REPTILES & AMPHIBIANS

Anophthalmia in a Greater Stream Horned Frog, *Xenophrys major* (Boulenger 1908), from Tamdil National Wetland, Mizoram, India: Pollution-induced or Predator-mediated?

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Despite being a source of human curiosity for centuries (e.g., Wurffbain 1683; Vallisneri 1706; De Superville 1740; Geoffroy Saint-Hilaire 1832, 1836), interest in amphibian anomalies in natural populations really came on the scene about 150 years ago (Henle and Dubois 2017). Increased environmental awareness, the global decline of amphibians (e.g., Henle and Streit 1990; Stuart et al. 2004), and the recent rediscovery of populations exhibiting mass anomalies (Burkhart et al. 2000; Souder 2002; Lannoo 2008, 2009) have instigated renewed interest in amphibian anomalies as potential indicators of environmental perturbations, with potential implications for human health (e.g., Tyler 1983; Burkhart et al. 2000; Ouellet 2000; Souder 2002; Vershinin 2002). Malformations represent primary errors in development, errors in chemical communication or translation of genetic information (Meteyer 2000). Johnson et al. (2001) described malformation as abnormal development triggered when external factors affect metamorphosis, disrupt hormonal systems (Orton and Tyler 2015), and cause permanent structural defects. Anophthalmia, a common ocular malformation in amphibians, is characterized by the absence of one or both eyes (Meteyer 2000; Mitchell et al. 2004; Ramalho et al. 2017). Herein I report anophthalmia (missing eye) in a Greater Stream Horned Frog (*Xenophrys major*).

Xenophrys major, listed by the IUCN as being of Least Concern (LC) (van Dijk et al. 2004), is known definitely

Fig. 1. Anophthalmia in a Greater Stream Horned Frog (*Xenophrys major*) in the Tamdil National Wetland, Mizoram, India. Photograph by H.T. Lalremsanga.

Fig. 2. Stream microhabitat of Greater Stream Horned Frogs (*Xenophrys major*) in the Tamdil National Wetland, Mizoram, India. Photograph by H.T. Lalremsanga.

Reptiles & Amphibians ISSN 2332-4961
https://doi.org/10.17161/randa.v29i1.16451

only from northeastern India (Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, and Nagaland), although currently undelimited members of the species complex are found from northeastern India through Myanmar and western Thailand to the highlands of Laos and Vietnam as well as China and extreme northeastern Cambodia (Frost 2022). It exclusively inhabits evergreen forest areas, breeds in streams, and tadpoles live in clear, swift-flowing streams during monsoons and in perennial rain climates (van Dijk et al. 2004). After a shower at 1900 h on 11 September 2015 during a herpetofaunal survey in the Tamdil National Wetland in Saitual District, Mizoram, India (23.741219°N, 92.948176°E; 910 m asl), I encountered an anophthalmic adult male *Xenophrys major* (SVL 70.4 mm) sitting on an exposed boulder in a stream (Fig. 1). The left eye was completely absent, although the upper eyelid covered the orbit. The frog appeared to be healthy and was active. As no signs of injury were detected, I assumed that the loss of the eye was not a recent incident. To the best of my knowledge, this is the first recorded case of anophthalmia in *Xenophrys major*. The specimen was collected and deposited in the Departmental Museum of Zoology, Mizoram University (MZMU2059).

Regmi et al. (2021) noted that malformations often are caused by environmental factors that affect development during larval stages and that the worldwide degree of variation in malformations suggests multiple causes. Major causes that have been identified include alien species, overexploitation, environmental degradation, UV radiation, contaminants, and diseases (e.g., Ouellet 2000; Alsop et al. 2004; Hussain and Pandit 2012; Henle et al. 2017). Of these, however, environmental degradation and pollution, especially from the agricultural sector, appear to be the major causes of malformation (Ouellet et al. 1997; Britson and Threlkeld 1998; Marco et al. 1999; Sparling et al. 2015; Koleshka and Jablonski 2016). Unlike the previous reports of anopthalmia in the Common Asian Toad (*Duttaphrynus melanostictus*) and the Marbled Globular Frog (*Uperodon systoma*), for which the trigger was thought to be surface runoff from agricultural fields sprayed with pesticides or other environmental pollutants (Ashaharraza and Mahapatra 2020; Regmi et al. 2021), the present incident occurred in a pristine forest in a protected area (Fig. 2). Moreover, no agricultural areas exist around the hilly catchment area of the stream or the headwaters of tributaries. Also, recent reports of hindlimb anomalies in other anurans (Nagaland Montane Torrent Toad, *Duttaphrynus chandai*; Mawphlang Odorous Frog, *Odorrana mawphlangensis*; and Tamenglong Horned Frog, *Xenophrys numhbumaeng*) from the Hmuifang Community Reserve Forest (Siammawii et al. 2021a, 2021b, 2021c) and in skinks (Indian Forest Skink, *Sphenomoorphus indicus*, and Spotted Forest Skin, *S. maculatus*) from the core area of the Dampa Tiger Reserve (Decemson et al. 2021) were in uncontaminated areas. Many authors have reported that anophthalmia in tadpoles can result from attacks by predators (e.g., Martof 1956; Ballengee and Sessions 2009; Gollmann and Gollmann 2012; Grosse and Simon 2015). Although developmental failure resulting from these may not result in immediate death, deformities often lead to reproductive failure (Hayes et al. 2010) and hence population declines. Although many factors appear to have the potential to cause anomalies in amphibians, the relevance of many of these factors in natural populations is unsettled (Sessions and Ballengee 2010; Skelly and Benard 2010). However, without a clear understanding of the causes of amphibian malformations, any link between malformations and widespread amphibian declines remains uncertain.

Acknowledgements

This work was conducted under a permit for herpetofaunal collection throughout Mizoram (No. A.33011/2/99-CWLW/225) issued by the Chief Wildlife Warden, Environment, Forest and Climate Change Department, Government of Mizoram, India. I acknowledge financial support from the Environment, Forest and Climate Change Department (No. B. 12012/12(2)/2021-DFO-A), Government of Mizoram, Department of Science and Technology (No. DST-SERB/EEQ/2021/000243) and Department of Biotechnology (No. DBT-NER/AAB/64/2017), Ministry of Science and Technology, Government of India, New Delhi.

Literature Cited

Alsop, D.H., S.B. Brown, and G.J. van der Kraak. 2004. Dietary retinoic acid induces hindlimb and eye deformities in *Xenopus laevis*. *Environmental Science & Technology* 38: 6290–6299. https://doi.org/10.1021/es049765n.

Ashaharraza, K. and C. Mahapatra. 2020. Anophthalmia in a Common Asian Toad, *Duttaphrynus melanostictus* (Amphibia: Anura: Bufonidae), from the Eastern Ghats of India. *Reptiles & Amphibians* 27: 44–45. https://doi.org/10.17161/randa.v27i1.14446.

Ballengee, B. and S.K. Sessions. 2009. Explanation for missing limbs in deformed amphibians. *Journal of Experimental Zoology* 312B: 770–779. https://doi.org/10.1002/jez.b.21296.

Britson, C.A. and S.T. Threlkeld. 1998. Abundance, metamorphosis, developmental, and behavioral abnormalities in *Hyla chrysoscelis* tadpoles following exposure to three agrichemicals and methyl mercury in outdoor mesocosms. *Bulletin of Environmental Contamination and Toxicology* 61: 154–161. https://doi.org/10.1007/s001289900742.

Burkhart, J.G., G. Ankley, H. Carpenter, D. Fort, D. Gardiner, H. Gardner, R. Hale, J.C. Helgen, P. Jepson, D. Johnson, M. Lannoo, D. Lee, J. Lary, R. Levey, J. Magner, C. Meteyer, M.D. Shelby, and G. Lucier. 2000. Strategies for assessing the implications of frog malformations for environmental and human health. *Environmental Health Perspectives* 108: 83–90. https://doi.org/10.1289/ehp.0010883.

Decemson, H., M. Vabeiryureilai and H.T. Lalremsanga. 2021. Erster Bericht über Gliedmaßenanomalien bei *Sphenomorphus indicus* (Gray, 1853) und *Sphenomorphus maculatus* (Blyth, 1853) im Dampa Tiger Reserve in Mizoraum, Indien. First report on limb anomalies in *Sphenomorphus indicus* (Gray, 1853) and *Sphenomorphus indicus* (Blyth, 1853) at the Dampa Tiger Reserve in Mizoram, India. *Sauria* 43(3): 69–72.

De Superville, D. 1740. Some reflections on generation, and on monsters, with a

description of some particular monsters. *Philosophical Transaction of the Royal Society of London* 41: 294–307. https://doi.org/10.1098/rstl.1739.0044.

Frost, D.R. 2022. *Amphibian Species of the World: An Online Reference*. Version 6.1. American Museum of Natural History, New York, New York, USA. https://doi.org/10.5531/db.vz.0001. <https://amphibiansoftheworld.amnh.org/index.php>.

Geoffroy Saint-Hilaire, I. 1832. *Histoire Générale et Particulière des Anomalies de l'Organisation chez l'Homme et les Animaux, ouvrage Comprenant des Recherches sur les Caractères, la Classification, l'Influence Physiologique et Pathologique, les Rapports Généraux, les Lois et les Causes des Monstruosités, des Variétés et Vices de Conformation, ou Traité de Tératologie. Tome Premier*. J.-B. Baillière, Paris, France.

Geoffroy Saint-Hilaire, I. 1836. *Histoire Générale et Particulière des Anomalies de l'Organisation chez l'Homme et les Animaux, ouvrage Comprenant des Recherches sur les Caractères, la Classification, l'Influence Physiologique et Pathologique, les Rapports Généraux, les Lois et les Causes des Monstruosités, des Variétés et Vices de Conformation, ou Traité de Tératologie. Tome Deuxième*. J.-B. Baillière, Paris, France.

Gollmann, B. and G. Gollmann. 2012. *Die Gelbbauchunke von der Suhle zur Radspur*. 2. Auflage. Zeitschrift für Feldherpetologie, Beiheft 4. Laurenti Verlag, Bielefeld, Germany.

Grosse, W.-R. and B. Simon. 2015. Feinde und Krankheiten heimischer Lurche und Kriechtiere. *Berichte des Landesamtes für Umweltschutz Sachsen-Anhalt* 4: 597–602.

Hayes, T.B., P. Falso, S. Gallipeau, and M. Stice. 2010. The cause of global amphibian declines: a developmental endocrinologist's perspective. *Journal of Experimental Biology* 213: 921–933. htpps://doi.org/10.1242/jeb.040865.

Henle, K. and A. Dubois (eds.). 2017. Studies on Anomalies in Natural Populations of Amphibians. Untersuchungen zu Anomalien in natürlichen Populationen von Amphibien. *Mertensiella* 25. Supplement zu *Salamandra*. Deutschen Gesellshaft für Herpetologie und Terrarienkunde e.V., Mannheim, Germany.

Henle, K. and B. Streit. 1990. Kritische Betrachtungen zum Artenrückgang bei Amphibien und Reptilien und zu dessen Ursachen. *Natur und Landschaft* 65: 347–361.

Henle, K., A. Dubois, K. Rimpp, and V. Vershinin. 2017. Mass anomalies in green toads (*Bufotes viridis*) at a quarry in Roswag, Germany: inbred hybrids, radioactivity, or an unresolved case?, pp. 185–242. In: K. Henle and A. Dubois (eds.), Studies on Anomalies in Natural Populations of Amphibians. Untersuchungen zu Anomalien in natürlichen Populationen von Amphibien. *Mertensiella* 25. Supplement zu *Salamandra*. Deutschen Gesellshaft für Herpetologie und Terrarienkunde e.V., Mannheim, Germany.

Hussain, Q.A. and A.K. Pandit. 2012. Global amphibian declines: a review. *International Journal of Biodiversity and Conservation* 4: 348–357. https://doi.org/10.5897/IJBC12.008.

Johnson, P.T., K.B. Lunde, E.G. Ritchie, J.K. Reaser, and A.E. Launer. 2001. Morphological abnormality patterns in a Californian amphibian community. *Herpetologica* 57: 336–352.

Koleska, D. and D. Jablonski. 2016. Two cases of unclear hindlimb malformation in *Bombina variegata*. *Ecologica Montenegrina* 9: 56–58. https://doi.org/10.37828/em.2016.9.10.

Lannoo, M.J. 2008. *Malformed Frogs. The Collapse of Aquatic Ecosystems.* University of California Press, Berkeley, California, USA.

Lannoo, M.J. 2009. Amphibian malformations, pp. 3089–3111. In: H. Heatwole and J.W. Wilkinson (eds.), *Amphibian Biology. Volume 8, Amphibian Decline: Diseases, Parasites, Maladies and Pollution*. Surrey Beatty & Sons, Chipping Norton, Australia.

Marco, A., C. Quilchano, and A.R. Blaustein. 1999. Sensitivity to nitrate and nitrite in pond-breeding amphibians from the Pacific Northwest, USA. *Environmental Toxicology and Chemistry* 18: 2836–2839. https://doi.org/10.1002/etc.5620181225.

Martof, B.S. 1956. Factors influencing size and composition of populations of *Rana clamitans*. *The American Midland Naturalist* 56: 224–245. https://doi.org/10.2307/2422457.

Meteyer, C.U. 2000. *Field Guide to Malformation of Frogs and Toads with Radiographic Interpretations*. Biological Science Report 2000-0005. U.S. Geological Survey, Reston, Virginia, USA.

Mitchell, J.C., E. Lanham, M. Kangas, H. Germaine, and W. Brown. 2004. *Plethodon cinereus* (Red-backed Salamander). Anophthalmia. *Herpetological Review* 35: 366.

Orton, F. and C.R. Tyler. 2015. Do hormone-modulating chemicals impact on reproduction and development of wild amphibians? *Biological Reviews* 90: 1100–1117. https://doi.org/10.1111/brv.12147.

Ouellet, M. 2000. Amphibian deformities: current state of knowledge. pp. 617–661. In: D.W. Sparling, G. Linder, and C.A. Bishop (eds.), *Ecotoxicology of Amphibians and Reptiles*. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, Florida, USA.

Ouellet, M., J. Bonin, J. Rodrigue, J.L. DesGranges, and S. Lair. 1997. Hindlimb deformities (ectromelia, ectrodactyly) in free-living anurans from agricultural habitats. *Journal of Wildlife Diseases* 33: 95–104. https://doi.org/10.7589/0090-3558-33.1.95.

Ramalho, W.P., F. Maffei, V. Guerra, D.P. da Silva, L.R. de Matos, and L.J. Vieira. 2017. Anophthalmia in adults of two Amazonian treefrogs (Anura: Hylidae). *The Herpetological Bulletin* 139: 43–44.

Regmi, T., J. Maheta, and D. Prajapati. 2022. Anophthalmia in a Marbled Globular Frog, *Uperodon systoma* (Schneider 1799), in Gujarat, India. *Reptiles & Amphibians* 28: 314–315. https:/doi.org/10.17161/randa.v28i2.15270.

Sessions, S.K. and B. Ballengee. 2010. Explanations for deformed frogs: plenty of research left to do (a reply to Skelly and Benard). *Journal of Experimental Zoology (Molecular and Developmental Evolution)* 314B: 341–346. https://doi.org/10.1002/jez.b.21351.

Siammawi, V., L. Biakzuala, and H.T. Lalremsanga. 2021a. *Duttaphrynus chandai* (Nagaland Montane Torrent Toad). Hindlimb malformation. *Herpetological Review* 52: 823.

Siammawi, V., M.V. Malsawmtluangi, L. Muansanga, L. Biakzuala, and H.T. Lalremsanga. 2021b. Adactyly in a Mawphlang Odorous Frog, *Odorrana mawphlangensis* (Pillai and Chanda 1977) (Ranidae), from Mizoram, India. *Reptiles & Amphibians* 28: 324–325. https://doi.org/10.17161/randa.v28i2.15598.

Siammawi, V., M.V. Malsawmtluangi, L. Muansanga, L. Biakzuala, and H.T. Lalremsanga. 2021c. Brachyphalangy in a Tamenglong Horned Frog, *Xenophrys numhbumaeng* (Mahony, Kamei, Teeling, and Biju 2020) (Megophryidae), from Mizoram, India. *Reptiles & Amphibians* 28: 322–323. https://doi.org/10.17161/randa.v28i2.15245.

Skelly, D.K. and M.F. Benard. 2010. Mystery unsolved: missing limbs in deformed amphibians. *Journal of Experimental Zoology (Molecular and Developmental Evolution)* 314B: 179–181. http://doi.org/10.1002/jez.b.21330.

Souder, W. 2002. *A Plague of Frogs. Unraveling an Environmental Mystery*. University of Minnesota Press, Minneapolis, Minnesota, USA.

Sparling, D.W., J. Bickham, D. Cowman, G.M. Fellers, T. Lacher, C.W. Matson, and L. McConnell. 2015. *In situ* effects of pesticides on amphibians in the Sierra Nevada. *Ecotoxicology* 24: 262–278. https://doi.org/10.1007/s10646-014-1375-7.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783–1786. https://doi.org/10.1126/science.1103538.

Tyler, M.J. 1983. Natural pollution monitors. *Australian Natural History* 21: 31–33.

Vallisneri, A. 1706. *La Galleria di Minerva overo Notizie Universali di Quanto e Stato Scritto da Letterati d'Europa non solo nel presente Secolo, mà ancora ne'già trascorsi, in qualunque materia Sacra, e Profana, Retorica, Poetica, Politica, Istorica, Cronologica, Geografica, Thelogica, Filosofica, Matematica, Medica, Legale, e finalmente in ogni Scienza, e in ogni Arte sì Mecanica come Liberale. Tomo Quinto*. Girolama Albrizzi, Venezia (= Venice), Italy.

van Dijk, P.P., B. Stuart, W. Guanfu, L. Shunqing, Y. Datong, S.U. Sarker, and S. Sengupta. 2004. *Megophrys major*. *IUCN Red List of Threatened Species* 2004: e.T57643A11668731. https://doi.org/10.2305/iucn.uk.2004.rlts.t57643a11668731.en.

Vershinin, V.L. 2002. Ecological specifity and microevolution in amphibian populations in urbanized areas. *Advances in Amphibian Research in the Former Soviet Union* 7: 1–161. https://doi.org/10.18502/kls.v4i3.2119.

Wurffbain, J.P. 1683. *Salamandrologia h.e. Descriptio Historico-Philologico-Philosophico-Medica Salamandræ quæ vulgò in igne vivere creditor, S.R.J. Academiæ Naturæ Curiosis exhibita, atq. Novis aliquot Capitibus, Experimentis, Figurisq;* æri *eleganter incises, nec non Rerum & Verborum Indice adaucta, Studio & Opera.*. Georg Scheurer, Norimbergæ (= Nürnberg), Germany.