

A possible case of mimicry involving a heteropteran insect and an anuran tadpole

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ABSTRACT - We report on the occurrence of similar aposematic colour pattern between two phylogenetically unrelated aquatic organisms, an insect and a tadpole. The limnocorid Heteroptera *Limnocoris porphyrus* and tadpoles of the hylid frog *Scinax machadoi* are found in sympatry and syntopy in several streams in the Serra do Cipó, a pristine area located in the Espinhaço Range, Minas Gerais state, southeastern Brazil. The similarity between these two organisms makes it difficult to distinguish them at first sight. We suggest that they are possibly part of a process of Müllerian mimicry, but we recognize an evaluation of palatability and population size estimates are needed to ascertain our suggestions.

APOSEMATISM, the use of bright colour patterns by noxious animals to deter predators, is a well-documented phenomenon in nature (Mallet & Joron, 1999; Joron, 2003; Wüster et al., 2004). In the evolutionary process of mimicry a species evolves coloration similar to another species. In Batesian mimicry a palatable prey species mimics the appearance of a noxious species reducing its risk of being attacked. In Müllerian mimicry, two aposematic organisms conform to the same aposematic signal to their mutual benefit (Joron, 2003).

Predators learn to avoid brightly patterned or otherwise conspicuous noxious prey items more rapidly than cryptic prey items (Guilford, 1986; Rowe & Guilford, 2000), and consequently aposematism and/or Batesian mimicry have usually been inferred in cases where the presumed mimic matches a brightly patterned model. Most of aposematism theory is based on two-species interactions, with one noxious prey (the signaller) and one predator (the receiver) (Wüster et al., 2004).

Many organisms present bright or conspicuous patterns of colour and observations under experimental conditions simulating naive avian predators have shown how these species are involved in so-called mimicry rings (Mallet & Joron, 1999; Joron, 2003). Elucidating conditions favouring co-evolution in mimicry is one of the oldest problems in Evolutionary Biology (Gilbert, 1983). This work presents a case of two sympatric aquatic species, an insect and a frog tadpole. The bright colour pattern of the insect and the tadpole is found in their early stages of its development.

The Serra do Espinhaço is a mountain range located in the states of Minas Gerais and Bahia, Brazil, and observations have been made at two localities at 95 km in a straight line from each other. In Serra do Cipó (19°12'–19°20' S, 43°30'–43°40' W), a high altitudinal area covered by savanna vegetation, xeric habitats and an abundance of sclerophyllous plants. Above 900 m ASL campo rupestre vegetation dominates with fragments of high altitude grassland vegetation (Ribeiro et al., 1990). Serra do Caraça (20°05' S, 43°28' W)

has altitudes between 900 and 2000 m ASL. It is characterised by Atlantic Rainforest and Savanna at low parts and campo rupestre vegetation at higher altitudes.

From surveys made between October 1999 and October 2001, young instars of *Limnocoris porphyrus* Nieser & Lopez Ruf, 2001 (Heteroptera, Naucoridae) and tadpoles of *Scinax machadoi* (Bokermann & Sazima, 1973) (Anura, Hylidae) (Fig. 1) were found sharing the same stream habitats.

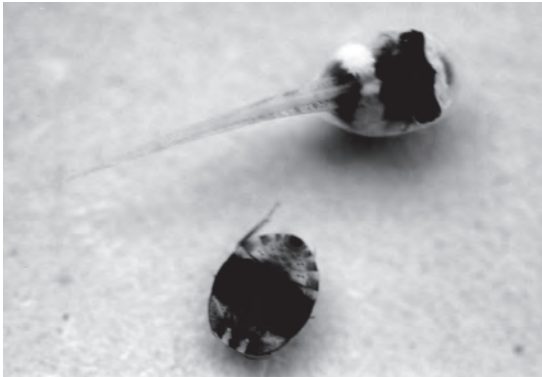


Figure 1. Larval stages of *Scinax machadoi* (Anura, Hylidae) and *Limnocoris porphyrus* (Heteroptera, Naucoridae) from Serra do Cipó, Southeastern Brazil.

In Serra do Cipó individuals of both species were collected in streams of clear water with a depth of about 40 cm and width varying between 1 and 3 m. In Córrego Indaiá, a stream located about 1400 m, the tadpoles and nymphs were found foraging next to each other on rocks in the stream. Due to their initial resemblance it was almost impossible for an observer to distinguish between them. Both were attached to the rocks and easily seen in the flowing water. In sampled aquatic habitats few organisms were seen as easily as the ones from this study though several other anuran and insect species also inhabit these streams (Nieser & Melo, 1997; Eterovick & Fernandes, 2001). The tadpoles of other anuran species that inhabit the freshwater habitats are cryptically colored, except those of *Bufo rubescens*, which are black and often observed in schools of hundreds of individuals.

The Naucoridae, or creeping water bugs, are predatory insects common in tropical aquatic systems (Sites & Nichols, 1990). Among

Heteroptera, this group are the best adapted to life in running water although many species live beneath or among submerged rocks or attached to leaves and branches on the stream bottom. *Limnocoris* is a widespread genus (Southeastern Brazil to Argentina) and the main representative of subfamily Limnecorinae (Nieser & Melo, 1997). *Limnocoris porphyrus* was only recently described from individuals collected in Serra do Cipó (Nieser & Lopez Ruf, 2001). Like the other members of the subfamily, *L. porphyrus* inhabits first and second order streams. These insects seem to be diurnal and are constantly moving on the rocks. The bright colour pattern is only present at the larval forms before the insect becomes adult. The young insects have a flattened-round body and non-developed wings covering the thorax. The body is yellowish with a single black stripe on the dorsal region over the pronotus. Adult body lengths averaged 7.8 (males) and 8.0 mm (females) (Nieser & Lopez Ruf, 2001). After its final moult, *L. porphyrus* loses its pattern and a brownish colour is observed for all adult forms that become cryptically colored. A behavioural change is also observed after last moult. The adults were no longer found foraging over the rocks.

Bokermann & Sazima (1973) described *Hyla machadoi*, later considered as *Scinax machadoi* (Duellman & Wiens, 1992), and pointed out the peculiar coloration of tadpoles (see Figure 7 in Bokerman & Sazima, 1973). However, these authors considered the tadpole colour as cryptic in relation to its freshwater environment. The tadpoles were also considered as nocturnal animals but presenting some activity during the day (Bokermann & Sazima, 1973). Like the naucorids, *S. machadoi* tadpoles present an oval body in dorsal view. The body has a yellowish coloration with two black stripes crossing it. The tail presents some conspicuous dark dots visible mostly when laterally viewed. Most of the time they remain attached to stones or beneath aquatic vegetation. The tadpoles observed herein were observed close to the *Limnocoris porphyrus* bugs, becoming almost impossible to distinguish them for an observer. The bright colour pattern of the tadpoles appeared to vary with age. Younger tadpoles had a more contrasting pattern in relation to the older ones. As individuals grow, the black

stripes became larger and the contrast between black and yellow decreased.

Bokermann & Sazima (1973) observed *S. machadoi* tadpoles throughout the year in freshwater habitats of Serra do Cipó. Information on population dynamics and distribution, life cycle, and larval development may elucidate aspects involving a possible coevolution of aposematism. Natural selection acting on larval forms might guarantee the future of the adult forms, that are likely to undergo other selective pressures. Nevertheless, changes in colour pattern may not mean lacking in protection. Although bright colours and patterns may enhance predator learning, experiments using captive birds have demonstrated that cryptic, noxious prey also gains protection against attack, albeit more slowly than conspicuous prey (Sillén-Tullberg, 1985). Mallet & Joron (1999) argued that any pattern could potentially generate predator avoidance, provided it is recognisable and memorable, even if no conspicuous coloration is involved. Endler & Mappes (2004) argued that conspicuous colours and patterns may have selective disadvantages. Such cases include those where an aposematic species has a specialist predator that can overcome its noxious features or the aposematic species is itself a predator. Wüster et al. (2004) argued that although it is in the signaller's interest to advertise its noxious qualities to a generalist predator, it will also be in its interest to avoid detection by specialist predators and by its own prey.

Despite the phylogenetic distance between *L. porphyryrus* and *S. machadoi*, biotic and abiotic factors may create selective constraints that induce these organisms to develop their bright colour pattern. Duping predators can be the main reason for a species to resemble another one. Nevertheless the resemblance between both species is not the only aspect involved in this study but also the aposematic coloration. Mimicry has an adaptive value when a predator learns which species is unpalatable in association with its colour.

That Batesian mimicry could be acting in these organisms is possible if one of the species is palatable and resembles a protected noxious model, followed by an accumulation and selection of characteristics that would progressively refine the mimicry (Nijhout, 2003). However, for Batesian

mimicry to be truly accepted it would be necessary that the model organism would be more abundant than its mimic (Joron, 2003). Observations herein indicate that *L. porphyryrus* and *S. machadoi* are equally abundant in the sampled streams. Additional collections are needed to quantify their relative abundance throughout a defined period of time. In cases of Batesian mimicry, simulated models have shown that for mimicry to evolve it is necessary that the mimic approaches the model faster than the model moves away and so long as the appearance of the two players is different (Holmgren & Enquist, 1999).

Müllerian mimics are sympatric aposematic species that share the same or similar warning patterns. If a predator learns to avoid a warning pattern of a species by a fixed number of encounters, then Müllerian mimics benefit as fewer individuals of each species would be killed educating naive predators (Skelhorn & Rowe, 2005). If observations described in this paper would be a case of Müllerian mimicry then it is expected that *L. porphyryrus* and *S. machadoi* are noxious with similar abundance acting together to advertise noxious qualities to a generalist predator. Skelhorn & Rowe (2005) show that the presence of two defence chemicals in a Müllerian mimicry system enhances predator learning and memory. However, the authors point out that this is only true if the species involved possess different defence chemicals.

Therefore if mimicry is occurring between *L. porphyryrus* and *S. machadoi* its proof is still unanswered. We suggest that further investigations must define the system of mimicry and the involved species. If a mimicry system is acting behind the aposematic pattern then observations and laboratory experiments should investigate the predators involved (generalists and specifics) and the lack of bright colour pattern in adult *L. porphyryrus*. Tests of palatability and data on relative abundance would greatly further this interesting paradigm.

Voucher specimens of insects were deposited in the collections of the Departamento de Parasitologia, Universidade Federal de Minas Gerais (DPIC, registered in ARNETT et al., 1993); vouchers specimens of tadpoles were deposited in the Herpetological Collection of the Departamento de Zoologia (UFMG).

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REFERENCES

- Arnett-Jr., R.H., Samuelson, G.A. & Nishida, G.M. (1993). *The Insect and Spider Collections of the World, 2nd Edition*. Gainesville: Sandhill Crane Press, Inc.
- Bokermann, W.C.A. & Sazima, I. (1973). Anfíbios da Serra do Cipó, Minas Gerais, Brasil. 1: duas espécies novas de *Hyla* (Anura, Hylidae). *Rev. Brasil. Biol.* **33**, 457-472.
- Duellman, W.E. & Wiens, J.J. (1992). The status of the hylid frog genus *Ololygon* and the recognition of *Scinax* Wagler, 1830. *Occ. Pap. Mus. Nat. Hist. Univ. Kansas* **191**, 1-23.
- Endler, J.A. & Mappes, J. (2004). Predator mixes and the conspicuousness of aposematic signals. *Am. Nat.* **163**, 532-547.
- Eterovick, P.C. & Fernandes, G.W. (2001). Tadpole distribution within montane meadow streams at the Serra do Cipó, southeastern Brazil: ecological or phylogenetic constraints? *J. Trop. Ecol.* **17**, 683-693.
- Gilbert, L.E. (1983). Coevolution and Mimicry. In: *Coevolution*. D.J. Futuyma & M. Slatkin (Eds.). Pp. 263-281. Sunderland: Sinauer Associates.
- Guilford, T. (1986). How do 'warning colours' work? Conspicuousness may reduce recognition errors in experienced predators. *Anim. Behav.* **34**, 286-288.
- Holmgren, N.M.A. & Enquist, M. (1999). Dynamics of mimicry evolution. *Biol. J. Linn. Soc.* **66**, 145-158.
- Joron, M. (2003). Mimicry. In: *Encyclopedia of Insects*. R.T. Carde & V.H. Resh (Eds.). Pp. 714-726. New York: Academic Press.
- Mallet, J. & Joron, M. (1999). The evolution of diversity in warning colour and mimicry: polymorphisms, shifting balance, and speciation. *Ann. Rev. Ecol. Syst.* **30**, 201-233.
- Nieser, N. & Lopez Ruf, M. (2001). A review of *Limnocoris* Stal (Heteroptera: Naucoridae) in Southern South America East of the Andes. *Tij. Entomol.* **144**, 261-328.
- Nieser, N. & Melo, A.L. (1997). Os Heterópteros Aquáticos de Minas Gerais. Guia Introductório com Chaves de Identificação para as Espécies de Nepomorpha e Gerromorpha. Belo Horizonte, Editora UFMG.
- Nijhout, H.F. (2003). Polymorphic mimicry in *Papilio dardanus*: mosaic dominance, big effects, and origins. *Evol. Dev.* **5**, 579-592.
- Ribeiro, S.P., Carneiro, M.A.A. & Fernandes, G. W. (1998). Free-feeding insect herbivores along environmental gradients in Serra do Cipó: basis for a management plan. *J. Insect Cons.* **2**, 107-118.
- Rowe, C. & Guilford, T. (2000). Aposematism: to be red or dead. *Trends Ecol. Evol.* **15**, 261-262.
- Sille'n-Tullberg, B. (1985). Higher survival of an aposematic than of a cryptic form of a distasteful bug. *Oecologia* **67**, 411-415.
- Sites, R.W. & Nichols, B.J. (1990). Life history and descriptions of immature stages of *Ambrysus lunatus lunatus* (Hemiptera: Naucoridae). *Ann. Entomol. Soc. Amer.* **83**, 800-808.
- Skelhorn, J. & Rowe, C. (2005). Tasting the difference: do multiple defence chemicals interact in Müllerian mimicry? *Proc. R. Soc. B.* **272**, 339-345.
- Wüster, W., Allum, C.S.E., Bjargardottir, I.B., Bailey, K.L., Dawson, K.J., Guenioui, J., Lewis, J., Mcgurk, J., Moore, A.G., Niskanen, M., & Pollard, C.P. (2004). Do aposematism and Batesian mimicry require bright colours? A test using European viper markings. *Proc. R. Soc. Lond. B* **271**, 2495-2499.