Use of artificial refuges by the northern viper *Vipera berus* - 1. Seasonal and life stage variations on chalk downland

RICK J. HODGES* & CLIFFORD SEABROOK

Kent Reptile and Amphibian Group, c/o KMBRC, Brogdale Farm, Brogdale Rd, Faversham, Kent, ME13 8XZ, UK
*Corresponding author Email: RickHodges123@gmail.com

ABSTRACT -During eight years of a continuing long-term study of *Vipera berus* in a chalk downland nature reserve, records were made of encounters with all life stages at artificial refuges and in the open. The refuges were paired sheets of galvanised corrugated-iron ('tins') and roofing felt, deployed at the rate of 2.7 to 4.2 pairs/ha. Distinctive seasonal patterns of encounters are reported for each life stage and provide insights into viper behaviour. For adults, encounters in the open and at refuges both contribute significantly to records while for immature stages records depended largely on their use of refuges as they were rarely encountered in the open. All life stages were encountered at tins more frequently than felts. Gross encounter rates have been refined by reference to observations on 483 individuals recognised by their head-scale patterns. The numbers of different individual adult males and adult females observed in the open were broadly similar, as were the numbers under tins, but the frequency with which these individuals were resighted was greater in the open for males and greater under tins for females. At least in the case of gravid females, refuge use may be a substitute for mosaic basking. Under the conditions of this study, roughly 70% of individual adult vipers used refuges at least once, usually much more frequently, whilst for immatures the proportion remains uncertain. These observations could be used to improve the planning and interpretation of long-term monitoring studies.

INTRODUCTION

Long-term monitoring of reptiles, and other wildlife, is essential for the collection of evidence on important conservation issues such as habitat management (Fuller et al., 2016) and response to climate change. In temperate climates, artificial refuges can contribute to long-term monitoring of reptiles. They offer both warmth and concealment (Joppa et al., 2009) and consequently are locations where reptiles accumulate and can be counted. The artificial refuges used in the UK are frequently rectangles of galvanised corrugated-iron ('tins') or roofing felt (Froglife, 1999; Reading, 1997) although both in the UK and elsewhere refuges may sometimes be made of other materials and have included *inter alia* Onduline, wood, carpet tiles, and fibrocement.

The northern viper (*Vipera berus*) is of conservation concern and in recent times a range reduction of about 39% has been suggested (Gleed-Owen, 2013). These vipers, especially adults, attain their preferred body temperatures by basking in more open areas either a short distance from vegetation cover or in the dappled sunlight of partial vegetation cover, the latter is referred to as 'mosaic' basking (Gaywood & Spellerberg, 1996). Nevertheless, vipers may also be encountered under artificial refuges that may assist in maintaining body temperature and in providing cover. To date there are no specific recommendations on how to undertake long-term refuge monitoring for *V. berus* or how to interpret the data generated, although there is excellent general advice on both survey technique (Froglife, 1999) and preparing and deploying tin refuges (Langham, 2011). Furthermore, a quantitative survey method with refuge tins, tested for reptiles on lowland heaths, has been proposed but is based on scant data in the case of *V. berus* (Reading, 1997) and is not necessarily intended for long-term monitoring. In the UK, long-term monitoring studies of reptile populations are rare but in a recent 9-year study of *Natrix natrix*, refuge tins were deployed at the rate of 2/ha. These refuges were repositioned annually both to prevent any 'bedding in' effect and also to ensure that if the snakes had learnt where the refuges were located then this factor would remain constant between years (Sewell et al., 2015).

As part of an on-going long-term monitoring programme of *V. berus* at a chalk downland reserve in Kent (UK), we deployed both tin and felt refuges and recorded our observations of different viper life stages at both refuges and in the open for a period of eight years. These observations may help in the future with the interpretation of monitoring data from both our own continuing study and those of others.

MATERIALS AND METHODS

Study site and refuges

The study site is a chalk downland nature reserve at about 51°N, 0°E. The reserve is managed by Kent Wildlife Trust and comprises three distinct open areas totalling 11.1ha of grassland with margins and islands of low scrub, generally sloping at 10° to 15° with aspects to the south, south west or west. The reserve is bordered by open farmland, housing, woodland and for a short stretch by a road, and apparently offers little prospect of connection with other viper populations.

Refuges consisted of galvanised corrugated-iron sheets (0.5mm thick and 0.5g/cm2), referred to as tins, and roofing felt (Garage felt, green slate finish, Homebase, #242805, 2mm thick and 0.3g/cm2). They were both cut to the same dimensions (50cm by 65cm) and pairs, comprising one of each type, were placed in sunny but inconspicuous locations backed by vegetation cover. Tins were camouflaged by spraying their upper surface with brown paint (Espresso, satin finish, Rust-oleum). At the start of the study there were 31 pairs but more were added over time so that the final total was 47 pairs (Table 1); refuge density consequently increased from 2.7 to 4.2 pairs/ha.

Making viper observations

Monitoring was initiated in 2004 and is still on-going although the data presented here are from 2008 to 2015. Observations were made by two or three surveyors during visits to the whole site in the reptile active period from February to October. The number of annual visits varied from 59 to 77 (Table 1) and for each visit the survey followed a standard route between refuge locations. Vipers were recorded at refuge locations and along the standard route in areas with more or less cover. The study involved no animal handling in order to minimise disturbance and stress. Observations were made morning and afternoon on days when weather conditions were not excessively wet or windy. To facilitate individual recognition, photographs were taken of head-scale patterns (Benson, 1999) either in the open at a distance (2-4m), using a long focal length lens, or much closer when individuals were under refuges. The scale patterns were coded and then entered into a database. There were 483 different head-scale records across all life stages, and during the eight year period some individuals contributed data at some or all of the different life stages. Head-scale patterns were found to be stable apart from a single exception (Hodges & Seabrook, 2014). Adult recruitment tables suggested that the density of adults varied from 3 to 5 adult vipers/ha in the study period; it is intended to describe these tables in more detail in future reports. Different life stages were recorded and recognised by their size and the following features - juveniles were individuals that had hibernated only once or had never hibernated (neonates); sub-adult males had completed two or three hibernations and sub-adult females had completed two to four hibernations; adult males were recognised by having completed at least 4 hibernations and in the case of females at least five hibernations. The life stages were known from their size, colour pattern and from individual records kept across years, but are likely subject to occasional inaccuracy. The gender of adults and sub-adults was determined by colouration and body proportions (Smith, 1951; Beebee & Griffiths, 2000) but there was no attempt to distinguish the gender of juveniles.

Statistical analysis

In the initial analysis and interpretation of this study, viper observations are treated as simply 'encounters' with no assumptions about the number of individual vipers that contributed the data, subsequent analysis was of data derived from the sightings of 'known individuals'. Where relevant, whole data sets for all life stages was assessed for underlying heterogeneity using the Kruskal-Wallis one way analysis of variance, and where such heterogeneity was detected pairwise *post hoc* testing of individual life stages for statistically significant differences was undertaken using the Mann Whitney U test (Siegal, 1956). Differences were treated as statistically significant when the probability of them occurring by chance was 5% or less ($p \leq 0.05$). Where data was highly skewed they have been presented as box and whisker plots. The statistical significance of simple linear correlation coefficients (r) were determined from standard tables (Bailey, 1966).

RESULTS

Annual and seasonal encounters rates with vipers at refuges or in the open

During eight years the total number of viper encounters were as follows, with the number of 'known' viper sightings in parenthesis: adult males 1071 (853); adult females 1077 (937); sub-adults 725 (521); and juveniles 582 (574). The proportion of vipers encountered at refuges remained above 70% during the first three years of study after which it became more erratic varying from 42% to 74% (Table 1). The total numbers of vipers encountered annually at refuges correlated poorly with either the number of refuge pairs deployed ($r = 0.27$, $n = 6$, $p>0.1$) or with the number of visits made ($r = 0.09$, $n = 6$, $p>0.1$). This suggests that, within the range of refuges densities and visit rates used in this study, other factors were more important in determining viper encounter rates. It was noticeable that for the first six years of study the numbers of vipers in the open per visit increased steadily and only since 2014 did it decline (Table 1). Again, the total annual encounter rate in the open correlated poorly with number of annual visits ($r = 0.215$, $n = 6$, $p>0.1$).

Table 1. The numbers of *V. berus* encounters in the period 2008 to 2015 and the proportion at refuges (both tins and felts)

Year	No. of site visits	No. of refuge pairs	At refuges	In the open	In the open/ visit	Total count	% at refuges
2008	76	31	343	86	1.13	429	80.0%
2009	69	32	314	83	1.20	397	79.1%
2010	65	33	255	108	1.66	363	70.3%
2011	64	35	200	147	2.30	347	57.6%
2012	65	40	458	159	2.45	617	74.2%
2013	59	41	251	191	3.24	442	56.8%
2014	79	46	296	235	2.97	531	55.7%
2015	77	47	139	190	2.47	329	42.3%

The mean monthly encounter rates for each life stage followed a distinctive pattern. In spring time (February - April) the number of adult encounters at refuges was low (Fig. 1), then rose in the summer (May - August) and fell in the autumn (Sept - Oct) as vipers submerged for hibernation.

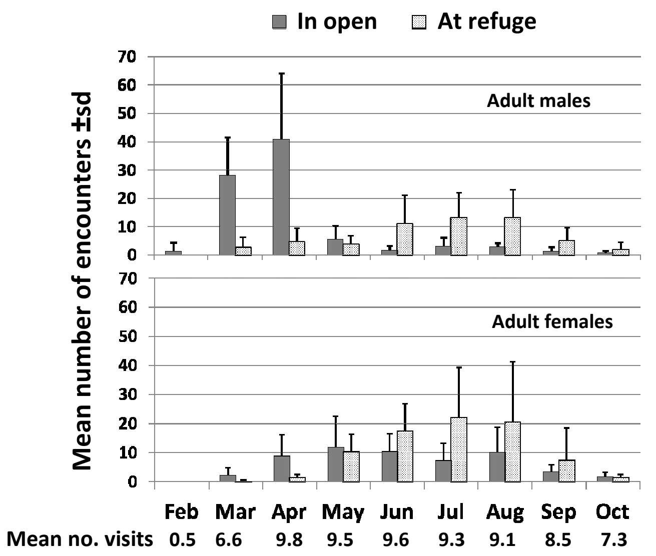

Figure 1. Mean monthly number of encounters (±sd) with adult male and adult female *V. berus* under refuges (tins and felts) or in the open, 2008 to 2015, also showing the mean number of monthly visits made to the site, (n = 8)

The highest encounter rates with adult males were recorded when they were basking openly ('lying out') or searching for mates in March/April. Of these records on average only about 5% were from refuges, while in the period May to October on average 78% of adult male encounters were at refuges. Unlike adult males, relatively few adult females were encountered in the spring (Fig. 1) and likewise these were mostly in the open with only 8% at refuges. From May onwards, the number of refuge encounters with females, especially those that were gravid, rose steeply so that in this period on average 63% of encounters were at refuges.

Throughout the year, encounters of sub-adults and juveniles were mostly at refuges (Fig. 2). In spring encounter rates were low but these rose steeply from May to July. Sub-adult encounters at refuges started to decline from August onwards, at least a month earlier than either adults or juveniles. In the case of juveniles, encounter rates were augmented by the arrival of neonates, when adult females gave birth in August and September, so that decline was not obvious until October (Fig.2).

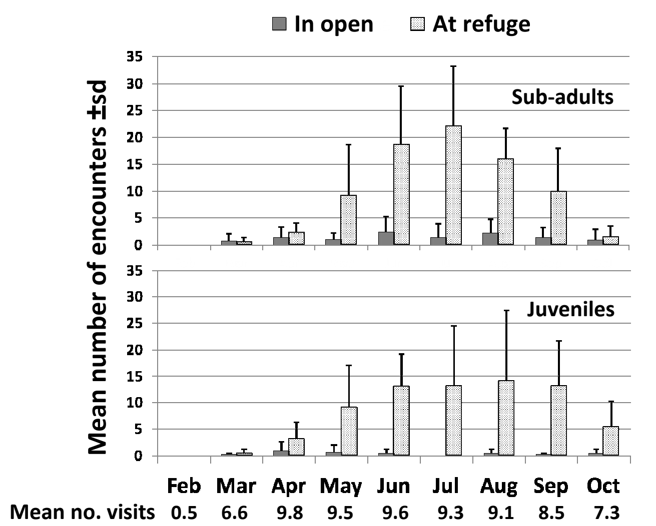

Figure 2. Mean monthly number of encounters (±sd) with sub-adults and juvenile *V. berus* under refuges (tins and felts) or in the open, 2008 to 2015, also showing the mean number of monthly visits made to the site, (n = 8)

Number and proportion of viper encounters at refuges or in the open

Over the eight years of study, the mean annual total (±sd) of adult encounters at refuges (tins and felts combined) amounted to 132.6±66.7, sub-adult 79.3±29.9, and juvenile 69.9±31.2. There was significant heterogeneity between the variables of the data set (Kruskal Wallis, $H = 6.5$, $df = 2$, $p<0.05$, $N = 24$) and pairwise comparisons showed that the adult encounter rate was significantly greater than that for sub-adults or juveniles (Mann Whitney, $p<0.05$), but that sub-adults and juveniles did not differ significantly.

The proportions of each viper life stage encountered at refuges, rather than in the open, were statistically heterogeneous (Kruskal Wallis, $H = 24.63$, $df = 4$, $p<0.001$, $N = 40$). At least 80% all encounters with immatures stages (sub-adult and juvenile) were from refuges (Fig. 3) and these proportions were significantly greater than those for either adult males or adult females. The percentage of adult females seen at refuges was significantly greater than for adult males (Fig. 3).

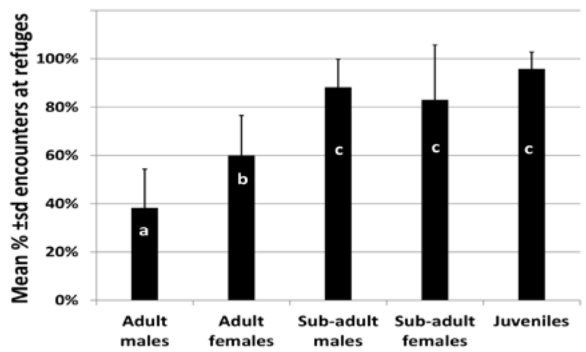

Figure 3. Mean % (±sd) of annual *V. berus* encounters at refuges, rather than in the open, 2008 - 2015. Values with no letter in common are significantly different (Mann Whitney, p<0.05), n = 8.

The proportion of all viper encounters at tins, rather than felts, rose quite steeply from 2008 to 2009 and thereafter more or less levelled off (Fig. 4). There was evidence of heterogeneity between years (Kruskal Wallis, $H = 19.8$, $df = 7$, $p<0.01$, $N = 40$) and in the first year, and possibly second year, tins appeared to be less favoured by vipers than the years that followed (Fig. 4).

Observation rates of known individual vipers at refuges and in the open

Over eight years of study, approximately equal numbers of individual adult males (87) and females (85) were detected, suggesting an equal sex ratio, and about 70% of these known adult males and females were observed at least once under a refuge (Table 2). The known immatures stages were more likely to have been observed using a refuge as 81-89% of sub-adults and 98% of juveniles were recorded using tins and/or felts at least once (Table 2). For all life stages, more individuals were recorded using only tins than either only felts or a combination of both refuge types (Table 2).

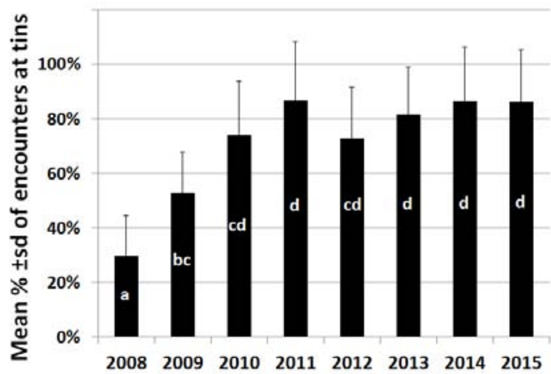

Figure 4. The mean % (±sd) of all life stages of *V. berus* encounters at tins, rather than felts, 2008 - 2015. Values with no letter in common are significantly different (Mann Whitney, p<0.05), n = 5.

Table 2. Proportions of individual known *V. berus* at each life stage observed at least once under corrugated iron (tin), roofing felt (felt) refuges, or both, from 2008-2015 (NB due to the length of the study some individuals were recorded in more than one life stage)

Life stage	Total no. indvs	% of known individuals found at			% of indvs found	
		Tins only	Both tins & felts	Felt only	At refuges	Only in the open
Adult male	87	40.0%	23.2%	6.3%	69.5%	30.5%
Adult female	85	43.5%	25.9%	11.8%	70.6%	29.4%
Sub-adult male	60	54.1%	24.6%	11.5%	88.5%	11.5%
Sub-adult female	76	49.3%	28.0%	4.0%	81.3%	18.7%
Juvenile	202	62.1%	19.4%	16.5%	98.1%	1.9%

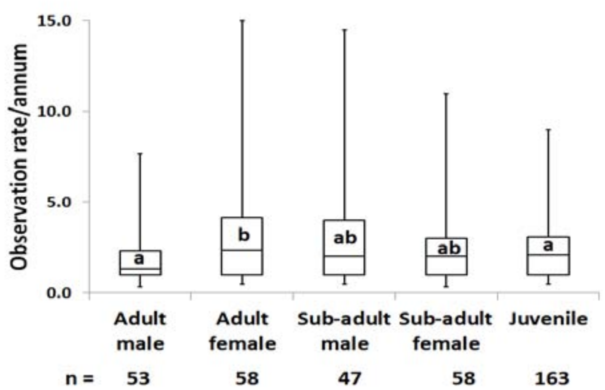

Figure 5. Observation rates/annum of known *V. berus* of each life stage at tin refuges over a period of 8 years. Shown are minimum, first quartile, median, third quartile and maximum rates; boxes with no letter in common are statistically significantly different (Mann Whitney, p<0.05), n = number of individual vipers.

For the eight years of study, the mean annual observation rates of individual vipers at tins, felts or in the open were significantly heterogeneous (Kruskal Wallis, H = 962.2, df = 14, P<0.001, N = 745). At tins, adult females were observed significantly more frequently than adult males or juveniles although did not differ from the sub-adults (Fig. 5). Although median values were similar, statistically significant differences was associated with wider value ranges.

The rate of use of felts by juveniles was significantly greater than for adult males but otherwise there were no significant differences between other life stages (Fig. 6).

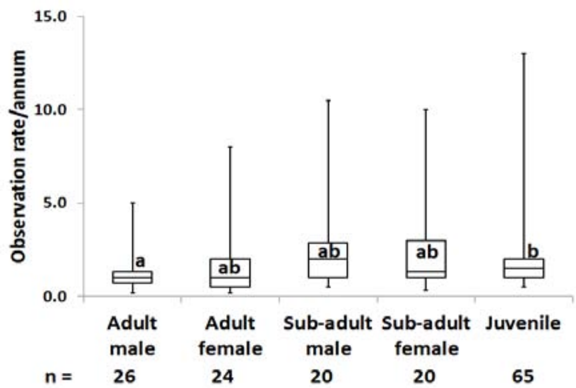

Figure 6. Observation rates/annum of known *V. berus* of each life stage at felt refuges over a period of 8 years. Legend as for Fig. 5.

In the open, adult males were observed significantly more frequently than the other life stages (Fig. 7). Adult females observation rates were significantly greater than those of the sub-adults, which in turn were significantly greater than juveniles (Fig. 7).

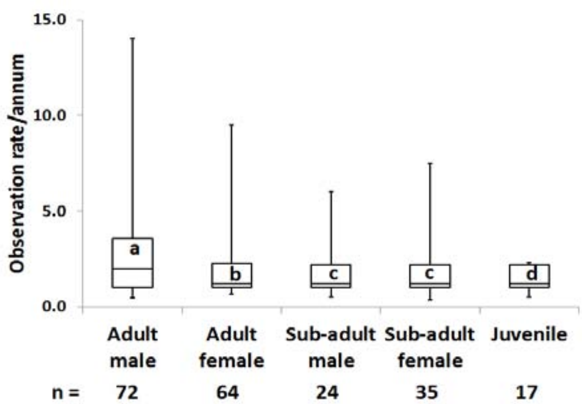

Figure 7. Observation rates/annum of known V. *berus* of each life stage in the open over a period of 8 years. Legend as for Fig. 5.

DISCUSSION

During eight years, there were more encounters with adult vipers than with sub-adults or with juveniles. Adults were also much more frequently encountered in the open than other life stages. In total there were similar numbers of different individual adult males and adult females observed in the open and under tins, but the frequency of resighting these individuals was greater in the open for males and greater under tins for females. All life stages were more commonly observed under tins than under felts.

There were differences between monthly patterns of adult viper encounters in the chalk downland reserve, at both refuges and in the open. Such differences had been expected from the descriptions of adder behaviour by earlier authors, albeit for different habitats. The early spring (Feb –April) abundance of adult males basking in the open (Fig. 1) followed by moulting and searching for females has been well documented previously, as has the emergence of the bulk of adult females at least two or three weeks after the males (Neumeyer, 1987; Prestt, 1971; Viitaten, 1967, *inter alia*). Adult females sun themselves in the open but are more difficult to detect as they keep closer to vegetation, are much less active, and less conspicuously coloured. In early spring, both adult male and female vipers were observed to make very limited use of refuges, instead most individuals warmed themselves by open basking. The surge in spring time observations in the open, particularly of adult males, is the basis of a viper monitoring project 'Make the adder count' (ARG UK) in the UK. Subsequently, in the period May to August, adult males and non-reproductive adult females become difficult to observe as they are foraging (Prestt, 1971; Viitaten, 1967), and in the current study their appearance at refuges was usually confined to times when they are either digesting food or in pre-moult. Adult female encounters rose from May onwards due to gravid females basking frequently either in the open or under refuges. Then in the autumn (September - October) encounter rates for both adult males and females declined as the vipers submerged for hibernation. The total number of encounters with adult males (1071) and adult females (1077) during the study, and different individual known males (87) and females (85), were more or less equal. *Viper berus* is known to have a 1:1 sex ratio (Volsøe, 1944; Prestt, 1971) which was confirmed in the current study (Table 2). However, as females normally breed on a biennial cycle (Prestt, 1971), on average only half the adult female population is likely to reproduce in any given year. In contrast, all adult males may reproduce annually. Potentially, this gives twice as many males lying out in spring as gravid females basking later in the year. Despite this, the total encounter rates for adult males and females are similar. This seems to result from fewer females basking for longer, four months (May to August), matched by a greater number of males that bask openly for only for two months (March to April). Further, given an equal sex ratio and a long period (eight years) there was sufficient time to encounter broadly similar numbers of different individual adult males and females.

Greater usage rate of tins by adult females, especially those that are gravid, could be interpreted as females using refuges instead of mosaic basking. If that interpretation is correct then if there had been no artificial refuges it is possible that the observation rate of adult females in the open would have been similar or even greater than that of adult males and this would be worth further investigation on a site without refuges. Nevertheless, there seems to be variation between females in willingness to use refuges. For example, a gravid female that in 2014 was at least 13 years old was observed 34 times close to a tin but under it only once. In contrast, a younger gravid female, in its 6th year in 2015, was observed close by the same tin four times but found under it a total of 15 times. It is noteworthy that the older female was already an adult before any artificial refuges were laid in the reserve whereas the younger female had a history of refuge use from when first observed as a sub-adult in 2011, albeit not the tin mentioned here. This suggests that some degree of learned behaviour may be important in determining refuge use rather than 'knowldege' of where tins are located since both individuals 'knew' and encountered the same tin.

In the literature there are only a few references to the encounter patterns with immature vipers (Prestt, 1971; Viitaten, 1967). As expected, open basking was relatively rare so that encounters with immature stages were largely dependent on refuge use; even more so for juveniles than sub-adults (Figs. 2 & 7). Avoidance of open basking is common among small snakes, probably so that they remain concealed from avian predators (Webb & Whiting, 2005). Sub-adults emerged from hibernation at roughly the same time as adult females (Neumeyer, 1987; Prestt, 1971; Viitaten, 1967) and reached a peak in July (Fig. 2) and then declined progressively in August and September; they were more or less submerged for hibernation in October (Fig. 2). The autumn decline of juveniles appeared much less pronounced (Fig. 2), but would have followed the same pattern as sub-adults if it had not been that new born vipers augmented observation rates in August and September.

It is tempting to refer to monthly variations in encounter rates (Figs 1 & 2) as 'activity patterns' but many individuals under refuges were either in a condition of pre-moult, digesting prey, promoting embryonic development, or warming themselves prior to foraging. Consequently, the observed patterns are a reflection of changes in seasonal behaviour more than of activity *per se*. The proportion of all viper observations attributable to refuges averaged 65%; roughly similar results were obtained in a study of refuge monitoring on dry lowland heath which yielded a value close to 50% but from a rather small sample size (Reading, 1997). At other sites, however, use of refuges by *V. berus* may vary drastically between years or they may be altogether shunned (Griffiths et al., 2006; Walter & Wolters, 1997). It is not clear what might cause such extreme variation. Possible explanations are that in the case of small populations chance factors may come into play and/or where the study site has relatively newly placed refuges results could be low as there had not been sufficient time for refuge use to become part of the vipers' behavioural repertoire. In the case of the current study, refuge use may have been favoured as refuge positions had been established for several years and, being in a habitat that was largely open, warm sheltered locations that facilitate mosaic basking may have been at a greater premium than in other more sheltered habitats.

More individuals used tins than felts; this preference for tins has been reported previously (Griffiths, et al. 2006; Rijksen, 2008). There was little evidence of differences between life stages in their preference for felts except that the rate of use by juveniles was significantly greater than by adult males. Felts are applied closely to the ground and so the animals using them would be warmed by direct contact with the felt; consequently they are particularly favoured by thigmotherms such as the slow worm *Anguis fragilis* (Spellerberg, 1976). *V. berus* is known to thermoregulate largely by moving to preferred locations and changing posture (Spellerberg, 1976); this would be easier under tins due to the additional space created by the corrugations. However, the use of felts by some vipers suggests that at least occasionally thermoregulation may be achieved by thigmothermy; this has been observed previously in a minority of cases but not specifically in relation to felts (Gaywood, 1990). During the first three years of the study there was a progressive increase in the use of tins and corresponding fall in the use of felts (Fig. 4). This coincided with the gradual loss of vegetation beneath the felts, so that in due course the ground beneath them was largely bare. It seems likely that this change, 'bedding in', may have made the felts less suitable for the vipers, as the felts would become more closely applied to the ground beneath. If refuges had been relocated annually then the proportion of viper records from felts could have been higher; however it cannot be concluded that the total number of records at refuges would have been greater since as felts became less favourable it is likely that there was a simple displacement of vipers from felts to the closely located tins with which they were paired. The relatively small contribution of felts suggests that their omission from programmes to monitor *V. berus* would have limited impact on the data gathered, although this is likely to be untrue of other species such as *A. fragilis*, which can be monitored simultaneously.

It was of some interest that the observation rate of vipers in the open increased for the first six years of the study (Table 1). An ability to see vipers basking/mosaic basking is a skill and some of the increase, probably most of that in the first two or three years, could be attributed to increasing surveyor skill and knowledge of the habitat. However, this is certainly not the only factor. The quality of springtime weather will affect the rate at which vipers can arrive at reproductive condition (Herczeg, et al. 2007); periods when sunshine is weaker will require more protracted basking, resulting in higher encounter rates. It is perhaps no coincidence that the year with the highest rate of observations in the open, 2013, was a year with particularly poor springtime weather. Another factor of importance is the number of individuals that would enter reproductive condition. Observation of an island population of *V. berus* in Sweden has shown that if food becomes limiting then adult males and females emerging from hibernation in the following year fail to engage in reproductive activity and instead proceeded directly with foraging (Andrén, 1982). Consequently, they were less frequently encountered in the open. Given the effects of climate and food supply, natural variation in encounter rates of adults in the open is to be expected and is not just a function of population size.

This study gives some indication of the proportion of the total viper population that actually uses refuges. Over the eight years of study at our site, the recruitment of individual adult vipers to our database became increasingly confined to newly matured individuals. Consequently, apart from this segment of the adult population it is assumed that most adult vipers are known (equivalent to mark recapture data where most adults are resightings/recaptures). In that case, from our observations of known vipers at refuges (Table 2) it can be concluded that about 70% of adults have used refuges on at least one occasion. Currently, it is not possible to estimate the proportion for immatures using refuges since there is much less confidence about the proportion of the population that is known to us. The relatively low encounter rate of immatures might be interpreted as reluctance to use refuges, an inability to find refuges, or simply that there are fewer immatures within the population than might be expected. Low numbers may be a reasonable explanation. In our study we recorded more individual juveniles (202) than sub-adults (136) but a relatively high number of individual adults (172). This pattern is similar to that described for other *V. berus* populations (Phelps, 2007), where there was very high mortality in the first three years of life (92%) but where adults were relatively long-lived, with significant numbers at least 25 years old; furthermore it was reported that recruitment was less than expected as females often bred less regularly than the typical biennial cycle (Phelps, 2007).

In the case of adult *V. berus*, observations in the open and at refuges are complimentary in providing encounter data and the use of refuges reveals the summer peaks of females and sub-adults and the arrival of neonates in the autumn. Vipers can be photographed in the open and even more easily at refuges to enable individual recognition by head-scale patterns. Individual recognition can help to resolve the wide annual variations in encounter rates, indicating whether this variation is due to the same vipers being encountered more often or the presence of a greater number of vipers. Any changes in numbers may give clues to the health and sustainability of *V. berus* populations due to factors such as climate, food supply, and habitat management methods. It is intended that the current long-term study will in due course report on population fluctuations and their possible causes. In relation to further development of monitoring, knowledge about how vipers use refuges and the extent of any thermal advantages they confer could improve the interpretation of data, could suggest improvements in refuge design and deployment, and could also indicate what conservation benefits the refuges themselves might offer. We have made a start on investigating these issues, which are documented in two further reports (Hodges & Seabrook, 2016 a&b).

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