Apparent envenomation of a captive blue dart frog (*Dendrobates tinctorius*) by an eyelash viper (*Bothriechis schlegelii*) without symptoms of toxicity

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Interactions between species are key factors in ecology and evolution (Crawley, 1992; Futuyma & Slatkin, 1983). However, direct observations of interspecific interactions between many reptile and amphibian species are relatively rare in the wild and captive observations can help supplement our knowledge. In the case of venomous predators, toxin resistance in prey has evolved on numerous occasions to facilitate escape (McCabe & Mackessy, 017). Herein we report a case of an eyelash viper (*Bothriechis schlegelii*) biting and seemingly envenomating a blue dart frog (*Dendrobates tinctorus*) in a multispecies enclosure in captivity maintained by one of the authors (MV).

The enclosure measured 80 cm x 40 cm x 50 cm and in addition to the two individuals involved in the interaction housed another two *D. tinctorus*, two *Phyllobates terribilis*, one *D. leucomelas*, and one *Epipedobates tricolor*. Temperature is maintained with a gradient of 25 °C to 32 °C using a spotlamp and relative humidity is kept high (ca. 80-90%) by twice daily spraying of water (including ensuring bromeliads are filled). Water is also provided in a dish which is changed daily. Substrate is ExoTerra Plantation Soil covered by a layer of moss, and drainage is enhanced by means of a layer of clay balls under the soil (separated by an antislip mat). A variety of plants are used to provide shelter (*Anthurium*, *Bromelia*, *Calathea*, *Dieffenbachia*, *Spathiphyllum*, *Codiaeum*, and *Epipremnum*) and dried vines provide opportunities for climbing. The eyelash viper is fed two thawed pinkie mice every two weeks from tweezers. The frogs are collectively fed every other day with fruitflies supplemented with Dendrocare Vitamin and Mineral Powder, and additional supplementation is given by spraying with a soluble vitamin and mineral solution once per week. Occasionally *P. terribilis* are fed additional young dubia cockroaches (*Blaptica dubia*) from tweezers as these frogs compete poorly for food in this enclosure.

On 14 September 2017 at 00:04 GMT+1 during spraying of the enclosure to maintain humidity, the *B. schlegelii* moved away from the spray and fell to the floor of the enclosure near several of the frogs. MV carefully nudged the frogs away from the snake using a snake hook and attempted to move the snake back onto the branches. However, the snake was very active and would not balance on the hook and so remained on the ground. Subsequently, one of the *D. tinctorius* jumped and landed directly on the *B. schlegelii*, which responded immediately by biting the frog on the proximal part of its rear-right leg (fangs entering on the dorsal surface; Fig. 1). The snake made 'chewing' movements and was attached to the frog for about four or five seconds, during which time the frog did not struggle. Upon release, drops of a straw-coloured fluid were visible on the fangs of the snake and at the bite site on the frog. This seems highly likely to be venom, particularly given the length of time the *B. schlegelii* held on for and the chewing behaviour, although we cannot conclusively discount the possibility of leaking lymph fluid. Nevertheless, we tentatively consider this evidence of envenomation. Approximately five minutes post-bite, the *D. tinctorius* was observed to sit in the water bowl for about 1.5 hours, and at the time of writing (170 hours post-bite) the frog has not shown any adverse reactions or obvious symptoms of toxicity from envenomation.

There are surprisingly few published records of resistance in frogs to snake venoms, making our observations an important addition to the literature. In fact, Minton & Minton (1981) found that frogs were more susceptible to Australian elapid venom than were lizards. Heatwole et al. (1999) reported resistance to *Agkistrodon*

Figure 1. Bitten individual *D. tinctorius* approximately 18 hours post-bite. Red circle highlights the location of the bite, though no clearly visible evidence remained at this time.

viper venom in bullfrogs (*Rana catesbeiana*), but although the post-envenomation survival time varied with age, all frogs died from the venom and so meaningful resistance is not clearly demonstrated in this case. Similarly, Gibbs & Mackessy (2009) reported that leopard frogs (*Rana pipiens*) had LD_{50}'s for *Sistrurus* rattlesnake venoms an order of magnitude higher than mice or lizards. However, those authors reported an LD_{50} of ~90 mg/kg in the frogs, but with the average venom yield they give of 30 mg there seems little chance of a frog surviving a bite, given *R. pipiens* weigh only ~25-45 g (Wright, 2005).

Although *B. schlegelii* has not been previously reported to predate *D. tinctorius* in the wild, we note that few dietary records exist and those that do suggest a broad diet including several frog species (Sorrell, 2009). Furthermore, although *B. schlegelii* is predominantly nocturnal (Sorrell, 2009) and *D. tinctorius* is diurnal (Born et al., 2010), *B. schlegelii* is occasionally active during the day and can catch prey during this time (Sorrell, 2009). Similarly, although *B. schlegelii* is an arboreal pitviper and *D. tinctorius* is predominantly terrestrial, the latter has been found to climb tree trunks to a height of up to 40 m (Born et al., 2010). Hence, these species may interact in the wild, although this is likely to be a relatively uncommon event. Despite the presumed rarity of this interaction occurring in the wild, the observations reported herein suggest that *D. tinctorius* may possess an ecologically-relevant degree of toxin resistance to the venom of *B. schlegelii*, and this is worthy of further investigation.

Finally, despite the incident reported here, the multispecies enclosure used has been maintained for about 5.5 months with no other antagonistic interactions. Hence, we suggest that dendrobatid frogs and eyelash vipers are generally suitable candidates for multispecies enclosures, particularly when rare antagonistic interactions seem to result in limited clinical effects (as reported here). Even the degree of stress that is likely inherent in any multispecies enclosures may be offset by possible benefits in the form of environmental enrichment (Burghardt, 2013), providing species are compatible.

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