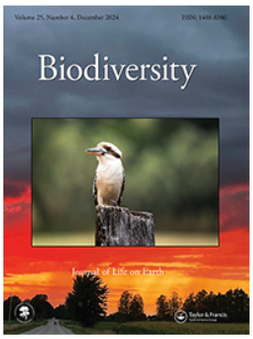

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LETTER TO THE EDITOR

The unsupported claim that 'Global online trade is driving poison dart frogs (family: Dendrobatidae) towards extinction'

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ABSTRACT

The global trade in threatened species for pets can impact wild populations, yet demonstrating this relationship requires careful analysis and interpretation. Junaid (2024) explored the role of online trade in poison dart frogs (family: Dendrobatidae) but drew unsupported conclusions, misrepresenting trade impacts. Here, we reanalyse Junaid's data, supplemented with additional websites, and show that most traded poison frogs originate from captive breeding or sustainable biocommerce sources, not wild harvests. Furthermore, Junaid's methodology lacked metadata and reproducibility standards, undermining its conclusions. Though captive breeding and biocommerce operations are increasingly common, we stress the need for increased population monitoring and population viability analyses for species that continue to be harvested from the wild. Contrary to Junaid's conclusions, online trade is not driving poison frogs to extinction and can even have conservation benefits when sustainable practices are used to meet demand.

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Wildlife trade; poison frog; pet trade; overexploitation; amphibians

Global trade in threatened species can negatively affect wild populations. In a recent assessment, Junaid (2024) attempted to examine the conservation-related impacts of the online trade in poison dart frogs (family: Dendrobatidae), highlighting important questions about the scope of trade and its consequences. Specifically, Junaid's study aimed to address specific questions that they suggested would demonstrate a relationship between the role of online trade and the potential that trade is causing wild population declines.

While we admire this attempt and agree with the author that available information quantifying the dynamics of the poison frog trade (and additional subtleties of the practice; Yeager, Baquero, and Zarling 2020) is currently poorly evaluated, the methodology applied and data supplied by Junaid (2024) falls short of supporting their claims (including and especially their title). Specifically, we highlight several inaccuracies and analytical limitations in Junaid's approach, particularly the misrepresentation of trade impact on wild populations without evidence. The paper also completely overlooked the degree of captive propagation supplying the trade and the role of sustainable breeding operations in promoting conservation (Yeager, Baquero, and Zarling 2020; Yeager, Scarpetta Gonzalez, and Shepack 2024).

First, and perhaps most critical, is the central claim that the international pet trade is driving poison frogs to extinction, which is totally unsupported. The author does not present any evidence, citations, or direct links that would assist the reader in connecting the dots between trade and population declines, a claim that is directly stated in their title. Rather, the article uses circular and incomplete logic to argue that because there are threatened species in the trade, the trade is in turn threatening the species. Such tautological arguments do not demonstrate the cause-and-effect relationship implied in the article. Instead, the article shows that 14 of 33 species (42.4%) sold online across 43 websites are assessed as threatened by the International Union for Conservation of Nature (IUCN) Red List. However, this proportion is not significantly different from that of species in a threatened category for dendrobatids overall: 48.8% of the 199 assessed poison frog species (chi square = 0.165, p = .68). Therefore, this line of evidence suggests that threatened poison frog species are no more likely to be traded than non-threatened ones (Edmonds 2021).

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In addition to faulty logic leading to the main conclusion of the study, the data presented by the author lacks minimum reproducibility standards. The study does not provide metadata, including the dates when the websites were accessed, the search text string used, or the inclusion and exclusion criteria. This type of information is crucial for replicability and reproducibility checks, which are critical for reducing waste in research (Moher et al. 2016). Additional concerns are raised when considering that reproducibility issues can impact conservation management decisions (Grames and Elphick 2020). Furthermore, not acknowledging the relevance of the metadata ignores important dynamics of the pet trade market. For example, the dates when some websites are sampled can reflect the seasonality and fluidity of the pet trade market.

We agree there is evidence that some species such as *Dendrobates auratus, D. tinctorius*, and *Oophaga pumilio* (all assessed as Least Concern by the Red List) are collected from the wild for the international pet trade (CITES 2024), while others are collected in unknown numbers and smuggled to North American, European, and Asian markets (Auliya et al. 2016; Betancourth-Cundar et al. 2020). However, central to our rebuttal is that Junaid neglected to report that most poison frogs in the trade are from captive origins, not wild ones. This distinction is important, as the source of animals being sold online determines the potential to impact wild populations. To highlight this point, we reanalysed Junaid's (2024) data, in addition to supplementing it with a systematic internet search (see the Supplemental Material for details), to determine the relative prevalence of captive-bred individuals compared to wild-caught species listed on pet websites. Our results clearly show an overwhelming proportion of species listed as captive-bred on these company websites (Figure 1). This finding agrees with Cavasos et al. (2023), who found that 90% of traded pet amphibians in the US were of domestic

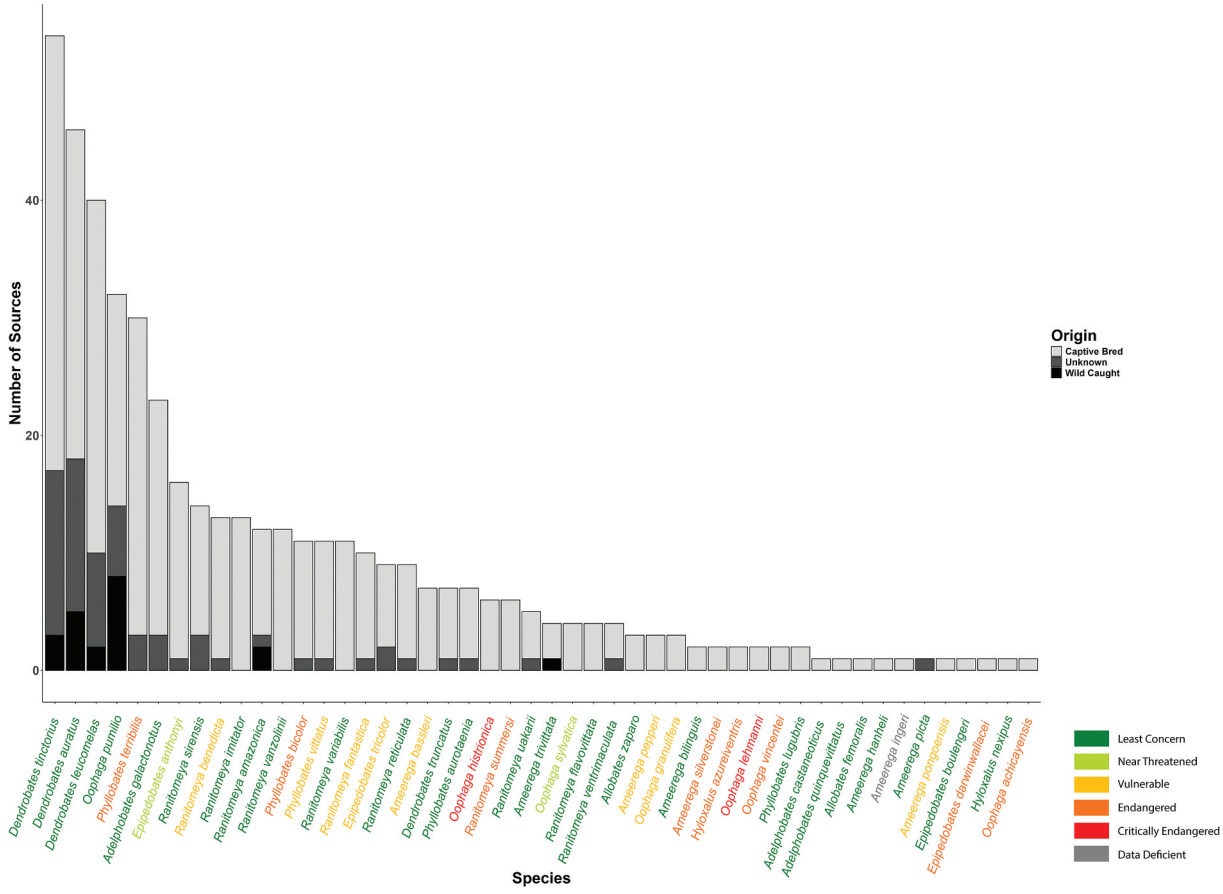

Figure 1. The conservation status and origin of frogs in the family Dendrobatidae involved in the pet trade, from Junaid (2024) and our additional web search. The bar graph shows the number of websites that list particular species as captive bred, wild caught, or no listing included (unknown), and the x-axis shows each species along with its International Union for Conservation of Nature (IUCN) conservation status. The four most common species on the websites (*Dendrobates tinctorius, D. auratus, D. leucomelas, Oophaga pumilio*), all of which are also the top wild-collected species, are listed by the IUCN as Least Concern. Specimens of the two Critically Endangered species, *Oophaga histrionica* and *Oophaga lehmanni*, all appear to be of captive-bred origin.

origin rather than imported. This finding is also in line with the claim that domestically bred dart frogs reduce the demand for imported frogs (Yeager, Scarpetta Gonzalez, and Shepack 2024).

Our analysis shows that all the species with evidence of being imported from the wild are listed by the IUCN as Least Concern, with a higher number of captive-bred listings for each species (Figure 1). The two most imperilled species identified in our search (IUCN – Critically Endangered), *Oophaga histrionica* and *O. lehmanni*, were found in low proportions and all likely captive bred, a finding consistent with the increase in frogs coming from Colombia after this country allowed legal exports of these species (Forero-Medina et al. 2024). This pattern is mirrored beyond the dart frog trade. For example, the axolotl (*Ambystoma mexicanum*) and crested gecko (*Correlophus ciliatus*) are widely bred in captivity and sold online, being some of the most commonly traded pet amphibians and reptiles in the US (Herrel and van der Mijden 2014; Prestridge, Fitzgerald, and Hibbitts 2011), yet are assessed as Critically Endangered and Vulnerable by the IUCN Red List. These lines of evidence directly negate claims of Junaid (2024) by illustrating that the presence of an imperilled species on a pet trade website does not equate to a decline in wild populations.

Even species exported from their native-range country are not necessarily sourced from the wild and rather may be captive bred in laboratory or semi-natural conditions (Yeager, Baquero, and Zarling 2020). For example, biocommerce operations in Ecuador, Colombia, and Peru are breeding poison frogs commercially for sale abroad to fund research and conservation efforts (Sinovas and Price 2015; Yeager, Baquero, and Zarling 2020). There was a shift towards these sustainable breeding operations from wild sources during 2010–2020 (Edmonds 2021). We specifically highlight that 13 of the 14 threatened species Junaid identified as being sold online have actually originated most recently from these types of sustainable breeding operations. As a specific example, *Oophaga histrionica* and *O. lehmanni*, identified in our re-analysis as the most imperilled dart frogs, were historically imported from wild stock. However, by 2017, 100% of the imports of these two species out of Colombia originated from sustainable biocommerce operations (Yeager, Baquero, and Zarling 2020). As public interest in captive amphibians is unlikely to subside, domestic captive breeding and sustainable biocommerce operations in the species' country of origin provide a viable conservation strategy that directly offsets the damage from harvesting wild individuals to initiate such efforts.

We are also concerned with the article's portrayal of the historical exploitation of select poison frog species, which we feel is misleading. Junaid suggests that many poison frogs have been overexploited for centuries due to their use in Indigenous hunting practices where alkaloid-laced darts were once used to hunt with blowguns (Myers and Daly 1983). However, very few species (only some in the genus *Phyllobates*) produce the alkaloids that were ancestrally used by Indigenous groups for hunting. To confirm that Indigenous hunting practices have not affected the population viability of these species, we reached out to a leader of one such tribe (the Siapidaarã) who is also the director of the Reserva Forestal Protectora Regional K'ôk'ôi Eujâ, an Indigenous reserve that protects the poison frog *Phyllobates terribilis*. He confirmed there is no evidence to suggest that this cultural practice has led to historic population declines. Moreover, he confirmed the practice ended around the late 1960s, well before commercial trade in these species began (CR Quiro, pers. comm). Claims of unsustainable harvesting of poison dart frogs by Indigenous people are thus unsupported.

While we highlight serious issues with the study, this is not to say that we feel trade cannot contribute to amphibian population declines, or negatively impact species. Indeed, as Junaid mentions, the IUCN Red List assessments note trade as a threat to many species of poison frogs. Even with legal protections, illegal harvesting of imperilled species for the pet trade can lead to sharp population declines (e.g. Jolly, Von Takach, and Webb 2021). However, determining whether a species is overexploited requires monitoring wild populations and/or robust data simulations, as just because an animal is harvested from the wild does not mean it is overexploited. Much of population modelling in ecology has focussed on quantifying sustainable harvest quotas for wildlife, and – importantly – the number of individuals removed from a population is not the only factor to consider (Fryxell et al. 2010). Age, size, and sex of individuals harvested also impact population dynamics, as does the season when animals are harvested and many other factors depending on context (Weinbaum et al. 2012). These factors can be integrated by performing population viability analyses (PVAs) to formally address the demographic pressures that populations face. While PVAs require large amounts of data that may be difficult to obtain (Lacey 2019), the specific influence of the illegal pet trade has been modelled using PVAs in various imperilled species (e.g. da Silva et al. 2016; Jolly, Von Takach, and Webb 2021). Unfortunately, no such analysis incorporating the role of the legal or illegal pet trade on population viability has been conducted in dendrobatid frogs, despite calls

for PVAs in other amphibian species also common in the pet market (e.g. the genus *Mantella* – Andreone, Mercurio, and Mattioli 2006). These analyses are crucial to test the claim made by Junaid (2024) that the pet trade is driving dart frogs to extinction.

Finally, we note that the suggestion to develop stricter trade policies for Dendrobatidae is also problematic. Many Central and South American countries already have strict regulations limiting wild amphibian exports, and all countries noted by Junaid are parties to the Convention on International Trade in Endangered Species (CITES) treaty. Therefore, a lack of regulations is not the central issue. Rather, inadequate enforcement of existing regulations and the considerable demand from hobbyists for new offerings are among the problems. Historically, complete trade bans are rarely highly effective when dealing with wildlife poaching. A more nuanced approach is needed that involves supporting sustainable breeding operations to lessen the demand for wild frogs, monitoring commercial harvest sites, and reforming border crossings where smuggling is frequent.

We commend the intent of Junaid (2024) to help raise awareness of the threats facing poison frogs and the possible impacts of the international pet trade. However, concrete, direct data to support the main arguments of the author were lacking or based on incorrect assumptions, which compromised the conclusions drawn and severely limited the paper's ability to accurately inform conservation efforts. We provide evidence that in poison dart frogs, captive breeding dominates most sales on prominent pet trade websites, which, combined with sustainable biocommerce, offsets the collection of wild specimens for the pet trade. We hope future studies will address key gaps in the dendrobatid conservation literature, particularly focussing on using PVAs to explicitly address the role the pet trade plays in population sustainability. Ultimately, these analyses will support conservation strategies that reflect the complexities of species management in the context of international trade.

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Disclosure statement

D. Edmonds participates in the poison frog trade.

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Notes on contributors

Devin Edmonds is a graduate student at the University of Illinois at Urbana-Champaign. He studies the ecological processes that drive species' responses to environmental change. Much of his work is rooted in Madagascar, a biodiversity hotspot with exceptional amphibian species richness and endemism. Here, he is using his Ph.D. to fill the research needs identified in a conservation action plan for the endangered frog *Mantella cowanii*.

Andrew J. Mularo is a postdoctoral research associate at Michigan State University and a former doctoral student at Purdue University. Andrew is interested in how natural populations are able to maintain sufficient variation to persist as they face demographic challenges and applies his research to both imperiled and invasive species. He is dedicated to applying his knowledge to make informed conservation management decisions and actively engages in public outreach to broadly disseminate his research.

Ximena E. Bernal is a professor in the Department of Biological Sciences at Purdue University and research associate at the Smithsonian Tropical Research Insitute. She has over two decades of experience working with anurans. With numerous publications, she is dedicated to investigating sensory ecology and animal communication focusing on frogs and their eavesdropping enemies. She is also actively engaged in community outreach and science education initiatives.

Justin Yeager is a professor in the research division of the Universidad de las Américas in Quito in the Biodiversity, Environment and Health research group. His research is centered in evolutionary biology working in themes such as sensory ecology, evolution of anti-predatory strategies, behavior and cognition, speciation as well as collaborating in the themes of public health such as phage therapy, conservation, and sustainable biocommerce.

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