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OPINION

Cave-dwelling gastropods of Brazil: a reply to Ferreira et al. (2023)

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ABSTRACT. In 2022, we published an article in this journal entitled "Cave-dwelling gastropods (Mollusca: Gastropoda) of Brazil: state of the art and conservation". In that study, we compiled all the available information about cave-dwelling gastropods in the country, including terrestrial and freshwater species. We focused on the troglobites but also included information regarding some troglophilic species that we deemed worthy of discussion. In 2023, Ferreira et al. also in this journal, raised concerns regarding our article. We respond to their observations here.

KEY WORDS. Conservation endemism, Gastropoda, troglobites, troglophilic species.

We recently published an article in this journal entitled "Cave-dwelling gastropods (Mollusca: Gastropoda) of Brazil: state of the art and conservation" (Salvador et al. 2022). In it, we compiled all the information available about cave-dwelling gastropods in Brazil, including terrestrial and freshwater species. We focused on the troglobites (following the classical definition of Racovitza (1907) grouping species as trogloxenes, troglophiles, and troglobites), but also included information regarding some troglophilic species that we deemed worthy of discussion. The latter include species only known from caves and their immediate vicinity (e.g., *Habeastrum strangei* Simone, Cavallari & Salvador, 2020, *Potamolithus* spp.). It is worthwhile noting that the three classical categories of Racovitza (1907) are all cave-dwelling, each with their particularities and evolutionary history in the subterranean habitat – see Trajano and Carvalho (2017) for a critical analysis of the Schiner-Racovitza system.

In 2023, Ferreira and colleagues published a reply in this journal raising concerns regarding our article (Ferreira et al. 2023a). While some of those are valid, others, we understand, are misguided. We address their comments below.

Their first concern was the inclusion of troglophiles (i.e., not true troglobites) in our list, choosing *Habeastrum strangei* as their example. That would be a reasonable point had we not clearly stated that we were, as mentioned above, including strongly troglophilic species in our review when worthy of discussion. Furthermore, in our original article, we stressed the species' status in their entry. For instance, to use their chosen example, in the entry on *H. strangei* (a species whose original description included two of the present authors), we acknowledged that "Given its ample distribution, this species is probably troglophilic and not strictly troglobitic, but specimens have not been recovered on surface environments as of writing" (Salvador et al. 2022: 2). To support their claim, Ferreira et al. (2023a) noted that *H. strangei* was shown not to be a troglobite by Simone (2022). Not only did we clearly state that the species was a troglophile and not a troglobite, but Simone (2022) is a book

chapter published after our article, so we could not possibly have considered that author's publication. Similar cases include the troglophilic *Potamolithus* spp. species complex (p. 4), as well as the dubious *Zilchogyra paulistana* (Hylton Scott, 1973) (p. 4) that lacks precise locality data but has been included in previous checklists of cave fauna (e.g., Gnaspini and Trajano 1994).

The main argument of Ferreira et al. (2023a) revolved around our classification of species as troglobites by using as criteria their (1) occurrence in caves and nowhere else and (2) presence of troglomorphisms (i.e., morphological features typical of cave-dwelling animals. In the first case, they suggested that we could not demonstrate the absence of populations on surface habitats to an extent they found acceptable. In some cases, the survey of neighboring surface areas is indeed incomplete – and Ferreira et al. (2023a) acknowledged the difficulties of surveying tropical invertebrate faunas –, but that is not true for all cases. Moreover, this goes both ways: one cannot use the absence of surface data to hypothesize that a cave-dwelling species might perhaps also live outside the cave; the unknowns may be as great or even greater than the reverse. We cannot hope to survey every square meter of land to satisfactorily address all the unknowns. We must work with the information that we currently have (mostly, occurrence data and morphological features), be explicit about the extent and quality of such information, and then use it to draw conclusions. These conclusions, of course, do not represent the final truth, because that is not how science works. With new evidence comes new interpretations, and there is ample space to correct things and to build on top of them, as exemplified by the data of Simone (2022) regarding *H. strangei*, published after our study. Furthermore, Ferreira and colleagues use criteria very similar to ours to classify species as troglobites in their own publications (e.g., Ferreira et al. 2023b), which is confusing if not incongruous.

One important point that Ferreira and colleagues raised is that we failed to account for the possibility of transport into the caves, and that was an actual oversight on our part. Nevertheless, transport by water into caves is extremely unlikely for most of the species we listed, as they are snails with small and fragile shells that would be destroyed during transportation – in particular by the method of transport proposed by Ferreira et al. (2023a: 2) that consists in is falling through vertical slits from the surface all the way down to the cave. Thus, there is a strong taphonomic bias against small fragile shells in transport, in favor of large, robust shells. The latter includes the examples correctly cited by Ferreira and colleagues: the species described by Simone and Casati (2013), which have robust and poorly preserved shells (except perhaps for *Clinispira insolita* Simone & Casati, 2013, whose extreme shell morphology could represent a troglomorphism). Those species may indeed have been transported and thus not be troglobites; in particular, two of them (*Cyclodontina capivara* Simone & Casati, 2013 and *Streptartemon molaris* Simone & Casati, 2013) are probably not troglobites, as they appear to be synonyms of other more widespread species, a matter that is still under investigation.

Regarding the second case, troglomorphisms, Ferreira et al. (2023a: 2) argued that the species we listed "do not exhibit any distinctive morphological features that would link them to a subterranean restricted life". We did provide enough evidence for most groups and based our assessment on morphological characters that are widely recognized in malacological literature as troglomorphisms (in general much better understood in freshwater snails when compared to terrestrial ones), including: reduction/absence of eyes, lack of body/periostracum pigmentation, translucent shell, miniaturization, morphological simplification, and extreme shell morphologies (e.g., Boeters 1979, Delicado 2018, Gladstone et al. 2021). Following malacological research, we consider those features to be good evidence of troglomorphisms. We would also like to point out that none of the authors in Ferreira et al. (2023a) are malacologists. In our article, we recognize shortcomings and note that some species (mostly terrestrial ones known only from shells; e.g., *Gonyostomus elinae* Simone, 2016 and *Rhinus gilbertus* Simone & Casati, 2013) do not have any visible troglomorphisms given the presently-available material (p. 5). Such uncertainties are part of the scientific endeavor and further evidence can either corroborate or rectify this. And again, Ferreira et al. (2023b) have similarly applied troglomorphisms to classify species as troglobites, evidencing perhaps a double standard.

Based on the rigid arguments and standards for establishing protection policies emphasized by Ferreira and colleagues, we could not help but ask ourselves: Is preventive protection of potential troglobite species really harmful in any way? Looking at the currently available data, the hypothesis that these species are apparently short-range endemics cannot be, by all means, discarded outright. Ferreira and colleagues argue strongly that such species do not deserve protection, and that protecting the cave environments where they live could be bad for other cave-dwelling species, which is a notable contradiction. They also strongly imply that we classified the species as troglobites solely to grant them protection, which is not the case. Our main objective was to summarize what was known about cave-dwelling snails in

Brazil at the time. We discussed each species and highlighted the troglophiles, so that stakeholders reading our paper would be able to extract that information and use it as they see fit when making their decisions.

Ferreira et al. (2023a) mentioned conservation concerns while arguing for species not to be protected. That approach dangerously borders the rhetoric of environmentally impacting sectors in Brazil, i.e., superficially adopting green sustainability discourses while advancing deleterious practices (Furtado 2021, Leal et al. 2023). This has been pointed out as a staple of mining ventures in Brazil (e.g., Crescencio 2011), some of which were responsible for the most severe environmental disasters in the country (e.g., Saes et al. 2021). Case in point, Jaffé et al. (2016) is a study about mining and the protection of Brazilian cave faunas that applies such rhetoric and is unsurprisingly funded by a giant in the mining sector. Mining is the most impactful activity threatening cave faunas in Brazil (Cavalcanti et al. 2012), so protection of troglobite or troglophile species should be prioritized over short-term and short-sighted profits (Saes and Muradian 2021).

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LITERATURE CITED

Boeters HD (1979) Species concept of prosobranch freshwater molluscs in Western Europe, I. Malacologia 18: 57–60.

Cavalcanti LF, Lim MF, Medeiros RCS, Meguerditchian I (2012) Plano de Ação Nacional para a Conservação do Patrimônio Espeleológico nas Áreas Cársticas da Bacia do Rio São Francisco. Instituto Chico Mendes, Brasília, 140 pp. https://repositorio.icmbio.gov.br/handle/cecav/100

Crescencio G (2011) Destruição de cavernas na maior província espeleológica do Brasil: Serra dos Carajás, Parauapebas-PA. In: Sociedade Brasileira de Espeleologia (Ed.) Anais do 31º Congresso Brasileiro de Espeleologia. Sociedade Brasileira de Espeleologia, Ponta Grossa, ISSN 2178-2113, 307–316. https://www.cavernas.org.br/wp-content/uploads/2021/07/31cbe_307-316.pdf

Delicado D (2018) A rare case of stygophily in the Hydrobiidae (Gastropoda: *Sadleriana*). Journal of Molluscan Studies 84: 480–485. https://doi.org/10.1093/mollus/eyy032

Ferreira RL, Souza-Silva M, Zampaulo RA (2023a) Cave-dwelling gastropods (Mollusca: Gastropoda) of Brazil, state of the art and conservation: a critical review. Zoologia 40: e22057. https://doi.org/10.1590/S1984-4689.v40.e22057

Ferreira RL, Berbert-Born M, Souza-Silva M (2023b) The Água Clara cave system in northeastern Brazil: the richest hotspot of subterranean biodiversity in South America. Diversity 15(6): 761. https://doi.org/10.3390/d15060761

Furtado F (2021) 'Nature-based solutions' and corporate territorial control: a fabricated consensus. World Rainforest Movement Bulletin 255: 25–29. https://www.wrm.org.uy/bulletin-articles/nature-based-solutions-and-corporate-territorial-control-a-fabricated-consensus

Gladstone NS, Niemiller ML, Hutchins B, Schwartz B, Czaja A, Slay ME, Whelan NV (2021) Subterranean freshwater gastropod biodiversity and conservation in the United States and Mexico. Conservation Biology 36(1): e13722. https://doi.org/10.1111/cobi.13722

Gnaspini P, Trajano L (1994) Brazilian cave invertebrates, with a checklist of troglomorphic taxa. Revista Brasileira de Entomologia 38: 549–584.

Jaffé R, Prous X, Zampaulo R, Giannini TC, Imperatriz-Fonseca VL, Maurity C, et al. (2016) Reconciling Mining with the conservation of cave biodiversity: a quantitative baseline to help establish conservation priorities. Plos One 11: e0168348. https://doi.org/10.1371/journal.pone.0168348

Leal LS, Angelo C, Araújo S (2023) Nunca Mais Outra Vez: 4 anos de desmonte ambiental sob Jair Bolsonaro. Observatório do Clima, Brazil, 100 pp. https://www.oc.eco.br/wp-content/uploads/2023/03/AF_reduzido_20220323_individuais_nunca-mais-outra-vez-1.pdf

Racovitza EG (1907) Essai sur les problèmes biospéologiques. Archives de Zoologie Expérimentale et Générale 6: 371–488.

Saes BM, Muradian R (2021) What misguides environmental risk perceptions in corporations? Explaining the failure of Vale to prevent the two largest mining disasters in Brazil. Resources Policy 72: 102022. https://doi.org/10.1016/j.resourpol.2021.102022

Saes BM, Del Bene D, Neyra R, Wagner L, Martínez-Alier J (2021) Environmental justice and corporate social irresponsibility: the case of the mining company Vale S.A. Revista Ambiente & Sociedade 24: 1–23. https://doi.org/10.1590/1809-4422asoc20210014vu2021L4ID

Salvador RB, Silva FS, Cavallari DC, Cunha CM, Bichuette ME (2022) Cave-dwelling gastropods (Mollusca: Gastropoda) of Brazil: state of the art and conservation. Zoologia 39: e21033. https://doi.org/10.1590/S1984-4689.v39.e21033

Simone LRL, Casati R (2013) New land mollusk fauna from Serra da Capivara, Piauí, Brazil, with a new genus and five new species (Gastropoda: Orthalicoidea, Streptaxidae, Subulinidae). Zootaxa 3683(2): 145–158. https://doi.org/10.11646/zootaxa.3683.2.4

Simone LRL (2022) Gastropoda. In: Zampaulo RA, Prous X (Eds) Fauna cavernícola do Brasil. Editora Rupestre, Belo Horizonte, 304–315.

Trajano E, Carvalho MR (2017) Towards a biologically meaningful classification of subterranean organisms: a critical analysis of the Schiner-Racovitza system from a historical perspective, difficulties of its application and implications for conservation. Subterranean Biology 22: 1–26. https://doi.org/10.3897/subtbiol.22.9759

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