

First report of ocular heterochromia in the treefrog *Boana albomarginata* (Spix, 1824) (Anura: Hylidae), Atlantic Forest, northeastern Brazil

Iuri Vieira de Melo¹, Ester Lacerda Correia de Quintela², Wellington Farias³, Mariana Ávila Caribé¹,

Cássio Lopes Lins¹, Felipe Paganelly Maciel da Silva¹, João Cláudio Cerqueira Viana¹ &

Marcelo Felgueiras Napoli^{3,4,*} 

¹Prime Ambiental Ltda., Av. Luiz Tarquínio Pontes, Buraquinho, 42700-000, Lauro de Freitas, BA, Brasil.

²Universidade Estadual de Santa Cruz, Campus Soane Nazaré de Andrade, Rodovia Jorge Amado, km 16, Salobrinho, 45662-900, Ilhéus, BA, Brasil.

³Universidade Federal da Bahia, Instituto de Biologia, Programa de Pós-Graduação em Biodiversidade e Evolução, Rua Barão de Jeremoabo, Campus universitário de Ondina, 40170-115, Salvador, BA, Brasil.

⁴Universidade Federal da Bahia, Instituto de Biologia, Museu de História Natural, Rua Barão de Jeremoabo, Campus universitário de Ondina, 40170-115, Salvador, BA, Brasil.

*Corresponding author: napoli@ufba.br

MELO, I.V., QUINTELA, E.L.C., FARIAS, W., CARIBÉ, M.A., LINS, C.L., SILVA, F.P.M., VIANA, J.C.C., NAPOLI, M.F. **First report of ocular heterochromia in the treefrog *Boana albomarginata* (Spix, 1824) (Anura: Hylidae), Atlantic Forest, northeastern Brazil.** *Biota Neotropica* 24(2): e20241624. <https://doi.org/10.1590/1676-0611-BN-2024-1624>

Abstract: The scientific literature on amphibian anomalies is large, but registered cases of amphibians' ocular heterochromia are almost absent, even considering anecdotal records. In the Brazilian territory, only two cases of ocular heterochromia were formerly registered for amphibians, both for anurans, the first from the Atlantic Forest of northeastern Brazil and the second from the Amazonian region of northern Brazil. In the present account, we report two cases of ocular heterochromia in the hylid treefrog *Boana albomarginata*, both from the Atlantic Forest biome, Bahia state, northeastern Brazil, representing the first record of ocular heterochromia for this species and the third case registered for an amphibian's species in Brazil. One eye of each observed specimen had an unusually flashy and homogeneous blue-colored iris, filling its entire surface or only its lower half, representing cases of complete and sectoral heterochromia, respectively. Furthermore, the unusual flashy blue iris was only detectable during daylight, when the iris background color was white. At night, the standard copper to golden iris background color remains unchanged, and the blue color cannot be detected. No other detectable anomalies or unusual behaviors were observed for both specimens. This is the first report of amphibian ocular heterochromia represented by a flashy blue color iris and limited to a daylight iris color pattern. Further studies are necessary to determine the nature of this anomaly and its potential consequences for the specimen and the species.

Keywords: *Amphibia; Bahia; eye coloration abnormal; northern and southern coast; ocular anomaly.*

Primeiro registro de heterocromia ocular na perereca *Boana albomarginata* (Spix, 1824) (Anura: Hylidae), Mata Atlântica, nordeste do Brasil

Resumo: A literatura científica sobre anomalias em anfíbios é vasta, mas casos registrados de heterocromia ocular em anfíbios estão quase ausentes, mesmo considerando registros anedóticos. No território brasileiro, apenas dois casos de heterocromia ocular foram registrados anteriormente para anfíbios, ambos para anuros, o primeiro para a Mata Atlântica do nordeste do Brasil e o segundo para a região amazônica do norte do Brasil. No presente relato, descrevemos dois casos de heterocromia ocular no hílideo *Boana albomarginata*, ambos no bioma Mata Atlântica, estado da Bahia, nordeste do Brasil, representando o primeiro registro de heterocromia ocular para esta espécie e o terceiro caso registrado para uma espécie de anfíbio no Brasil. Um olho de cada exemplar observado apresentava atipicamente íris de cor azul chamativa e homogênea, preenchendo toda sua superfície ou apenas a metade inferior, representando casos de heterocromia completa e setorial, respectivamente. Além disso, a não-usual íris azul só esteve detectável sob a luz do dia, quando a cor de fundo da íris era branca. À noite, a cor de fundo padrão da íris cobreada ou dourada permaneceu inalterada e a cor azul não pôde ser detectada. Nenhuma outra anomalia detectável ou comportamento incomum foi observada para ambos os exemplares. Este

é o primeiro relato de heterocromia ocular em anfíbios representado por uma cor azul bem-marcada e limitada a um padrão diurno de cor da íris. Mais estudos são necessários para determinar a natureza desta anomalia e suas potenciais consequências para o indivíduo e para a espécie.

Palavras-chave: *Amphibia*; *anomalia ocular*; *Bahia*; *coloração do olho anormal*; *litoral sul e norte*.

Introduction

The possible relationship between the decline in amphibians' populations, morphological anomalies, and external anthropogenic factors has worldwide increased the interest of researchers in registering (e.g., Szkudlarek 2020, Rebouças et al. 2021a, b) and reviewing (e.g., Ouellet 2000, Henle and Dubois 2017, Souza et al. 2021) several types of anomalies, their potential causes, and consequences in this taxonomic group. Anomalies can be due to genetic and congenital causes but also induced by external factors like exposure to chemical pollutants, ultraviolet radiation, predators, and parasites (Henle and Dubois 2017), highlighting the importance of mapping their geographical occurrences within animal conservation efforts. Nevertheless, anomalies in amphibians' natural populations are still underestimated (Souza et al. 2021), and their respective causal factors remain insufficiently understood (Henle and Dubois 2017).

Among non-skeleton morphological anomalies in amphibians, there is the 'color anomalies' category of Henle and Dubois (2017), in which the most usual are albinism, blue individuals, erythrism, flavism, melanism, translucent skin, and black-eyedness. On the other hand, the current knowledge on amphibians' ocular heterochromia is almost absent in the literature (e.g., Lourenço-de-Moraes et al. 2013, Pedroso-Santos et al. 2022, Alvarez et al. 2023), even considering anecdotal records, even though the scientific literature on amphibian anomalies is huge (Henle and Dubois 2017). In the Brazilian territory, only two cases were formerly registered for amphibians, both for anurans, one for the hyliid treefrog *Nyctimantis arapapa* (Pimenta, Napoli and Haddad, 2009) from the Atlantic Forest of Bahia state, northeastern Brazil (Lourenço-de-Moraes et al. 2013), and a second case for the hyliid treefrog *Osteocephalus oophagus* Jungfer and Schiesari, 1995, from the Amazonian region of northern Brazil (Pedroso-Santos et al. 2022).

The ocular heterochromia is related to color differences in the iris, may include only one eye (uniocular) or both eyes (binocular), and may be complete (the iris ring of one eye has a distinct color from the other eye) or partial (Gladstone 1969). The partial heterochromia is usually subdivided into sectoral and central (Saniasiaya 2020). In the sectoral heterochromia, just one portion of the iris has a distinct color. In the central heterochromia, there is a ring around the pupil of distinct colors or spikes of various color tones emanating from the pupil (Gladstone 2021). The heterochromia is mostly sporadic and benign, a consequence of genetic and congenital alterations not accompanied by other detectable anomalies, but specific syndromes may be associated to it, as known in humans (e.g., Saniasiaya 2020, Silva et al. 2021) and in other animals (e.g., Macy et al. 1972, Chomdej et al. 2018). It also may be acquired due to diseases or injuries such as trauma in the eyes, intraocular foreign bodies, benign tumors, diabetes mellitus, melanoma, ocular siderosis, and iritis or uveitis, all registered in humans (Silva et al. 2021).

In the present account, we report two cases of ocular heterochromia in the treefrog *Boana albomarginata* (Spix, 1824), both from the

Atlantic Forest biome, Bahia state, northeastern Brazil, representing the first record of ocular heterochromia for this species and the third case registered for an amphibian's species in the Brazilian territory.

Material and Methods

Description of the morphological parts of anuran eyes follows Glaw and Vences (1997). After the photograph sections, the two captured specimens of *Boana albomarginata* were released at their original sampling areas. Geographical coordinates and elevations were obtained using Global Positioning Systems (GPS), with WGS84 datum, and mapped using the software QGIS ver. 3.4 (QGIS.org 2018). The satellite images of the sampling areas were obtained using Google Earth (2024).

The first observation of heterochromia for *B. albomarginata* was from an adult specimen captured in Itanagra municipality, northern coast of Bahia state, Brazil, in a stretch of the Highway BA-504 known as Green Line (12°20'22.063" S, 37°57'57.636" W, 39 m asl, WGS84 datum), on 25 January 2021, at 08:41 h, by IVM (Figure 1A). The specimen was released at 12°20'21.095" S 37°57'56.858" W, 39 m asl, WGS84 datum, at 08:51 h, on 25 January 2021, by IVM (Figure 1A). The sampling area was characterized as a dense ombrophilous forest fragment (*sensu* IBGE 2004) at the medium regeneration stage, surrounded by eucalyptus plantations (*Eucalyptus grandis* and *E. urophylla*), and directly impacted by vegetation suppression for both highway implementation and forestry and pesticides in the latter. The forest edge consisted of small shrubs and medium-sized arboreal vegetation, with damp areas and floods near a small watercourse.

The second observation of heterochromia for *B. albomarginata* was from an adult specimen from Ponta da Tulha (14°36'06.5" S 39°03'22.8" W, 9 m asl, WGS84 datum), Aritaguá district, Ilhéus municipality, southern coast of Bahia state, Brazil, on 27 March 2023, at 19:13 h, by EL (Figure 1B). The sampling area was a clay road near the sea, an anthropized area with coconut plantations near ombrophilous forest fragments, both with pluvial water bodies on the ground.

The usual diurnal and nocturnal eye color patterns of *B. albomarginata* were characterized by us using 74 photographs from ten live specimens from the Brazilian states of Bahia, Espírito Santo, and Sergipe, all available in the images database of the "Laboratory of Taxonomy and Natural History of Amphibians (AMPHIBIA)" housed in the Federal University of Bahia (UFBA), Biology Institute, municipality of Salvador, Bahia state, Brazil.

Results and Discussion

The usual nocturnal eye color of *Boana albomarginata* is characterized by an ovoid horizontal black pupil externally bordered by a narrow brown (copper/golden) color band from the iris. The iris background color varies between individuals, but it can be generalized as an amalgamation of brown color (copper/golden) with white areas of different extensions marbled with thin black vermiculation. The

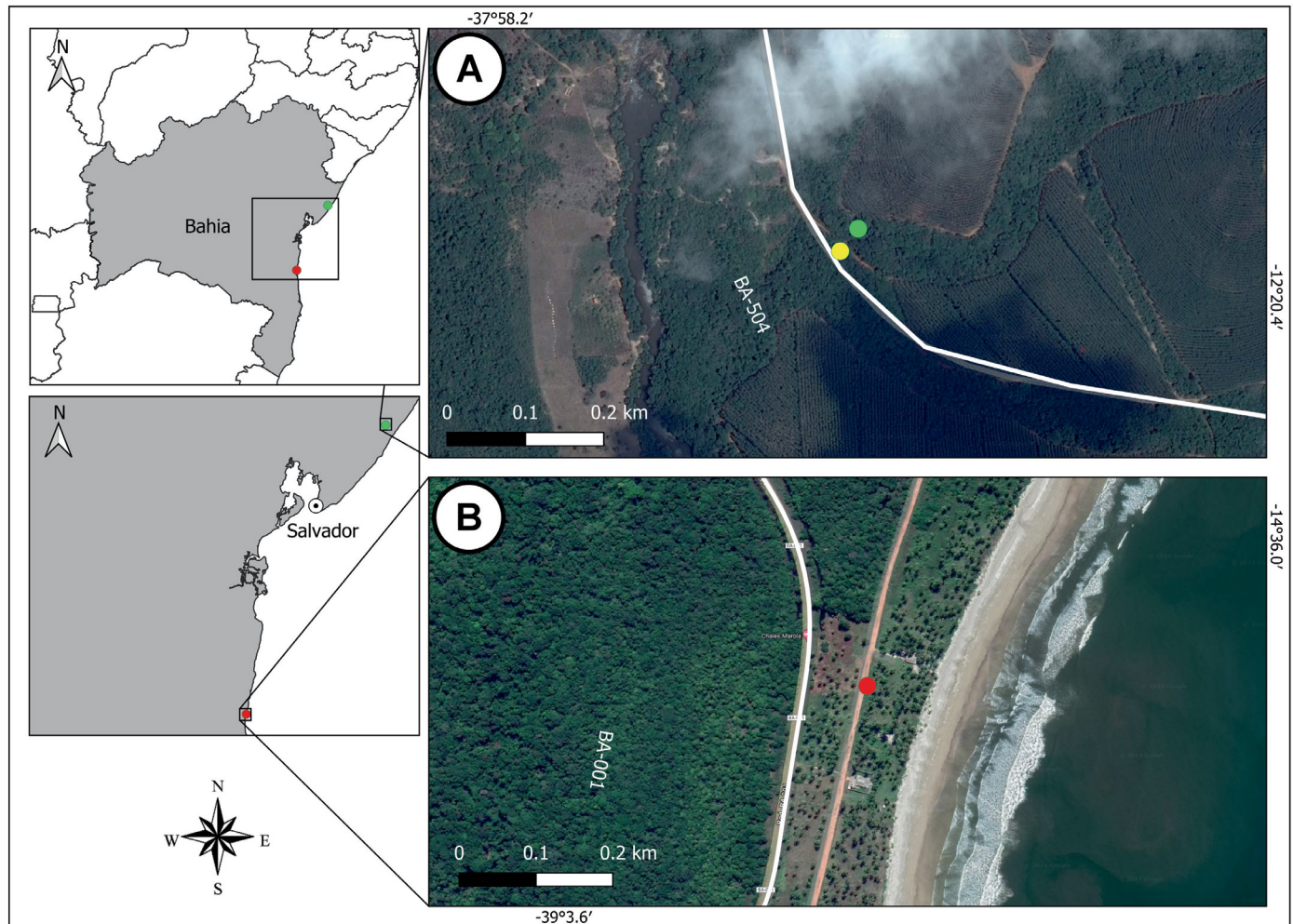


Figure 1. Geographical distribution map and satellite photographs for the sampling localities of *Boana albomarginata* representing the two registered cases of ocular heterochromia. The red and green circles represent the sampling points of *B. albomarginata*, and the yellow circle represents the exact specimen release point in the Itanagra municipality, Bahia state, Brazil. The exact release point of the specimen from the Ilhéus municipality is unknown.

iris's periphery is delimited by a black ring, and the eye periphery by a greenish blue ring (Figure 2A, B). In the diurnal phase, the pupil becomes a thin horizontal black line dividing the iris into two halves that may become white, with or without black vermiculation (Figure 2C, D). This latter condition was already briefly described by B. Lutz (1973) as a sleep condition, and it is a response to the amount of light that reaches the retina (Glaw and Vences 1997). The tadpole of *B. albomarginata* has an iris of copper background color maculated by black vermiculation (Peixoto and Cruz 1983).

The specimen of *B. albomarginata* from the Bahia's northern coast was active, camouflaged over the foliage of herbaceous vegetation at the forest edge, and was not vocalizing (the specimen was released before sex identification). In the morning, the treefrog had one eye with a different iris color from the usual species pattern. The right eye had an entirely white iris (Figure 2E, F), coinciding with the species diurnal color pattern (Figure 2C). However, the iris from the left eye was of an unusually full and homogeneous flashy blue color (Figure 2E, F) of a similar color tone to the species' usual greenish-blue ring of the eye periphery (Figure 2A–C). The iris's periphery was delimited

by a remarkable black ring, as usually seen for the species, but the greenish-blue ring of the eye periphery was less visible. No observation in loco or photographs of this specimen at night were available. We identified this condition as an unioocular complete heterochromia. No other detectable anomalies and unusual specimen behavior were observed by IVM in loco or through our visual inspection of photographs. There were no other syntopic anurans with this specimen of *B. albomarginata*, but considering the overall sampling area, none of the remaining 43 registered anurans' specimens by IVM visually had external morphological anomalies, including another individual of *B. albomarginata*.

The specimen of *B. albomarginata* from the Bahia's southern coast was found at night when the animal jumped on the car where EL was traveling on a strong rainy day. The treefrog was captured to avoid accidental injuries, photographed, and then released in the same area at 21:30 h (the specimen was released without sex identification). The photographs immediately taken after its encounter, at night and in the dark (Figure 2G), revealed the typical nocturnal eye color pattern above described for *B. albomarginata* (Figure 2A, B), but with a distinct small

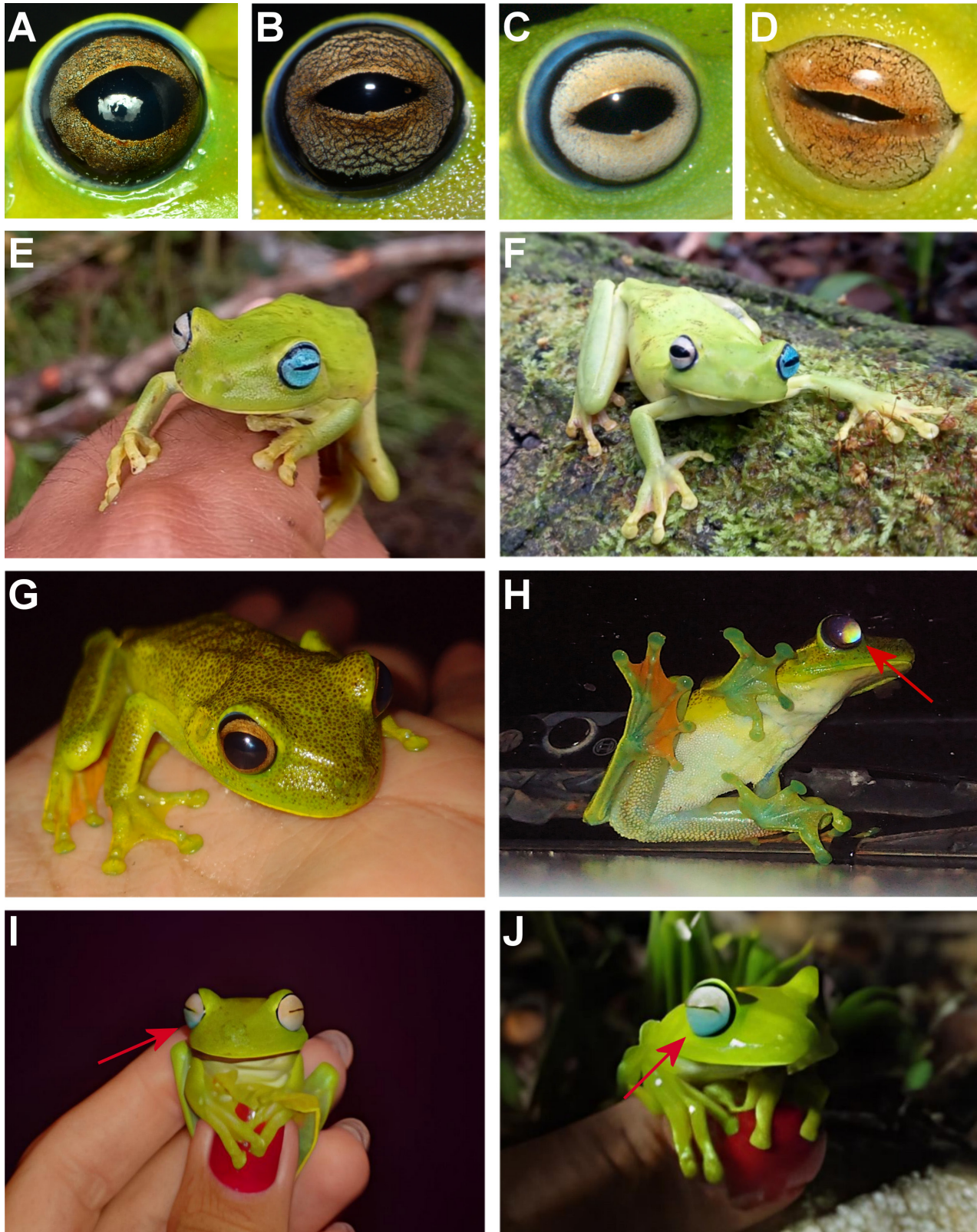


Figure 2. Eye color patterns from adult live specimens of *Boana albomarginata* from northeastern Brazil. A–B, usual color patterns observed at night or in the dark: A, Capela municipality, Sergipe state; B, Esplanada municipality, Bahia state. C–D, usual color patterns observed in the morning or after a period of exposition to light: C, Ilhéus municipality, Bahia state; D, São Roque do Paraguaçu district, Maragogipe municipality, Bahia state. E–F, a specimen with complete ocular heterochromia from Itanagra municipality, northern coast of Bahia state, Brazil, photographed in the morning at about 08:40 h. G–H, a specimen with sectoral ocular heterochromia from Ponta da Tulha, Ilhéus municipality, Bahia state, photographed between 19:00 and 21:00 h: G–H, photographs taken in the dark immediately after its capture; I–J, photographs were taken after two hours of exposition to fluorescent white light. The red arrows indicate the flashy blue area on the iris. Photographs: A–D, Rafael O. Abreu; E–F, Iuri V. Melo; G–J, Ester Lacerda.

translucid blue area visible across the pupil at the lower half of the right eye (Figure 2H). During the specimen's exposition to fluorescent white light for a period of about 2h30min (ca. 19:30 to 21:00 h), the iris became white in both eyes (Figure 2I, J) like the known diurnal iris color pattern for the species (Figure 2C), but in the right eye, the lower half of the iris turned to an unusual flashy blue color. This blue color tone resembles the reflexive blue color revealed in Figure 2H and the blue-colored iris of the specimen from Bahia's northern coast (Figure E, F). A black ring delimited the iris's periphery, and the greenish-blue ring in the eye's periphery was poorly discernible. No other detectable anomalies and unusual specimen behavior were observed in loco by EL or through our visual inspection of photographs. We identified this condition as unioocular sectoral heterochromia, only noticeable when the iris became white.

The ocular heterochromia registered for *Nyctimantis arapapa* by Lourenço-de-Moraes et al. (2013) included a juvenile (unioocular sectoral heterochromia, Figure 2A of Lourenço-de-Moraes *op. cit.*) and a second juvenile (binocular heterochromia, not figured in Lourenço-de-Moraes *op. cit.*), represented by an unusually blue colored iris following the authors; yet, the authors also stated that the remaining metamorphic treefrogs, juveniles, and an adult male had red colored iris (figures 2B–C of Lourenço-de-Moraes *op. cit.*). Even so, our visual inspection of the iris from the referred Figure 2A did not reveal the flashy blue color pattern observed in the iris color of *B. albomarginata*, but instead, a faded white reddish iris mainly in its upper half and depigmented to white color in its lower half, what could be identified within the “eye discoloration category” of Lannoo (2008) described as “iris pigment discolored or missing.” This pattern of unioocular heterochromia in adult specimens of *N. arapapa* is usual for the species on the southern coast of the Bahia state, with a frequency of around 30% of the adult specimens already registered (Mirco Solé, personal communication). This information is important because if the local prevalence of anomalies in an amphibian's natural local population crosses a 5% threshold (Blaustein and Johnson 2003), at any time when it was sampled, a hotspot for malformed frogs could be established, as proposed by the Minnesota Pollution Control Center (see Lannoo *op. cit.* for examples and discussion on the identification of hotspots for malformed frogs). Considering that one specimen of *B. albomarginata* displaying ocular heterochromia was also found in the Ilhéus municipality, external factors should not be neglected as potential causes. On the other hand, local populations of *N. arapapa* are somewhat ecologically isolated within its limited geographic distribution, which could contribute to inbreeding and the high prevalence of ocular heterochromia in the species (M. Solé, personal communication). This latter statement could not be argued for *B. albomarginata* because the known prevalence for the species is low, as only two cases are known up till now, and the species is widespread along the Atlantic Forest, from southern to northeastern Brazil (Frost 2024).

The complete unioocular heterochromia registered for the adult specimen of *Osteocephalus oophagus* by Pedroso-Santos et al. (2022) clearly showed an unusually white-colored iris in the right eye contrasting to a typically yellow-colored iris in the left eye (Figure 1B of Pedroso-Santos et al. 2022). The specimen was found at about 11:30 h, and the photograph session was taken the next morning. However, the unusual white iris's coloration was also observed at night in the dark (Fillipe Pedroso-Santos, personal communication). It deserves

to be highlighted that the heterochromia condition in both specimens of *B. albomarginata* (this study) and the specimen of *O. oophagus* had a white iris background color performing as, or contrasting to, the unusually colored iris, all cases including direct exposition to light at some moment.

The search for causes and consequences of the heterochromia registered for *B. albomarginata* herein exceeds the purpose of this anecdotal report. Nevertheless, we highlight that due to the unknown iris's flashy blue color within the available data on amphibians' ocular heterochromia and its singular property of being restricted to a diurnal color pattern, this special case of ocular heterochromia deserves clarification regarding its physiological nature and potential consequences for its owners and the local population. Finally, a potential common extrinsic factor driving both cases of heterochromia in the species should not be prematurely rejected because both individuals were from anthropized areas bordered by silviculture that may use pesticides and other toxic agents. Therefore, analyzing each population to seek other cases and common extrinsic factors mediating the related heterochromia under a robust experimental design will be important.

Acknowledgments

We acknowledge the Prime Ambiental Ltda. for allowing us to use data from the “Execution report of the fauna's drive away and rescue plan in the implementation works of the BA-504 highway section (Itanagra/BA – Linha Verde)”, and to all company's employees for logistical and technical support. We are grateful to Gustavo Brito (Federal University of Maranhão – UFMA) for producing the distribution maps; Mirco Solé Kienle (Santa Cruz State University - UESC) for valuable comments on *Nyctimantis arapapa*; Fillipe Pedroso-Santos (Federal University of Amapá – UNIFAP) for additional data on the ocular heterochromia registered for *Osteocephalus oophagus*; and Rafael Oliveira de Abreu (Federal University of Bahia - UFBA) for photographs of *Boana albomarginata*. IVM thanks Rafael O. Abreu (UFBA) and Clara Loiola (UFMA) for the initial encouragement and valuable suggestions for the first manuscript version. MFN thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico for his productivity grant (CNPq 314496/2021-1). WF thanks the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior for his master fellowship (CAPES 88887.804225/2023-00). The Instituto do Meio Ambiente e Recursos Hídricos for the authorization of animal management and transport (INEMA ordinance number 16.590, process number 2014.001.001068/INEMA/LIC-01068).

Associate Editor

Denise de Cerqueira Rossa-Feres

Author Contributions

Iuri Vieira de Melo: conceptualization, formal analysis, methodology, investigation, writing original draft, and writing review and editing.

Ester Lacerda Correia de Quintela: methodology, investigation, and writing review and editing.

Wellington Farias: conceptualization, formal analysis, writing original draft, and writing review and editing.

Mariana Ávila Caribé: funding acquisition, project administration, and writing review and editing.

Cássio Lopes Lins: funding acquisition, project administration, and writing review and editing.

Felipe Paganelly Maciel da Silva: funding acquisition, project administration, and writing review and editing.

João Cláudio Cerqueira Viana: funding acquisition, project administration, and writing review and editing.

Marcelo Felgueiras Napoli: conceptualization, formal analysis, investigation, writing original draft, and writing review and editing.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

All data are available in the paper.

References

- ALVAREZ, A.J., DRYER, T., ANDERSON, R., AHMED, B., BYLIN, S., CASBY, A., DALEY, J., FALICKI, M., FEE, M., FREEMAN, A., GAUDIO, J., GRAVES, J., HAMILTON, C., HERRERA, K., JACKSON, I. & ZIMMERMAN, M. 2023. A case of idiopathic ocular heterochromia in *Ensatina eschscholtzii xanthoptica* Stebbins, 1949, in northern California, USA. *Herpetology Notes* 16:49–50. <https://www.biotaxa.org/hn/article/view/75641>.
- BLAUSTEIN, A.R. & JOHNSON, P.T.J. 2003. The complexity of deformed amphibians. *Frontiers in Ecology and Environment* 1(2):87–94.
- CHOMDEJ, S., LEEAWATTANAKUL, P., BUDDHACHAT, K., PRADIT, W., SIENGDEE, P., PHONGROOP, K. & NGANVONGPANIT, K. 2018. Preliminary study on association of EDNRB gene with heterochromia iridis in cats (*Felis catus*). *Kafkas Universitesi Veteriner Fakültesi Dergisi* 24(6):853–858. <https://doi.org/10.9775/kvfd.2018.20082>.
- FROST, D.R. 2024. Amphibian species of the world: an online reference. Version 6.2 (16 February 2024). Electronic Database accessible at <https://amphibiansoftheworld.amnh.org/index.php>. American Museum of Natural History, New York, USA. <https://doi.org/10.5531/db.vz.0001>.
- GLADSTONE, R.M. 1969. Development and significance of the heterochromia of the iris. *Archives of Neurology* 21(2):184–192. <https://doi.org/10.1001/archneur.1969.00480140084008>.
- GLADSTONE, J. 2021. An overview on heterochromia iridum. *Journal of Clinical Ophthalmology* 5(5):457. <https://www.alliedacademies.org/articles/an-overview-on-heterochromia-iridum.pdf>.
- GLAW, F. & VENCES, M. 1997. Anuran eye colouration: definitions, variation, taxonomic implications and possible functions. In W. BOHEME, W. BISCHOFF and T. ZIBGLER, (Eds.) *Herpetologia Bonnensis*, (pp. 125–138). https://amphibiaweb.org/refs/pdfs/Glaw_and_Vences_1997.pdf.
- GOOGLE EARTH. 2024. Map showing the location of the sampling points of *Boana albomarginata* specimens with ocular heterochromia. Map data ©2024 Maxar Technologies and CNES/Airbus. *Google Earth*, <http://earth.google.com/web/>.
- HENLE, K., DUBOIS, A. & VERSHININ, V. 2017. A review of anomalies in natural populations of amphibians and their potential causes. *Mertensiella* 25:57–164.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. 2004. Mapa de vegetação do Brasil, 1:5.000.000. https://geoftp.ibge.gov.br/informacoes_ambientais/vegetacao/mapas/brasil/vegetacao.pdf.
- LANNOO, M. 2008. *Malformed frogs: the collapse of aquatic ecosystems*. University of California Press.
- LOURENÇO-DE-MORAES, R., LANTYER-SILVA, A.S.F., TOLEDO, L.F. & SOLÉ, M. 2013. Tadpole, oophagy, advertisement call, and geographic distribution of *Aparasphenodon arapapa* Pimenta, Napoli, and Haddad, 2009 (Anura, Hylidae). *Journal of Herpetology* 47(4):575–579. <https://doi.org/10.1670/11-326>.
- LUTZ, B. 1973. *Brazilian species of Hyla*. University of Texas Press.
- MACY, R.M., STANLEY, A.J. & GUMBREK, L.G. 1972. Genetic factors involved in heterochromia in the Norway rat. *Journal of Heredity* 63(4):189–190. <https://doi.org/10.1093/oxfordjournals.jhered.a108271>.
- OUELLET, M. 2000. Amphibian deformities: current state of knowledge. In D.W. SPARLING, G. LINDER, and C.A. BISHOP, (Eds.) *Ecotoxicology of amphibians and reptiles* (pp. 617–661). SETAC Press.
- PEDROSO-SANTOS, F., ANAISSI, J.S.C., DE LIMA, P.H.G. & COSTA-CAMPOS, C.E. 2022. Ocular anomalies in two species of *Osteocephalus* (Anura: Hylidae) from the Amazonian region of northern Brazil. *Phyllomedusa: Journal of Herpetology* 21(2):211–214. <https://doi.org/10.11606/issn.2316-9079.v21i2p211-214>.
- PEIXOTO, O.L. & CRUZ, C.A.G. 1983. Girinos de espécies de *Hyla* do grupo “albomarginata” do sudeste brasileiro (Amphibia, Anura, Hylidae). *Arquivos da Universidade Federal Rural do Rio de Janeiro* 6(2):155–163.
- QGIS.ORG. 2018. *QGIS Geographic Information System*. Version 3.4. Open Source Geospatial Foundation Project. <http://qgis.org>.
- REBOUÇAS, R., BECKER, C.G., BACON, J.P. & TOLEDO, L.F. 2021a. Anthropogenic habitat modification linked to deformities in Cururu Toads from Fernando de Noronha. *Salamandra* 57(3):389–399.
- REBOUÇAS, R., da SILVA, H.R. & SOLÉ, M. 2021b. Malformations in insular and coastal populations of toads in Rio de Janeiro, Southeastern Brazil. *South American Journal of Herpetology* 14(1):12–18. <https://doi.org/10.2994/SAJH-D-17-00031.1>.
- SANIASIAYA, J. 2020. Heterochromia iridis: more than beautiful eyes. *Postgraduate Medical Journal* 96(1141), 721. <https://doi.org/10.1136/postgradmedj-2020-137621>.
- SILVA, L.F., LIMA, A.S.B., DALL’OGLIO, C.F. & HALLAL-JR, R.J. 2021. Heterochromia de íris: uma revisão das condições que podem afetar a pigmentação iridiana. *Revista Brasileira de Oftalmologia* 80(6):e0050. <https://doi.org/10.37039/1982.8551.20210050>.
- SOUZA, F.C., SILVA, A.L.F., ANJOS, C.S., ESTEVINHO, T.F., LISBOA, M.O. & MENIN, M. 2021. New records of morphological anomalies in anurans, with a review for Brazil. *Herpetology Notes* 14:31–41. <https://www.biotaxa.org/hn/article/view/62505>.
- SZKUDLAREK, M. 2020. Ocular anomalies in four species of European toad. *Herpetological Bulletin* 154:26–28. <https://doi.org/10.33256/hb154.2628>.

Received: 23/02/2024

Accepted: 24/06/2024

Published online: 29/07/2024