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SHORT COMMUNICATION

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Hibernation cell construction by the viviparous lizard *Zootoca vivipara*

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The viviparous lizard (*Zootoca vivipara*) has a Eurasian distribution that extends further north than any other lizard species, crossing the Arctic Circle in Scandinavia and Siberia, reaching to at least 71° N. To survive cold winter conditions, viviparous lizards hibernate in suitable shelters where they remain torpid until warmer weather prevails. The lizard has evolved some remarkable physiological adaptations to survive freezing winters and consequently can endure sub-zero temperatures in either a supercooled or a frozen state (Costanzol et al., 1995) but the lizard's choice of hibernaculum is also relevant to its survival. However, Beebee and Griffiths (2000) noted in relation to this species in Britain that, "We still know little about the hibernacula, but they are probably frost free refugia below ground or beneath large rocks or woodpiles." In a subsequent study of *Z. vivipara* hibernation in Siberia, Berman et al. (2016) report that all hibernating lizards were in various distinct cavities: burrows of the dung beetle *Anoplotrupes stercorosus*, tunnels left behind by decomposed roots, etc. No hibernating lizards were found in areas with loose soil. They concluded that the presence of small and stable cavities may be a necessary condition for hibernation. Furthermore, they suggest that relatively dry soil is required, as lizards survived hibernation at sub-zero temperatures in soil at 15 % moisture content (m.c.) but under experimental conditions all died at 70-80 % m.c.

This article relates incidental observations of hibernating *Z. vivipara* during a long-term study of reptile populations in a chalk grassland nature reserve in southern England (approx. 51˚ N, 0˚ E). Reptiles were detected in the open along a specific survey path (~6 km) and under artificial refuges placed along the path. These artificial refuges consisted of galvanised corrugated iron sheets (0.5 mm thick and 0.5 g/cm^2) and roofing felt (2 mm thick and 0.3 g/cm^2). They were both cut to the same dimensions (50 cm by 65 cm) and a total of 50 pairs, comprising one of each type, were placed along the path. From March to the end of October, 7-10 survey visits were made monthly giving about 70 visits each year since 2008. Normally, refuges were removed at the end of October but those felts with inactive lizards beneath them were retained – usually this affected only three or four of the fifty felts but in some years none. Soil moisture content beneath refuges, within 10 cm of hibernating lizards, was measured from time to time using an Extech M0750 moisture probe inserted to a depth of 10 cm and the measurements repeated three times. Adult viviparous lizards are sexually dimorphic and in dorsal view (the ventral view remained hidden as this study did not involve handling) males can be distinguished from females by a penial swelling at the base of the tail, a broader head, and the absence of a continuous thin dark, dorsal stripe. Immature stages cannot be assigned to sex under these circumstances.

With the onset of colder weather in late September or October, the lizards begin entering hibernation and so are seen less frequently. When refuges were lifted in October, most lizards moved off quickly and gave no sign of being in hibernation. However, occasionally under felts, but never under corrugated iron, curled individuals were observed in an ovoid depression or cell (Fig. 1A). These individuals were torpid or nearly torpid as they failed to move or moved only slightly when disturbed. During October, the most common life stage to appear under the felts were neonates (Fig. 2) but surprisingly, nearly all individuals observed in cells were adult males with the exception of one sub-adult specimen (Fig. 1B) and only one neonate (Fig. 1C). Furthermore, it was common for at least two individuals to be present in the same cell (Fig. 1A & B).

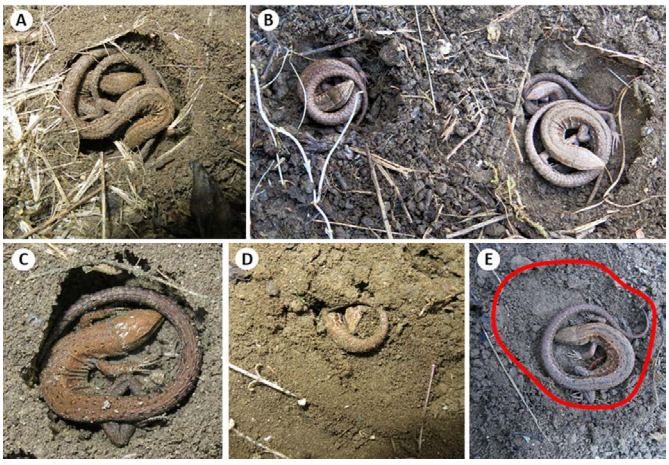

Figure 1. *Zootoca vivipara* in hibernation cells observed below roofing felt used as artifical refuges – **A.** Two adult males in a recently constructed cell in soft, relatively high moisture content soil, Oct 2021, **B.** Two cells, one with an adult male (left), the other containing an adult male and a sub-adult toward the end of hibernation Feb 2017, **C.** Neonate in a cell excavated on about 28 Oct 2021, **D.** Adult male excavating a cell in soft, relatively high moisture content soil, in Oct 2021, **E.** Adult male in cleared area (limits of the cell shown by red line) that has remained very shallow, the soil was hard and of relatively low moisture content, Oct 2021

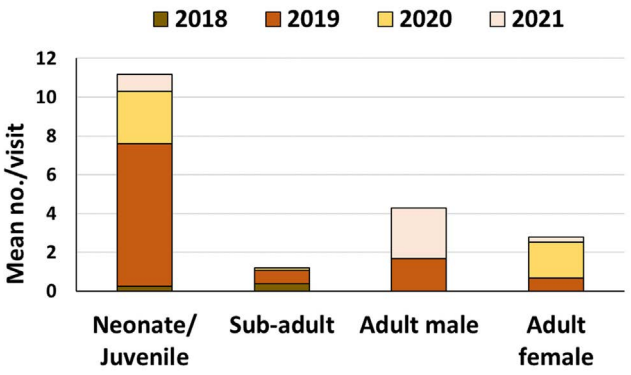

Figure 2. The frequency with which the life stages of *Zootoca vivipara* were seen in October under felt refuges placed on a chalk grassland nature reserve (2018 – 2021, 50 felt refuges visted a total of 29 times)

The cells in which the lizards were found appear to have been dug by the lizards themselves. As the cells are dug (Fig. 1D) the excess soil is used to fill the gap between felt refuge and the soil surface, consequently the cell is separated from the exterior with the felt forming the 'roof' to the cell. The depth of the cells varied and examination of deep cells (Fig. 1A & B) shows the soil to be soft and the mean moisture content (± s.d.) was relatively high (15.6 % ± 0.89 and 17.1 % ± 0.59 respectively) while a shallow cell (Fig. 1E) was in drier, harder soil (mean of 7.9 % ± 0.67).

It is noticeable that the cells were a relatively tight fit for the lizards that had dug them (Fig. 1A, B, C). However, individuals do vacate cells before the end of hibernation and may not return, consequently in multi-occupancy cells one individual may be left in an unusually large cell. This was the case in Figure 3A and subsequently also happened in the case of the cell shown in Figure 1A. The cells themselves appear to be created quite rapidly. Refuges were visited as part of the routine monitoring programme every 3 or 4 days and cells would appear completely formed between visits. It was rare to actually find evidence of cells in the process of construction (such as in Fig. 1D). The tendency of some individuals to vacate their cells long before the end of hibernation may be due to disturbance as the felts are lifted, warmer weather, and/or even colder weather forcing them to move to more sheltered situations. In 2013/2014, we followed the fate of two individual males observed in a single cell in October 2013; we buried a temperature logger beneath the felt (Gemini TK-4014, TinyTag Talk 2, accuracy ± 0.4° C, recording at 3 h intervals) housed in an aluminium cylinder flush with the soil surface and 20 cm from the lizards' cell. One of the males vacated the cell in November but the other (Fig. 3A) remained there until sometime between 2nd - 9th March 2014. Over the period the lowest temperature recorded was 1.4° C, well above the sub-zero temperatures at which the lizard can survive (Costanzol et al., 1995). It is clear that in some cases cells beneath felts end up being only temporary shelters but certainly not in all cases. Given that cells are constructed at a time when falling temperatures start to limit activity and that there is considerable effort involved in making them, it would seem unlikely that they are 'intended' to be temporary.

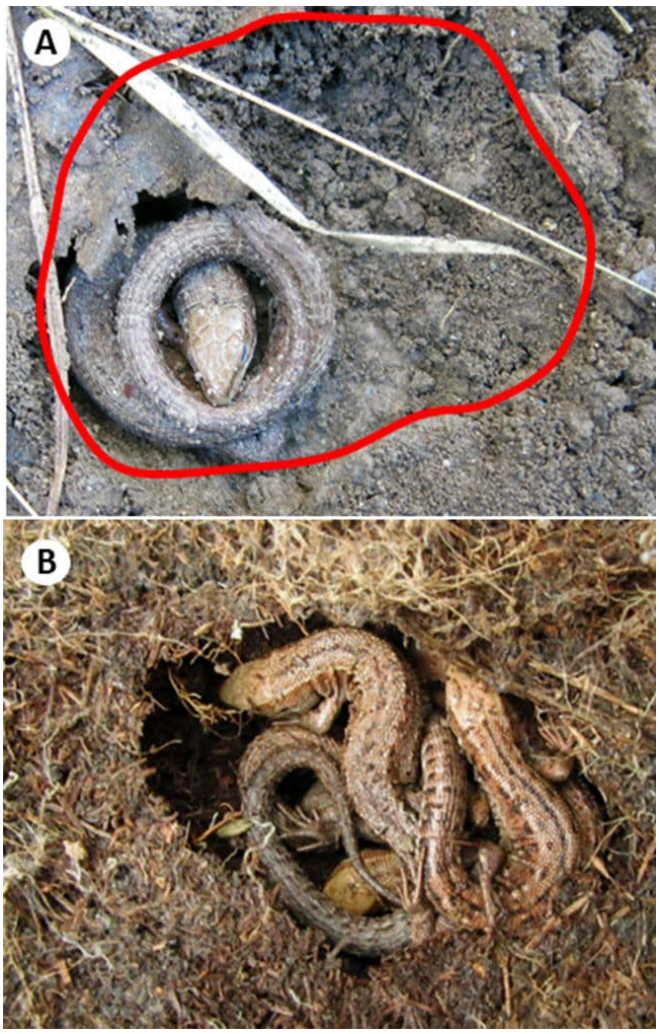

Figure 3. Viviparous lizards in hibernation cells – **A.** Adult male in a cell in Nov 2013 (limits of the cell shown by red line) where there is excess space that was originally occupied by a second male last seen in Oct 2013, **B.** Three common lizards (one adult female and probably two adult males) observed in a hibernation cell beneath a rock in County Antrim, N. Ireland on 19 Oct 2015 photographed by Philip McErlean

This is apparently the first written report of viviparous lizards actively creating a hibernation cell although there are photographs on the internet that look like the same thing. One in particular, by Philip McErlean (Flickr, https://www.flickr.com/photos/64320477@N05/21689021213), is of an adult female and two adult male *Z. vivipara* (Fig. 3B) in N. Ireland, that were discovered beneath a rock in a cell created in peaty soil suffused with many fine roots. The disposition of these three lizards, more or less filling an ovoid cell, is otherwise identical to that shown for the lizards in Figure 1. Furthermore, what appears to be a hibernation cell has been described in the northern taiga of Western Siberia where a lizard was found in an oval hibernaculum matching the size of the curled animal, positioned about 10 cm deep in a layer of humid peat with partially decomposed roots and wood debris (Bulakhova et al. 2011, quoted in Berman et al., 2016). The creation of a cell in soil with fine roots would be more

difficult than in the softer, looser soil beneath the felt refuges and is an indication of the physical abilities of the lizards. However, it would be difficult for the lizards to create such cells at greater depths unless there was already a cavity to receive the displaced soil. In Siberia, where all hibernacula were observed at depths of 5 to 13 cm, no obvious cell construction was reported (Berman et al., 2016). It may well be that cell construction is an activity that is generally confined to positions closer to the soil surface.

The creation of a distinct hibernation cell is an interesting feature of the viviparous lizard's behavioural repertoire. Such behaviour would be expected to have a distinct survival advantage, perhaps providing protection from predators, reducing water ingress (higher moisture conditions are associated with lower hibernation survival rates, Berman et al. 2016), and/or shielding the lizards from frost laden air thus slowing the rate at which the lizards are exposed to temperature drops. The predominance of adult males hibernating in cells is noteworthy. It suggests that adult males tolerate hibernation at shallower depths and this may be consistent with the observation that adult males emerge from hibernation one or two weeks before adult females in order to complete spermiogenesis (Beebee & Griffiths, 2000). It is therefore conceivable that cell formation close to the surface has a role in the reproductive biology of the viviparous lizard and furthermore that there could be differences between sexes and life stages in cold hardiness. The construction of hibernation cells in reasonably soft soil below felt refuges offers a convenient situation for further investigation of cell construction and its wider biological implications.

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