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RESEARCH ARTICLE

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Evidence that agri-environmental measures in arable fields could be a conservation benefit to northern vipers *Vipera berus* and other reptiles

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ABSTRACT – In Britain, some reptiles species have been formally recorded inhabiting arable field margins but previous reports on the incidence of northern vipers or adders *Vipera berus* in this situation have been anecdotal. In 2017, reptile monitoring was initiated in a field margin that had been created ten years earlier and was located near two chalk grassland nature reserves with established viper populations. In the first three years of recording, numbers of vipers in the field margin were low and limited to a few juveniles and adults. In the fourth year, there was a noticeable increase in number, which were now represented by all life stages. In the fifth year the population doubled again and then remained stable in the sixth year. A similar encounter trajectory was observed for grass snakes, while slow worms and common lizard encounters had different trajectories. There was some evidence of vipers moving between the nature reserves and field margin, even crossing a road to do so, but at least 75 % of vipers in the field margin were only ever detected there. The arable field was mostly used for cropping cereals and oilseeds but, exceptionally, in the three years from 2016 to 2018 it was put down to herbal leys of red clover and grass. In the USA and continental Europe, red clover is known to be a preferred dietary item of voles *Microtus* spp and has been associated with vole population increase. It is suggested that the increase in the viper population in the field margin may relate to a rise in the number of voles, which are an important component of the viper diet. Likewise, for grass snakes, small mammals may contribute 25 % or more of their diet. The use of herbal leys may present an important opportunity for the conservation of northern vipers in field margins and other adjacent habitats.

INTRODUCTION

In Britain, the northern viper or adder *Vipera berus* is a widespread species but is of some conservation concern (Gardner et al., 2019; Julian & Hodges, 2019). These vipers occupy a range of habitats including lowland heath, chalk grassland, moorland and woodland rides (Beebee & Griffiths, 2000) but, to date, evidence for their colonisation of arable field margins is only anecdotal. During a 2-year study in England, the occurrence of reptile species in field margins was investigated by the Amphibian and Reptile Conservation Trust (Salazar et al., 2016). This involved ten farms, across four counties (Oxfordshire, Berkshire, Wiltshire, and Hampshire), each with eight 100 m study transects in their field margins. While viviparous lizards *Zootoca vivipara*, slow worms *Anguis fragilis* and grass snakes *Natrix helvetica* were detected, northern vipers were not. It was suggested that the patchy distribution of vipers, rather than any rejection of field margins, accounted for their apparent absence.

Arable field margins, sometimes referred to as buffer strips, are supported by agri-environmental schemes for the benefit of the environment and of wildlife. Typically, in Britain they are managed under a combination of Entry Level and Higher Level Stewardship schemes (ELS & HLS), where the margin can be created by sowing or by natural regeneration. For margins that are 6 m or more wide, the half closer to the crop may be mown annually in the autumn, where the cuttings are removed or chopped and spread. The half margin further from the crop would be cut in the autumn on a longer cycle of every few years. As far as possible the margins are excluded from spray treatments of fertiliser, herbicide or pesticide.

During a long-term study of vipers on two chalk grassland nature reserves in west Kent (England), it became apparent that a small number of individuals were moving between the two reserves and that the potential corridor between them must have been the margin of an arable field. From 2017 onwards, this prompted a more detailed study of this margin and the results presented here show an increasing colonisation of the field margin by vipers over a period of six years. Some insights are offered into the factors that may have favoured this rise in viper numbers.

MATERIALS & METHODS

Study location

The arable field under study is located in the Darent valley of west Kent (England) and has a total area of about 13 ha (approx. location 51° 21’ N, 0° 11’ E). It occupies part of a slope (inclined at about 5°–7°) on the eastern side of the

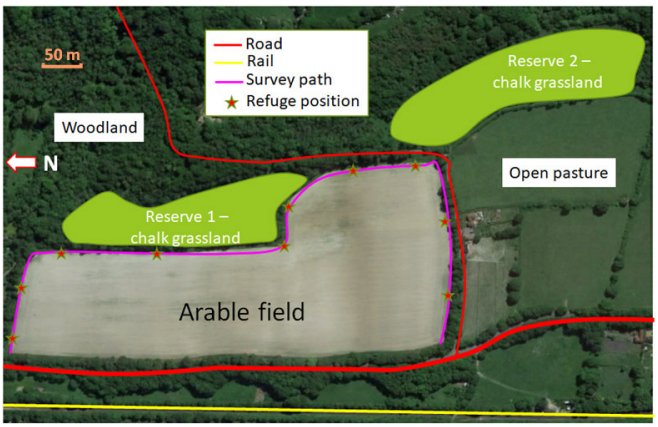

Figure 1. The location of the arable field relative to transport infrastructure and two chalk grassland nature reserves. Note that Reserve 2 is the other side of the road from both the arable field and Reserve 1. Photo from Google Earth.

valley and has a long history of cereal agriculture since at least the 1940s. It was a patchwork of smaller fields until the 1960s and since then has become one large field. On the slope above the field there is a belt of woodland above which there is a chalk grassland nature reserve (Reserve 1, Fig. 1). On the slope above this reserve there is a road and above that woodland and then, at the top of the slope, livestock and arable fields. Also beyond the road and on the slope just to the south-east of the arable field there is a second chalk grassland reserve (Reserve 2, Fig. 1). Both chalk grassland reserves have viper populations. For comparative purposes, reptile monitoring results for the field margin are compared mostly with those for chalk grassland Reserve 2 as since 2008 it has been subject to more intensive reptile monitoring than Reserve 1 (Table 1).

Since 2007, a 6–8 m uncultivated margin has been maintained in the arable field as part of the environmental stewardship scheme (ELS/HLS)(Fig. 2). The 3 m of field margin closest to the crop, which is grassy, is cut usually in November/December while the portion further from the crop is more 'woody' and cut for woody growth every few years, also in November/December.

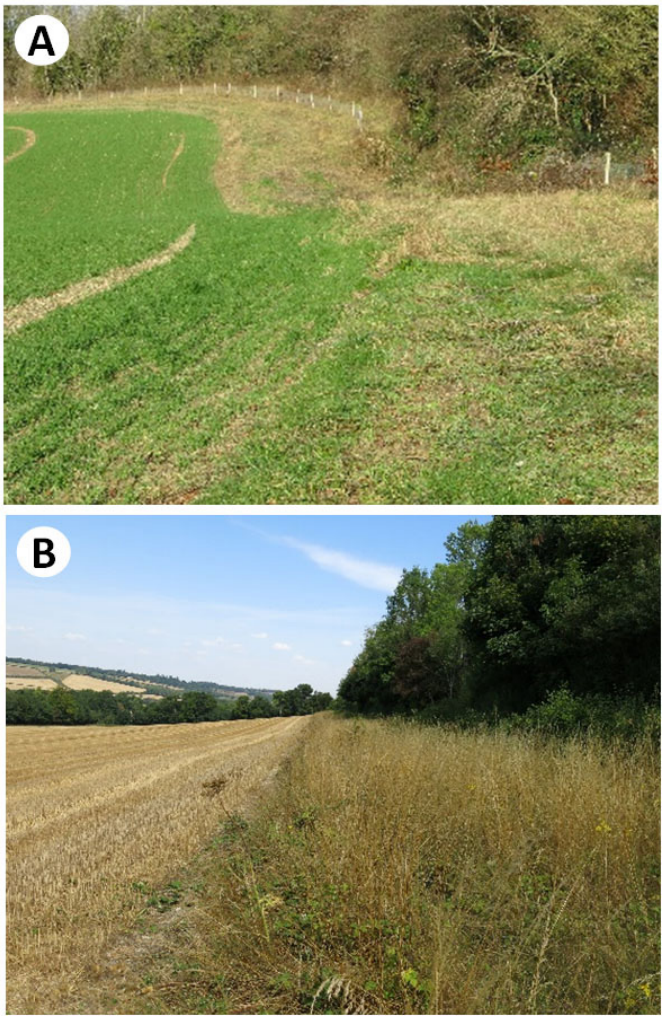

Figure 2. Margin of the arable field in 2022 - **A.** In January soon after mowing, and **B.** In August soon after harvesting winter wheat

Monitoring technique

A detailed account of our reptile monitoring methodology has already been published (Hodges & Seabrook, 2018). The data presented here were collected from 2017 to 2022 during visits to the field margin and the two chalk grassland reserves in the reptile active period from March to October; the number of annual visits varied between the sites (Table 1). For each visit, we followed standard survey paths (Table 1) and at intervals along the paths there were refuge positions where paired artificial refuges of galvanised-corrugated iron and roofing felt (each 50 cm x 60 cm) were placed. In the field margin, refuge positions were divided equally between the grassier and 'woody' portions. Vipers were recorded at refuge locations and along the survey paths. To facilitate individual recognition, close-up photographs were taken of viper head-scale patterns (Benson, 1999) when they were located under refuges or, by using a long-focus lens when they were basking in the open; the patterns were coded and then entered into a database. The study involved no animal handling in order to minimise disturbance and stress. Different life stages were defined as follows: neonates had not yet hibernated; juveniles had hibernated only once; and the sub-adult stages in the case of males were normally completed in two years and in females three years. Adults were recognised by having completed a total at least 4 hibernations in the case of males and, normally, a minimum of five in the case of females. In this study, assigning age class to individuals was relatively easy as many vipers had been observed initially as neonates, juveniles, or young sub-adults and consequently the surveyors were well acquainted with the relationship between size and age. The sex of adults and sub-adults was determined by colouration and body proportions (Smith, 1951; Beebee & Griffiths, 2000) while that of juveniles was assigned by colour and confirmed when they had developed to later stages. Full details of the life stages of all 'known' adders and their observations across six years are presented in Table 1S and the dataset of viper observations by year is given in Table 2S (see Supplementary Material).

Table 1. Characteristics of the monitoring regime in the arable field margin and two chalk grassland reserves 2017–2022

Parameter	Field margin	Reserve 1	Reserve 2
Survey path length	1.08 km	0.82 km	1.03 km
Open habitat (ha)	0.78 ha	1.1 ha	3.28 ha
No. refuge positions	10	10–11	16
No. surveys/season	26–64	8–27	66–70

Statistical analysis

To enable comparison between reptile encounter rates between sites and between years in situations where monitoring parameters may vary, encounter rates were expressed as an Encounter Index (EI) (Hodges & Seabrook, 2018). The EI for any particular year is estimated as the geometric mean of encounters at refuges ($Encounters_r$) and those along the survey path ($Encounters_{sp}$), normalised by the annual monitoring effort as follows:

$$\text{Encounter Index} = \frac{\sqrt{2(\text{Encounters}_r * \text{Encounters}_{sp})}}{\text{Monitoring effort}}$$

where monitoring effort is

$$\text{Monitoring effort} = \text{monitoring infrastructure} * \text{no. annual visits}$$

and monitoring infrastructure is

$$\text{Monitoring infrastructure} = \sqrt{2}(\text{No. refuges} * \text{Survey path length})$$

The EI was used for vipers, grass snakes and viviparous lizards but slow worms are almost only recorded at refuges, so instead, a simple encounter rate was calculated as the number of observations per refuge pair, per visit. In the case of vipers, EI values were plotted against the numbers of known individuals to assess the extent to which rises in EI were actually a result of increasing numbers of vipers, rather than perhaps the improvement of weather conditions. EI values over time were assessed visually, as there was not a sufficient number of time points for meaningful time series analysis, and the dependence of a given year's result on previous years precluded valid analysis through other means (e.g. ANOVA or Kruskal-Wallis).

For vipers and grass snakes a Pearson correlation coefficient (r) was determined for their annual EI values to indicate the degree to which the populations were following the same trajectory. The increase in numbers of known vipers was plotted against the annual crop plantings since 2007 to look for any associations between the cropping history since 2007 and change in viper numbers.

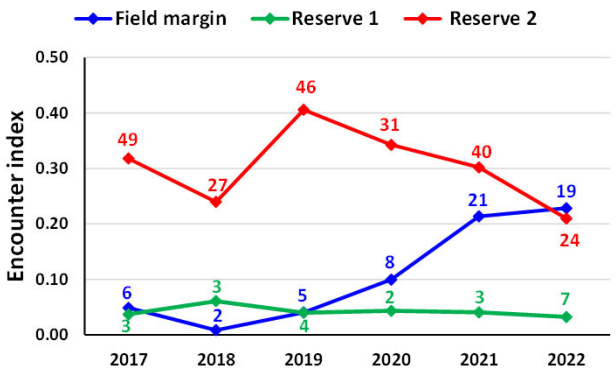

Figure 3. The Encounter Index values for *Vipera berus* in an arable field margin and in chalk grassland Reserves 1 and 2 detected 2017–2022. The coloured numbers show the number of individually recognised vipers detected in each year at each location (except for neonates, which are excluded to avoid distortions created by sudden high numbers at the end of the season).

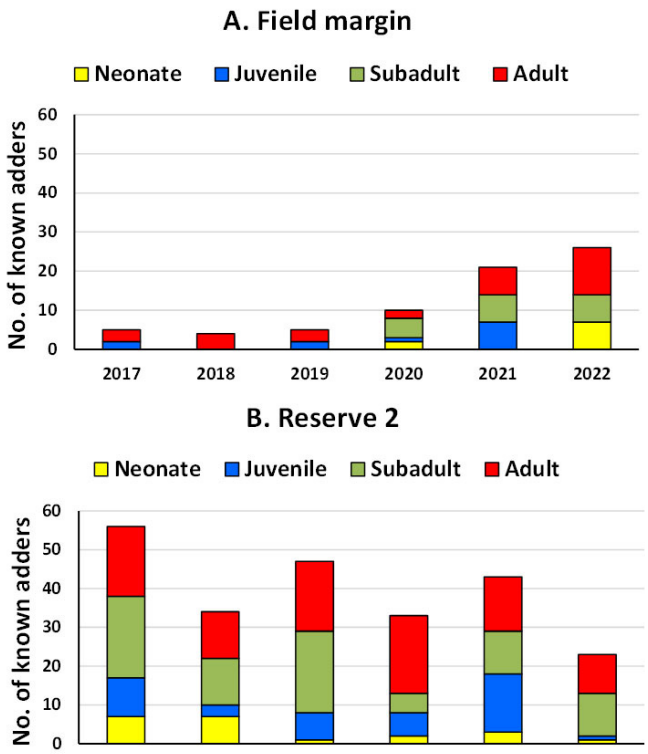

Figure 4. Life stages of individually recognised *Vipera berus* detected 2017–2022 - **A.** In the field margin, and **B.** In Reserve 2. Bars are stacked neonate to adult, from bottom to top and the data for the field margin is shown in Table 1S.

RESULTS

Viper populations

The encounter rate of vipers in the field margin was more or less constant from 2017 to 2019 and thereafter began to rise (Fig. 3), doubling in 2020 and doubling again in 2021 before apparently stabilising in 2022. The numbers of individual vipers observed in the field margin increased more or less in proportion to the encounter rate, indicating a genuine rise in viper numbers rather than purely the same vipers being detected more frequently. The monitoring results for Reserves 1 and 2 followed different trajectories. In Reserve 1 the encounter rate remained low throughout and the field

margin viper population diverged from it in 2020. Reserve 2 maintained a much higher encounter rate than the field margin or Reserve 1 until at least 2020, thereafter it began to fall and by 2022 had converged with the field margin (Fig. 3). The numbers of individual vipers recorded in Reserve 2 was again more or less in proportion to the encounter rate except in 2021 when the number (40) appears rather high for the observed encounter rate (Fig. 3).

During 2017 to 2019, the life stages of vipers in the field margin were confined to only a few adults and juveniles but in 2020 for the first time all life stages (neonates, juveniles, sub-adults and adults) were detected (Fig. 4A). No neonates were detected in 2021, while in 2022 greater numbers of neonates (7) and adults were detected but no juveniles. In contrast, from 2017 to 2022 all life stages were detected in Reserve 2 (Fig. 4B). The details of the life stages and their observations across six years in the field margin are presented in Table 1S (see Supplementary Material).

Potential impacts of field cropping pattern

In the period from the inception of the field margin in 2007 to 2015, the field supported crops of cereals and oilseed (Fig. 5). For the three years from 2016 to 2018 the field was put down to herbal leys (red clover/grass) that were harvested three times annually for big bale silage, no herbicide was used and there was reduced fertiliser application. At the end of the third year the red clover was ploughed in. It is noticeable that the rise in viper numbers was detected from four years after the start of herbal ley cultivation (Fig. 5).

Other reptile species

During the period of study, encounters with grass snakes in both the field margin and Reserve 2 (Fig. 6) were much lower that for vipers (Fig. 3). Nevertheless, the grass snake encounter rate had a similar trajectory to that of vipers, apart from a noticeable fall in 2022, and was closely correlated ($r = 0.92$, $df = 10$, $p < 0.001$).

The detection rate of slow worms in the field margin was actually higher than that in Reserve 2 from the start of the study period and was particularly high in 2021 (Fig. 7).

The encounter rate for viviparous lizards in the field margin remained lower than that in Reserve 2 throughout the study period (Fig. 8).

Interconnections between viper populations

A few vipers were observed to have moved between the field margin and two reserves, although no individual was detected in all three locations. Of the 41 individual vipers known in the field margin, eight vipers (6 males and 2 females) were also encountered in Reserve 1, which is further up the same slope, and two vipers (1 male and 1 female) were shared with Reserve 2 (Fig. 9). Reserve 1 also shared 2 vipers (both males) with Reserve 2. To share vipers with Reserve 2 requires them to cross the road; a total of 4 vipers are known to have crossed the road. Of these vipers (3 males and 1 female) one, a sub-adult female, generally took up a position close to the road and crossed it four times between May 2020 and April 2022 (Fig. 10).

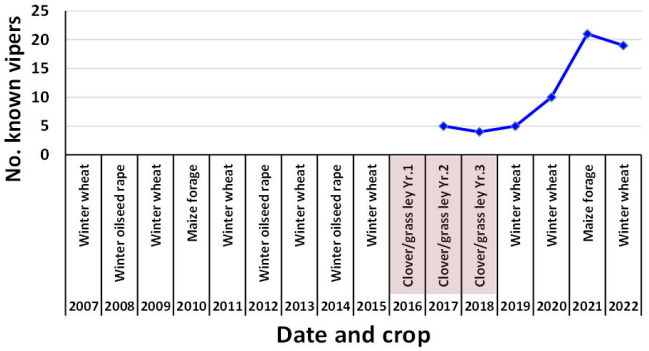

Figure 5. The crops grown in the field under study in the period 2007–2022 plotted against the number of individual vipers detected in the period of study 2017–2022 (excluding neonates), herbal leys in pink

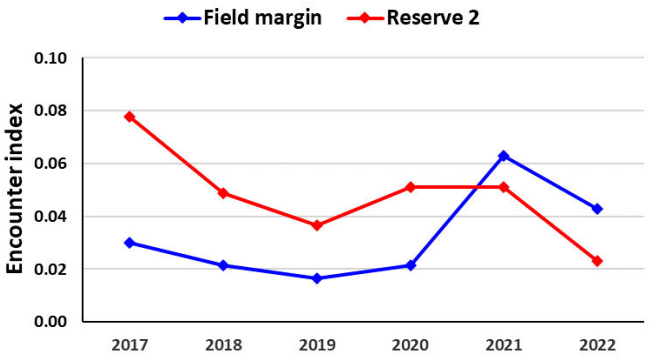

Figure 6. Encounter index for grass snakes *Natrix helvetica* in the field margin and in Reserve 2 in the period 2017–2022

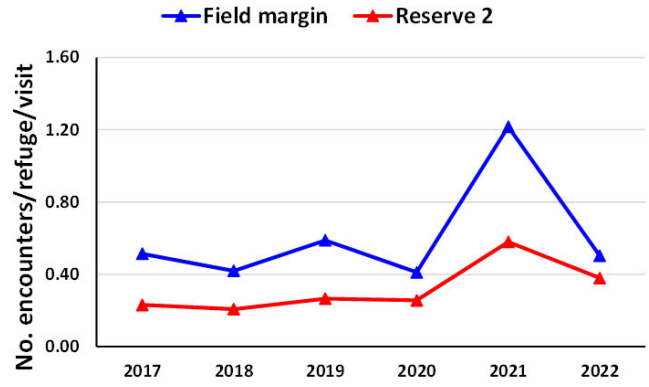

Figure 7. Encounter rates for slow worms *Anguis fragilis* in the field margin and on Reserve 2 in the period 2017–2022

DISCUSSION

Our observations of vipers in the margin of this arable field over a period of six years make it clear that such margins can support a viper population. During the period of study there was an increase in viper population as evidenced by the simultaneous rise in encounter rates, the number of individuals known from their head scale patterns, and in the number of life cycle stages represented. Of the 41 individual vipers observed in the field margin, 10 were also observed in other locations which suggests that as many as

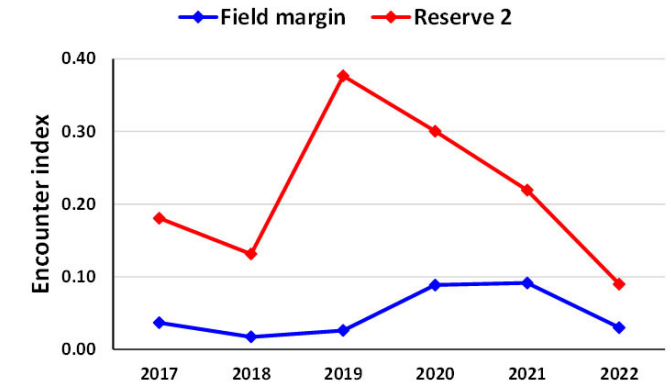

Figure 8. Encounter index for viviparous lizards *Zootoca vivipara* in the field margin and on Reserve 2 in the period 2017–2022

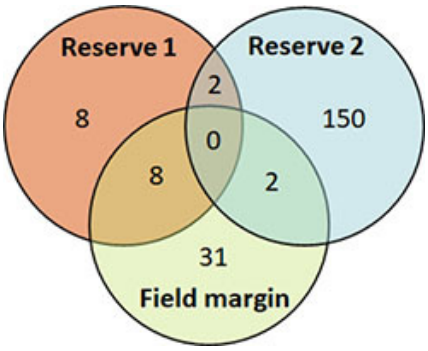

Figure 9. Numbers of vipers of all stages found exclusively in one location or shared between locations in the period 2017–2022. The four vipers shared with Reserve 2 must have crossed a road.

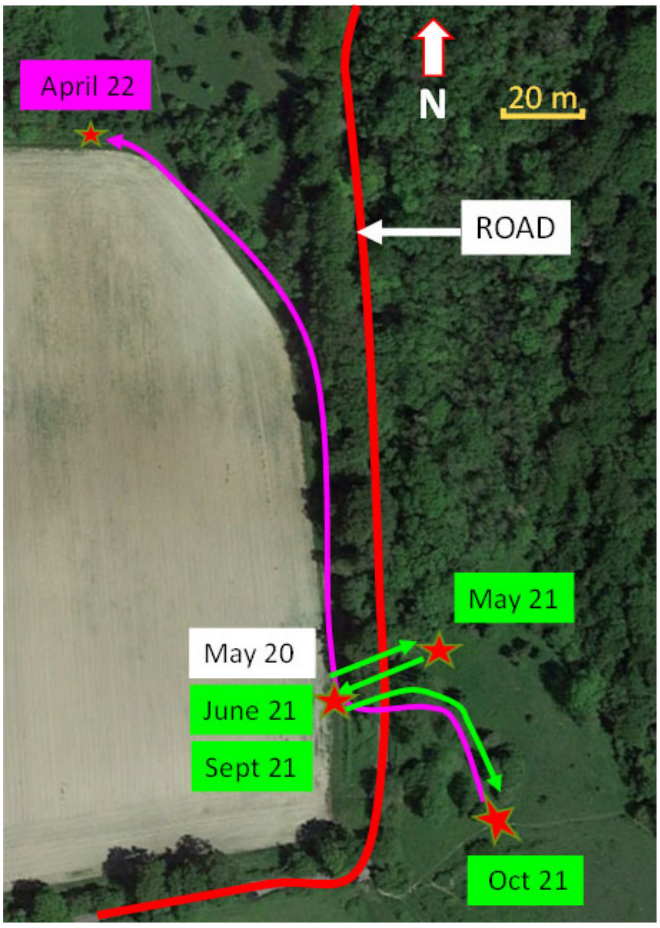

Figure 10. Observation on the road crossing behaviour of one individual sub-adult female viper, red stars are refuge positions. The dates closest to refuge positions indicate observations of this snake.

75 % of the vipers could have been primarily resident in the field margin. The viper increase was mirrored by increase in grass snake numbers, although grass snakes themselves were recorded much less frequently and did relatively poorly in 2022. The weather in 2022 was particularly hot and dry and was associated with lowered recording rates of all four widespread reptile species at several site in west Kent (unpublished data).

It was noticeable that the encounters with slow worms and common lizards followed quite different trajectories from the two snake species. The field margin constitutes a meadow habitat and was potentially more favourable for slow worms than the chalk grassland by offering a greater food supply and possibly better protection of its food supply (molluscs and worms) from desiccating conditions. It was therefore not surprising that the field margin had greater slow worm encounter rates during the whole study period. Conversely, common lizards were encountered less frequently in the field margin than in Reserve 2. This was perhaps not surprising as in the taller grass of the field margin they were more difficult to detect and had fewer basking opportunities.

It is of interest to speculate why the number of vipers and grass snakes both increased over the period of study. It seems unlikely that it could simply be the lag time for the field margin to become suitable for reptiles since the margin was likely to have been in a stable vegetative state within two or three years of establishment, i.e. at least seven years before this study. Instead, perhaps the cultivation of herbal leys (red clover and grass) in the arable field from 2016 to 2018 holds the clue. The absence of herbicide and pesticide spraying with this crop would be expected to be beneficial for wildlife. Furthermore, the clover crop would potentially provide both cover and food for the prey of snakes. In the USA, red clover crops are associated with much increased vole populations, where *Microtus pennsylvanicus* commonly prefers red clover to other crops (Thompson, 1965; Prieur & Swihart, 2020) and the European common vole *Microtus arvalis* prefers red clover to cereals (Lantová & Lanta, 2009); it is assumed that in Britain the field vole *Microtus agrestis* would have a similar dietary preference. Voles are an important food source for vipers (Smith, 1951) and in the case of grass snakes it has been suggested that in south-eastern England that 25 % or more of their diet may consist of small mammals (Gregory & Issac, 2004). An increase in vole numbers could both attract more snakes to the field margin and provide a more abundant food supply. This would lead to better body condition and higher reproductive output for both species and may account for why the trajectories of the two species were closely correlated. About 4 years after the herbal leys were first planted, the viper population rose and the first neonates were detected. This may well be a typical lag time for both viper and grass snake population response.

In the case of fields taken out of agricultural production for 'set aside', it takes about 2 years for the numbers of field voles *M. agrestis* to begin to rise (Tattersall et al., 2000). The detection of neonates in 2020 and then again in 2022, i.e. in alternate years, suggests the presence of a small number of adult females that are reproducing in synchrony in alternate years; female *V. berus* typically reproduce every other year or less frequently if conditions are unfavourable (Bauwens & Claus, 2019).

We detected relatively few movement of vipers from the chalk grassland reserves to the field margin, and most of these were from Reserve 1, which clearly offers an immediate source of vipers for the colonisation of the field margin. Vipers also came from Reserve 2, crossing the road to do so. During the course of our long-term investigation of reptiles in this area we have observed several fatalities of adders on this road both from motor vehicles and, in one case, a bicycle, indicating the risk for animals crossing. It was surprising to find one individual that was willing to cross the road relatively frequently, even though at busy times of the day there would be vehicles passing along it every two or three minutes; early morning and late afternoon would be much quieter (a vehicle every 10 to 15 minutes). Such a willingness to cross the roads suggests that Reserve 2 was also potentially a greater source of colonisation than might have been expected.

In this particular study the potentially important factors for viper colonisation of the field margins seem to be - 1) A supply of immigrants from nearby colonies (even crossing a road to get there), 2) A field margin established for 10 years since the initiation of the study (immigration takes time, potentially linked to maturation of suitable habitat to attract and hold immigrants), 3) Mowing of field margin restricted to the period when reptiles are inactive, November–February, and 4) A herbal ley crop possibly offering food and shelter for prey species. For the future, we will continue to monitor the fate of the viper population to observe whether it declines with time since herbal ley cultivation. The next crop of herbal leys is expected in 2026 or beyond and a positive response to this by the viper population would strengthen our confidence in what is currently a circumstantial association. If red clover/grass leys really do improve prey availability then their use could offer a significant advantage in the conservation of northern vipers in arable field margins and adjacent habitats as well as to other predators such as barn owls.

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