Deimatic behaviour exhibited by the green and black poison frog (*Dendrobates auratus*) after exposure from a cover object

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Anurans employ a variety of morphological and behavioural strategies to avoid or prevent predation. Deimatic behaviours are characterised as sudden postures or displays that are intended to deter predators from attacking, and are common among aposematic organisms (Skelhorn et al., 2015; Umbers et al., 2017). For example, the unken reflex in certain salamanders involves lifting of the appendages, body arching, and exposing conspicuously coloured throat and ventral regions (Toledo et al., 2011). Body raising is another deimatic behaviour in which anurans stretch out their appendages vertically or laterally, lifting their bodies off the ground and enhancing conspicuous colouration (Toledo et al., 2011). This defensive behaviour has been described in certain members of Hylidae, Leptodactylidae, Leiuperidae, and Bufonidae (Toledo et al., 2011), observed in the field in *Ameerega* (*Epipedobates*) *flavopicta* (Dendrobatidae) (Toledo et al., 2004), and was recently reported in lab-raised *Dendrobates auratus* (Dendrobatidae) when individuals were exposed from under a cover object or after experiencing simulated predation (Blanchette & Saporito, 2016). Herein, we report deimatic vertical body raising behaviour in a natural population of *D. auratus* from the Firestone Center for Restoration Ecology (FCRE) in the Pacific lowlands of Costa Rica (9.2749°N, -83.8589°W).

Between 13 June 2016 and 25 June 2016, and as a part of a larger field-based study on antipredator behaviour, 20 adult *D. auratus* were captured and housed in small plastic containers with leaf-litter. The goal of the study was to understand how *D. auratus* respond to different simulated predators (humans and birds) as measured by their escape behaviours. As part of the larger study, behavioural assays were conducted on a black plastic experimental arena (30.5 × 30.5 cm) that was flat, level, and flush against the ground in a forest clearing. To begin each assay, an individual *D. auratus* was placed in the center of the arena under a darkened plastic cover object (10 × 10 × 7.5 cm) for a five-minute acclimatisation period. Frogs were handled minimally between initial capture and their use in behavioural trials. Following acclimatisation, the cover object was lifted and removed from the arena by a researcher that was ca. 2.5 m away and behind a blind. Frogs were then allowed 10 seconds to adjust to their surroundings before one of the two simulated predators approached from a starting distance of 9 m away. The human approached by walking at a speed of approximately 1.8 m/s and stopped when *D. auratus* began moving. If the frog did not move, the human stopped once it reached the arena. The model bird was constructed using a 3D printer, and was made of white hard plastic and painted cream with gray tipped wings to represent a general bird form (body length: 28 cm; wingspan: 33 cm; body depth: 6.4 cm). The bird was fitted to glide silently on a nylon line at approximately 1.8 m/s, after being released by a researcher. The bird began at a height of 2 m, was at a height of 50 cm when directly overhead the frog, and came to rest approximately 6.5 m behind the frog. Over the course of the experiment, each individual frog was exposed to both simulated predators once, with approximately 24 hours in between each behavioural trial. In total, 10 out of 20 individual *D. auratus* exhibited body raising each time they were exposed to the outside environment from under the cover object (Fig. 1). The body raising behaviour was exhibited by individuals in response to the removal of the cover object, independent of the direction they were facing or the type of simulated predator. All individuals exhibited body raising for the entire 10 second adjustment period, and slowly relaxed their bodies to the ground before the predator began its approach. The larger research project included the study of two additional natural populations of *D. auratus* in the Atlantic lowlands of Costa Rica; however, only individuals from FCRE exhibited body raising.

Figure 1. Adult *D. auratus* exhibiting body raising by vertical stretching of the legs

Body raising was previously reported in captive, lab-raised *D. auratus* upon exposure from under a cover object in a lab setting (Blanchette and Saporito, 2016), which is identical to the present report of this behaviour in the field. In both instances, the cover object may have been

considered a safe location for individuals, whereas quickly lifting the object was perceived as dangerous, prompting immediate body raising as a defensive behaviour. On the basis of our observations, body raising in *D. auratus* appears to provide increased exposure of their chemically defended dorsum to a potential predator, while also enhancing their aposematic signal. The absence of body raising in some populations of *D. auratus* suggests that this behaviour may be an adaptive response to differences in predation pressure; however, the nature of this behaviour in *D. auratus* (and other dendrobatids) will certainly require further study. Individuals that exhibit this behaviour may gain a fitness advantage by startling a predator and deterring attack, preventing the loss of an acquired resource (e.g., mate, territory, food) or energy expended in escape. To the best of our knowledge, this is the first report of deimatic body raising in a natural population of *D. auratus*, and supports the previous finding of this defensive behaviour in captive lab-raised *D. auratus*.

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