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Influence of artificial refuge type on the success of a presence/ absence surveys for slow worms *Anguis fragilis*

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ABSTRACT – Artificial refuges are widely used to improve detection rates when surveying for reptiles. We compared the efficacy of refuges constructed from four different materials to detect slow worms *Anguis fragilis*. The refuges included two types that were flat - roofing felt (bitumen) and carpet tiles, and two types that were corrugated - one constructed of roofing felt (bitumen-soaked fibres) and the other of metal. The proportion of occupied refuges (i.e. sheltering at least one slow worm) varied greatly by month with the highest proportions in June. The effect of refuge type was not statistically significant on its own, but the interaction between the type and month was significant. The proportion of occupied refuges was most affected by refuge type in the months with intermediate slow worm occupancy rates (May & July). Flat roofing felt and the corrugated roofing felt appear to be the most different, the former higher in July and the latter higher in May and June. Using a mixture of refuge types simultaneously during surveys could potentially increase the detection rate of slow worms.

INTRODUCTION

In herpetological field research, the use of artificial refuges that may be made of various materials is a widely accepted and successful method of surveying (e.g. Madani et al., 2023). They are placed on the ground, in the preferred habitat of a target species, and work in the same way as natural-cover objects, for example, logs or leaf litter, by creating suitable microhabitats beneath them. Consequently, they concentrate secretive reptiles beneath them, which improves detection rates (Willson & Gibbons, 2010). While the impacts of artificial refuge distribution have been studied (Reading, 1996; 1997; Harrison, 2018), research on the effect of the material used is limited.

Depending on the target species, research budget and habitat, refuges can be made of several different materials (Willson & Gibbons, 2010), however, their success is related to their ability to generate microclimates that reptiles may use for basking and sheltering (Reading, 1997). As the refuges may be used for thermoregulation, their efficiency can be improved by positioning them so that they get enough sunlight to provide warm conditions (Sewell et al., 2013) and by using materials with heat-retentive properties appropriate to the target species (Hesed, 2012). Thermal resistance (R-value) is widely used as a measure of heat-retentive properties and is defined as the resistance of a body to transmit thermal energy, where the higher the R-value the greater heat retention exhibited, and the slower the rate of heat loss (Schaschke, 2014). Corrugated metal has been recommended by the National Amphibian & Reptile Recording Scheme (NARRS) (Cheung & Gent, 1996). Metal heats quickly, which may create microhabitats that become too hot and dry for target species to tolerate (Willson & Gibbons, 2010; Riddell, 1996). Alternative refuge materials that have been recommended include bitumen roofing felt and Onduline (corrugated bitumen-soaked fibre product), both of which have higher heat-retentive properties (NARRS, n.d.; Riddell, 1996; Edgar et al., 2010). Using two different but complementary refuges types has been recommended as a means of widening the microclimates on offer and so improving reptile detection rates, e.g. bitumen roofing felt together with corrugated metal refuges (Sewell et al., 2013) and 'spider' tubes together with concrete roof tiles (Mandani et al., 2023).

Slow worms are semi-fossorial, legless lizards that feed mostly on molluscs (slugs and snails) and sometimes earthworms and other small invertebrates. Generally, they obtain their body warmth by applying their bodies to warm objects rather than basking in sunlight, i.e. they are thigmotherms rather than heliotherms (Brown & Roberts, 2008). The success of a refuge is linked to the ability of slow worms to obtain warmth from it and inhabit the microhabitats it creates (Edgar et al., 2010). Consequently, it might be expected that refuge types with higher heat-retentive properties would be more attractive than those with lower values. Moisture retention under refuges might also play a role as slow worms' preferred foods tend to prefer such conditions. From this perspective, corrugated materials might increase ventilation and make microhabitats less attractive for slow worms.

A translocation of over 100 slow worms *Anguis fragilis* to a site near Hertford in 2014 provided us with an opportunity in 2016 to assess the efficacy of four different refuge materials, as well as the independent and interactive influence of time of year and location, on the detection rate of slow worms at refuges.

Figure 1. Locations of the three grassland habitats surveyed in this study at The University of Hertfordshire Bayfordbury Field Station Campus (Google Earth, 2024)

MATERIALS & METHODS

Study locations

The study was undertaken at three grassland locations in a 40 hectare area of the University of Hertfordshire's Bayfordbury Campus (51° 46'33'' N, 0° 05'30'' W) near Hertford, Hertfordshire, United Kingdom. Besides grassland, the area includes woodland, ponds and frequently-mown lawns around buildings. The study area bedrock geology consists of chalk and the surface geology is mostly diamicton deposits laid down approximately 2 million years ago. Additionally, a branch of superficial sand and gravel deposits are also present. Soil texture is loam to clay with the pH being slightly acidic (British Geological Survey, 2016).

Two of the grassland locations were at Rough Hills - Rough Hills Central (RHC) and Rough Hills South (RHS) - and the third at Hooks Grove (HGG) (Fig. 1). Mowing is the main form of management in these grasslands and is undertaken at least biennially to avoid scrub invasion. The grass is not mown too short so that some cover habitat for reptiles remains; grass cuttings are usually removed. Slow worms and grass snakes have both been recorded on the site in the past. In 2014 Bayfordbury was identified as a suitable receptor site for approximately 100 slow worms, which were released in parts of the site where slow worms had not been recorded previously.

Field survey

Four different refuge types (Table 1; Fig. 2) were selected for testing as they had previously been recommended for slow worm surveys, two were flat products - flat roofing felt (FRF) and carpet tile (CT), and two were corrugated products - corrugated metal (CM) and corrugated roofing felt (CRF) similar to Onduline (Riddell, 1996; NARRS, n.d.; Scheffers et al., 2009; Edgar et al., 2010).

Field surveys were undertaken between April and October 2016. A total of 30 refuges of each type, dimensions 50 x 50

Table 1. Types of refuges used to detect slow worms

Material	Size	Thickness
Flat refuges		
Roofing felt	50 x 50 cm	1 mm
Carpet tile	50 x 50 cm	5 mm
Corrugated refuges		
Roofing felt	50 x 50 cm	2.6 mm
Metal	50 x 50 cm	1 mm

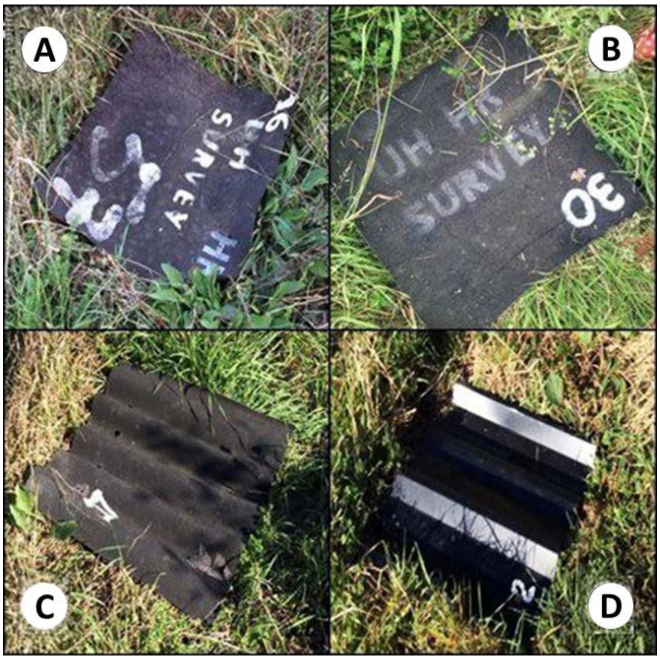

Figure 2. Refuges used to detect slow worms – The flat products **A.** Roofing felt, **B.** Carpet tile; and the corrugated products **C.** Roofing felt, similar to Onduline, and **D.** Metal

Table 2. Sampling effort and counts of occupied refuges by month

Month	Total no. refuges checked	% Refuge checking effort	No. refuges occupied	% of total refuges occupied	Occupied/ checked proportion
April	357	19	2	2	0.006
May	486	26	12	13	0.025
June	104	6	12	13	0.115
July	653	35	50	56	0.077
August	247	13	13	15	0.053
Total	**1847**	**100**	**89**	**100**	

Table 3. Sampling effort and counts of occupied refuges by location

Location	Total no. refuges checked	% Refuges checking effort	No. refuges occupied	% of total refuges occupied	Occupied/ checked proportion
HGG	424	23	29	33	0.07
RHC	676	37	20	22	0.03
RHS	747	40	40	45	0.05
Total	**1847**	**100**	**89**	**100**	

cm, were distributed across the three selected grasslands in a 5 x 10 m grid. Each of the three sites had ten refuges of each of the four types (Fig. 2). A Latin square grid design was partially replicated within each field where each refuge type occurred only once per row, and refuges of the same type were never adjacent (Cheung & Gent, 1996).

Refuges were laid in March and data collection commenced in April, allowing for one month of "weathering-in time" (Reading, 1996). The refuges were visited mostly from 09:30–13:00 h. If at least one slow worm was recorded under a refuge then this was considered 'occupied'. Sampling effort varied between months and location (Tables 2 & 3) but was reasonably consistent for the refuges of different types (Table 4). During the study period (April–October 2016), monthly average temperatures recorded at Bayfordbury ranged from 7.9 °C to 17.9 °C with the maximum temperature recorded during the study period 32.3 °C and the minimum -1.3 °C (Supplementary Material Fig. 1S). The mean monthly rainfall was highest in June at 37.8 mm (Supplementary Material Fig. 2S).

We excluded data from September and October because the counts were low, at least in part due to low sampling effort in this period.

Statistical analysis

Presence-absence of slow worms under each refuge (1,847 observations) was used for the analysis. The analysis was performed in R (R Core Team, 2015). To assess the effect of refuge type, month and location on the presence-absence of slow worms, a mixed-effect model with binomial errors of the form glmer(SW.presence ~ type * month * location + (1|location/refugeID), data, family = binomial()) was used (lme4 package, Bates et al., 2015). The combined effect of

Table 4. Sampling effort and counts of occupied refuges by different refuge type

Refuge type	Total no. refuges checked	% Refuges checking effort	No. refuges occupied	% of total refuges occupied	Occupied/ checked proportion
Flat refuges					
Roofing felt	445	24	27	30	0.06
Carpet tile	465	25	26	29	0.06
Corrugated refuges					
Roofing felt	473	26	19	21	0.04
Metal	464	25	17	19	0.04
Total	**1847**	**100**	**89**	**100**	

refuge type, month and location was tested first (with month and location considered as potential confounding variables), followed by model reduction to obtain the minimal adequate model (Crawley, 2015). Analysis of deviance was used to calculate p-values for the significance of the overall effect of the variables (Hastie & Pregibon, 1992) and in model reduction of the form anova(model1.result, model2.result, test = "Chisq"). We used Akaike Information Criteria (AIC) in model reduction to choose the model with the lowest AIC where the choice of a term to drop was not obvious based on p-values. We then sequentially combined the factor levels to find the model with the least number of categories as an alternative to pairwise comparison for the variables remaining in the minimal adequate model. Probabilities of refuges being occupied were estimated from the final models with the reduced number of categories by exponentiating the estimated parameters to obtain odds and using the odds/1+odds formula to calculate the probabilities.

RESULTS

Some caution is required in interpretation of the data as the sampling effort was not even between months. Counts of occupied refuges varied greatly between months with the highest number of occupied refuges in July (Fig. 3A). However, the highest proportion of occupied refuges occurred in June (0.115), followed by July (0.077) and August (0.053) while April and May had the lowest proportion (0.006 and 0.024 respectively) (Fig. 3C; Table 2). Across the areas, the highest count of occupied refuges was in RHS (Fig. 3B), but the highest proportion of occupied refuges was in HGG (Fig. 3D). Considering refuge type, flat roofing felt and carpet tile had the higher number and percentage of occupied refuges (27 or 30% for flat roofing felt and 26 or 29% for carpet tile) followed by corrugated roofing felt (19, 21%) and corrugated metal (17, 19%) (Table 4).

Starting with the full model, 'slow worm presence' depended on the type, month, location and all interaction' (see Supplementary Material Table 1S for the parameter estimates and standard errors), the minimal model was slow worm presence depends on the interaction between month

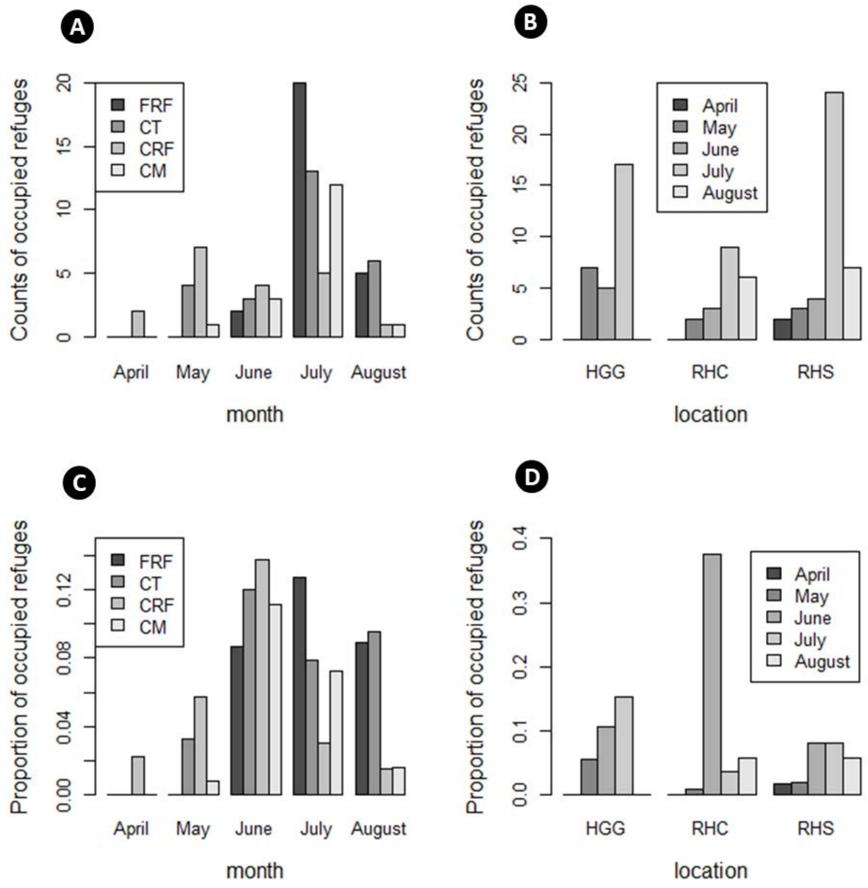

Figure 3. Numbers/proportions of different refuge types, flat roofing felt (FRF), carpet tile (CT), corrugated roofing felt (CRF), and corrugated metal (CM), sheltering at least one slow worm from April to August 2016 - **A.** Count of occupied refuges, **B.** Count of occupied refuges by location, **C.** Proportion of occupied refuges, **D.** Proportion of occupied refuges by location

Table 5. Model reduction process. P-values refer to the difference between the full model and the reduced model. The formulae ignore the random component (1|Location/refugeID)

Step	Model	AIC	p-value
0	SW ~ type*month*location	699.80	
1	SW ~ typel*month*location- type:month:location	662.46	0.99
2	SW ~ type + month + location + type:month + month:location	660.68	0.89
3	SW ~ type + location + type:month + month:location	660.68	0.89
4	SW ~ location + type:month + month:location	660.68	0.89
5	SW ~ type:month + location:month	660.68	0.89

Table 6. Model reduction for the effect of refuge type by month showing AIC, the combined levels and the model estimates of the probability of refuge being occupied for the groups. Only the months in which the effect of the refuge type was significant are shown.

Month	AIC, all levels	AIC, reduced	Groups (estimated probabilities)
May	111.18	109.44	FRF + CM (0.004), CT + CRF (0.044)
July	347.76	346.93	FRF + CT + CM (0.094), CRF (0.031)
August	105.52	101.54	FRF + CT (0.090), CRF + CM (0.016)

Table 7. Model reduction for the effect of the month by location showing AIC, the combined levels and the model estimates of the probability of refuge being occupied for the groups

Location	AIC, all levels	AIC, reduced	Groups (estimated probabilities)
HGG	192.95	189.58	April + August (<0.001), May (0.055), June + July (0.139)
RHC	165.58	164.34	April + May (0.006), June (0.381), July + August (0.039)
RHS	309.51	304.34	April + May (0.018), June + July + August (0.073)

and location (χ^2 = 26.57, df = 10, p = 0.003) and interaction between month and type (χ^2 = 36.51, df = 15, p = 0.001)' (Table 5). The effect of refuge type was significant in May (χ^2 = 11.87, p = 0.008), July (χ^2 = 10.41, p = 0.015), and weakly in August (χ^2 = 7.31, p = 0.062) (Table 6). In May, flat roofing felt could be grouped with corrugated metal and carpet tile grouped with corrugated roofing felt with the probabilities of refuge being occupied of 0.004 and 0.045 respectively. In July, flat roofing felt, carpet and corrugated metal could be grouped with a probability of refuge being occupied of 0.094 while the corrugated roofing felt had a probability of 0.031. In August, flat roofing felt and carpet tile formed one group while corrugated roofing felt and corrugated metal formed the second group with probabilities of refuge being occupied of 0.090 and 0.016 respectively. The effect of the month was significant in all three locations – HGG (χ^2 = 30.52, p = <0.001), RHC (χ^2 = 25.06, p = <0.001) and RHS (χ^2 = 13.71, p = 0.008) (Table 7). In HGG, the best grouping was April + August with the probability of refuge being occupied less than 0.001, May (0.055) and June + July (0.139). In RHC, the best grouping was April + May (0.006), June (0.381) and July + August (0.039). In RHS, the best grouping was April + May (0.018) and June + July + August (0.073).

DISCUSSION

The effect of refuge type on slow worm occupancy was not significant on its own but the interaction between the type and month was significant. The effect was not detectable when the proportion of occupied refuges was very low (April) or relatively high (June) but was detectable at intermediate occupancy levels (in May, July and August). There was substantial variation in which types were more occupied by slow worms. The only consistent pattern seems to be that flat roofing felt and corrugated roofing felt were always in different groups although which group was most occupied changed between months. Since flat and corrugated roofing felts are both bituminous products but differ in shape, it is suggested that their shape may have played an important role. In July and August, the probability of refuges being occupied was higher in the flat than the corrugated roofing felt group (about three times in July and five times in August) while in May, it was nearly ten times lower. It could be expected that refuge efficacy is weather dependent with corrugated roofing felt better in cool or moister weather (May) while flat roofing felt better in hotter or drier weather (July). This difference cannot be explained by the heat-retention properties as they are made from similar materials but perhaps the shape or size also affects the efficiency – corrugated roofing felt might lose moisture beneath it more quickly which might be not a problem in May, when there is relatively high soil moisture content, but could make the conditions too dry in July. Grouping refuge types simplified the interpretation of the results but might mask subtle variations between them.

In Britain, corrugated metal refuges are widely used but in our study they were not statistically significantly different from the others we tested, although corrugated roofing felt and corrugated metal were occupied less often by slow worms than the flat refuges (flat roofing felt and carpet tiles). The efficacy of flat roofing felt confirms an earlier recommendation of using flat roofing felt in combination with corrugated metal, the two being complimentary as the corrugated metal warms and cools faster than bitumen while the latter maintains a moister environment (Sewell et al., 2013). Carpet tile refuges, which also provide a damp microclimate beneath them (Scheffers et al., 2009), also had a higher success rate along with the flat roofing felt suggesting that moisture retention might be more important than heat-retention.

Overall, it could be concluded that the effect of refuge type was not important in June when the slow worms were most active, but there was a detectable difference when the counts were intermediate (in May & July). This suggests that variation in which refuge type is more occupied by slow worms depends on the prevailing weather conditions and that the simultaneous use of a variety of refuges types may improve slow worm detection rates.

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