Photoluminescent yellow wing markings of Eastern Tube-nosed Fruit Bats (*Nyctimene robinsoni*)

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Abstract

Eastern Tube-nosed Fruit Bats (*Nyctimene robinsoni*) have distinctive yellowish spots over the dorsal wing surfaces, ears and nostrils. The externally visible spots serve as camouflage when the bats are at rest during the day. When examined with ultraviolet to violet light, these wing spots photoluminesce bright yellow. The wing surfaces of seven other species of bat exhibited no photoluminescence. Here I present observations of natural photoluminescence in bat skin. The luminophores causing this photoluminescence have not been investigated.

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Introduction

With their brown, yellow and pale green splotches, Tube-nosed Fruit Bats have amongst the most colourful wings of all bats. The patterning acts as camouflage, resembling dead leaves when at rest amongst rainforest trees (Hall & Richards 2000). However, their colouration had only been examined in white light. Udall *et al*. (1964) found the fur, teeth and nails of live and freshly dead Trinidadian bats to fluoresce in varying colours and intensities under ultraviolet light. Turner *et al*. (2014) used ultraviolet light to examine the wing membranes of hibernating bats, but only to detect the fluorescent orange-yellow fungal skin lesions of white-nose syndrome.

Methods

Five frozen specimens (three male and two female) of Eastern Tube-nosed Fruit Bats (*Nyctimene robinsoni* Thomas, 1904) were examined for photoluminescence (fluorescence and/or phosphorescence). One specimen, presumed collected from its wild habitat in the Cairns area in Far North Queensland, Australia, of unknown collection date and cause of death, had been stored in a freezer at James Cook University, Cairns. Four specimens collected from the southern Atherton Tablelands to the Palmerston Highway during the current year were sourced from the freezer at the Tolga Bat Hospital. These four bats had been found alive caught on barbed wire fences, and euthanased on arrival due to their injuries. The bats were examined with torches of wavelengths 310, 365, 380, 395–410 and 470 nanometres (nm). Photoluminescence photographs were taken with a Panasonic Lumix TZ-80 camera (no filter), while light from a 365 nm ultraviolet torch (OLight 1,500 lumens LED) was shone evenly over the animal. A further three live female Eastern Tube-nosed Fruit Bats in captivity at the Tolga Bat Hospital were briefly viewed with an ultraviolet torch as they rested. These animals had also been brought in from barbed wire fences, from South Johnstone, Mission Beach and the Gillies Highway, and kept in captivity for five months, seven months and three and a half years respectively.

I also examined two female Spectacled Flying-foxes (*Pteropus conspicillatus* Gould, 1850), one female Little Red Flying-fox (*Pteropus scapulatus* Peters, 1862), one female Forest Bat (*Vespadelus* sp. Troughton, 1944) (collected from the Evelyn

Highway, Atherton Tablelands in 2002), one female Gould's Wattled Bat (*Chalinolobus gouldii* Gray, 1841), one Eastern Free-tailed Bat (*Mormopterus ridei* Felten, 1964), one female Eastern Horseshoe Bat (*Rhinolophus megaphyllus* Gray, 1834) and one male and one female Eastern Bent-wing Bat (*Miniopterus schreibersii* Kuhl, 1817) for photoluminescence. The first four species were from the James Cook University freezer collection (collection details unknown apart from the Forest Bat), and the last three species were from the freezer at the Tolga Bat Hospital (all found on barbed wire fences in the southern Atherton Tablelands to Palmerston Highway area during the current year, either found dead or euthanased on arrival).

Results

In regular white light, the Eastern Tube-nosed Fruit Bats had light brown fur, darker brown wings and yellow skin markings (Fig. 1). In ultraviolet light, the fur of the head and ventral body photoluminesced light blue. This blue glow was visible in all eight bats, similar in the live captive bats to the frozen bats. However, intensity varied between individuals, from relatively mild in the university specimen to reasonably bright in the Tolga bats. The photoluminescence of the fur was outshone by a strikingly bright yellow photoluminescence to the wing markings. In all five of the frozen bats, all yellow parts of the skin, including the nose and ears, photoluminesced bright neon yellow (Figs. 2, 3). Even other skin areas inside the wings and on the face photoluminesced bright yellow. There was bright yellow photoluminescence along the bones on the ventral wing surfaces, emanating from the surface of the skin rather than from the bones themselves, giving the appearance of the veins of decaying leaves, which was not evident in white light. The skin of the ventral wing surfaces photoluminesced yellow more in the males than in the females. In all three of the males, the penis photoluminesced bright yellow, whereas it was not brightly coloured in white light. When the bats were in a resting posture, the external appearance of fur and skin spot photoluminescence was similar across males and females (Fig. 4). Both the blue fur and the yellow skin photoluminescence was evident across all ultraviolet and violet wavelengths, but most conspicuous at 365 nm. No such photoluminescence was elicited at 470 nm blue light excitation. In the university specimen, the photoluminescence faded somewhat after the wing skin was left out to dry in a dark air-conditioned laboratory for a couple of weeks. The yellow skin spots of the three live captive bats did not noticeably photoluminesce under ultraviolet light. If photoluminescence was activated, it was hardly perceptible. The yellow skin of these captive bats remained its regular white-light colouration.

The other bat species variously had a blue-grey, greenish grey or yellowish photoluminescence to the tips of the fur, usually very mild, and the Gould's Wattled Bat did not photoluminesce at all. The male Eastern Bent-wing Bat only had very mild greenish yellow photoluminescence in the fur tips on both the dorsal and ventral torso at 395–410 nm. However, the female Eastern Bent-wing Bat had mild pale grey photoluminescent fur from 365 to 395–410 nm. The female's fur photoluminescence was confined to the ventral torso, and was brighter on the lower abdomen. Both Eastern Bent-wing Bats showed bright pale blue photoluminescence of the wing bones, visible through the ventral wing surface. The female's claws also

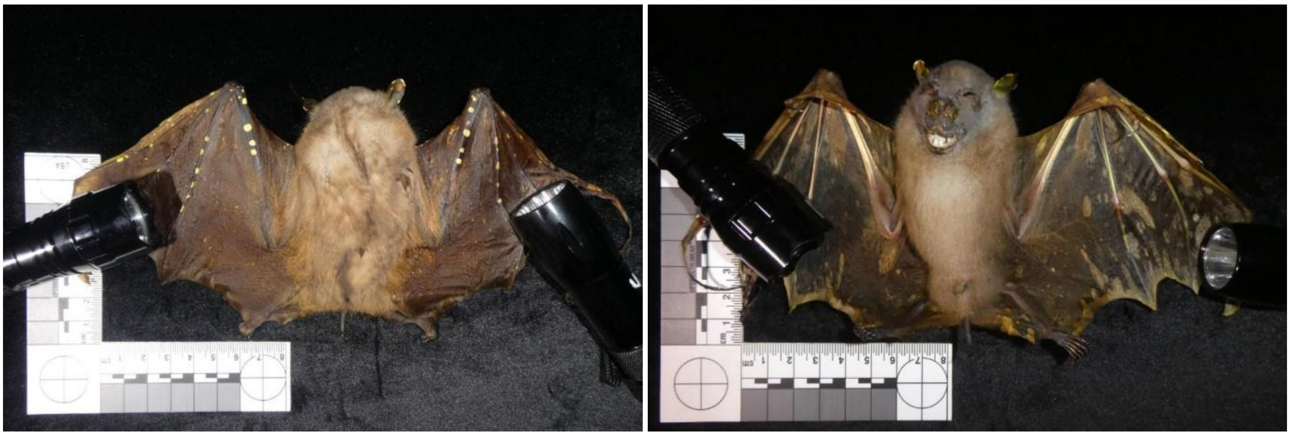

Figure 1. Male Eastern Tube-nosed Fruit Bat (*Nyctimene robinsoni*) under white flash. Torches are only functioning to hold the wings out in place. Left – dorsal; right – ventral.

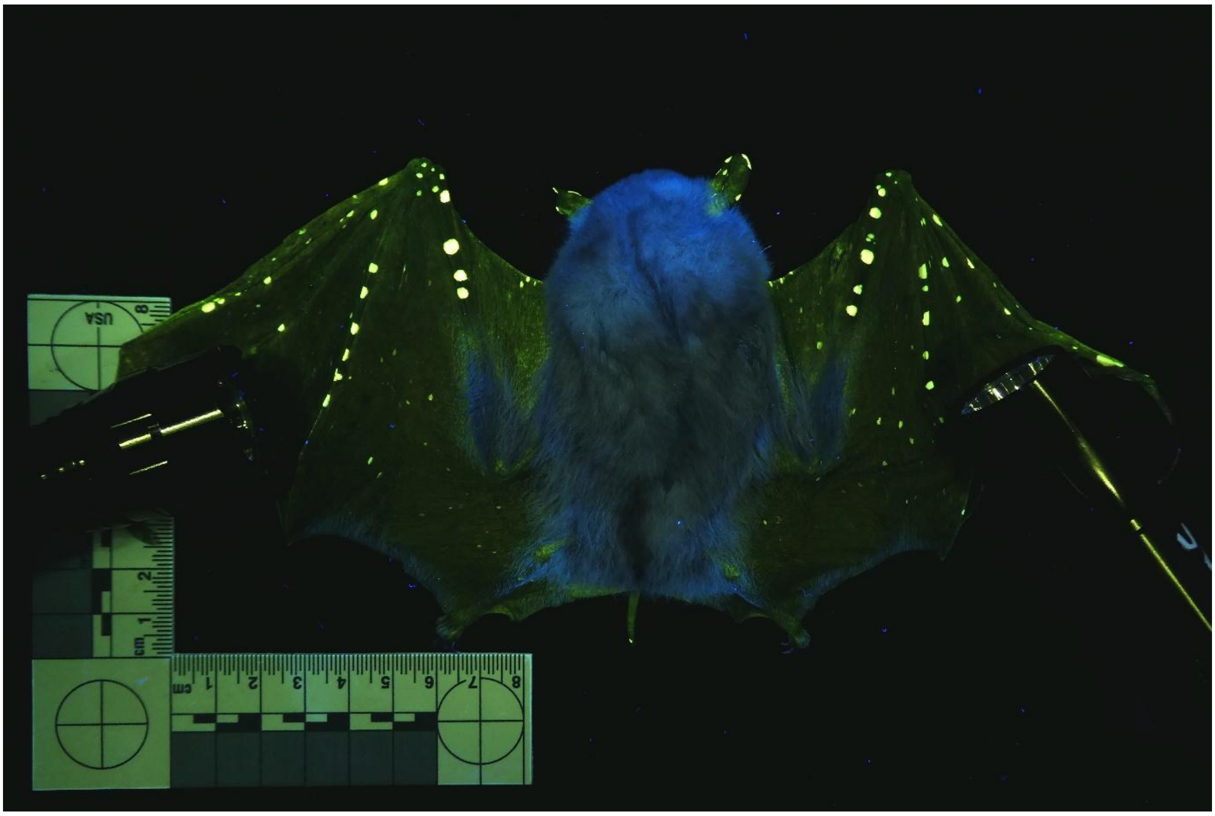

Figure 2. Male Eastern Tube-nosed Fruit Bat photoluminescing, dorsal. Displaying vivid yellow photoluminescence of the wing spots and ears. Under 365 nm torchlight, six second exposure.

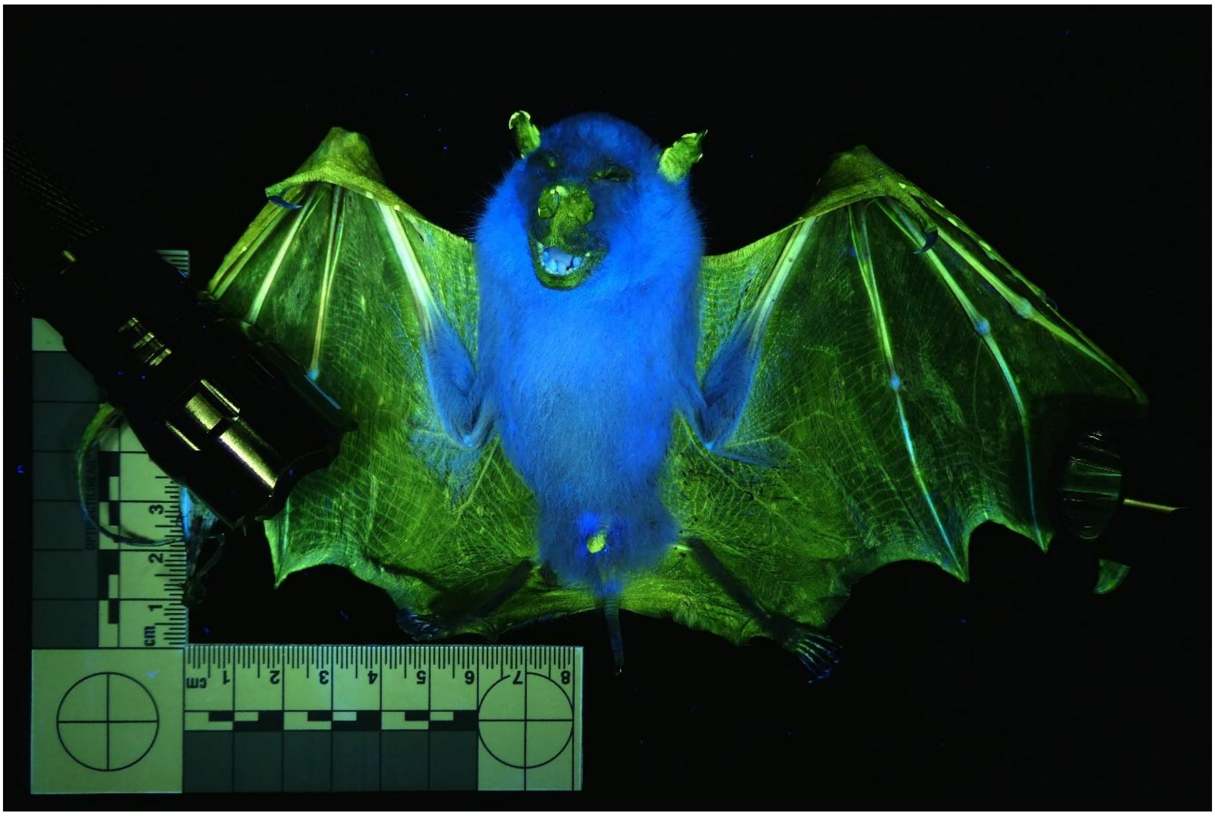

Figure 3. Male Eastern Tube-nosed Fruit Bat photoluminescing, ventral.
Displaying light blue fur photoluminescence, and bright yellow photoluminescence of the ears, nose, penis and other skin surfaces. Under 365 nm torchlight, six second exposure.

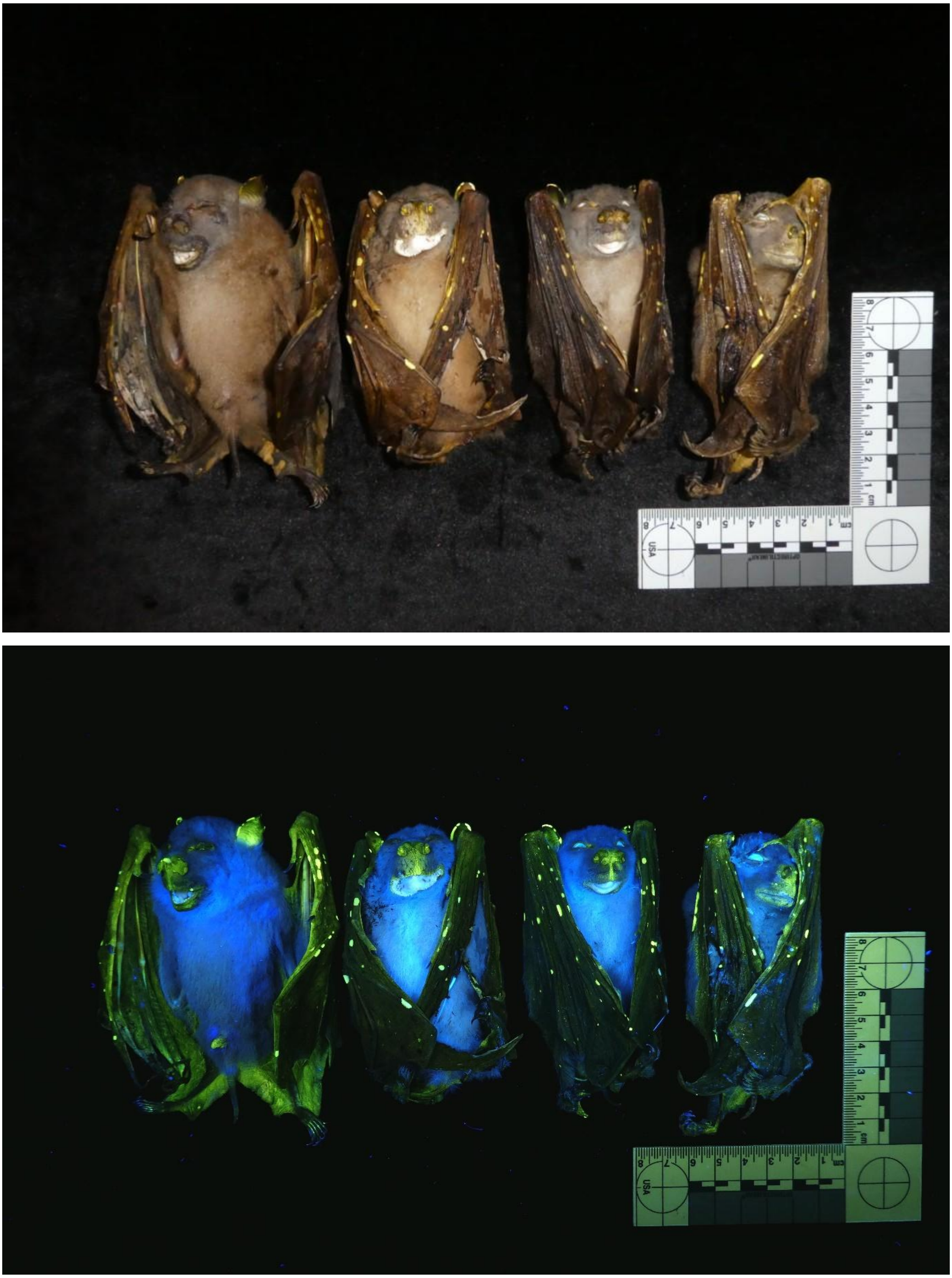

Figure 4. Eastern Tube-nosed Fruit Bats, male-female-male-female.
The two on the left are thawed, and the two on the right are still frozen. All four displaying similarly photoluminescent fur and external skin markings. Above – under white flash; below – under 365 nm torchlight, ten second exposure.

photoluminesced light blue. The Eastern Horseshoe Bat also had light blue photoluminescence of the wing bones visible through the ventral wing surface. The Eastern Horseshoe Bat's fur photoluminescence was mild greenish yellow and confined to the ventral torso apart from a band around the back of the neck, and stronger at 395–410 nm. None of these other species showed photoluminescence of the wings or other skin surfaces.

Discussion

The observations presented here document strikingly bright external photoluminescence of bat skin markings, not from a fungal disease but from the animal itself. All yellow skin markings, visible during daytime rest, photoluminesced bright yellow. Skin that was not otherwise bright yellow in white light on the ventral side of the animal, including the penis and patagium, also photoluminesced yellow. This patterning indicates that photoluminescence is linked to regular yellow colouration on the dorsal surface, but not on the ventral surface of the bats. Photoluminescence was examined in Eastern Tube-nosed Fruit Bats, but may be common to other members of the genus. Brightly patterned wing skin photoluminescence does not seem to occur in bats in general.

The observation that the yellow markings of the three live bats in captivity did not photoluminesce similarly to the five frozen bats is intriguing. A loss of photoluminescence in captivity may indicate that the yellow skin luminophores require dietary replenishment. In the wild, Eastern Tube-nosed Fruit Bats feed on local rainforest fruits including quandongs, guavas and figs. In captivity, their diet is predominantly lychees, custard apples, apples and bananas, but varies with seasonal availability and the bats' individual preferences, and one of the bats also consumes mealworms (Jenny Mclean, Tolga Bat Hospital, Queensland, personal communication November 2022). Further research could check the photoluminescence of a bat's skin on arrival from the wild, then after time intervals in captivity under a known diet.

Mammalian skin colouration was long thought to be restricted to melanins (Galván *et al*. 2016) or structural colours (Prum & Torres 2004). However, extracts from the skin of a Honduran White Bat (*Ectophylla alba* Allen 1892) were recently identified as a carotenoid (the xanthophyll lutein) (Galván *et al*. 2016). Dietary carotenoids are probably also responsible for yellow skin markings on many species of tent-roosting bats (Stenodermatinae; Galván *et al*. 2020). Carotenoids are photoluminescent (Gillbro & Cogdell 1989), though not necessarily strongly nor emitting in the visible spectrum (Wolf & Stevens 1967; Needham 1974). Neither Galván *et al*. (2016) nor Galván *et al*. (2020) reported their bats' carotenoid markings photoluminescing under low-wavelength excitation, only being coloured yellow in white light. Further research is needed to determine if the yellow pigments/luminophores in Tube-nosed Fruit Bat skin are also carotenoids, or involve another mechanism such as psittacofulvin pigments, pterins, kynurenine or an undiscovered molecule (McGraw *et al*. 2007; Cooke *et al*. 2017).

The camouflage effect of the Tube-nosed Fruit Bats' coloured wing spots is enacted in the dappled sunlight of their daytime roosts (Hall & Richards 2000). Since bright sunlight contains enough low-wavelength light to excite most natural photoluminescence (Marshall & Johnsen 2017), it is plausible that yellow photoluminescence adds to the yellow reflectance, intensifying the colour (Baird 2015). Visibility of photoluminescent yellow would depend on natural lighting conditions and the ocular filtering and sensitivity of the viewer (Marshall & Johnsen 2017). The visual pigments of bats themselves are mostly tuned to 560 nm, close to the 565–590 nm wavelength of yellow (Simões *et al.* 2019). Whether an increased saturation or glow of yellow would serve to deepen camouflage with similarly photoluminescent decaying leaves remains to be tested. The optical properties of the luminophores may equally plausibly be a latent by-product of the bats' skin chemistry.

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References

Baird C. 2015. What makes a "fluorescent" highlighter marker so bright? *Science Questions with Surprising Answers*. West Texas A&M University. *https://wtamu.edu/~cbaird/sq/2015/05/15/what-makes-a-fluorescent-highlighter-marker-so-bright/*, accessed 19 April 2021.

Cooke TF, Fischer CR *et al*. 2017. Genetic mapping and biochemical basis of yellow feather pigmentation in budgerigars. *Cell* 171: 427-439.

Galván I, Garrido-Fernández J *et al*. 2016. Tropical bat as mammalian model for skin carotenoid metabolism. *Proceedings of the National Academy of Sciences* 113: 10932-10937.

Galván I, Vargas-Mena JC, Rodríguez-Herrera B. 2020. Tent-roosting may have driven the evolution of yellow skin coloration in Stenodermatinae bats. *Journal of Zoological Systematics and Evolutionary Research* 58: 519-527.

Gillbro T, Cogdell RJ. 1989. Carotenoid fluorescence. *Chemical Physics Letters* 158: 312-316.

Hall LS, Richards G. 2000. *Flying Foxes: Fruit and Blossom Bats of Australia*. UNSW Press: Sydney.

Marshall J, Johnsen S. 2017. Fluorescence as a means of colour signal enhancement. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 372: 20160335.

McGraw KJ, Toomey MB, *et al*. 2007. A description of unique fluorescent yellow pigments in penguin feathers. *Pigment Cell Research* 20: 301-304.

Needham AE. 2012. *The Significance of Zoochromes*. Volume 3. Springer-Verlag: Berlin.

Prum RO, Torres RH. 2004. Structural colouration of mammalian skin: convergent evolution of coherently scattering dermal collagen arrays. *Journal of Experimental Biology* 207: 2157-2172.

Simões BF, Foley NM *et al*. 2019. As blind as a bat? Opsin phylogenetics illuminates the evolution of color vision in bats. *Molecular biology and evolution* 36: 54-68.

Turner GG, Meteyer CU *et al*. 2014. Nonlethal screening of bat-wing skin with the use of ultraviolet fluorescence to detect lesions indicative of white-nose syndrome. *Journal of Wildlife Diseases* 50: 566-573.

Udall SL, Briggs FP, Pautzke CF, Janzen DH. 1964. Fluorescence studies. In *Wildlife Research: Problems Programs Progress 1963. Activities of the Branch of Wildlife Research in the Bureau of Sport Fisheries and Wildlife for the Calendar Year 1963. Circular 188*, p. 64. United States Department of the Interior, Fish and Wildlife Service and Bureau of Sport Fisheries and Wildlife: Washington DC, USA;.

Wolf FT, Stevens MV. 1967. The fluorescence of carotenoids. *Photochemistry and Photobiology* 6: 597-599.