

## Do juvenile four-lined snakes *Elaphe quatuorlineata* mimic their sympatric viper?

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In Batesian mimicry, harmless species gain protection from predators by mimicking the warning signals of sympatric species that are more dangerous or venomous than themselves (Ruxton et al., 2004). This mimicry is well documented among many different groups of animals, including snakes (Brodie & Brodie, 2004), and may include aspects of morphology, behaviour, secretions or even sounds (Caro, 2014). In the case of the rat snake genus *Elaphe*, both adult and juvenile individuals of at least two species are known to mimic viper species; *Elaphe davidi* mimics the colouration and head shape of *Gloydius* spp., and *Elaphe xiphodonta* is proposed as a mimic of the pitviper, *Protobothrops jerdonii* in body shape, colouration and pattern and even cloacal gland odour (Qi et al., 2021). Among the European *Elaphe* spp, none has yet been proposed as a potential viper mimic.

In this note, we describe a case of a juvenile four-lined snake, *Elaphe quatuorlineata* (Lacépède, 1789) displaying bluffing behaviour. Besides providing a description of the context which elicited the behaviour, we argue that this could be a case of Batesian mimicry between juvenile *E. quatuorlineata* and the sympatric nose-horned viper, *Vipera ammodytes meridionalis* (Boulenger, 1903) due to the close geographical association between these species, similar colour pattern and defensive behaviours.

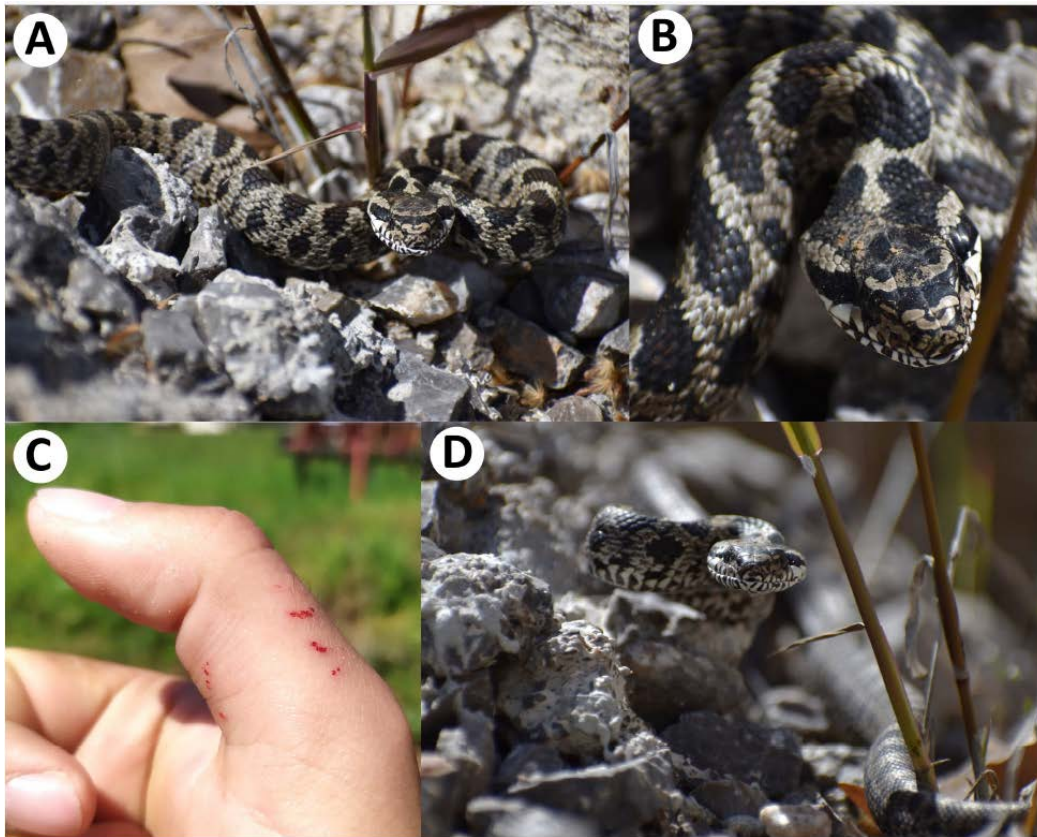
*Elaphe quatuorlineata* is a large and robust snake, inhabiting humid and densely vegetated Mediterranean

habitats (Speybroeck et al., 2016). Adults of this species are usually grey, olive, or beige, often darker on the back with paired black lines running along each flank. In stark contrast, juveniles display a distinct pattern, featuring dark, black-bordered irregular patches on the back and a row of black blotches on each flank, typically with a more greyish hue than the adult colour (Fig. 1A). From morpho-ecological (Cattaneo & Grano, 2012) and molecular studies (Kornilios et al., 2014; Thanou et al., 2020), it appears that the nominotypical subspecies inhabits the study area. *Elaphe quatuorlineata* is generally characterised as a docile snake, rarely biting when handled and usually resorting to hissing and tail displays to distract predators when threatened (Böhme & Ščerbak, 1993; Schulz, 1996; Valakos et al., 2008; Speybroeck et al., 2016). However, these observations are likely drawn from adult snakes, as juvenile defence behaviours tend to be overlooked. A previous study that used machine deep-learning to uncover potential cases of mimicry between non-venomous and venomous Western Palearctic snakes, failed to identify *E. quatuorlineata* as a potential mimetic species (de Solan et al., 2020) probably because only adult, rather than juvenile colouration, was considered.

On 14 April 2023, 14:17 h EEST, a juvenile of *E. quatuorlineata* was observed swimming in the shallow waters of the Messapios River, a torrent located in central Euboea (Evia) Island, Greece. Around the riverbed, there



**Figure 1.** Comparison between the recorded individual four-lined snake *Elaphe quatuorlineata* and a sympatric viper - **A.** Juvenile *Elaphe quatuorlineata* swimming in the shallow waters of Messapios River, central Euboea, Greece, **B.** Male nose-horned viper *Vipera ammodytes meridionalis* from central Euboea



**Figure 2.** Viper-like behaviour of a juvenile four-lined snake, *Elaphe quatuorlineata* - **A.** Defensive body posture, **B.** Flattened triangular head, **C.** Wounds caused by the bite, **D.** Raised, flattened triangular head

were a variety of habitats, including plane trees, macchia, fields for agriculture, olive groves and urban habitats. *Elaphe quatuorlineata* seemed to be the most common snake in the area living in sympatry with *V. ammodytes*, the eastern Montpellier snake *Malpolon insignitus*, the grass snake *Natrix natrix*, the leopard snake *Zamenis situla*, the Balkan whip snake *Hierophis gemonensis* and Dahl's whip snake *Platyceps najadum* (Valakos et al., 2008; pers. obs.). The *E. quatuorlineata* was easily identifiable due to its distinct colouration, which also served to determine the sexual maturity (Fig. 1A). The snake, upon spotting the first author (FA), left the water trying to hide between the rocks of the bank. Failing to find an adequate hiding place and with FA still approaching, the snake assumed a defensive stance, raising the forebody and flattening the head giving it a more triangular appearance (Fig. 2A & B). The individual also bit FA when he was in close proximity to the snake taking photographs (Fig. 2C), although no effects of the bite were experienced thereafter. When FA retreated from the snake, it started to flee but was still maintaining a defensive posture, keeping the flattened triangular head raised (Fig. 2D). When the snake found a hole among the rocks, it hid immediately.

In this case, the juvenile *E. quatuorlineata* exhibited defence behaviours commonly used by European vipers. Head flattening behaviour is common among snakes and has been proposed as an important warning signal against avian predators (Valkonen et al., 2011, Dell'Aglio et al., 2012), which in combination with zigzag patterns seemingly reduce successful predator attacks (Niskanen & Mappes, 2005;

Guimarães & Sawaya, 2011). Head flattening is regularly considered as mimicry when displayed by non-venomous snakes. A good example is the species of the genus *Natrix* which often show increased head flattening, and other bluffing behaviours, when living in close proximity with vipers (Kabisch, 1974; Brodie & Brodie, 2004; Tuniyev et al., 2011; Valkonen et al., 2011; Bjelica et al., 2023). This viper-like behaviour can not only mislead predators but even humans (Hayakawa et al., 2011; Valkonen et al., 2018; Frynta et al., 2023). Head flattening has only previously been mentioned for *E. quatuorlineata* by Schulz (1996), but at that time the taxonomic status of the species was still under investigation, while Böhme & Ščerbak (1993) specify this defensive behaviour only for the blotched snake, the former subspecies *E. q. sauromates* and now currently the full species *Elaphe sauromates*.

Besides defence behaviour, the juvenile colour pattern of *E. quatuorlineata* at this locality bears some resemblance to those typical of vipers (Valakos et al., 2008), consequently we suggest that both behaviour and colour pattern both contribute to Batesian mimicry. However, the possibility remains that the colour pattern of juvenile of *E. quatuorlineata* is simply convergent evolution of disruptive colouration to help hide the snake.

It is noteworthy that *E. quatuorlineata* undergoes a drastic change in colour when reaching adult size. What is also interesting is that it adopts a significantly different approach to its defence against predators, resorting to flight and hissing. Smaller individuals are likely under greater predation

pressure (Bonnet et al., 2005; Gray, 2015; Bjelica et al., 2023) and so may have to have evolved bluffing displays to increase their chances of survival. It would be of interest to use *E. quatuorlineata* as a model for exploring ontogenetic shifts in colour and defence behaviour. Future studies should also test the variety of defensive responses in four-lined snakes and examine the factors that may affect them, especially age, body size and colour pattern. As far as confirming the hypothesis that juvenile *E. quatuorlineata* are viper mimics, an interesting future study would be a comparative analysis of the defence responses in juvenile individuals of different *E. quatuorlineata* subspecies — *E. q. quatuorlineata* (Lacépède, 1789), *E. q. muenteri* (Bedriaga, 1882) *E. q. scyrensis* (Cattaneo, 1999) and *E. q. parensis* (Cattaneo, 1999). All of the subspecies, save *E. q. scyrensis* (no vipers in Skyros Island; Cattaneo, 1998) are widely sympatric with *V. ammodytes*, and thus should be more ‘viper-like’ in appearance and behaviour than *E. q. scyrensis*.

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