

SHORT COMMUNICATION

Ocular abnormalities in two sympatric salamanders (Caudata: Plethodontidae) in a pine-oak forest of La Malinche National Park, Mexico

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Palabras clave: Anfibios endémicos, Anoftalmia, Anomalías, *Aquiloerycea cephalica*, Ausencia ocular, *Pseudoeurycea leprosa*.

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Abnormalities are permanent structural defects caused by errors in the morphogenesis of organisms due to genetic factors (flawed genes), epigenetic factors (e.g., contamination, poor nutrition), and physical trauma (Lannoo 2008, Sánchez-Domene *et al.* 2018, Ferreira *et al.* 2019). Abnormalities have been described in various structures (e.g., the spine, limbs, toes and fingers, head, jaw, skin color, and eyes), and each one arises during different periods of development; for example, in the embryonic period, prior to or during metamorphosis (Sánchez-Domene *et al.* 2018).

In amphibians, most cases of malformations have been primarily documented in anurans (Lannoo 2008, Ferreira *et al.* 2019, Bosch *et al.* 2021, Venerozo-Tlazalo *et al.* 2022); nevertheless,

this could be related to the fact that salamanders and caecilians exhibit more cryptic habits that make them less detectable (Davic and Welsh Jr. 2004, Gower *et al.* 2004, Müller *et al.* 2020, Cante-Bazán 2022). In Mexico, the documentation of malformations in salamanders is scarce in comparison to anurans (Cruz-Pérez *et al.* 2009, Soto-Rojas *et al.* 2017, Venerozo-Tlazalo *et al.* 2022), and the malformations most frequently observed are associated with frog limbs (Aguillón-Gutiérrez and Ramírez-Bautista 2015, Monroy-Vilchis *et al.* 2015, Domínguez-Moreno *et al.* 2018, Carmona-Zamora *et al.* 2020, Reyes-Servín and Díaz-García 2023). Ocular abnormalities have been recorded in salamanders in only two studies (Díaz-García *et al.* 2019, Venerozo-Tlazalo *et al.* 2022). We present the first records of abnormalities in two species of salamanders that inhabit in sympatry in a temperate forest of Mexico.

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Aquiloerycea cephalica (Cope, 1865) and *Pseudoeurycea leprosa* (Cope, 1869) are plethodontid salamanders endemic to Mexico. They are distributed in mountainous regions of the Transmexican Volcanic Belt, Sierra Madre del Sur, and the Gulf of Mexico. In addition, the species share their distribution in the state of México, México City, Veracruz, and Hidalgo, and coexist in sympatry in the La Malinche mountain, located between the states of Puebla and Tlaxcala (Ramírez-Bautista and Arizmendi 2004, Díaz de la Vega-Pérez *et al.* 2019, Frost 2023). They are considered by the International Union for Conservation of Nature in the category of least concern (IUCN 2016, 2020); nevertheless, both species are listed as threatened in accordance with national laws (Norma Oficial Mexicana-059-SEMARNAT-2010; DOF 2019).

During the sampling to determine the population size of *P. leprosa*, on 06 August 2020, we collected an *A. cephalica* hatchling that presented a case of proptosis. In this case, the right eye was notably swollen and protruding from its orbital socket, possibly due to trauma (Figure 1A). On the other hand, on the 07 August 2020, we recorded another hatchling of *P. leprosa* without the presence of the right eye and with the orbital socket reduced and completely covered by tissue, indicating anophthalmia (Figure 1B). We found a total of 153 individuals of *P. leprosa* and just one presented an abnormality; in the case of *A. cephalica*, we did not record the number of individuals, and the encounter with the individual with malformation was fortuitous. We found both organisms actively moving in leaf litter within a pine-oak forest located in La Malinche mountain, Mexico (19°17'34.7" N, 98°02'28.8" W) and released them after examination.


Abnormalities in amphibians have been the subject of growing concern. Some of the causes that give rise them include contamination by heavy metals and pesticides, fungal infections (*Batrachochytrium dendrobatidis* Longcore, Pessier, and D. K. Nichols, 1999 and *Batrachochytrium salamandrivorans* A. Martel,



Figure 1. (A) Lateral view of the ocular malformation observed in *Aquiloerycea cephalica*. (B) Dorsolateral view of the case of anophthalmia in *Pseudoeurycea leprosa*. La Malinche National Park, Mexico. The arrow indicates the malformation in the individual.

M. Blooi, F. Bossuyt, F. Pasmans, 2013), and parasitism, such as that caused by flukes of the *Ribeiroia* genus (Lannoo 2008, Aguillón-Gutiérrez and Ramírez-Bautista 2015, Monroy-Vilchis *et al.* 2015, Silva 2022). However, although it has been suggested that ocular abnormalities are linked to teratogenic agents, such as UVB radiation, nickel contamination, and hybridization (Rengel *et al.* 1994, Ouellet 2000), the causes have not been explored as widely as those related to bone structure and limbs (Ouellet 2000). Additionally, there is the difficulty of identifying the potential agents responsible for the abnormalities in the field. In this regard, some authors suggest that this type of abnormalities could arise due to natural mutation rates (Sánchez-Domene *et al.* 2018) or as a result of failed predation attempts (Ferreira *et al.* 2019).

Although we could not determine the causes of the observed abnormalities, these observations represent the first report of ocular anomalies in the two sympatric species of the family Plethodontidae inhabiting a temperate forest in Mexico. Furthermore, they constitute the first record of anomalies in salamanders for the state of Puebla, and are significant as they exemplify the repercussions of disturbances impacting the health of ecosystems for Mexican amphibians, particularly plethodontids. They have the potential to guide future investigations in this region aimed at determining the presence of these and other abnormalities, as well as uncovering their underlying causes. This, in turn, will contribute to a better understanding of the physiological and morphological health of salamanders and amphibians in general.

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