ÖGH Herpetozoa
Austrian Herpetological Society

Herpetozoa 39: 381–387 (2026)
DOI 10.3897/herpetozoa.39.e208000

Iris pattern recognition as a non-invasive method for individual identification in *Osteocephalus oophagus* (Hylidae)

Lauriane Bégué[1], Fabrice Petel[1], Vincent Premel[1,2], Gaëlle Raboisson[1], Eva Ringler[1], Max Ringler[1,3], Moric Toszeghi[1], Victor Vacher[1], Mélissa Peignier[1]

1 *Division of Behavioural Ecology, Institute of Ecology and Evolution, University of Bern, Wohlenstrasse 50a, CH-3032 Hinterkappelen, Switzerland*
2 *13 rue de l'hippodrome, 44115 Basse Goulaine, France*
3 *Institute of Electronic Music and Acoustics, University of Music and Performing Arts, Inffeldgasse 10/3, 8010 Graz, Austria*

https://zoobank.org/8CF17D9D-0D72-4213-A221-AC45F8E0CED2

Corresponding author: Mélissa Peignier (melissapeignier@hotmail.fr)

Academic editor: Peter Mikulíček ♦ **Received** 15 July 2026 ♦ **Accepted** 9 September 2026 ♦ **Published** 12 October 2026

Abstract

Reliable individual identification is fundamental to ecological and behavioural studies, yet many marking techniques are invasive and may affect animal behaviour or survival. Biometric identification approaches offer a non-invasive alternative for individual recognition using phenotypic traits. In amphibians, body patterns, especially colouration, have been used to identify individuals, but species lacking permanent body patterns require alternative traits. This study evaluated whether iris patterns could serve as a marker for individual recognition in the treefrog *Osteocephalus oophagus*. A capture-recapture study was conducted over three breeding seasons (2021–2023) in French Guiana. At each encounter, eye photographs were compared with an image library to identify individuals without handling. Manual identifications were independently verified using Wild-ID software. Across 392 capture events involving 103 individuals, iris patterns were highly distinctive among individuals and enabled repeated identification across encounters. Within-season recapture rates ranged from 56% to 80%, indicating that iris patterns remained sufficiently stable for short-term monitoring. However, only three individuals were re-identified across years, preventing a robust assessment of long-term pattern stability. As these individuals showed no substantial alteration in iris patterns, the low interannual recapture rate was more likely explained by population turnover or emigration than by changes in iris morphology. The findings suggest that iris recognition provides an effective, non-invasive method for short-term individual identification in *O. oophagus*, reducing the need for repeated handling and supporting ethical wildlife research. Further studies are needed to assess the long-term stability of iris patterns and evaluate the applicability of this method to other amphibian species.

Key Words

amphibian, biometrics, capture-recapture, eye, treefrog

Introduction

Individual identification is an essential tool for studying animal behaviour and ecology. It enables the estimation of population parameters in capture-recapture analyses, as well as the assessment of individual life-history and behavioural traits (Lebreton et al. 1992; Nichols 1992; Pradel 1996). Marking techniques, including external or internal tags, branding, hair or faecal sampling, and tissue removal, have traditionally been used for repeated recognition of the same individual over time (Nietfeld et al. 1994; Silvy 2020). Although these methods enable effi-

Copyright *Lauriane Bégué et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

PENSOFT

cient individual identification, their feasibility and invasiveness vary among species. For example, while genetic identification from faecal samples is feasible in large mammals, amphibians often require toe clipping, a procedure that may affect survival, physiology, and behaviour (Donnelly et al. 1994; Drechsler et al. 2015; Ringler et al. 2015). Biometric techniques therefore represent promising non-invasive alternatives for individual recognition in amphibians.

Animal biometrics encompasses quantitative methods for characterising and identifying species or individuals based on measurable phenotypic features (Bugge et al. 2011; Kühl and Burghardt 2013; Petso et al. 2021). The variability and uniqueness of biometric signatures make them particularly valuable for non-invasive individual identification in both humans and animals. In humans, traits such as irises (Wildes 1997), fingerprints (Caplan 1990), and facial features (Turk and Pentland 1991) are routinely used for identification. In animals, similar biometric approaches are employed, although identification often relies on a wider range of externally visible phenotypic features. Examples include eyespots on butterfly wings (Silveira and Monteiro 2009), injury marks in white sharks (Domeier and Nasby-Lucas 2007), stripe arrangements in zebras (Lahiri et al. 2011) or tigers (Hiby et al. 2009), and even nose prints in cattle (Bello et al. 2020). In amphibians, skin patterns have been used for photographic identification of juveniles or adults in many species (Carafa and Biondi 2004; Ribeiro and Rebelo 2011; Caorsi et al. 2012; Ringler et al. 2015). However, this approach is not applicable to species in which some or all individuals lack distinct patterns or markings.

Although iris recognition was originally developed for humans (Wildes 1997), it has also been tested in geckos (Rocha et al. 2013), cattle (Lu et al. 2014), goats (De and Ghoshal 2016), and tigers (Ghoshal et al. 2012). Amphibian eyes have been studied with respect to pupil shape and diversity (Cervino et al. 2021; Thomas et al. 2022), and a recent study has demonstrated that iris characteristics can be used for species identification (De and Chakrabarti 2025), but individual recognition using iris patterns has not been tested. Several anuran species possess complex irises with a seemingly unique appearance, including *Osteocephalus oophagus*, *Osteocephalus taurinus*, *Hyloscirtus tigrinus*, *Trachycephalus hadroceps*, and *Sachatamia ilex*. *Osteocephalus oophagus*, for instance, has golden eyes with thin, black, radial lines around the pupil, whose arrangement appears to create a unique pattern in each individual. Given the importance of animal welfare in biological research, evaluating species-specific non-invasive identification methods is essential. This study investigates whether iris patterns in the Neotropical hylid treefrog *Osteocephalus oophagus* Jungfer & Schiesari, 1995 are (i) individually distinct and (ii) temporally stable. Specifically, the study assesses whether iris patterns can be reliably used for capture-recapture studies within and between seasons.

Methods

Osteocephalus oophagus is a treefrog occurring in the Amazon Basin. It typically inhabits the forest canopy during the day and descends to heights of approximately 2 metres at night. Females descend every 4–7 days, whereas males descend nightly and vocalise to attract females (Jungfer and Schiesari 1995; Jungfer and Weygoldt 1999). Although the species exhibits some dorsal patterns, these are often very limited, are not consistently present across individuals, or are restricted to specific body regions, making systematic comparisons difficult (Fig. 1). In contrast, its eyes display complex golden irises with radiating lines (Figs 1, 2), suggesting a unique, fingerprint-like pattern.

A capture-recapture study was conducted on an approximately 5 ha river island in lowland rainforest during the rainy seasons (March–May) of 2021, 2022, and 2023. The island is located in the "Les Nouragues" nature reserve in French Guiana (4°02'N, 52°41'W; Bongers et al. 2001), near the "Saut Pararé" field camp of the CNRS Nouragues Ecological Research Station (Ringler et al. 2016). Frogs were sampled primarily at an array of 39 artificial pool sites, spaced every 20 m along the trails covering the island, each consisting of three pools of different sizes installed at a height of 130 cm. The pools consisted of flower pots with capacities of 0.1 L, 0.3 L, and 1 L, designed to mimic natu-

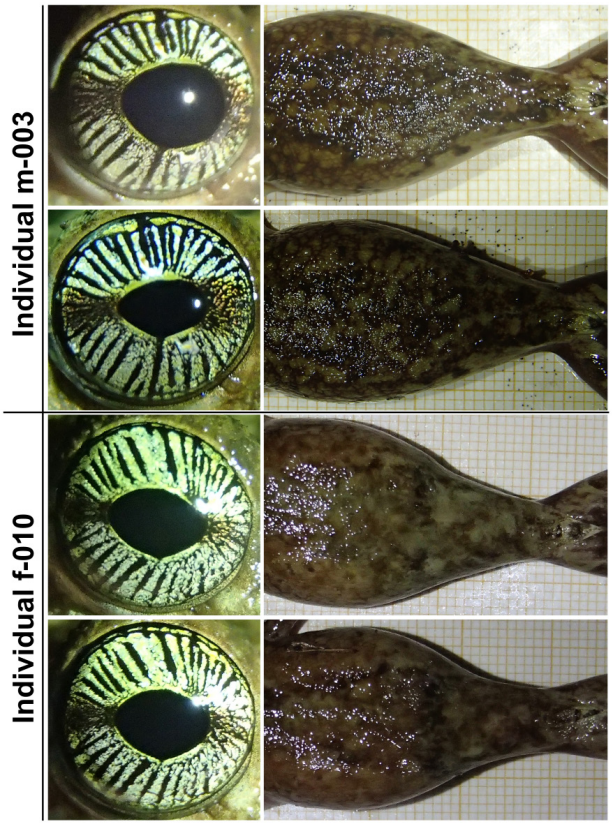

Figure 1. Eye and dorsal patterns of one male (m-003) and one female (f-010) of *Osteocephalus oophagus* photographed during two capture events in French Guiana (4°02'N, 52°41'W; Bongers et al. 2001) between March and May 2022.

Figure 2. *Osteocephalus oophagus in situ*: frog on a tree (top left), in a pool (bottom left), and in amplexus on a tree (right), photographed in French Guiana (4°02'N, 52°41'W; Bongers et al. 2001) between March and May 2021.

ral breeding pools used by treefrogs. They were originally installed as part of another study investigating breeding pool preferences and facilitated frog sampling. In addition to the artificial pools, natural breeding sites throughout the island, such as tree hollows, were also surveyed.

Frogs were systematically searched for in and around artificial and natural pools between 18:40 h and 02:00 h, with the aim of sampling all adult males and females present on the island during each study period. Upon first encounter, the frog was caught by hand, and digital photographs were taken using TG-620 and TG-630 cameras (Olympus, Tokyo, Japan), including both eyes, the dorsal and ventral sides, and the hind legs, before the animal was released at the capture site. Frogs encountered in amplexus typically resumed amplexus within an hour.

The photographs were later cropped to isolate the eye, and the resulting iris images were compiled into a reference library on rugged Windows 10 tablets (K72H and K86H; KCOSIT Tech LTD, Shenzhen, China). During subsequent encounters, both eyes were photographed without any direct contact. If the frog could be identified using the reference library on the tablet, it was left undisturbed. Otherwise, it was processed following the protocol used for a first encounter.

Manual in-field identifications were verified using Wild-ID 1.0.0 (Bolger et al. 2012). The software was run twice, once using only left-eye images and once using only right-eye images, thereby allowing independent verification of each iris pattern.

Results

In-field identification using the reference library proved efficient, as iris patterns were sufficiently distinct to enable rapid identification of individual frogs from eye photographs alone, without the need for handling (Figs 3, 4). For most in-field identifications, one eye was sufficient to reliably identify the individual, and the second eye served only as confirmation. Over the three study seasons, 103 individuals were sampled across 392 captures: 128 in 2021, 217 in 2022, and 47 in 2023. In 2021, the study area was sampled for 22 days, and 24 individuals were encountered. Of these, 16 individuals (66.7%) were

Figure 3. Example of the diversity of iris patterns from eight *Osteocephalus oophagus* individuals photographed in French Guiana (4°02'N, 52°41'W; Bongers et al. 2001) between March and May 2021, 2022, and 2023.

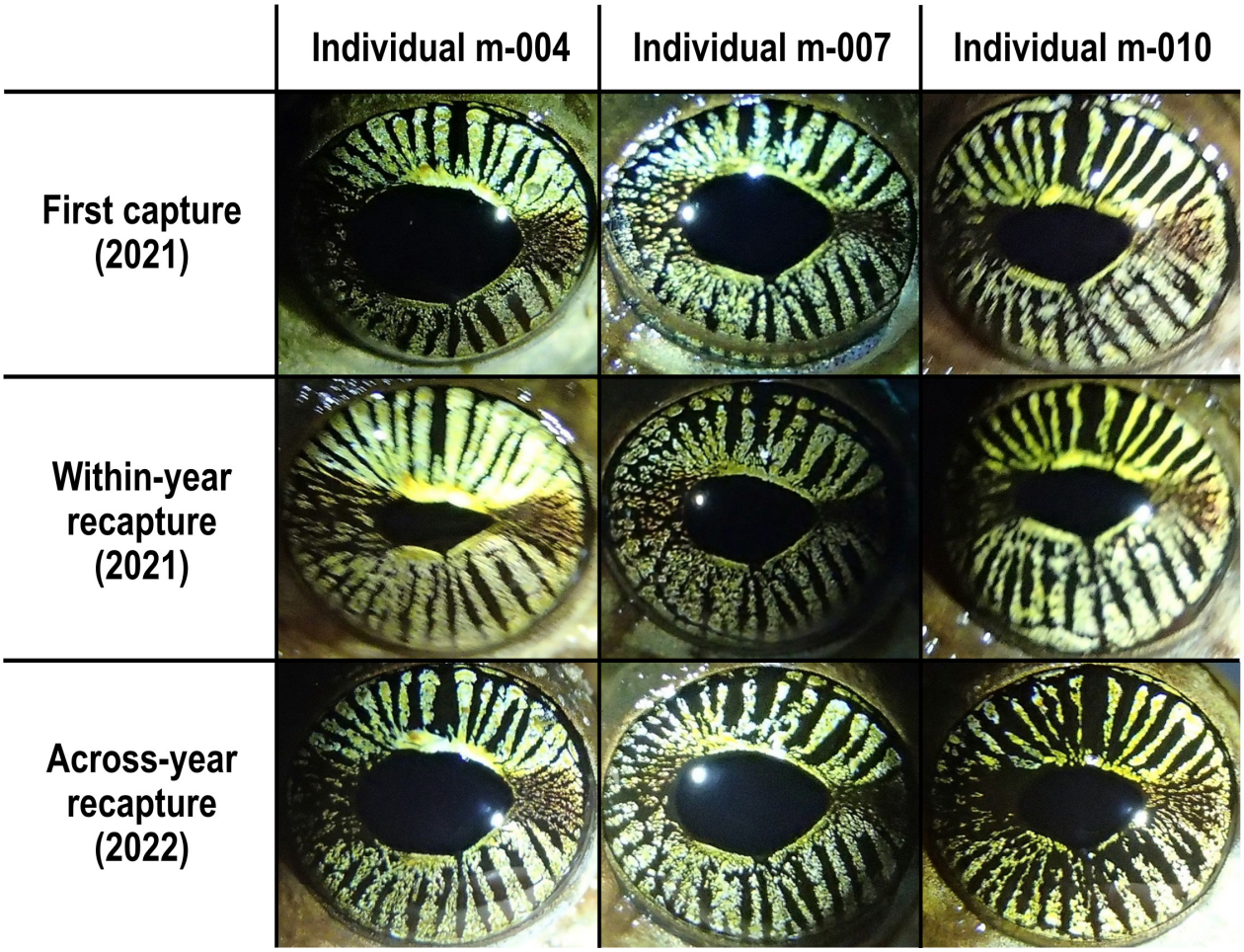

Figure 4. Examples of individual identification upon capture and recapture based on iris patterns in three male *Osteocephalus oophagus* photographed in French Guiana (4°02'N, 52°41'W; Bongers et al. 2001) between March and May 2021 and 2022.

recaptured during the same season. Individuals were captured an average of 5.8 ± 5.3 times. In 2022, the study area was sampled for 24 days, and 59 individuals were encountered. Of these, 47 individuals (79.7%) were recaptured during the season. Individuals were captured an average of 9.0 ± 6.2 times. In addition, three individuals first captured in 2021 were recaptured (Fig. 4). In 2023, sampling was conducted for 17 days, and 23 individuals were encountered, none of which had been captured during the previous two years. Thirteen of the 23 individuals (56.5%) were recaptured during the season. Individuals were captured an average of 2.8 ± 1.8 times.

Discussion

The results suggest that iris patterns provide a reliable means of distinguishing and identifying individuals within a single year. However, the very low or absent interannual recapture rate prevented a robust assessment of their suitability for long-term capture-recapture studies. Iris patterns enabled the identification of over 100 individuals, indicating that the variability and uniqueness of iris patterns in *O. oophagus* make this trait suitable for individual recognition (Fig. 3). These findings are consistent with studies in humans, where iris texture is sufficiently complex to serve as a biometric signature (Daugman and Downing 2001). Within each year, more than half of the identified individuals were recaptured and consistently re-identified based on their iris patterns, indicating that these patterns remain sufficiently stable for short-term identification in amphibians. Furthermore, eye photographs could be obtained while frogs were perched on natural structures (Fig. 2), regardless of whether individuals were alone or in amplexus, making this method readily compatible with ethical and animal welfare guidelines such as the 3Rs.

In contrast, interannual recapture rates were very low or absent across the three consecutive years of the study. As no additional marking or identification technique was used, it was not possible to determine whether previously identified individuals remained in the study population but were no longer identifiable, or whether they were genuinely absent. Although human iris patterns are known to remain stable throughout life (Wildes 1997), comparable data are lacking for amphibians. Nevertheless, identification of recaptured individuals within and across seasons was generally unambiguous, with little to no discernible change in iris patterns (Fig. 4), suggesting that individual absence rather than changes in iris patterns was the more likely explanation. Although comparable studies in amphibians are lacking, evidence from other poikilothermic vertebrates regarding the stability of iris patterns is mixed. In the Atlantic salmon (*Salmo salar*), iris patterns were found to remain stable only over several months (Foldvik et al. 2020), whereas long-term stability has been demonstrated in geckos (*Tarentola boettgeri bischoffi*; Rocha et al. 2013). In this case, the scarcity of interannual recaptures is interpreted as more likely reflecting population turnover and emigration than changes in iris patterns rendering individuals unidentifiable. Future studies on captive individuals or field studies combining iris photography with an independent identification method (e.g. genetic identification or permanent marking) are needed to assess iris stability across multiple years. Integrating monitoring or tracking approaches will be essential to determine whether the findings primarily reflect the population dynamics of *O. oophagus* or temporal changes in iris patterns.

Conclusion

The study suggests that iris patterns in the treefrog *O. oophagus* are individually distinct and enable reliable short-term individual identification. This approach is therefore recommended as a non-invasive method for individual recognition within a single reproductive season. Further research is needed to evaluate the potential of iris patterns for long-term identification in *O. oophagus* and to assess their applicability to other anuran species with complex irises, such as *Osteocephalus taurinus*, *Hyloscirtus tigrinus*, *Trachycephalus resinifictrix*, or *Sachatamia ilex*. However, the suitability of this method is likely to vary among species depending on iris complexity. Highly complex iris patterns may hinder rapid identification in the field, as may occur in *Trachycephalus hadroceps*, whereas uniform or patternless irises may provide insufficient interindividual variation for reliable identification, as potentially observed in *Agalychnis callidryas*. It is therefore recommended that the reliability of iris patterns for individual re-identification be evaluated on a species-by-species basis before applying this method more broadly. Overall, iris pattern identification has the potential to become a powerful, non-invasive tool for rapid field-based individual identification, opening new opportunities for individual-level studies in amphibians.

Acknowledgements

The authors thank the staff of the Nouragues Station for logistical support. The authors thank the Nouragues research field station (managed by CNRS), which benefits from “Investissement d’Avenir” grants managed by Agence Nationale de la Recherche (AnaEE France ANR-11-INBS-0001; Labex CEBA ANR-10-LABX-25-01). This work was conducted in the Nouragues Nature Reserve.

References

ASAB [ASAB Ethical Committee/ABS Animal Care Committee] (2024) Guidelines for the ethical treatment of nonhuman animals in behavioural research and teaching. Animal Behaviour, 207, I–XI. https://doi.org/10.1016/s0003-3472(23)00317-2

Bello RW, Olubummo DA, Seiyaboh Z, Enuma OC, Talib AZ, Mohamed ASA (2020) Cattle identification: the history of nose prints approach

in brief. IOP Conference Series: Earth and Environmental Science 594: 012026. https://doi.org/10.1088/1755-1315/594/1/012026

Bolger DT, Morrison TA, Vance B, Lee D, Farid H (2012) A computer-assisted system for photographic mark–recapture analysis. Methods in Ecology and Evolution 3: 813–822. https://doi.org/10.1111/j.2041-210X.2012.00212.x

Bongers F, Charles-Dominique P, Forget P-M, Théry M (2001) Nouragues: Dynamics and plant-animal interactions in a neotropical rainforest. Kluwer Academic Publishers, Dordrecht, 451 pp.

Bugge CE, Burkhardt J, Dugstad KS, Berge Enger T, Kasprzycka M, Kleinauskas A, Myhre M, Scheffler K, Ström S, Vetlesen S (2011) Biometric methods of animal identification. Course notes Laboratory Animal Science. Norwegian School of Veterinary Science, Oslo (Norway), 1–6.

Caorsi VZ, Santos RR, Grant T (2012) Clip or snap? An evaluation of toe-clipping and photo-identification methods for identifying individual Southern Red-Bellied toads, *Melanophryniscus cambaraensis*. South American Journal of Herpetology 7: 79–84. https://doi.org/10.2994/057.007.0210

Caplan RM (1990) How fingerprints came into use for personal identification. Journal of the American Academy of Dermatology 23: 109–114. https://doi.org/10.1016/0190-9622(90)70194-M

Carafa M, Biondi M (2004) Application of a method for individual photographic identification during a study on *Salamandra salamandra gigliolii* in central Italy. Italian Journal of Zoology 71: 181–184. https://doi.org/10.1080/11250000409356631

Cervino NG, Elias-Costa AJ, Pereyra MO, Faivovich J (2021) A closer look at pupil diversity and evolution in frogs and toads. Proceedings of the Royal Society B: Biological Sciences 288: 20211402. https://doi.org/10.1098/rspb.2021.1402

Daugman J, Downing C (2001) Epigenetic randomness, complexity and singularity of human iris patterns. Proceedings of the Royal Society B: Biological Sciences 268: 1737–1740. https://doi.org/10.1098/rspb.2001.1696

De P, Ghoshal D (2016) Recognition of non circular iris pattern of the goat by structural, statistical and Fourier descriptors. Procedia Computer Science 89: 845–849. https://doi.org/10.1016/j.procs.2016.06.070

De P, Chakrabarti S (2025) Classification of various iris patterns of amphibians using geometric and color features. In: Dhar S, Goswami S, Unni Krishnan DK, Bose I, Dubey R, Mazumdar C (Eds) Analytics, Machine Learning, and Artificial Intelligence. Springer Nature Switzerland, Cham, 104–125. https://doi.org/10.1007/978-3-031-75157-8_8

Domeier ML, Nasby-Lucas N (2007) Annual re-sightings of photographically identified white sharks (*Carcharodon carcharias*) at an eastern Pacific aggregation site (Guadalupe Island, Mexico). Marine Biology 150: 977–984. https://doi.org/10.1007/s00227-006-0380-7

Donnelly MA, Guyer C, Juterbock JE, Alford RA (1994) Techniques for marking amphibians. In: Heyer WR, Donnelly MA, McDiarmid RW, Hayek L-AC, Foster MS (Eds) Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington, DC, 277–284.

Drechsler A, Helling T, Steinfartz S (2015) Genetic fingerprinting proves cross-correlated automatic photo-identification of individuals as highly efficient in large capture–mark–recapture studies. Ecology and Evolution 5: 141–151. https://doi.org/10.1002/ece3.1340

Foldvik A, Jakobsen F, Ulvan EM (2020) Individual recognition of Atlantic salmon using iris biometry. Ichthyology & Herpetology 108: 767–771. https://doi.org/10.1643/CI2020035

Ghoshal D, De P, Saha B (2012) Identification of tigers for census by the method of tiger iris pattern matching and recognition. International Journal of Computer Applications 49: 19–23. https://doi.org/10.5120/7600-0316

Hiby L, Lovell P, Patil N, Kumar NS, Gopalaswamy AM, Karanth KU (2009) A tiger cannot change its stripes: using a three-dimensional model to match images of living tigers and tiger skins. Biology Letters 5: 383–386. https://doi.org/10.1098/rsbl.2009.0028

Jungfer K-H, Weygoldt P (1999) Biparental care in the tadpole-feeding Amazonian treefrog *Osteocephalus oophagus*. Amphibia-Reptilia 20: 235–249. https://doi.org/10.1163/156853899X00277

Jungfer K-H, Schiesari LC (1995) Description of a central Amazonian and Guianan tree frog, genus *Osteocephalus* (Anura, Hylidae), with oophagous tadpoles. Alytes: International Journal of Batrachology 13: 1–13.

Kühl HS, Burghardt T (2013) Animal biometrics: quantifying and detecting phenotypic appearance. Trends in Ecology & Evolution 28: 432–441. https://doi.org/10.1016/j.tree.2013.02.013

Lahiri M, Tantipathananandh C, Warungu R, Rubenstein DI, Berger-Wolf TY (2011) Biometric animal databases from field photographs: identification of individual zebra in the wild. In: Proceedings of the 1st ACM International Conference on Multimedia Retrieval, Trento (Italy), 2011: 695–703. https://doi.org/10.1145/1991996.1992002

Lebreton J-D, Burnham KP, Clobert J, Anderson DR (1992) Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62: 67–118. https://doi.org/10.2307/2937171

Lu Y, He X, Wen Y, Wang PSP (2014) A new cow identification system based on iris analysis and recognition. International Journal of Biometrics 6: 18–32. https://doi.org/10.1504/IJBM.2014.059639

Nichols JD (1992) Capture-recapture models. BioScience 42: 94–102. https://doi.org/10.2307/1311650

Nietfeld MT, Barrett MW, Silvy NJ (1994) Wildlife marking techniques. In: Bookhout TA (Ed) Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, 140–168.

Petso T, Jamisola RS, Mpoeleng D (2021) Review on methods used for wildlife species and individual identification. European Journal of Wildlife Research 68: 3. https://doi.org/10.1007/s10344-021-01549-4

Pradel R (1996) Utilization of capture-mark-recapture for the study of recruitment and population growth rate. Biometrics 52: 703–709. https://doi.org/10.2307/2532908

Ribeiro J, Rebelo R (2011) Survival of *Alytes cisternasii* tadpoles in stream pools: a capture-recapture study using photo-identification. Amphibia-Reptilia 32: 365–374. https://doi.org/10.1163/017353711X584186

Ringler E, Mangione R, Ringler M (2015) Where have all the tadpoles gone? Individual genetic tracking of amphibian larvae until adulthood. Molecular Ecology Resources 15: 737–746. https://doi.org/10.1111/1755-0998.12345

Ringler M, Mangione R, Pašukonis A, Rainer G, Gyimesi K, Felling J, Kronaus H, Réjou-Méchain M, Chave J, Reiter K, Ringler E (2016) High-resolution forest mapping for behavioural studies in the Nature Reserve 'Les Nouragues', French Guiana. Journal of Maps 12: 26–32. https://doi.org/10.1080/17445647.2014.972995

Rocha R, Carrilho T, Rebelo R (2013) Iris photo-identification: A new methodology for the individual recognition of *Tarentola* geckos. Amphibia-Reptilia 34: 590–596. https://doi.org/10.1163/15685381-00002918

Silveira M, Monteiro A (2009) Automatic recognition and measurement of butterfly eyespot patterns. Biosystems 95: 130–136. https://doi.org/10.1016/j.biosystems.2008.09.004

Silvy NJ (2020) The wildlife techniques manual: Volume 1: Research. Volume 2: Management. Johns Hopkins University Press, Baltimore, USA, 1401 pp.

Thomas KN, Rich C, Quock RC, Streicher JW, Gower DJ, Schott RK, Fujita MK, Douglas RH, Bell RC (2022) Diversity and evolution of amphibian pupil shapes. Biological Journal of the Linnean Society 137: 434–449. https://doi.org/10.1093/biolinnean/blac095

Turk M, Pentland A (1991) Eigenfaces for recognition. Journal of Cognitive Neuroscience 3: 71–86. https://doi.org/10.1162/jocn.1991.3.1.71

Wildes RP (1997) Iris recognition: an emerging biometric technology. Proceedings of the IEEE 85: 1348–1363. https://doi.org/10.1109/5.628669

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

This study was approved by the scientific committee of the "Nouragues Ecological Research Station". Sampling for this study was conducted in strict accordance with current French and EU law and followed the ASAB (2024) guidelines on the treatment of study animals. Work permits were provided by CNRS Guyane ("Centre National de la Recherche Scientifique Guyane").

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
The following AI tools were used in the preparation of this manuscript:
AI tools: Claude.
Used for: Language, style and writing.
Description: AI-assisted tools were used to improve English language quality and manuscript readability.

Funding

This work was funded by the Swiss National Science Foundation (SNSF) via projects 310030_197921 and 310030_215049 (PI: ER) and by the University of Bern via the Young Academics Support Open Round 2021 to MP. MR was supported by the Austrian Science Fund (FWF) via project P33728.

Author contributions

Conceptualisation: LB, ER, MR, MP; Investigation: LB, FP, VP, GR, MT, VV, MP; Data curation: LB, GR, MR, VV, MP; Formal analysis: LB; Visualisation: LB, MP; Writing – original draft: LB, MP; Writing – review and editing: LB, FP, VP, GR, ER, MR, MT, VV, MP; Project administration: MP; Funding acquisition: ER, MP.

Author ORCIDs

L. Bégué https://orcid.org/0009-0000-3189-798X
V. Premel https://orcid.org/0009-0008-1725-9736
G. Raboisson https://orcid.org/0000-0001-6786-387X
E. Ringler https://orcid.org/0000-0003-3273-6568
M. Ringler https://orcid.org/0000-0002-4530-4919
M. Peignier https://orcid.org/0000-0003-0849-4407

Data availability

The datasets generated and analysed during the current study are available from the authors upon request.