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Observations of Caudal Pseudoautotomy in Two Asian Natricid Snakes

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Self-induced tail loss is one of the most efficient anti-predator adaptations in lepidosaurian reptiles, which is known to occur in Rhynchocephalia and Squamata (Arnold 1984). Among squamates, it is quite common in several lizard groups, including gekkonids, scincids, lacertids, and iguanids. While less common in snakes, several species of colubroid snakes exhibit frequent tail breakage (Kaufman and Gibbons 1975; Cooper and Alfieri 1993; Crnobrnja-Isailović et al. 2016; Abegg et al. 2020; Dutta et al. 2022; Karunarathna et al. 2023). Caudal autotomy is defined as self-induced (Cooper and Alfieri 1993) and followed by regeneration (Costa et al. 2014). When regeneration does not follow tail breakage, it is defined as caudal pseudoautotomy (Savage and Slowinski 1996; Costa et al. 2014; Crnobrnja-Isailović et al. 2016).

In lizards the tail can be detached by muscle contraction in intra-vertebral fracture planes, whereas in snakes it happens with a quick longitudinal rotation of the body, breaking off the tail at an intervertebral point (Costa et al. 2014). The tail then thrashes in a manner similar to that of autotomized lizard tails (Fitch 1965; Cooper and Alfieri 1993; Savage and Slowinski 1996). However, broken tails in snakes never regenerate (Savage and Slowinski 1996; Pleguezuelos et al. 2010). Therefore, when confirmed to be voluntary, snakes display caudal pseudoautotomy. Even though trail breakage has been documented in the colubroid families Viperidae, Elapidae, Colubridae (sensu lato) and Lamprophiidae, only the latter two families seem to use caudal pseudoautotomy as an anti-predator adaptation (Crnobrnja-Isailovićet al. 2016). However, recent reports of caudal pseudoautotomy in the viperids *Daboia russelii* (Karunarathna et al. 2023) and *Vipera ammodytes* (Strugariu et al. 2018) indicate that this behaviour might be more taxonomically widespread.

Snakes in the family Natricidae occur in North America, Europe, Africa, and Asia. Most are strong swimmers and are considered semi-aquatic (Mattison 2007). Several species in this lineage exhibit urotomy and caudal pseudoautotomy (Cooper and Alfieri 1993; Gregory and Isaac 2005; Santos et al. 2011; Crnobrnja-Isailovićet al. 2016). I herein report caudal pseudoautotomy in two species of Asian natricids in which tail breakage has not been reported.

At approximately 1100 h on 19 August 2016 I encountered an adult Olive Keelback, *Trimerodytes percarinatus* (Boulenger 1899), swimming upstream in a creek in Dajishan National Park, Tonglu, Hangzhou, China (Fig. 1). The species can be readily distinguished from other snakes in the region by having round pupils, an elongated head, and an olive dorsum with white saddles surrounded by brown (K. Messenger, pers. comm.). To remove it from the vicinity of a frightened group of people, an unidentified individual grabbed it by the tail, after which it immediately began spinning violently along its longitudinal axis, which led to the tail breaking about 15–20 cm from the tip, after which the snake successfully escaped. The broken portion of the tail started writhing (Fig. 2) but began to slow down after a minute until it eventually stopped. No bleeding was observed either from the detached or attached portions of the tail.

Around 2300 h on 23 January 2017, I encountered a Triangle Keelback, *Xenochrophis trianguligerus* (Boie1827), swimming across a pond in a forest by the Batang Kali–

Figure 1. An Olive Keelback (*Trimerodytes percarinatus*) that displayed caudal pseudoautotomy in Dajishan National Park, China. Photograph by Damien Esquerré.

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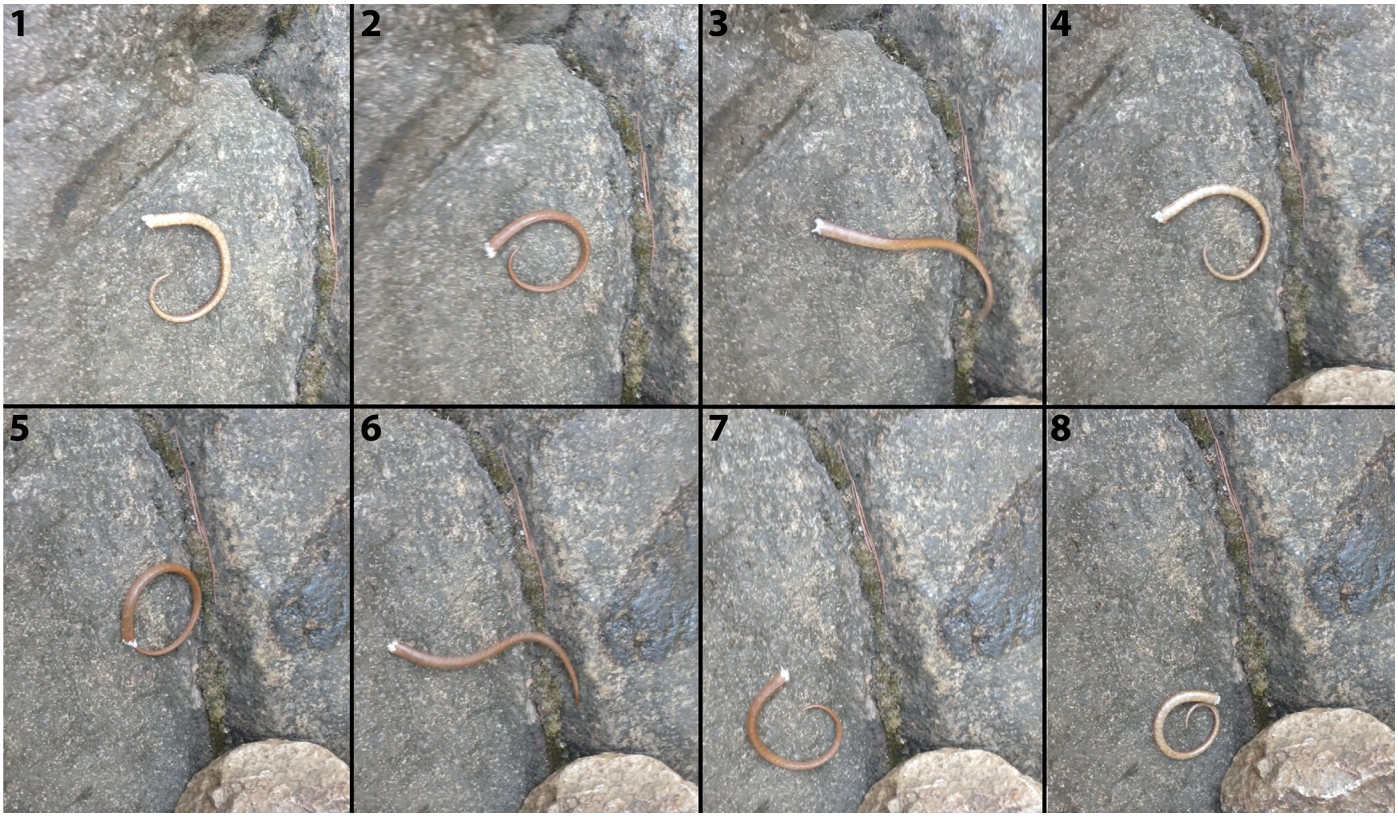

Figure 2. Snapshots from a video recording the movement of the detached tail of an Olive Keelback (*Trimerodytes percarinatus*) about 30 sec after the tail was broken. This sequence encompasses 5 sec of movement. The full video is available at https://vimeo.com/226386774. Video by Damien Esquerré.

Genting Highlands Road, Selangor, Malaysia, which I identified by the presence of broad olive dorsum, dark reticulations, and reddish sides with dark triangular blotches. Another person in the group accidentally stepped on its tail, upon which it immediately detached from the body and started wriggling like that in the first observation and again with no evidence of bleeding. No photographs were taken of the snake.

On both occasions tail breakage was quick and seemingly easy and, at least in the first case, it happened after a deliberate action by the snake. I thus suggest that tail loss was intentional, therefore classified as caudal pseudoautotomy. Moreover, the lack of bleeding in both cases suggests that vessel contraction and possibly other physiological mechanisms came into action. Finally, the fact that the tails were wriggling violently after the event provides further evidence that instead of an accident, the loss of the tail was a means of distracting a potential predator.

Even though tail loss has been documented in many snakes, direct observations or experimentation is necessary to distinguish accidental events from caudal pseudoautotomy (Crnobrnja-Isailović et al. 2016). Since Arnold (1984) indicated that intravertebral caudal autotomy is the ancestral state for squamates, that it is so well developed in some squamate groups, and undeveloped or nonexistent in others (e.g., agamids, varanids, and many snakes) suggests that it might independently have been lost in several lineages. However, caudal pseudoautotomy appears to be largely restricted to actively foraging species (Pleguezuelos et al. 2010), which presumably are at much greater risk of predation, and might have evolved independently in those lineages (Costa et al. 2014).

Apart from widespread simple urotomy in natricid snakes, several genera in the family are known to employ pseudoautotomy. To date, it has been reported in *Natrix* (Crnobrnja-Isailović et al. 2016) in Europe; *Nerodia* (Fitch 1965; Kaufman and Gibbons 1975; Bowen 2004; Hampton 2007; Lockhart and Amiel 2011) and *Thamnophis* (Willis et al. 1982; Cooper and Alfieri 1993; Fitch 2003; Placyk and Burghardt 2005; Todd and Wassersug 2010) in North America; *Natriciteres* (Broadley 1987) in Africa; and *Amphiesma* (Sharma 1980), *Rhabdophis* (Dutta et al. 2022), and *Xenochrophis* (Ananjeva and Orlov 1994) in Asia. I herein add a new species (*Xenochrophis trianguligerus*) and a new genus (*Trimerodytes*) to the known snake taxa that display pseudoautotomy.

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