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How many Data Deficient amphibians are threatened? IUCN Red List assessments for amphibian species previously classed as Data Deficient

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ABSTRACT – At the time of our research in 2022, 16.4% of amphibian species on the IUCN Red List were assessed as Data Deficient (DD). There is minimal funding allocated to the research and reassessment of DD taxa, this prevents them from being prioritised for conservation. We identified 656 non-DD amphibian species that were previously assessed as DD and used their subsequent assessment trajectories to predict the extinction risk of remaining DD taxa. Assuming similarity of the distribution of these taxa between extinction risk categories to those of currently DD species, we compared this dataset with the risk category distribution of assessed amphibians that had never been assessed as DD. Previously DD amphibians, when compared to those that were never DD, were found to be more threatened (52.1% vs. 39.6%) and less likely to be non-threatened (22.4% vs. 60.0%). When explored further at the level of Order, more previously DD amphibians in the Order Gymnophiona were reassessed as 'Near Threatened', more Caudata 'Critically Endangered' with fewer 'Least Concern', and more Anura 'Vulnerable' and 'Endangered' with fewer 'Least Concern' than counterparts that were never assessed as DD. Based on these previously-DD amphibian data, we estimated that around half (49.6%, n = 592) of currently DD amphibians are likely threatened by extinction. Our approach arrives at similar conclusions to authors using other approaches and bolsters the argument that conservationists and funding organisations should implement recommendations to address concerns for DD amphibians, especially DD Caudata.

INTRODUCTION

Amphibians are one of the world's most threatened Classes of vertebrates (Howard & Bickford, 2014; González-del-Pliego et al., 2019; Luedtke et al., 2023), with 41% of species assessed by the International Union for Conservation of Nature (IUCN) facing risk of extinction when this research was conducted (IUCN, 2022). The drivers of extinction are multifaceted, interlinked and often anthropogenic in nature (Young et al., 2004; Hoffmann et al., 2010; Howard & Bickford, 2014; Grant et al., 2016; Ortega-Andrade et al., 2021; Luedtke et al., 2023).

The IUCN Red List of Threatened Species (hereafter the "Red List") assesses the extinction risk of species that have been described by science. These assessments underpin conservation prioritisation tools and influence policy and conventions to determine which species receive conservation attention (Mace et al., 2008; Parsons, 2016; Tapley et al., 2018). The Red List has become the most widely accepted comprehensive international database for the assessment of individual species and their extinction risks (Mace et al., 2008; Hoffmann et al., 2010). As well as assessing the extinction risk to specific species, the Red List authority aims to increase the proportion of assessed species in order to monitor the status of the world's biodiversity (Bland et al., 2017). However, if there is insufficient information with which to assess the extinction risk posed to a species, it is usually assessed as 'Data Deficient' (IUCN, 2012). At the time of conducting this research, 16.4% (1193 of 7296 assessed amphibian species) were assessed as Data Deficient (DD) (IUCN, 2022). Although the current proportion of DD species is smaller than it has been in previous years (>25% in 2017; Bland et al., 2017), concerns remain because it is thought that DD taxa have a higher average extinction risk than assessed species (Morais et al., 2013; Howard & Bickford, 2014; Tapley et al., 2018). Nevertheless, conservation prioritisation tools such as the EDGE of Existence Programme (Isaac et al., 2012; 2018; Gumbs et al., 2018), as well as regional conservation policy, typically deprioritise DD taxa for research and funding due to their uncertain extinction risk (Howard & Bickford, 2014; Bland et al., 2017).

Attempts to quantify the probable extinction risk categories for DD amphibian species have been made using species trait, phylogenetic and distribution data (Morais et al., 2013; Howard & Bickford, 2014; González-del-Pliego et al., 2019). These studies found that overall, amphibians are at a higher risk of extinction, and DD species are more likely to be threatened based on their traits, distribution and time since being described.

We adopted a different approach to estimating the proportions of DD species that may fall into each Red List category, using the eventual category into which previously DD species were placed after reassessment to inform the likely designation of species still assessed as DD.

METHODS

Data sources

Extinction risk category terminology follows the IUCN Red List (IUCN, 2012); Least Concern (LC); Near Threatened (NT) Vulnerable (VU); Endangered (EN); Critically Endangered (CR); Extinct in the Wild (EW); Extinct (EX). Using the Red List database (IUCN, 2022), we reviewed the assessment information for all 7296 IUCN amphibian extinction risk assessments; the assessment information provides the extinction risk according to previously published Red List assessments. For species that were assessed as DD at any point since 2004 onwards and were subsequently reassessed and allocated to another extinction risk category, we collected the following information: common and scientific name, date of most recent DD assessment, current extinction risk category (as some species were assessed as DD for multiple assessments), and date of assessment for current extinction risk category. This formed our 'focal dataset'. Species that were previously assessed as DD prior to 2004 were excluded from the focal dataset (n = 49), because they were reassessed for the Global Amphibian Assessment of 2004 (Stuart et al., 2004), allowing 2004 to be a baseline for all amphibian species in our investigation. The 'comparison dataset' consisted of assessed amphibian species that had never been assessed as DD from 2004 onwards (i.e. had been assigned an extinction risk category other than DD from initial assessment) and we recorded the following information: common and scientific name, current extinction risk category and date of most recent assessment. Species that were never assessed as DD but previously assessed as "Insufficiently Known" (a category removed after 1994; Groombridge, 1993), were also excluded from both our datasets (n = 10), because the definition did not meet the same criteria as DD (category established in 1994 and used from 1996 onwards (IUCN, 1994; 1996)). Species were retained in our datasets if they were recognised by Frost (2021).

These data were organised by amphibian Order for comparison. The data spanned from 2004 to 2020 as none of the species in our focal dataset was assessed after 2020. Once the data were collected, we enumerated how many species in the focal dataset transitioned from DD to each of the other extinction risk categories. We counted the number of species in each extinction risk category for the comparison dataset.

Statistical analyses

Using R (version 4.2.2; R Core Team, 2022) in R Studio (RStudio Team, 2022), we carried out a Pearson's Chi squared (χ^2) test for Independence, with P value simulation (using 2000 iterations and standardised residuals) to deal with small expected counts (Hope, 1968; Zaiontz, 2021); consequently no degrees of freedom are reported for analysis outcomes. This analysis compared observed counts with the counts expected if focal and comparison data sets came from the same distribution. The Chi squared test was used to make comparisons between our focal and comparison datasets at the level of Class (all amphibian Orders) and Order (Gymnophiona, Caudata and Anura separately).

Post hoc pairwise comparisons were carried out using the Bonferroni method upon any rejection of the null hypothesis, to see which categories were responsible for deviation from the null hypothesis.

Estimation of extinction risk for currently DD amphibians

The current distribution of all IUCN assessed amphibians in general, and the counts from our focal and comparison dataset distributions, were used to estimate how many of the 1193 DD species could be at potential risk of extinction. We calculated the percentage of amphibians that were potentially threatened (CR, EN, VU) and extinct (EW and EX) using the proportions calculated in each dataset (current, focal and comparison distributions) to observe the difference in estimates based on the different distributions. The following equation was used to estimate how many species would be assigned to a single extinction risk category within a single Order, repeated for each dataset:

$$\frac{no. of\ species\ in\ risk\ category\ within\ Order}{total\ no. of\ species\ within\ Order} \times no. of\ currently\ DD\ species\ within\ Order$$

For proportion threatened, our study reports the mid-point percentages (i.e. (CR+EN+VU)/(Assessed–EX–DD)), as recommended by the IUCN Guidelines for Reporting on Proportion Threatened (IUCN, 2016), as opposed to the lower-bound percentages (i.e. (CR+EN+VU)/(Assessed)).

RESULTS

Chi squared analysis

For amphibians overall, a significant difference was identified in the distribution of amphibians amongst the IUCN extinction risk categories between the focal and comparison datasets (χ^2 = 55.2, p = 0.0005). The post-hoc tests showed that fewer than expected previously-DD amphibians were reassessed as LC based on comparison data (p < 0.0001), and more were reassessed as EN (p < 0.0001); there were no differences for other categories.

Further comparisons of the amphibian Orders showed a significant difference in the distribution of Gymnophiona amongst the IUCN extinction risk categories between focal and comparison datasets (χ^2 = 10.3, p = 0.0345). The post-hoc tests showed that more previously-DD Gymnophiona were reassessed as NT than expected, based on comparison data (p = 0.0373), with no other differences identified.

A significant difference in the distribution of Caudata between extinction risk categories was also found (χ^2 = 46.5, p = 0.0005), and post-hoc tests showed that fewer than the expected previously-DD caudates were reassessed as LC (p = 0.0028), based on the comparison data, with more reassessed as CR (p < 0.0001); no other differences were found.

A significant difference in distribution of Anura was found (χ^2 = 64.0, p = 0.0005), and the post-hoc tests showed that fewer previously-DD Anura were reassessed as LC (p < 0.0001) than the expected, based on comparison data, with more reassessed as VU (p = 0.0067) and EN (p < 0.0001).

Table 1. Number of amphibian species in each dataset by IUCN extinction risk category. G, Gymnophiona; C, Caudata; A, Anura; DD, Data Deficient; LC, Least Concern; NT, Near Threatened; VU, Vulnerable; EN, Endangered; CR, Critically Endangered; EW, Extinct In The Wild; EX, Extinct. Value in bold indicates absolute total in each dataset and overall percentage threatened in each dataset. Threatened categories include VU, EN and CR. Proportion of threatened is calculated using mid-point percentages (i.e. (CR+EN+VU)/(Assessed–EX–DD), which excludes the DD and EX categories from the total) as stated in the IUCN Guidelines for Reporting on Proportion Threatened (IUCN, 2016).

	Current IUCN Distribution				Focal Dataset				Comparison Dataset			
Category	**G**	**C**	**A**	**Total**	**G**	**C**	**A**	**Total**	**G**	**C**	**A**	**Total**
DD	99	50	1044	1193								
LC	69	184	2907	3160	15	3	245	263	54	180	2640	2874
NT	3	64	351	418	3	2	46	51	0	58	300	358
VU	4	118	608	730	2	3	91	96	2	112	510	624
EN	10	161	914	1085	3	17	150	170	7	143	757	907
CR	3	121	549	673	1	25	49	75	2	94	493	589
EW	0	0	2	2	0	0	0	0	0	0	2	2
EX	0	3	32	35	0	0	1	1	0	3	31	34
Total	188	701	6407	**7296**	24	50	582	**656**	65	590	4733	**5388**
Proportion threatened	19.1%	61.7%	38.8%	**41.0%**	25%	90%	49.8%	**52.1%**	16.9%	59.5%	37.4%	**39.6%**

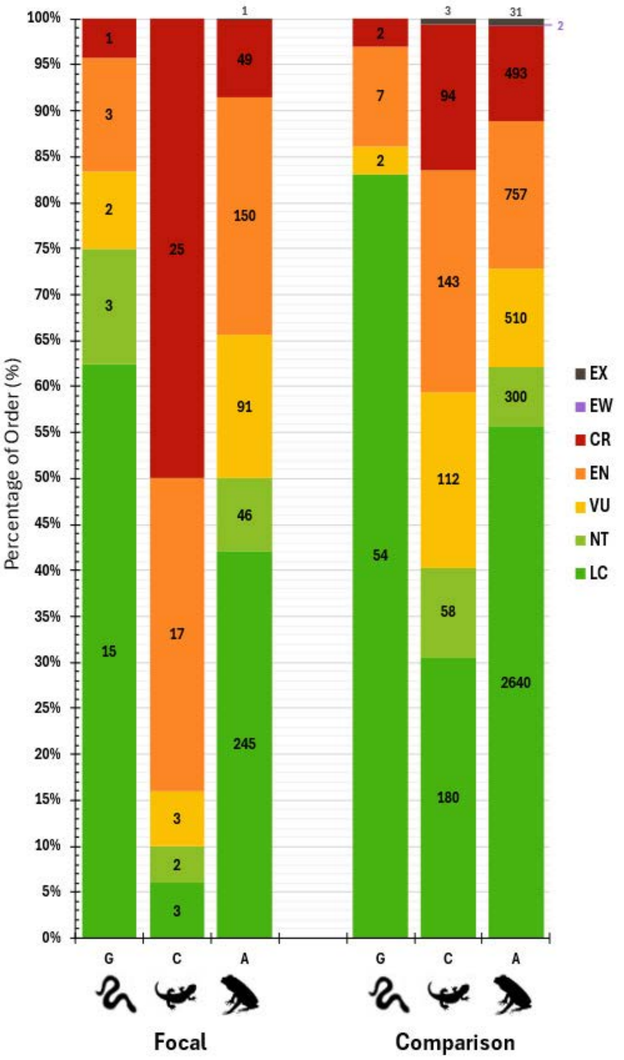

Figure 1. Distribution of focal and comparison datasets into the IUCN extinction risk categories by amphibian Order. Focal n = 656, Comparison n = 5388. Abbreviations: LC - Least Concern, NT - Near Threatened, VU - Vulnerable, EN - Endangered, CR - Critically Endangered, EW - Extinct in the Wild, EX - Extinct. Values on bars represent the number of species.

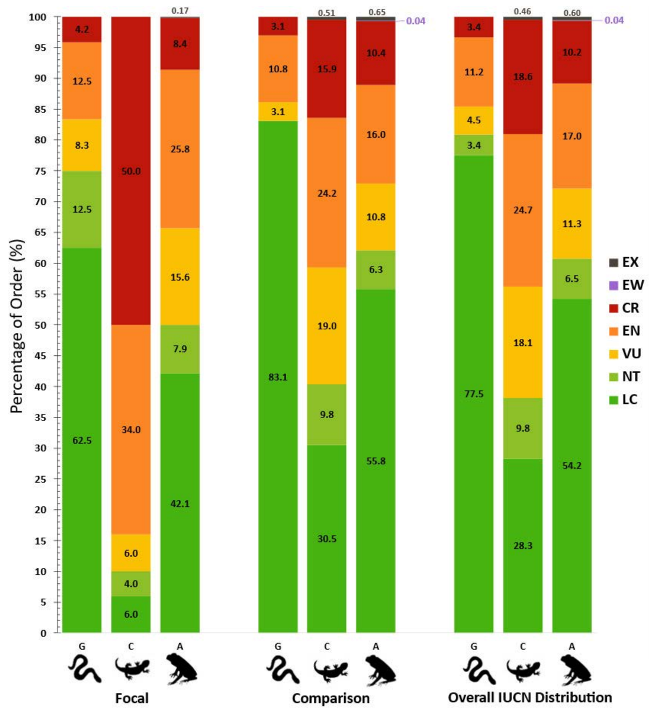

Figure 2. Estimates of the number of species in each IUCN extinction risk category by Order and dataset for currently DD Amphibia. Overall DD amphibians n = 1193; Gymnophiona n = 99, Caudata n = 50, Anura n = 1044. Values on bars represent percentages. Abbreviations: C - Caudata, G - Gymnophiona, A - Anura, DD - Data Deficient. For other abbreviations, see legend to Figure 1.

Differences in the proportion of threatened amphibians among datasets

For amphibians that were previously assessed as DD, 52.1% (n = 341) were subsequently reassessed as threatened (CR, VU, and EN) (Table 1 and Fig. 1). For species that were never DD, the proportion of threatened amphibians was 39.6% (n = 2120). At the Order level Caudata were proportionately the most threatened and Gymnophiona were the least threatened among all distributions (Table 1 and Fig. 1).

Estimates of DD species potentially threatened

Based on our focal data estimates (Fig. 2), 49.6% (n = 592) of currently DD amphibian species are suspected to be threatened, 12.6 percentage points more than if estimates are based on species that were never DD (37.1%, n = 442), and 11.1 percentage points more than if estimates are based solely on the overall IUCN distribution (38.5%, n = 460). A higher proportion of DD Caudata are suspected to be threatened based on previously DD Caudata (90%, n = 45) than compared to estimates based on previously non-DD Caudata (59.7%, n = 30). Half (50%, n = 522) of the currently DD Anura are suspected to be threatened based on previously DD species, compared to 37.9% (n = 395) threatened based on Anura that were never assessed as DD. A quarter (25%, n = 25) of DD Gymnophiona are suspected to be threatened based on previously DD Gymnophiona, compared to 16.9% (n = 17) based on those that were never assessed as DD. Overall, using our estimates from previously DD species, the projected total estimates for each category would be LC = 3664 (50.2%), NT = 515 (7.06%), VU = 905 (12.4%), EN = 1383 (19%), CR = 790 (10.8%), EW = 2 (0.027%), EX = 37 (0.51%). This brings the overall proportion of threatened amphibians up to 42.2%, with specifically Gymnophiona increasing to 22.2%, Caudata to 63.5% and Anura to 40.4%.

DISCUSSION

Estimates using our data and approach suggest that, based on the assessment trajectories of previously DD species, DD amphibians are more likely to be subsequently assigned to threatened categories than if their extinction risk category distribution was the same as for species never assessed as DD. Previously DD amphibians were specifically more likely to be EN and less likely to be LC than species that were never DD, providing cause for concern for amphibians that are currently assessed as DD. Other estimations based on distribution and extinction risk data (Howard & Bickford, 2014), have shown that 63% of DD species were suspected to be threatened in 2014, out of the 1249 assessed as DD at the time. This estimate is greater than our estimates (49.6%). Based on distribution, extinction risk, phylogenetic, and species-trait data, González-del-Pliego et al. (2019) estimated 47% of DD species to be threatened in 2019, which is very similar to our estimate and more comparable in timepoint. Machine learning-derived probabilities of DD amphibian species being threatened with extinction found that 85% of the 1130 DD amphibians were threatened with extinction (Borgelt et al., 2022), a figure much greater than our estimate. Ultimately, all estimates show that DD species are suspected to be more threatened.

Data from the recently published Global Amphibian Assessment II show that Caudata are, on average, more threatened than both Anura and Gymnophiona (Re:wild, Synchronicity Earth, IUCN SSC Amphibian Specialist Group, 2023). Our findings support this; we found previously DD Caudata to be more threatened, compared to non-DD Caudata, with a higher proportion of threatened (90%) than Gymnophiona and Anura. Additionally, previously DD Caudata show a 28.3% difference in proportion of threatened than the overall IUCN assessed, in comparison to only 5.9% for Gymnophiona, and 11% for Anura. Therefore, IUCN best estimates heavily underestimate the proportion of DD Caudata presumed threatened based on extinction risk status.

We found that previously DD Anura were more threatened than previously non-DD Anura. Morais et al. (2013), focusing specifically on Brazilian Anuran species, estimated 57% (37 of 65) of DD species to be threatened (from those not reassessed as DD), which is slightly higher than our estimate, but overall supports that DD Anura are proportionately more threatened than non-DD Anura. A recent national Red List assessment for amphibians in Ecuador (Ortega-Andrade et al., 2021) reported 72.7% of Caudata and 56.7% of Anura as threatened, affirming our trends for these Orders, although only on a national scale. This study also reported a much larger proportion of threatened Gymnophiona (60.9%) compared to our dataset (16.9 – 25%). This could be due to the high proportion of DD and out-of-date assessments for Gymnophiona as they are more cryptic in nature, making them rarer to encounter during surveys (Gower & Wilkinson, 2005). However, the density of DD species is known to differ geographically, for example, 24% of amphibians in Indonesia are assessed as DD and there are no amphibians assessed as DD in Europe (Re:wild, Synchronicity Earth, IUCN SSC Amphibian Specialist Group, 2023).

The extinction risk status of a species is important for conservation planning and prioritisation (Morais et al., 2013). Therefore, reassessment of DD species is important in preventing silent extinctions (Liu et al., 2022). Also, recommendations for improving the DD category should be implemented (Parsons, 2016; Bland et al., 2017). This is increasingly important given the high rate of amphibian species descriptions (Tapley et al., 2018; Liu et al., 2022) and the effect of species splitting on estimated population size (Funk et al., 2012). Funding for reassessment of these species is important, but only a few organisations award funding specifically to DD species, e.g. the Mohamed Bin Zayed Species Conservation Fund, which has awarded 4.5% of grant funding to DD species (0.36% to Amphibians) (The Mohamed bin Zayed Species Conservation Fund, 2024). More organisations should take the initiative to invest additional time, money and research into this field of work. Previously, there was less incentive for funding organisations to explore DD biodiversity (Howard & Bickford, 2014), but our study, among others, provides evidence for the need to focus additional attention on DD amphibians and highlights some gaps requiring research. At least it is encouraging that the proportion of species assessed as DD has decreased from 23% from the first Global Amphibian Assessment in 2004 to 11% in the second assessment in 2023 (Re:wild, Synchronicity Earth, IUCN SSC Amphibian Specialist Group, 2023).

The methods used in this work are relatively simple compared with previous analyses, which used species life history and distribution traits to predict extinction risk of DD species (Howard & Bickford, 2014; González-del-Pliego et al., 2019). Our approach makes use of historic Red List data recording assessment trajectories of species previously assessed as DD, which was not accounted for by previous analyses, and may provide a framework that could be readily applied to other taxa. However, an inherent assumption of this approach is that species in the focal and comparison datasets come from the same distribution of extinction risk, which is a limitation of our analyses.

In conclusion, we used novel methodology to independently estimate extinction risk among DD amphibians. Our findings add to, and broadly agree with, the existing body of evidence that DD amphibians are more likely to be threatened than might be estimated by simple extrapolation of extinction risk category proportions for assessed, non-DD taxa. This finding highlights the need for greater investment in the study and subsequent reassessment and conservation of DD amphibians, particularly Caudata.

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