Herpetology Notes, volume 11: 963-965 (2018) (published online on 19 November 2018)

First records of keratophagy in *Zootoca vivipara* (Lichtenstein, 1823) suggest a common occurrence in free-ranging populations (Reptilia: Lacertidae)

Emiliya Vacheva[1]

Partial or complete consumption of a reptile's shed skin is known as keratophagy or dermatophagy. In a detailed review of this phenomenon, Mitchell et al. (2006) suggested the use of the term keratophagy for all cases of consumption of shed skin, which I will use in this paper. Among the class Reptilia keratophagy has been documented only for squamates, in 248 species of lizards from 16 families and 19 species of snakes in four families (Mitchell et al., 2006). Most cases were observed in captive animals (Weldon et al., 1993). Although widespread among geckos and iguanids (Bustard and Maderson, 1965; Mitchell et al., 2006), keratopahagy is known only in four species of Lacertidae, including *Heliobolus lugubris* (Smith, 1838), *Pedioplanis lineoocellata* (Duméril and Bibron, 1839), *P. namaquensis* (Castanzo and Bauer, 1998), and *Lacerta agilis* (Gvozdik, 1997). Here I present the first observations on the presence of shed skin parts in faecal samples of the Viviparous Lizard, *Zootoca vivipara* (Lichtenstein, 1823).

Zootoca vivipara is a small-sized, cold-adapted lizard, with widest distribution of all reptiles in Eurasia (from Ireland to Japan, and from southern Europe to regions north of the Arctic Circle; see Ananjeva et al., 2004; Speybroeck et al., 2016). In the southern parts of its range, such as in Bulgaria, this species is a glacial relict, restricted to mountainous areas. In Bulgaria, *Z. vivipara* is known from isolated populations in the mountains of Stara Planina, Vitosha, Rila, Pirin, Osogovo, and Western Rhodopes, where it inhabits open humid areas at elevations from 1200–2900 m (for a review, see Stojanov et al., 2011). In spite of its wide distribution, there is still lack of knowledge on its dietary habits, especially from the southern part of the range.

As part of a dietary research project, three sites in Bulgaria, including Mount Vitosha (42.591°N, 23.284°E; elevation 1820 m), Mount Rila (42.214°N, 23.306°E; elevation 2170 m), and Mount Stara Planina (42.743°N, 24.786°E, elevation 1500–1720 m) were visited in 2016 and 2017 during the active season (May–September) for 16, 12, and 23 days respectively. I captured by hand 343 individuals of *Zootoca vivipara* (124 at Vitosha, 100 at Rila, and 119 at Stara Planina). All specimens were aged and sexed. Common morphometric characters were measured with a transparent ruler (to the nearest 0.5 mm) and digital callipers (to the nearest 0.1 mm). Animals with snout–vent lengths (SVL) > 45 mm in females and > 40 mm in males were considered adults (Horváthová et al., 2013).

Lizards were taken to the laboratory and placed into individual terraria or plastic boxes for 2–3 days until they defecated. Water was given *ad libitum*. After collecting faecal samples, lizards were released at the site of capture. Faecal samples were collected from 266 different individuals (92 from Vitosha, 72 from Rila, 102 from Stara Planina) and preserved separately in 96% ethanol. For inspection, each sample was gently broken down using water and examined under a binocular microscope.

Shed skin pieces were observed in faecal pellets of 17 individuals (6% of all samples). In these samples, other food particles (invertebrate remains) also were found. The shed skin parts were found embedded inside the faecal pellets, excluding possible contamination of the samples with shed skin after the lizard defecated. Some lizards defecated immediately or shortly after capture, so I excluded the consumption of shed skin as a result of stress due to handling. Based on the size

[1] National Museum of Natural History, Bulgarian Academy of Sciences, 1 Tzar Osvoboditel Blvd, 1000 Sofia, Bulgaria. E-mail: emilia.vacheva@gmail.com

and characteristics of the scalation, I identified that the consumed skin was predominantly from the tail and from the legs.

Zootoca vivipara is allotopic in the studied sites, thus the probability of shed skin belonging to other lacertid species is low. In the study area in Stara Planina the Common wall lizard, *Podarcis muralis* (Laurenti, 1768), was also present but it occurs in different types of habitats. In Vitosha, the Sand lizard, *Lacerta agilis bosnica* Schreiber, 1912, occurs at high elevations, but it inhabits meadows between 1100 and 1500 m, whereas *Z. vivipara* occurs there at 1432–2285 m (see Tzankov et al., 2014), and the potential occurrence of the former at higher elevations must be assumed as rare. During the sampling period I did not observe *L. a. bosnica* at the study site. In the study area in Rila, *Z. vivipara* is the only lizard species present. Therefore, it is most likely that the shed skin is from *Z. vivipara*.

In 2016, keratophagy was detected only at Vitosha, in nine animals out of 69 collected (13.0%). In 2017, keratophagy was observed at all three locations – in five lizards out of 23 (21.7%) in Vitosha, but only in 3.33% in both Rila (one in 30 individuals) and Stara Planina (two of 60). Observations in Vitosha were made in June, July, and August. The highest incidence of keratophagy was in July, in three males and two females among a total of 17 lizards (29.4%). In June, keratophagy was observed in three of 34 (8.8%) lizards, and in August in six out of 52 (11.5%) samples, all females. All cases of keratophagy in Rila and Stara Planina were seen in June.

Overall, keratophagy was observed in 17 cases out of 266 lizards (6.4%) with the highest proportion of animals captured in Vitosha (15.2%). It was more common in females than males – 13 of the 17 lizards were females (including three gravid females) and only four were males. The SVL for these individuals was 51–64 mm for adult females (n = 11), 40 and 44 mm in two subadult females, and 42.5–50 mm for adult males (n = 4).

The biological significance of this phenomenon is still unknown. It seems to be widespread among captive squamates but the circumstances in which it occurs in nature are uncertain. It could be thought of as a mechanism to reclaim epidermal proteins or vitamin D (Bustard and Maderson, 1965). Mitchell et al. (2006) discussed a number of hypotheses and supposed that there may be ecological, nutritional, survival, and evolutionary fitness benefits, at least for lizards. *Zootoca vivipara* usually slough their skin over a period of 2–4 weeks (Bryant et al., 1967; pers. obs.), hence the presence of shed skin during multiple months may suggest that keratophagy occurs after every shedding cycle and is a frequent event. It could be thought of as an adaptation to life at higher elevations, which are characterized by scarce resources, especially in the driest and hottest months. This hypothesis could be more significant for females in regard to being gravid during this period and in need of higher nutrient levels. It is also possible that it is an adjustment to allow assimilation of valuable ingredients, such as vitamin D, in view of the shorter activity period at higher elevations. Pieces of the skin could also be consumed by accident while ingesting prey but in the cases described here, the presence of shed skin was registered in a relatively large number of wild-captured animals (more than 6%), which minimizes the probability of accidental consumption and supports intentional ingestion during moulting. Moreover, the results presented here and my personal observations of the presence of shed skin observed in faecal pellets from three other lacertid species, including *Podarcis muralis*, *Darevskia praticola* (Eversmann, 1834), and *Lacerta viridis* (Laurenti, 1768), strongly suggest that the keratophagy in free-ranging lacertid lizards is not as rare as it previously thought, implying it likely has an important biological function.

Acknowledgements. Lizards were collected under permit No. 656/08.12.2015 issued by the Bulgarian Ministry of Environment and Water. Fieldwork was partially supported and funded by the Bulgarian Biodiversity Foundation. I am greatly indebted to Borislav Naumov and Yurii Kornilev for the helpful suggestions and corrections on the manuscript, and to Simeon Lukanov for improving English expression. I also thank Radostina Pravcheva, Angel Dyugmedzhiev, Kostadin Andonov, Ivan Telenchev, and many other friends and colleagues for their help during fieldwork, and Ema Gateva for the hospitality during the stay at Ambaritsa hut.

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Accepted by Spartak Litvinchuk