Records of blue-coloured European tree frog, *Hyla arborea* (Linnaeus, 1758)

ADNAN ZIMIĆ[1,3*] & ANA ĆURIĆ[2,3]

[1] National Museum of Bosnia and Herzegovina, Zmaja od Bosne 3,
71000 Sarajevo, Bosnia and Herzegovina
*Corresponding author e-mail: adnan.zimic@gmail.com

[2] Republic Institute for the protection of cultural, historical and natural heritage,
Vuka Karadžića 4, 78000 Banja Luka, Bosnia and Herzegovina
e-mail: a.curic@kipn.vladars.net

[3] Herpetological Association in Bosnia and Hercegovina ATRA,
Urijan Dedina 137, 71000 Sarajevo, Bosnia and Herzegovina
e-mail: bhhu.atra@gmail.com

Received: 10 October 2023; Accepted: 30 October 2023
Original scientific paper
UDK: 597.82 (497.6 + 437.6) " 20 "

Abstract: Many colour variations have been observed in *Hyla arborea*, but blue is considered to be extremely rare, atypical, and even abnormal by certain authors. Two blue-coloured specimens were observed during recent fieldwork in Bosnia and Herzegovina and Slovakia. The possibility that the blue colouration is a result of temperature fluctuations is discussed.

Key words: colouration, Anura, amphibian, skin, pigment, chromatophores, Bosnia and Herzegovina, Slovakia

INTRODUCTION

Intraspecific colouration (colour polymorphism) can vary widely in amphibians, with this being genetically determined (Hoffman & Blouin, 2000; Rudh & Qvarnstorm, 2013). The ability to reversibly change colour is also controlled by physiological changes (Figon & Casas, 2018). Chromatophores work together as a unit to generate the colour variations found in amphibian skin (Bagnara & Hadley, 1973; Bagnara et al., 1988; Bagnara & Matsumoto, 2006), with the dermal chromatophore unit being a combination of the three chromatophores residing in the dermis just beneath the basal lamina: (1) melanophores with black/brown pigment, (2) xanthophores with yellow and red pigment, and (3) iridophores with light-reflecting properties (Umbers, 2013; Vitt & Caldwell, 2014).

The process of physiological colour change (also known as colour adaptation) is controlled by the interaction of external stimuli, such as environmental (background) colour, light composition, humidity level, habitat temperature and stress/adrenaline level (Figon & Casas, 2018), and is used for crypsis, hydro- and thermo-regulation, UV protection, and intra- and interspecific communication (Stegen at al., 2004; Stuart-Fox & Moussalli, 2009; Caro at al., 2016; Duarte at al., 2017; Figon & Casas, 2018). As well as this, genetic abnormalities – commonly caused by gene mutations that can affect either limited areas of the body or the entire surface – can result in a lack of chromatophores; such colouration effects can range between white (leucism/albinism), yellow (flavism), red (erythrism), blue, black and brown (Jablonski at al., 2014; Kolenda at al., 2017 and references therein). Blue and dark variants can result from a lack of iridophores (ax-

Figure 1. Light blue individual of *Hyla arborea* from Bosnia and Herzegovina (a) and Slovakia (b).

anthism), although this can easily be mistaken for melanism (Jablonski at al., 2014).

Hyla arborea, or the European tree frog, is a small tree frog (Speybroeck at al., 2016) that has a uniformly bright green-coloured dorsal, white belly and slightly green-transparent fingers. Because this species is able to change its skin colour, a wide range of dorsal colour varieties and numerous transitional colourations have been recorded – ranging from yellow-green, through pale, olive and dark green, brown, grey, black, turquoise and blue – as well as mottled/marbled (bicolour, tricolour) variations thereof (Koren & Jelić, 2011; Đorđević et al., 2016; Zimić, 2018). Werner (1890) reported a blue-coloured *H. arborea*, which was, together with the yellow-green colour variant, later described as an abnormality by Nielsen (1980).

MATERIALS AND METHODS

During our visit to the "Vrelo Bosne" Natural Monument, Sarajevo, Bosnia and Herzegovina (GPS coordinates X=43.8180, Y=18.27443) on 13 December 2019 at 14:30, a single light-blue-coloured male of *Hyla arborea* was observed in foggy weather on a shrubby meadow (GPS coordinates X=43.8180, Y=18.27443) (Fig. 1a). No other individuals of any amphibian species were observed during this visit; it was expected that amphibians would be hibernating during that time of the year. Another blue-coloured *Hyla arborea* individual was observed on 19 April 2021 at 12:20 in Pánska Morava, Slovakia (GPS coordinates X=48.511812, Y=16.9257342), on meadow close to a pond (GPS coordinates X =48.511812, Y=16.9257342) (Fig. 1b). Nomenclature according to Frost (1998-2021).

RESULTS AND DISCUSSION

The individual at Vrelo Bosne showed low activity with slow movement; at the time of observation, the air temperature was around 8°C, and it may be assumed that the animal was awakened from hibernation due to a warmer temperature in over the preceding days. The second blue individual of *Hyla arborea* observed in Pánska Morava had small patches of green colouration around the hind limbs. As in the previous case, no other amphibians were observed during the visit, and air temperature was around 10°C. To our knowledge, these are only the second and third case of blue-coloured *H. arborea* to ever be recorded, and the first to be documented by photograph (Figs. 1a, b).

Blue colouration (i.e. the blue part of the visible spectrum: 450-490 nm) can be perceived by most animal taxa (Umbers, 2013), including amphibians (Sillman, 1987). However, the trade-offs of blue colour production in animals are still unclear (Umbers, 2013). While blue pigment-containing cells are not found in amphibians, the blue colour is a result of iridophore reflecting the light in the absence of xanthophores, or the yellow pigments that they contain (Bagnara et al., 2007; Vitt & Caldwell, 2014). Blue or partially blue colour variants have been reported within several species of frogs, especially those of the family Ranidae (Jablonski et al., 2014). *Rana temporaria* males have blue throats, while *Rana arvalis* males completely change colour from brown to blue and violet during the mating season (Ries et al., 2008; Hettyey et al., 2009; Speybroeck et al., 2016), where blue colouration acts as a direct visual signal between males to facilitate gender recognition during scramble competition (Ries et al., 2008) and also signals genetic quality (Sheldon et al., 2003), which increases mating success (Hettyey et al., 2009).

The possible cause of blue colour in these individuals of *H. arborea* could be physiological change due to temperature fluctuation at the beginning and end of the activity season resulting in increased stress levels. In the first case, 15 days before the observation, temperatures fluctuated between 0°C and 12°C for three consecutive days. The day immediately preceding the observation, the temperature dropped to around 0°C and then increased to 8°C during the day on which the observation was made. In the second case, temperature fluctuations were also considerable. Before the observation, three days in row, temperatures dropped to 3°C before increasing to 13°C. Such temperature oscillations may be confusing for ectotherms, as they hinder complete hibernation, potentially leading to stressful conditions that likely forced the individual to actively search for a cooler microhabitat. Such pre-hibernation movements to more stable sites are known amongst amphibians (e.g. Green & Yagi, 2018). In this case, we believe that this change in temperature and accumulation of stress may have been the cause of the physiological deviation that provoked colour change from green to blue. In the absence of yellow pigment, the iridophore reflects shorter wavelengths of light, making the organism appear blue-coloured (Rohrlich, 1974; Clothier & Lythgoe, 1987; Bagnara et al., 2007). It has been shown that increased adrenaline levels cause a lightening of colour in *H. arborea* (Nielsen, 1978), with an interruption in hibernation – as is likely to have been the case for both of these specimens – being the likely cause of significant stress. While the occurrence and frequency of blue colouration within the species *Hyla arborea* remains a mystery, *ex-situ* behavioural experiments may help us gain an understanding of the possible link between specific body colouration and stress in the species.

ACKNOWLEDGMENT

We would like to express our gratitude to Prof. Dr. Suvad Lelo, Nedim Šuta, PhD and Tomáš Tedla for field data.

REFERENCES

Bagnara, J.T. & Hadley, M.E. 1973. Chromatophores and color change the comparative physiology of animal pigmentation. Prentice-Hall, Englewood Cliffs, N.J.

Bagnara, J.T., & Matsumoto, J. 2006. Comparative anatomy and physiology of pigment cells in non-mammalian tissues. In: Nordlund, J.J., Boissy, R.E., Hearing, V.J., King, R.A., Oetting, W.S. & Ortonne, J.-P. (eds.): The Pigmentary System, 2nd Edn, Oxford, Blackwell Publishing, pp. 1229.

Bagnara, J.T., Fernandez, P.J. & Fujii, R. 2007. On the blue coloration of vertebrates. Pigment Cell Research, 20(1): 14-26.

Bagnara, J.T., Kreutzfeld, K.L., Fernandez, P.J. & Cohen, A.C. 1988. The presence of pteridine pigments in iridophore reflecting platelets. Pigment Cell Res. 1: 361-365.

Caro, T, Sherratt, T.N. & Stevens, M. 2016. The ecology of multiple colour defences. Evol. Ecol. 30: 797-809.

Clothier, J. & Lythgoe, J. 1987. Light-induced colour changes by the iridophores of the Neon tetra, *Paracheirodon innesi*. Journal of cell science, 88(5): 663-668.

Đorđević, S., Simović, A. Krizmanić, I. & Tomović, LJ. 2016. Colour variations in the European tree frog, *Hyla arborea* (Linnaeus,1758), from two small adjacent ponds in the Vojvodina province, Serbia. Ecologica Montenegrina, 5: 18-21.

Duarte, R.C, Flores, A.A.V. & Stevens, M. 2017. Camouflage through colour change: mechanisms, adaptive value and ecological significance. Philos. Trans. R. Soc. Lond. B. Biol. Sci., 372(1724): 2016.0342.

Figon, F. & Casas, J. 2018. Morphological and physiological colour changes in the animal kingdom. In: eLS. John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0028065

Frost, D. 1998-2021. Amphibians of the world, an online reference. The American Museum of Natural History. https://amphibiansoftheworld.amnh.org/ (Downloaded 06/10/2022).

Green, D.M. & Yagi, K.T. 2018 .Ready for bed: Pre-hibernation movements and habitat use by Fowler's Toads (*Anaxyrus fowleri*). The Canadian Field-Naturalist, 132(1): 46-52.

Hettyey, A., Herczeg, G., Laurila, A., Crochet, P.-A. & Merilä, J. 2009. Body temperature, size, nuptial colouration and mating success in male Moor Frogs (*Rana arvalis*). Amphibia-Reptilia, 30: 37-43.

Hoffman, E.A. & Blouin M.S. 2000. A review of colour and pattern polymorphisms in anurans. Biological Journal of the Linnean Society, 70: 633-665.

Jablonski, D., Alena, A., Vlček, P. & Jandzik, D. 2014. Axanthismin amphibians: A review and the first record in the widespreadtoad of the *Bufotes viridis* complex (Amphibia: Bufonidae). Belgian Journal of Zoology 144: 93–101.

Kolenda, K., Najbar, B., Najbar, A., Kaczmarek, P., Kaczmarski, M. & Skawiński, T. 2017. Rare colour aberrations and anomalies of amphibians and reptiles recorded in Poland. Herpetology Notes, 10: 103-109.

Koren, T. & Jelić, D. 2011. Interesting color forms of the European tree frog, *Hyla arborea* (Linnaeus,1758) (Amphibia: Ranidae) from Croatia. Hyla Herpetological Bulletin, 2011(2): 27-29.

Nielsen, H. 1978. Ultrastructural changes in the dermal chromatophore unit of *Hyla arborea* during color change. Cell and Tissue Research, 194: 405-418.

Nielsen, H.I. 1980. Colour and color adaptation of the European tree frog, *Hyla arborea*. The Journal of Experimental Zoology, 211: 143-151.

Ries, C., Spaethe, J., Sztatecsny, M., Strondl, C. & Hödl, W. 2008. Turning blue and ultraviolet: sex-specific colour change during the mating season in the Balkan moor frog. J. Zool., 276: 229-236.

Rohrlich, S.T. 1974. Fine structural demonstration of ordered arrays of cytoplasmic filaments in vertebrate iridophores: a comparative survey. J. Cell Biol., 62: 295-304.

Rudh, A. & Qvarnstrom, A. 2013. Adaptive coloration in amphibians. Seminars in Cell and Developmental Biology, 24(6-7): 553-561.

Sheldon, B.C., Arponen, H., Laurila, A., Crochet, P.-A. & Merilä, J. 2003. Sire coloration influences offspring survival under predation risk in the moor frog. J. Evol. Biol., 16: 1288-1295.

Sillman, A.J. 1987. Extraction and characterisation of the blue-sensitive visual pigment of the toad *Bufo marinus*. Can. J. Zool., 65: 884-887.

Speybroeck, J., Beukema, W., Bok, B. & Van Der Voort, J. 2016. Field Guide to the Amphibians and Reptiles of Britain and Europe. Bloomsbury Publishing, pp. 432.

Stegen, J.C., Giener, C.M. & Sun, L. 2004. The control of color change in the Pacific tree frog, *Hyla regilla*. Canadian Journal of Zoology, 82: 889-896.

Stuart-Fox, D. & Moussalli, A. 2009. Camouflage, communication and thermoregulation: lessons from colour changing organisms. Philos. Trans. R. Soc. Lond. B. Biol. Sci., 364(1516): 463-70.

Umbers, K.D.L. 2013. On the perception, production and function of blue colouration in animals. Journal of Zoology, 289: 229-242.

Vitt, L.J. & Caldwell, J.P. 2014. Herpetology: An Introductory Biology of Amphibians and Reptiles, 4th Ed. Elsevier, pp.776.

Werner, F. 1890. Ueber die Veränderung der Hautfarbe bei europäischen Batrachiern. Verhandlungen der Zoologisch-Botanischen Gesellaschaft, Wien, 40: 169-176.

Zimić, A. 2018. Colour variations in the European tree frog, *Hyla arborea* (Linnaeus, 1758). 2nd Balkan Herpetological Symposium within 13th Croatian biological congress, 19th-23rd September 2018, Poreč, Croatia.

SAŽETAK

Uočene su mnoge varijacije boja kod vrste *Hyla arborea*, ali plava boja se smatra ekstremno rijetkom, atipičnom i abnormalnom. Dvije plave jedinke posmatrane su u toku terenskog istraživanja u Bosni i Hercegovini i Slovačkoj. U radu je diskutovana mogućnost uzroka plave boje kao rezultata temperaturne fluktuacije.