Biofluorescence in the Madeiran Pipistrelle, *Pipistrellus maderensis* (Dobson, 1878)

Biofluorescence under ultraviolet (UV) light occurs when living organisms absorb short-wavelength radiation and re-emit it at longer, visible wavelengths (Lamb & Davis 2020). Ultraviolet vision within the 300–400 nm range is well documented across a variety of vertebrate taxa (Hunt et al. 2001, Travouillon et al. 2023, Reinhold et al. 2023, Botelho et al. 2024, Reinhold et al. 2025). While ultraviolet sensitivity was once considered rare among extant mammals, it is now established that certain clades—including Chiroptera, Eulipotyphla, Rodentia, and Marsupialia—retain functional short-wavelength-sensitive (SWS1) opsins responsive to UV light (Gorresen et al. 2015). Among these vertebrates, nocturnal and crepuscular mammals have shown instances of biofluorescence, including one vespertilionid bat and several bats from Trinidad (Udall et al. 1964), one pteropodid bat (Reinhold 2022), as well as 74 species of phyllostomid bats (Rojas et al. 2021). More recently, fluorescence has also been documented in *Tadarida brasiliensis*, *Myotis velifer* (Gual-Suárez et al. 2024), *Rhinolophus hipposideros*, and *Rhinolophus blasii* (Schofield et al. 2025). While this trait may be adaptive in low-light environments, as observed in nocturnal and crepuscular species (Anich et al. 2021), there remains a lack of direct experimental evidence supporting a functional role for biofluorescence in mammals. Differentiating whether photoluminescence serves a biological function or is merely a byproduct of pigments or molecules poses a significant challenge (Marshall & Johnsen 2017, Gual-Suárez et al. 2024).

In this context, the Madeiran pipistrelle (*Pipistrellus maderensis*) (Figure 1) is a small vespertilionid bat endemic to the Macaronesian Archipelago, comprising the islands of Madeira, the Azores, and the Canary Islands (Masseti 2010, Teixeira 2023). Measuring between 29.5 and 34.0 mm in forearm length (Teixeira & Jesus 2009) and exhibiting a fur coloration ranging from chocolate-brown to orange-brown (Palmeirim et al. 1999), *P. maderensis* is recognized as one of the most threatened bat species in Europe (Barova & Streit 2018), facing a high risk of extinction due to habitat loss and anthropogenic pressures (Alcaldé & Juste 2022).

To explore the potential for UV-induced fluorescence in *Pipistrellus maderensis*, we employed two ultraviolet light sources, as commonly used in similar studies (Reinhold 2022, Schofield et al. 2025). The first was a Lepro flashlight (model: 51 LEDs UV Light Handheld Blacklight, 5 watts), emitting at 395 nm. The second was a DARKBEAM flashlight with a 365 nm wavelength and a ZWB2 filter. Fluorescence was observed under 395 nm, but no visible fluorescence was detected under 365 nm.

All used specimens were found deceased in the wild; no animals were sacrificed for this study. The two *P. maderensis* specimens were generously provided by the Pedagogical Collection of the University of Madeira. Given the vulnerable conservation status, the capture or handling of live individuals could result in injury or death, posing a potentially devastating impact on already fragile populations. Of the two specimens analysed, one was discovered in a trapping device used for monitoring the pinewood nematode vector and likely died from hypothermia or starvation. It was found in Sítio das Ginjas, São Vicente (32.786138, -17.038988) in 2015. The other specimen was collected in Chão da Ribeira (32.823702, -17.107971) in the same year, already deceased, presumably due to predation by *Felis silvestris catus*. Both specimens have been preserved in 70% ethanol since 2015 and stored in glass containers at room temperature, without exposure to sunlight, to maintain their condition.

To maximize detection of fluorescence, the bats were exposed to UV light from all body sides, with the light source positioned approximately 30 cm above the specimen and perpendicular to the plane. Photographs were taken of the dorsal and ventral aspects of the bat's feet using a Nikon P1000 digital camera, following methodologies adapted from Gual-Suárez et al. (2024). The images were later analysed to count and measure photoluminescent areas, providing a detailed description of this phenomenon in *P. maderensis*.

The bats analysed in this study exhibited fluorescence exclusively in their feet (Figure 2), with no detectable luminescence observed in other body parts (Figure 3). A similar pattern has been reported in the bat species *Tadarida brasiliensis*, in which fluorescence was restricted to the claws (Gual-Suárez et al. 2024). This phenomenon may be associated with the keratin structure of bat claws, as keratinized tissues are known to incorporate photoluminescent amino acids such as tryptophan and tyrosine (Melhuish & Smith 1993). Keratinization has previously been linked to green photoluminescence, as observed in *Pipistrellus maderensis*, as well as in particular rodent species (Sobral & Souza-Gudinho 2022). However, in other mammal species, biofluorescence is not restricted to claws alone. For instance, *Rhinolophus hipposideros* and *R. blasii* exhibit widespread fluorescence across the entire body pelage (Schofield et al. 2025), while *Rhinonicteris aurantia* displays strong fluorescence in the wings, particularly, along the wing membranes, as well as in the hind limbs and tail region (Travouillon et al. 2023).

As for the potential function of fluorescence, it could play an essential role in communication or environmental interaction, as UV vision has been observed in species of the same family (Gorresen et al. 2015). During flight, the bat's feet are held with the ventral aspect facing downward (Pohland 2007). In this case, we propose the same hypothesis as Gual-Suárez et al. (2024), who used the study of flying squirrels to suggest that photoluminescence aids in their intraspecific communication, proposing that bats may also use photoluminescence as a relatively bright and unambiguous visual cue to locate each other in the UV-enriched environment of the night sky. However, we currently lack information on both the exact excitation/emission ranges of these photoluminescent structures and the spectral sensitivity of *P. maderensis*' eyes.

These findings add another record of a vespertilionid bat with a well-defined UV-induced photoluminescent structure. Further studies are needed to assess the impact of UV light on *P. maderensis* populations, particularly to determine whether this species, like some of its relatives, possesses UV vision and how this might influence its behavior.

Figure 1. *Pipistrellus maderensis* in the wild (Photo: José Jesus, 2009).

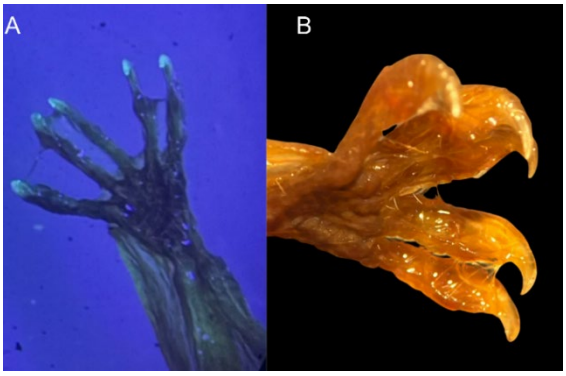

Figure 2. A. *Pipistrellus maderensis* feet under UV light (395 nm); B. *Pipistrellus maderensis* feet under white light.

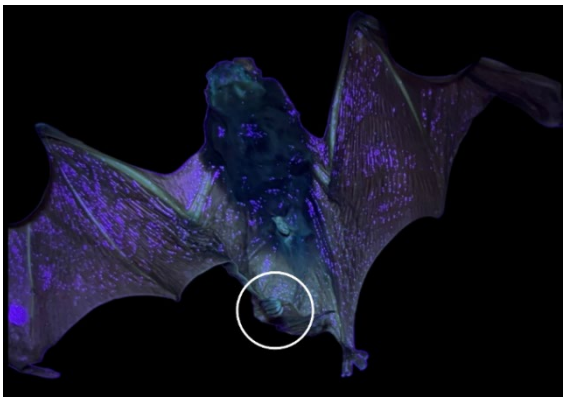

Figure 3. *Pipistrellus maderensis* under UV light (395 nm).

Acknowledgements. We are grateful to the reviewers for their valuable feedback.

References

Alcaldé, J., Juste, J. (2022): *Pipistrellus maderensis* (errata version published in 2022). The IUCN Red List of Threatened Species.

Anich, P.S., Anthony, S., Carlson, M., Gunnelson, A., Kohler, A.M., Martin, J.G., Olson, E.R. (2021): Biofluorescence in the platypus *Ornithorhynchus anatinus*. Mammalia 85: 179–181.

Barova, S., Streit, A. (2018): Action plan for the conservation of all bat species in the European Union 2018–2024. European Commission & UNEP/EUROBATS, 86 pp.

Botelho, L., Martins, S., Melocco, G., Toledo, L., Sazima, I., Muscat, E. (2024): Fluorescence in amphibians and reptiles: new cases and insights. Acta Herpetologica 19: 75-80.

Gorresen, P.M., Cryan, P.M., Dalton, D.C., Wolf, S., Bonaccorso, F.J. (2015): Ultraviolet vision may be widespread in bats. Acta Chiropterologica 17: 193–198.

Gual-Suárez, F., Ramos-H., D., García, F., Pérez-Montes, L., Narro Delgado, A., Medellín, R. (2024): Ultraviolet-induced photoluminescent bristles on the feet of the Mexican free-tailed bat *Tadarida brasiliensis*. Mammalian Biology 104: 751–756.

Hunt, S., Cuthill, I.C., Bennett, A.T.D., Church, S.C., Partridge, J.C. (2001): Is the ultraviolet waveband a special communication channel in avian mate choice? Journal of Experimental Biology 204: 2499–2507.

Lamb, J., Davis, M. (2020): Salamanders and other amphibians are aglow with biofluorescence. Scientific Reports 10: 2821.

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

Masseti, M. (2010): Mammals of the Macaronesian islands (the Azores, Madeira, the Canary and Cape Verde islands): redefinition of the ecological equilibrium. Mammalia 74: 3–34.

Melhuish, W.H., Smith, G.J. (1993): Photobleachable fluorescent species in wool keratin. Journal of the Society of Dyers and Colourists 109: 163–165.

Palmeirim, J.M., Rodrigues, L., Rainho, A., Ramos, M.J. (1999): Chiroptera - Rhinolophidae, Vespertilionidae, Miniopteridae, Molossidae. pp. 41-95. In: Mathias, M.L., Santos-Reis, M., Palmeirim, J.M., Ramalhinho, M.G. (eds.), Mamíferos Terrestres de Portugal Continental, Açores e Madeira. Instituto da Conservação da Natureza e Centro de Biologia Ambiental, Lisboa.

Pohland, G. (2007): Spectral data of avian plumage. Dissertation, Rheinische Friedrich-Wilhelms-Universität Bonn.

Reinhold, L. (2022): Photoluminescent yellow wing markings of eastern tube-nosed fruit bats (*Nyctimene robinsoni*). North Queensland Natural 52: 69–74.

Reinhold, L.M., Rymer, T.L., Helgen, K.M., Wilson, D.T. (2023): Photoluminescence in mammal fur: 111 years of research. Journal of Mammalogy 104(4): 892–906.

Reinhold, L.M., Rymer, T.L., Wilson, D.T. (2025): Luminophores in the fur of seven Australian Wet Tropics mammals. PLoS ONE 20(4): e0320432.

Rojas, D., Mosquera-Izquierdo, E., Murillo-García, O.E. (2021): Correlatos ecológicos de la biofluorescencia al ultravioleta en murciélagos filostómidos. pp. 22–23. In: Lizcano, D., Concha-Osbahr, D., Ramírez-Chaves, H., Trujillo-Acosta, A., Agámez, C. (eds.), IV Congreso Colombiano de Mastozoología: Libro de Resúmenes. Sociedad Colombiana de Mastozoología, Bogotá, Colombia.

Schofield, H., Zrnčić, V., Smith, D., Budinski, I., Hargreaves, D., Damant, C. (2025): Full pelage ultra-violet fluorescence occurs in both lesser horseshoe bat, *Rhinolophus hipposideros* (André, 1797) and Blasius's horseshoe bat *R. blasii* Peters, 1867. Hystrix, the Italian Journal of Mammalogy 36(1): https://doi.org/10.4404/hystrix-00737-2024.

Sobral, G., Souza-Gudinho, F. (2022): Fluorescence and UV–Visible reflectance in the fur of several Rodentia genera. Scientific Reports 12: 1–7.

Teixeira, S. (2023): On the destruction of threatened endemic insular bat roosts: The case of the Macaronesian Madeira pipistrelle *Pipistrellus maderensis* on Madeira Archipelago. Online Journal of Ecology & Environmental Sciences 1(4), http://dx.doi.org/10.33552/OJEES.2023.01.000516.

Teixeira, S., Jesus, J. (2009): Echolocation calls of bats from Madeira Island: acoustic characterization and implications for surveys. Acta Chiropterologica 11: 183–190.

Travouillon, K.J., Cooper, C., Bouzin, C.J.T., Umbrello, L.S., Lewis, S.W. (2023): All-a-glow: spectral characteristics confirm widespread fluorescence for mammals. Royal Society Open Science 10(10): 230325.

Udall, S.L., Briggs, F.P., Pautzke, C.F., Janzen, D.H. (1964): Fluorescence studies. Wildlife Research: Problems, Programs, Progress 1963. Fish and Wildlife Service and Bureau of Sport Fisheries and Wildlife, Washington, p. 64. Circular 188. United States Department of the Interior.

Keywords: biofluorescence, Chiroptera, Vespertilionidae, nocturnal mammal, Madeira Island.

Article No.: e257701
Received: 10 January 2025 / Accepted: 25 May 2025
Available online: July 2025 / Printed: December 2025

José CÂMARA [1, *] and José JESUS [1, 2]

1. Universidade da Madeira, Faculdade de Ciências da Vida. 9000-082, Funchal, Ilha da Madeira, Portugal.
2. Madeira Botanical Group (GBM), Universidade da Madeira, Faculdade de Ciências da Vida. 9000-082, Funchal, Ilha da Madeira, Portugal.

* Corresponding author: J. Câmara, E-mail: tomaschool@outlook.com.