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Successful multimodal amphibian defence in the neotropical frog *Trachycephalus*, including handling and recovery costs to would-be predators

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When prey species are encountered by would-be predators there are a wide variety of mechanisms individuals can employ to reduce the risk of predation. Amphibians are widely known for possessing a variety of defences to avoid attacks, including behaviours such as puffing their bodies or death feigning (Toledo et al., 2011), or they may utilize chemical defences (Saporito et al., 2012). While details pertaining to the chemical composition of defences are becoming more readily available, descriptions detailing their efficacy in mitigating predation (e.g. Leary and Razafindratsita, 1998) are comparatively rare.

Here we describe the successful implementation of multimodal defensive strategies, comprised of a release vocalization and a secreted chemical defence, employed by the milk frog (*Trachycephalus typhonius* Frost 2018) on the parrot snake (*Leptophis ahaetulla* Linnaeus 1758). *Trachycephalus typhonius* are known to release defensive collagen proteins from both mucous and granular glands (Rigolo et al., 2008) which are released in a bulk discharged holocrine secretions (Delfino et al., 2002). Previous observations have documented successful predation attempts (until interrupted by the authors) by *L. ahaetulla* on congeners such as *Trachycephalus cf. mesophaeus* (Solé et al., 2010). We add to these observations by detailing a secondary consequence of milky defensive compounds, and further compare handling costs incurred by several species of would-be predator species attributable to the defences possessed by *T. typhonius*.

In addition to attracting mates, some species of amphibians are known to produce vocalizations in circumstances such as distress (Dorado-Rodrigues et al., 2012) which can alert nearby conspecifics causing them to retreat to tree holes (Leary and Razafindratsita, 1998). Additionally, vocalizations can also be utilized by heterospecifics to form a multimodal defence (Toledo et al., 2009; Forti et al., 2017). On 18th of April 2016 at 10:35AM at the Reserva Natural Tanimboca in Leticia, Colombia we were alerted by a loud distress call emitted from a tree, approximately 4-5m elevation. Upon further inspection a *L. ahaetulla* individual was witnessed having captured a *T. typhonius* by its left leg and was attempting to consume it.

After roughly four minutes of struggling with the frog the snake had begun to accrue sticky defensive chemicals in its face and released the *T. typhonius*. For the next approximately 11 minutes the snake made lateral movements, rubbing its face against nearby leaves and branches in an attempt to dislodge the collagenous proteins. During this time a number of ants (species unknown, Figure 1) occupying the tree and branches became ensnared within the *T. typhonius* excretions and they began to release defensive compounds into the eyes, face and mouth of the *L. ahaetulla*. After a total of eighteen minutes of observation time (10:53 AM), the snake was able to finally rid itself of defensive mucous and escape out of sight.

We believe this interaction affords several important observational insights. First it provides additional evidence of the combination of auditory and chemical defence techniques employed by *Trachycephalus* species, which led to it successfully mitigating a predation attempt by a predator species known to be successful

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Figure 1. During the predation attempt by *L. ahaetulla*, defensive chemicals released by *T. venulosa* incidentally trapped ants which additionally began stinging the eyes, face and mouth of the snake during the eighteen minutes the *L. ahaetulla* struggled to free itself of *T. venulosa* defensive mucous.

in eating frogs such as *Trachycephalus*. Through this observation we also add additional empirical data related to handling costs to common batrachophagous species such as *L. ahaetulla*, while comparing it with other predation observations. Observations of successful predatory avoidance are rare and often between different predator/prey mixes, we therefore place our observation in context with other would-be predators of *T. typhonius*. Other reports of attempted predation by another snake (*Leptodeira annulata ashmeadii*) report a prolonged struggle of three hours with nearly 24 until full recovery (Manzanilla et al., 1998), though others more aligned with ours (six minute handling time, *Drymarchon corais*; Leary and Razafindratsita, 1998). This indicates variance in either defensive compounds across the geographic distribution of *T. typhonius*, the quantity of compounds passed to predators, and/or species-specific responses by various predator species. These types of data derived from field observations are rare and will provide important empirical contributions into models of predatory/prey dynamics.

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