growth favours future reproductive success as larger females produce larger broods/litters (Andrén & Nilson, 1983; Madsen, 1988). However, investment in energy storage influences clutch mass (Andrén & Nilson, 1983; Forsman, 1991) and post-partum survival (Andrén, 1982, Madsen & Shine, 1993). AF091's SVL was not re-measured and so it is not known whether she had allocated energy to growth at the expense of energy storage, nevertheless, an increase in mass is expected to accompany an increase in SVL. It is possible that a decrease in mass reflects low prey availability or high intraspecific competition however more data are required.

Alternatively, AF091 may have been gravid but may have fed opportunistically close to the time she was re-captured. This could account for the lack of change in her mass. Gravid adders feed readily in captivity (Kelleway, cited in Madsen & Shine, 1992) and are reported to predate

prey that wanders within striking distance (Madsen & Shine, 1993). However, there are no published data on feeding frequencies of wild populations. Data gathered from a population of adders in southern England indicate that mass change varies among gravid females (Prestt, 1971). As a consequence, it can be difficult to determine a female's reproductive status on mass alone.

Discussion

Despite the limited success of radio telemetry during summer 2015, data gathered from radio telemetry in spring 2014 has given interesting insights to adder behaviour at Marley Common. Radio telemetry and visual encounter data have revealed that adders frequently re-visit the same features, providing further evidence of high philopatry in this species. High fidelity for hibernacula and mating areas has been reported in previous studies (Phelps, 2004, 2007); however, long-term monitoring is necessary to determine whether adult females consistently return to the same mating areas.

Data have revealed that some reproductive females move away from their hibernacula to mate; typically to more secluded areas such as woodland glades. For example, AF023 appears to make direct, non-random movements to the area in which she subsequently mates with AM064. Adders are especially vulnerable during the mating period due to their conspicuous behaviour and increased activity (Andrén, 1986; Madsen & Shine, 1993, 1994; Madsen, 2011; Phelps, 2007). Sheltered areas, such as woodland glades are likely to provide protection from predators during this time. It is therefore important that mating areas are identified and incorporated into management plans. Encounter data show that mating areas are visited by a number of individuals, further highlighting the importance of retaining these features.

Unfortunately, there were insufficient data from adult males to inform us about foraging behaviour and habitat utilisation during the summer months. However, summer telemetry did show that female and immature adders may remain within a relatively small area for a period of several weeks to over a month. Furthermore, some adders (e.g. AF091 and

Imm_M079) appear to exhibit pronounced attachment to specific features. This high fidelity suggests that adders may be affected negatively by damage or destruction of favoured features. Therefore, care should be taken to identify and map important features, such as surface dens used by adders prior to habitat management (Edgar et al. 2010).

The poor success of radio telemetry in the summer resulted from tag failures, tag detachment and shedding. Tag detachment in the summer may have occurred due to food passing through the gut which stretches the tape securing the tag, making it more prone to becoming snagged on vegetation. Male adders in particular are likely to spend more time within dense vegetation during the summer, which may have resulted in damage to the transmitter or detachment. Shedding is highly likely to interfere with tracking during the summer. Furthermore, previous radio telemetry projects have found that reconditioned transmitters are less reliable than new transmitters (N. Hand 2018, pers. comm., 17 January), presumably due to damage and wear. Finally, telemetry is not well suited to small movements (less than 5m) due to variation in the accuracy of GPS data. Results of this project suggest telemetry is most successful during the spring.

Despite these setbacks, radio telemetry has the advantage of locating adders when they are not visible and has the potential to reveal more about their behaviour. For example, although most adders are observed basking along the edge of vegetation, radio telemetry revealed that adders also bask under the cover of vegetation, for example within stands of mature gorse – a behaviour known as mosaic basking. Radio telemetry is thus a valuable tool in elucidating the more secretive aspects of adder behaviour and is crucial to a more complete understanding of the adder's habitat requirements.

A total of 93 individual adders have been identified from visual encounter surveys across both years of the project. This is incredibly encouraging however it is not possible to determine the status of the population from this data alone. The visual encounter data gathered from spring 2014 and summer 2015 are not suitable for estimating abundance due to spatial, temporal and individual variation in encounter probabilities (Sutherland & Royle, 2016). Encounter probability was also influenced by variation in survey effort across space and time.
Adder populations are known to fluctuate naturally due to factors such as variation in weather

and prey availability (Forsman, 1997; Forsman & Lindell, 1997; Hodges, 2016). Therefore, long-term monitoring is necessary to determine population trends. This can be achieved by conducting spring emergence surveys and identifying individual adders by taking photos in situ, thus minimizing disturbance. Survey methodology should be carefully designed to ensure equal survey effort across the entire common, under optimal conditions. Rotating sectors will avoid the same area being surveyed at the same time of day on each visit. Each area should be revisited to reduce the probability that individuals are missed due to chance. Although visual encounter data is influenced strongly by detectability, systematic surveys may yield data that can be used to indicate adder population trends (Baker et al. 2004; Reading et al. 2010).

Long-term monitoring will enable the construction of encounter histories used in mark recapture analysis to estimate abundance and also has the potential to inform us about population demographics such as sex ratio, age structure, survivorship and recruitment. Measuring and weighing specimens on a yearly basis will reveal more about adder growth rates as well as the health and viability of the population. Mass and growth rates are strongly linked to prey availability (Forsman & Lindell, 1991; Lindell, 1997) and resource competition (Lindell & Forsman, 1996), which in turn influence survival (Andrén, 1982; Forsman, 1991,1997; Forsman & Lindell, 1997) and reproductive output (Andrén & Nilson, 1983; Lindell, 1997; Madsen, 1988; Madsen & Shine, 1992).

For the first time at Marley Common, GPS data recorded from visual encounter surveys have been used to map the location of adder hibernacula and mating areas. In addition, summer visual encounter data has been used to map the distribution of adder encounters across the common, highlighting potentially important features as well as areas of poor habitat suitability. Such data can be used to inform future habitat management at Marley Common and is essential to mitigate against the potentially negative impacts of habitat management (Gleed-Owen & Langham, 2012). This is especially relevant in light of widespread adder declines, which are increasingly attributed to inappropriate management or loss of suitable habitat resulting from neglect (Baker et al. 2004; Edgar et al. 2010). Habitat managers are tasked with the challenge of maintaining open heathland whilst balancing the interests of species with conflicting habitat requirements.

Reptiles require habitat with a structurally diverse mosaic, including open areas for basking

and areas of dense vegetation for foraging and refuge (Edgar et al. 2010; Offer et al. 2003). Management practices such as sustained, heavy grazing and extensive flailing aimed at scrub control are likely to impact reptile populations negatively by removing cover and reducing structural diversity (Edgar et al. 2010; Gleed-Owen & Langham, 2012; Offer et al. 2003). Removal of vegetation cover can increase exposure to predators particularly when adders emerge in the spring (Edgar et al. 2010). Mature males are especially vulnerable to predation due to their increased activity and movement during the mating period (Madsen & Shine, 1994; Phelps, 2007). As such, sensitive management techniques such as hand-cutting are preferable near adder foci, hibernacula and mating areas (Gleed-Owen & Langham, 2012).

Birch and gorse are prevalent and widespread at Marley Common. If left unmanaged, the heath will rapidly succeed to woodland, becoming unfavourable for reptiles. This is particularly evident in area D1, where there is a high density of Birch saplings and gorse. However, during the summer, a number of adult females were encountered in the more structurally diverse parts of area D1 and the discovery of a neonate in late August indicates that at least one female gave birth here.

The use of tractor-mounted flails in area D1 is likely to be detrimental to adders, especially to neonates that remain in the area over winter. Adders displaced to margins, will experience reduced vegetation cover, which may in turn have a negative effect on foraging success. Furthermore, existing mature heather is less likely to regenerate from flailing (Cymes & Day, 2003, p.101) and subsequent grazing of young pioneer heather may suppress regrowth, resulting in poor structure (Bullock & Pakeman, 1997; Lake et al. 2001). There is also a risk of soil compaction and erosion if the area becomes more attractive and accessible to cattle (Lake et al. 2001). It is important that such risks and dynamics are considered before work is undertaken. Adders will benefit from sensitive management in area D1 for example by a combination of herbicide treatment in the summer, with cutting and pulling by hand during the winter (Cymes and Day, 2003, pp. 93-95, 131; Marrs, 1984). More cost-effective and efficient alternatives may be considered in areas where adder encounter rates are low, such as area B1 and the large open areas of C1. Here, the risk of direct and indirect mortality is reduced.

The aim of reptile habitat management is to maintain a continuity of high-quality habitat

throughout time and space (Edgar et al. 2010). The current project demonstrates how telemetry and visual encounter data can be used to target and prioritise management as well as to plan and inform appropriate practice. For example, low adder encounter rates indicate areas of poor habitat suitability and thus where restoration and improvements to structure diversity and connectivity are a priority.

Area C1 is characterised by isolated thickets surrounded by large areas of unsuitable habitat. Improved connectivity between existing adder foci can be achieved by allowing corridors of vegetation to 'scrub up', increasing edge habitat and creating ecotones, providing increased opportunities for basking, refuge and foraging (Edgar et al. 2010). Furthermore, restoration of an acid grass/heath mosaic is likely to lead to an increase in the abundance of invertebrates and small mammals, in turn supporting a greater number of adders as well as slow worms, common lizards and grass snakes (C. Reading 2018, pers. comm., 5 July; Edgar et al. 2010; Lake et al. 2001; Offer et al. 2003; Reading & Jofré, 2016).

The impact of grazing on lowland heathland is poorly understood due to the lack of long term, fully replicated and controlled studies (Newton et al. 2009). A review of current literature suggests that grazing generally increases structural diversity and overall plant diversity (Bokdam & Gleichman, 2000; Lake et al. 2001; Offer et al. 2003; Jofré & Reading, 2012). However, the effects of grazing vary significantly depending on a range of factors including the species, breed and age of livestock; livestock behaviour (e.g. ranging and grazing patterns), stocking density; the existing plant community, structure and distribution; soil fertility; historic and current management; timing, duration and frequency of grazing (Bokdam & Gleichman, 2000; Lake et al. 2001; Offer et al. 2003). The colonization dynamics of heathland vegetation is strongly influenced by differences in the competitive ability and grazing tolerance of different plant species. Therefore, changes to soil fertility and vegetation structure resulting from grazing will determine patterns of colonization and mosaic dynamics (Bokdam & Gleichman, 2000).

Inappropriate grazing, especially on small sites, may be detrimental to reptile populations due to damage of sensitive vegetation (Offer et al. 2003; Symes & Day 2003, pp.109-113). Mature and degenerate heather is especially susceptible to damage from heavy grazing and trampling

(Bokdam & Gliechman, 2000; Lake et al. 2001; Symes & Day, 2003, p.112). Sustained, heavy grazing has also been shown to lead to a decrease in the abundance of small mammals, depleting crucial prey for adders (Lake et al. 2001; Offer et al. 2003; Jofré & Reading, 2012). Recent research has demonstrated an increase in the abundance of slow worms, common lizards and grass snakes in areas of heathland excluded from grazing (Reading & Jofré, 2016).

At Marley Common, 4 cattle have access to an area of approximately 21ha, including woodland. This is equivalent to a stocking rate of 0.2 Livestock Units/ha/year which is a stocking density considered suitable for reptiles (Edgar et al. 2010). However, preferential grazing is likely to lead to an uneven grazing pressure across the site, effectively resulting in a higher grazing density than intended in patches favoured by livestock (Bokdam & Gleichman, 2000; Lake et al. 2001; Reading & Jofré, 2015).

Area A1 of Marley Common was frequently visited by cattle during the summer of 2015, possibly due to the presence of a nearby pond. Mature heather in this area shows signs of damage from trampling and grazing (Fig. 43 & 44). Furthermore, evidence of dunging suggests increased nutrient deposition, which may increase the competitive advantage of species such as bramble and bracken (Bokdam & Gleichman, 2000). The prevalence of birch saplings and large swathes of gorse regeneration (Fig. 44) suggest that grazing has not been effective at curtailing scrub invasion. Furthermore, grazing of young heather in area F1 following mowing may be suppressing regrowth and maturation of the heather canopy (Bullock & Pakemen, 1997).

The presence of negative indicators at Marley Common strongly supports the need for long-term monitoring of the impacts of year-round grazing and its effectiveness at achieving site objectives (Edgar et al. 2010, Reading & Jofré, 2015). This may be achieved by sampling fixed plots and establishing sample areas excluded from grazing (Cymes & Day 2003, pp.189-192; Lake et al. 2001). Grazing was introduced to Marley Common to help control scrub invasion (M. Bramich 2017, pers. comm., 12 April) however current studies suggest that grazing is unlikely to play a major role in scrub management (Bokdam & Gleichman, 2000; Jofré & Reading, 2012; Lake et al. 2001). Furthermore, Jofré and Reading (2012) propose that increased nutrient deposition through dunging may in fact accelerate succession to woodland

however empirical evidence is needed. Bokdam & Gleichman (2000) conclude that summer grazing combined with cutting of invasive scrub is necessary to keep an open heath with grass/heather mosaics.

Figure 43. Evidence of degradation in area A1 caused by trampling and grazing. Reduced heather cover and large open areas of short sward and bare ground indicate overgrazing (Edgar et al, 2010). Dunging is also evident in the area and may lead to nutrient enrichment. Dwarf Gorse is grazed preferentially in autumn (Lake et al, 2001) which may cause damage to surface dens.

Figure 44. An example of gorse regrowth in Area 1 where it had previously been mowed. Large patches of short sward and bare ground are indicators of overgrazing (Edgar et al. 2010).

The effects of habitat management on Marley's adder population are unlikely to be observed in the short term. For example, a decrease in recruitment due to poor reproductive success or increased mortality will not be recorded for 3-5 years due to the time taken for adders to reach sexual maturity (Hodges, 2016). The current project has demonstrated the advantages of long-term monitoring of adders and their habitat in order to inform appropriate management for this species. The benefits of informed management are likely to extend to other species and thus enhance the overall distribution, abundance diversity of species at Marley Common.

The long-term aim for Marley Common should be to improve habitat quality by enhancing structural diversity, restoring the acid grass/heath mosaic and retaining an appropriate amount of scrub to create valuable ecotones. Lowland heathland is recognized as a rare and threatened habitat and is listed as a priority habitat under the UK Biodiversity Action Plan (The UK BAP, 1995; JNCC, 2016b). The UK has 58,000 ha of lowland heathland, accounting for 20%

of the international total (The UK BAP, 1995). Heathland restoration and improvement of existing heath are priority objectives of the UK BAP which underpins the UK post-2010 Biodiversity Framework (JNCC, 2018). The future of the adders of Marley depends on a continuity of suitable habitat throughout time and space, which includes enhancing connectivity to surrounding heathland, especially to wet heath which is an important foraging habitat for adders in the summer (McInerny, 2014; Phelps, 2004; Prestt, 1971). Baker, Suckling & Carey (2004) reported a greater frequency of adder declines and fewer stable populations among small, isolated sites. Improving connectivity will improve the local metapopulation's resilience to catastrophic events such as fire or disease and increase opportunity for gene flow, reducing the risk of inbreeding depression (Lake et al. 2001; Madsen et al. 1999; Madsen et al. 2004). Restoration of heathland to a favourable condition and improving connectivity to other local patches is therefore a priority to reversing the national decline of this species.

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