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Predation of common wall lizards: experiences from a study using scentless plasticine lizards

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Abstract. The potential influence of predators on lacertid lizards has been studied by using models made of plasticine which shows the attack marks of predators and as such allows their identification and estimation of predation pressure. The general aim was to study predation on plasticine models of lizards and to improve methods, since the results depend on the number of plasticine models used, their spatial pattern and the duration of experiments. We estimated the density of the common wall lizard *Podarcis muralis* population on stone walls of a vineyard in the city of Pécs (Hungary) in August 2015 in order to imitate the real density in our experiment with plasticine models. The density of common wall lizards was 8.2 ind. /100 m^2 and accordingly we placed 25 scentless plasticine lizards on the stone walls on the first transect with 10 m distance between them, which imitates the real pattern. In the second transect 25 lizard models were placed more sparsely, the distance between them being 20 m. During four weeks the predation rate was 24% in densely spaced plasticine lizards and 40% in sparsely spaced plasticine lizards, but the difference was not significant. The daily survival rate of densely spaced lizards was 0.99 (=99.1%) and that of sparsely spaced lizard models was 0.98 (=98.25%), but this difference was not significant either. On the basis of marks left on plasticine lizards, mammal predators (e.g. beech marten) dominated, while the impact of bird predators was smaller than expected. Predators attacked the head of plasticine lizards more frequently than their trunk, tail or limbs, but a significant preference of body parts was not detected. From our experience it is important to study the distribution and density of real animals, to imitate their real pattern, instead of an arbitrarily designed experiment with models. The typical scent of plasticine also could influence the results, which can be avoided by using scentless plasticine models coated with liquid rubber. We suggest the calculation of daily survival rates in order to produce results that allow the comparison of different studies.

Keywords. Abundance, density dependence, Hungary, *Podarcis muralis*, survival rates.

INTRODUCTION

Predator-prey interactions have been in the focus of ecological and evolutionary research (e.g., Cooper and Blumstein, 2015). There are many difficulties in studying predation events directly in the wild, especially on small vertebrates; therefore during the last decades models made of soft materials (e.g., plasticine) have been used (Bateman et al., 2016). The potential influence of predators on lacertid lizards has been also studied by using plasticine models which show the attack marks of predators and as such allow their identification and estimation of predation pressures (e.g., Castilla and Labra, 1998; Castilla et al., 1999; Diego-Rasilla, 2003a,b; Shepard, 2007; Vervust et al., 2007, 2011; Pérez-Mellado, 2014; Sato et al., 2014; Fresnillo et al., 2015; Stellatelli et al., 2015). The results of these studies mainly depend on the quality of materials and the number of plasticine models used, on

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the duration of experiment and also on how often they were checked for evidences of attack (Bateman et al., 2016). A further problem is that the unnatural smell of plasticine can influence the results, through modifying the behaviour of mammal predators which rely on olfactory cues (Bayne and Hobbson, 1999; Purger et al., 2012; Fresnillo et al., 2015). These models are immobile, while bird predators relying on visual cues mostly react to a moving prey (Rangen et al., 2000). The many lizard species are diurnal animals and their main predators are birds (e.g., Vervust et al., 2007; Pérez-Mellado, 2014; Fresnillo et al., 2015), therefore the unnatural attractiveness of models for nocturnal mammal predators should be avoided by using scentless models (Purger et al., 2012).

The duration of experiments performed with plasticine lizards was mostly arbitrarily decided (e.g., Diego-Rasilla, 2003a,b) in dependence of the abundance of potential predators and their ability to discover and predate the models (e.g., Castilla and Labra, 1998). Since predation events depend on the density of prey, it is important to study the pattern (e.g., distribution, density) of real animals in the particular area before starting an experiment with models, to imitate real pattern, instead of an arbitrarily designed experiment. In some studies the distance between models was only 2 m (Vervust et al., 2007, 2011) or 5 m (e.g., Castilla et al., 1999; Diego-Rasilla, 2003a,b; Pérez-Mellado, 2014), which suggest a high density, while in other studies the distance was at least 100 m apart from one to another (Fresnillo et al., 2015) or the models were placed scattered (Pérez-Mellado, 2014). Predation rates are influenced by different circumstances therefore the results of different studies are difficult to compare.

Our study was performed as an attempt to standardise predation experiments with lizard models. Our specific goals were: a) to find out whether predation is dependent on lizard density; b) to estimate predation rates and the daily survival rates of scentless plasticine lizards; c) to identify the predators; d) to find out if predators prefer any parts of the prey's body.

MATERIAL AND METHODS

The study was carried out at the St. Nicholas Hill Research Station (46°04'N, 18°09'E) of the Institute of Viticulture and Oenology, University of Pécs, on the southern slopes of Mecsek Mts., 180-240 m a.s.l., 5 km to the west from the centre of the city of Pécs, Hungary. This area (14 ha) has been used as a vineyard since the 1750's. Its surface is slightly undulating with stone walls between fields. The soil is Ramann-type brown forest soil formed on Pannonian red sandstone (Teszlák et al., 2013). From the north the area is bordered by manna ash-downy oak (*Fraxino-Quercetum*) dry forest.

The common wall lizard *Podarcis muralis* (Laurenti, 1768) is the most common lizard species in Europe (Guillaume, 1997), occurring everywhere in Hungary with the exception of the Great Hungarian Plain (Puky et al., 2005). In suitable habitats such as open rocky hillsides, quarries and stone walls in urban environments with warm microclimate it can reach considerable densities (Trócsányi and Korsós, 2004). Active individuals of the species are observable even on warmer days of winter months in the southern region of the country (Trócsányi et al., 2007). It is an opportunistic species so habitat requirements are variable, it often lives in vineyards (Vogrin, 1998), but their densities could be influenced by shelter, food and the effects of predators (Gruschwitz and Böhme, 1986). Natural predators of this species are among mammals, birds and snakes which occur in their habitats (Gruschwitz and Böhme, 1986).

We estimated the density of the wall lizard population on stone walls in the summer of 2015 (before the study) in order to imitate the real density in our experiment with plasticine models. The density was not estimated by capturing the animals. But instead lizards were counted by walking on the top of all six stonewalls (0.5-2.5 m high and ca. 0.4 m width) which divided vineyard terraces. The average length of stonewalls was 310 m (SD = 149.93) and the average of top surface area was 124 m^2 (SD = 59.97). Counting was performed by the same person, during six days from 24 August 2015, always beginning at 16:00 h, on one stonewall randomly selected each day. During counting the lizards escaped due to human appearance, and hid on the side of the walls, therefore they were counted only once. Before the experiment the workers in the vineyards were informed about our study and they tried to not cause disturbance.

For our study lizard replicas were created using non-toxic natural colour plasticine (produced by KOH-I-NOOR Hardtmuth, Czech Republic). The lizard models were made of plasticine with a wire axis which was used also for hanging them on the stone wall. We used plasticine lizard models whose body size cca. 15 cm (±1 cm) and shape were similar to those of adult wall lizards (Diego-Rasilla, 2003a,b). The basic colour of male and female is similar (Arnold and Ovenden, 2002), therefore the sculpted plasticine lizards were painted uniformly in taupe colour (tempera, produced by Pannoncolor, Hungary) based on the colour of observed and photographed lizards in the study area. Then models were coated with uncoloured liquid rubber spray (PlastiDip®, USA) and were aired for two weeks in order to eliminate the scent of plasticine and thus allow equal chances for avian and mammal predators in their visual search (Purger et al., 2012).

In the morning of 7 September 2015 we placed 25 scentless plasticine lizards on the top of a stone wall in the first transect with 10 m spacing, imitating real density pattern. In the second transect 25 lizard models were sparsely spaced; the distance between them was 20 m. They were placed in an open area and were fully visible to avian predators (Pérez-Mellado, 2015). The study sites were homogeneous, very similar linear habitats, 50-70 m apart from each other; therefore we assume that there were no differences in predator communities. On the south facing side of stone walls 50 plasticine lizards were placed (25 densely and 25 sparsely spaced). Unfortunately the majority of models placed on the vertical side of walls melted due high solar radiation during the experiment, and these two transects were not included in the analysis.

We checked the condition of lizard models after their placement, on the afternoon of days 1, 3, 7, 14, 17, 21 and 28 between 16:00 h and 18:00 h. Attacked models were removed during regular checking to avoid pseudoreplication. On the last checking day we gathered the remaining models. A lizard model was considered as being attacked by a predator when bill marks of birds, tooth marks of mammals were found, or if it had disappeared (e.g., Castilla and Labra, 1998; Castilla et al., 1999; Diego-Rasilla, 2003a,b). We recorded which body part of the lizards (head, trunk, tail or limbs) had been damaged by predators (Vervust et al., 2011). Based on the marks on plasticine models, mammal predators were identified by the help of our collection of mammal skulls (Fig. 1.).

Predation rates on lizard models arranged in the two transect were calculated as percentage of damaged (predated) models. Daily survival rate is the probability that a lizard survives a single day. We used Mayfield's (1975) method (common in ornithological studies) for estimating the daily survival rate of a sample of plasticine wall lizards using exposure days (the cumulative number of days that the lizards in the sample were monitored) and the number of known losses. According to the Mayfield method, the estimated daily survival was calculated as 1 - [(number of lizard losses) / (total exposure days)]. In our study, for the comparison of daily survival rates the test proposed by Johnson (1979) was applied, calculating with the free software „J-test" developed by K. Halupka (2009). For comparing the proportions of predation causes and number of attacks on different body parts, chi-square goodness of fit for two and four categories was used (Zar, 1999). A minimum tail probability level of $P < 0.05$ was accepted for all the statistical tests, and all P-values were two-tailed.

RESULTS AND DISCUSSION

On the top of stone walls (total length 1860 m, surface area cca. 744 m^2) 61 common wall lizards (8.2 individuals/100 m^2) and five eastern green lizards *Lacerta viridis* (0.7 ind. /100 m^2) were counted, which means there was at least one lizard in every cca. 10 m^2. Our estimation of common wall lizard population density showed similarity to the results quoted by Puky et al. (2005). These authors summarised data from literature and concluded that the territory of common wall lizard ranges between 3 and 50 m^2. Such great variation in lizard density is affected by a complex variety of factors; e.g., habitat diversity, availability of resources, presence of predators, competitors and human disturbances (Pérez-Mellado et al., 2008). Trócsányi and Korsós (2004, 2007) suggest that in Mecsek Mts. near the city of Pécs the density of wall lizards on a brick wall was 36 individuals/100 m^2 while there was only 6.5 individuals/100 m^2 in a quarry. In comparison with these values the density of wall lizards estimated in the vineyard was low. Applying of some sampling methods often resulted in underestimation of lizard density (e.g., Smolensky and Fitzgerald, 2010; Ruiz de Infante Anton et al., 2013), however, these values may be useful in experiments with artificial models.

During our study 24% of the densely spaced lizards and 40% of sparsely spaced lizards were damaged by predators, but based on the number of predation events the difference was not significant (χ^2 with Yates corrections = 0.56; df = 1; P = 0.546). Density-dependent predation was not detected by using plasticine lizards. With a view to the fact that a high variability in the density of common wall lizards in different habitats is shown (Trócsányi and Korsós, 2004, 2007), we can say that in our experiment the imitated density of the same habitat was low in both transects, and therefore we could not detect significant differences between predation rates. Despite this, we suggest taking into consideration the density of the studied species and placing the replicas accordingly in order to achieve more realistic results.

The daily survival rate of densely spaced lizard models (total exposure days = 662, number of lizard losses = 6) was 0.99 (99.1%, 95% Confidence Intervals: 98.37-99.83) and that of scarcely spaced lizards (total exposure days = 560.5, number of lizard losses = 10) was 0.98 (98.25%, 95% CI: 97.15-99.35), but this difference was not significant (Z = 1.296, two tailed P = 0.195). The duration of our study (four weeks) was quite long because we had to wait for the first predation event to occur; scarce predation resulted in high daily survival rates. Similar studies took few days or a week since they used high density (2-5 m) of prey models (e.g., Castilla and Labra, 1998; Castilla et al., 1999; Diego-Rasilla, 2003a,b; Sato et al., 2014, Stellatelli et al., 2015) or even 20 days in the study with models 100 m apart from each other (Fresnillo et al., 2015). Our experience showed that in the case of few predators in the study area the studies should last longer, until the predation rate reach at least 30-40%, or the study should be repeated.

We identified one mark of a bird, two marks of small mammals, two marks of weasel *Mustela nivalis*, three of red fox *Vulpes vulpes* (Fig. 1.) and six bites of beech marten *Martes foina* on the plasticine models. Two of the lizard models disappeared; we suppose that they were taken by large mammals. Predators did not damage two lizard models placed next to each other at the same occasion, which means that the liquid rubber obscured the plasticine smell, or maybe because the attacked lizard model was unpalatable and then the predator did not attack the other nearest. It is known that mammal predators use mainly olfactory cues during hunting (Rangen et al., 2000), but in our study it seems that the smell of plasticine did not attract the mammal predators. Noc-

Fig. 1. Tooth prints left on plasticine models were compared with skulls and in this case red fox was identified as predator.

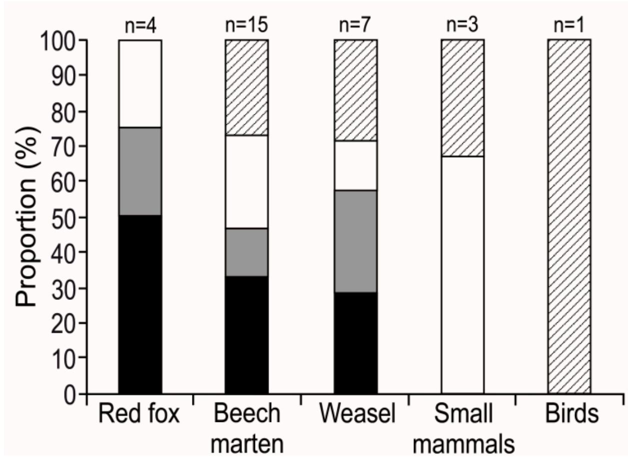

Fig. 2. Number of attacks by different predators on various body parts of plasticine wall lizard models (black bars – head, grey bars – trunk, white bars – limbs, hatched bars – tail).

turnal mammals did not identify lizard models as prey; we found droppings of beech marten three times on the same lizard model, which means that it marked its revier (Seiler et al., 1994). Red foxes, beech martens, weasels and cats *Felis catus* were seen regularly in the study area and we found their traces and droppings. Most of them are known for preying upon lizards (e.g., Castilla et al., 1999; Diego-Rasilla, 2003a). We presume that in habitats with a lot of hiding places, preying upon small bodied fast moving lizards require big energy investment. According to ecological studies of mammal feeding, red fox, weasel and beech marten are reported to consume lizards periodically (occasionally) or rarely (e.g., Lanszki et al., 1999; Lanszki, 2003, 2012; Lanszki and Heltai, 2007). In our study the predation role of small mammals was not considerable, but it was not negligible either. Among small mammals shrew (Soricidae) species are often mentioned as wall lizard predators (Gruschwitz and Böhme, 1986), however in some predation studies replicas showing marks of rodents were considered as non-attacked (e.g., Castilla et al., 1999). In our study avian predation rate was also very low. Common kestrel *Falco tinnunculus* and common buzzard *Buteo buteo*, both being potential lizard predators (e.g., Castilla et al., 1999; Diego-Rasilla, 2003a; Vervust et al., 2011), were frequent in the study area. Also, there were hooded crows *Corvus cornix* and Eurasian jays *Garrulus glandarius* which, too, were identified as egg predators in our earlier study (Purger et al., 2004). There is evidence that birds are able to visually recognize lizards as prey, based on their shape and colour pattern, even if the animals remain immobile (e.g., Stuart-Fox et al., 2003; Shepard, 2007; Stellatelli et al., 2015). The possible reason for less attack by avian predators in our experiment may be that models did not resemble wall lizard coloration and pattern with sufficient precision, similarly to the study of Marshall et al. (2015). During our study we observed a smooth snake *Coronella austriaca* just when preying on a wall lizard, but tooth marks of this well-known lizard predator (Diego-Rasilla, 2003a; Amo et al., 2004) were not found on any of the lizard models.

Based on the low number of predation events recorded (n = 30) the only fact we could determine was that tooth marks of large mammals were found on the head of plasticine lizards more frequently than on their trunk, tail or limbs (Fig. 2.), but significant preference of body parts was not detected ($\chi^2 = 1.2$; df = 3; P = 0.753). Predators could grab different parts of the body with equal chance, since plasticine lizards were immobile. According to the results of experiments with lizard replicas (Castilla et al., 1999; Vervust et al., 2011) mammals tend to attack the head of a prey more often.

From our experience in studies of daily active animals we suggest using scentless plasticine animal replicas coated with liquid rubber which eliminate unnatural plasticine smell and reduce the impact of nocturnal predators. It is important to study the recent distribution and density of real animals in the particular area, to imitate their real pattern, instead of an arbitrarily designed experiment with models. Since predation rate depends mainly on the pattern of prey, the activity of members of predator community, as well as on the duration of experiments, we suggest the calculation of daily survival rates in order to produce results that allow the comparison of different studies.

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