

Status and Trends of Amphibian Declines and Extinctions Worldwide

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The first global assessment of amphibians provides new context to the well-publicised phenomenon of amphibian declines. Amphibians are more threatened, and are declining more rapidly, than either birds or mammals. Although many declines are due to habitat loss and over-utilization, other, unidentified processes threaten 48% of rapidly declining species, and are driving species most quickly to extinction. Declines are non-random in terms of species' ecological preferences, geographic ranges and taxonomic associations, and are most prevalent among Neotropical montane, stream-associated species. The lack of conservation remedies for these poorly understood declines means that hundreds of amphibian species now face extinction.

Scientists first became concerned about widespread amphibian population declines when they met in 1989 at the First World Congress of Herpetology. Historical data indicate that declines began as early as the 1970s in the western United States (1, 2), Puerto Rico (3) and northeastern Australia (4). Subsequent reports revealed the severity of the declines. At one site in Costa Rica, 40% of the amphibian fauna disappeared over a short period in the late 1980s (5). Sudden disappearances of montane species were noted simultaneously in Costa Rica, Ecuador and Venezuela (5–8). In some regions, many declines took place in seemingly pristine habitats (1–8). These reports were initially received with some skepticism, as amphibian populations often fluctuate widely (9), but tests of probabilistic null models showed that the declines were far more widespread and severe than would be expected under normal demographic variation (5). This finding, in addition to many further reports of declines in the 1990s (8, 10–13), was pivotal in convincing most herpetologists that amphibian declines are non-random, unidirectional events.

The lack of a comprehensive picture of the extent and severity of amphibian declines prompted us to conduct the IUCN—The World Conservation Union Global Amphibian Assessment (GAA) to gather data on the distribution, abundance, population trends, habitat associations and threats

for all 5,743 described species of amphibians (14, 15). From this information, we used the IUCN Red List Criteria (16) to determine the level of threat to every species. The raw GAA data are publicly available (14). The results demonstrate that amphibians are far more threatened than either birds (17) or mammals (18), with 1,856 species (32.5%) being globally threatened (i.e., listed in the IUCN Red List Categories (16) of Vulnerable, Endangered or Critically Endangered), compared with 12% of birds (1,211 species) (17) and 23% of mammals (1,130 species) (18). At least 2,468 amphibian species (43.2%) are experiencing some form of population decrease, while only 28 (0.5%) are increasing and 1,552 (27.2%) are stable; 1,661 (29.1%) species have an unknown trend.

Many amphibian species are on the brink of extinction, with 427 species (7.4%) listed as Critically Endangered (CR - the IUCN Category of highest threat), compared with 179 birds (1.8%) (17) and 184 mammals (3.8%) (18). The level of threat to amphibians is undoubtedly underestimated because 1,294 species (22.5%) are too poorly known to assess (Data Deficient - DD), compared with only 78 birds (0.8%) (17) and 256 mammals (5.3%) (18). A significant proportion of DD amphibians is likely to be globally threatened. Analysis of trends in population and habitat availability indicates a deterioration in the status of amphibians since 1980 (15), when 1,772 species (31.0%) would have been globally threatened, including 231 species (4.0%) in the CR category. Thus, in 1980, the percentage of CR amphibians would have been similar to that of mammals today, but the number of CR amphibians has almost doubled since then.

Only 34 species of amphibian are reported to have become extinct since 1500, compared with 129 birds (17) and 74 mammals (18), but there is strong evidence that this situation is worsening because nine of these extinctions took place since 1980 (compared with five birds (17) and no mammals (18)). Of greater concern is the number of species that can no longer be found ("possibly extinct" - not formally "Extinct" until exhaustive surveys to establish their disappearance are completed). The GAA lists 122 such species, and it appears

that up to 113 of these have almost or completely disappeared since 1980. Proving extinction beyond reasonable doubt is often very difficult, as many of these declines have been very rapid and have happened only recently, and a few species that were thought to be extinct have been rediscovered in recent years (19). The GAA estimates that between nine and 122 amphibian species have therefore become extinct since 1980, and extensive fieldwork is needed to produce a more precise number.

There are 435 species that qualify for listing in IUCN categories of higher threat than they would have in 1980 (15). We define these as “rapidly declining” species, and divide them into three groups based on the causes of their decline (15): “over-exploited”—declining because of heavy extraction (50 species); “reduced-habitat”—suffering significant habitat loss (183 species); and “enigmatic-decline”—declining, even where suitable habitat remains, for reasons that are not fully understood, although disease and climate change are emerging as the most commonly cited causes (207 species) (3, 7, 13, 20–24). Five species fall into both the “over-exploited” and “enigmatic-decline” groupings. “Over-exploited” and “reduced-habitat” species are widely recorded in many taxonomic groups, such as birds and mammals (17–18), and are the traditional focus of conservation efforts. However, “enigmatic-decline” species have never previously been recorded at a level comparable to that currently observed in amphibians. The percentage of “enigmatic-decline” species increases with increasing extinction risk, from 9.7% of the “rapidly declining” species in the IUCN Category Near Threatened, to 25.0% in Vulnerable, 47.3% in Endangered, 57.1% in Critically Endangered, and 92.4% in Critically Endangered (Possibly Extinct). This observation suggests that the factors causing “enigmatic” declines are driving species towards extinction particularly rapidly.

The geographic distribution of “rapidly declining” species is non-random (Table 1) (15). Neotropical species are much more affected than, for example, those in the Afrotropical and Indomalayan Realms. Species from the Australasian-Oceanic Realm show average numbers of “rapidly declining” species, but if Australia and New Zealand are considered as a separate group, they have significantly more “enigmatic-decline” species than the average for amphibians as a whole. The geographic distribution of “rapidly declining” species (Fig. 1) shows that: “over-exploited” species are concentrated in East and Southeast Asia; “reduced-habitat” species occur more widely, but especially in Southeast Asia, West Africa, and the Caribbean; and “enigmatic-decline” species are restricted mostly to South America, Mesoamerica, Puerto Rico and Australia. There is remarkably little geographic overlap between concentrations of species in the three groupings.

“Enigmatic-decline” species present the greatest challenge for conservation because there are currently no known techniques for ensuring their survival in the wild. Such declines have taken place even within well-protected areas, such as Yosemite National Park (California, 1), Monteverde Cloud Forest Preserve (Costa Rica, 5–6) and Eungella National Park (Australia, 14). “Enigmatic-decline” species are positively associated with streams at high elevations in the tropics, and negatively associated with still water and low elevations (Table 1). Several studies indicate that the virulence of the fungal disease chytridiomycosis—one of the most commonly cited causes of “enigmatic” declines (22–24)—is greater at higher elevations and among streamside species (3, 7, 25). Most “enigmatic” declines have been recorded from the Americas south to Ecuador and Brazil, Australia and New Zealand, but they are spreading, for instance to Peru, Chile, Dominica, Spain and Tanzania (14, 26, 27). It is likely that the GAA underestimates the number and geographical extent of “enigmatic” declines, particularly in the tropics, where amphibians have been insufficiently monitored. Indeed, these declines tend to be very rapid, and few of them have actually been observed taking place. More commonly, researchers return to a site to find that several species have disappeared since the last visit. For example, scientists only recently documented disappearances of frogs in southern Mexico, although some of these declines probably took place in the early 1980s (28). Accordingly, well-sampled countries tend to have a higher incidence of “enigmatic” declines: for example, 12.9% in Costa Rica, compared to 6.0% in the entire geographic region where most “enigmatic” declines have taken place. It is also possible that some species are not experiencing “enigmatic” declines yet but are susceptible to doing so, particularly if these are the results of factors such as the spread of a contagious disease (13, 22–24) or increasing severity in environmental conditions due to climate change (20–21).

Rapid amphibian declines exhibit important taxonomic as well as regional patterns. Four amphibian families have significantly more “rapidly declining” species than the average for all amphibians: Rheobatrachidae (gastric-brooding frogs), Leptodactylidae (typical Neotropical frogs), Bufonidae (true toads), and the Ambystomatidae (mole salamanders) (Fig. 2) (15). Both known species of Rheobatrachidae are now extinct. Eight families have significantly fewer than the average percentage of “rapidly declining” species (Fig. 2), but for the two caecilian families, Caeciliidae and Ichthyophidae, this result might be an artifact caused by the large percentages of Data Deficient species (61% and 82% respectively). The analysis depicted in Fig. 2 compares the percentage of “rapidly declining” species per family with the average for amphibians as a whole. However, taxa such as birds and mammals have few “rapidly declining”

species, suggesting that rapid declines are usually rare occurrences. From this perspective, most amphibian families have significantly more “rapidly declining” species than should be expected.

Four families contribute overwhelmingly to the total number of “rapidly declining” species: Bufonidae, Leptodactylidae, Hylidae (treefrogs) and Ranidae (true frogs) (Fig. 3). The three kinds of decline vary in their importance to each family. Over-exploitation is much more important in the Ranidae than in the other large families, reflecting the extensive harvest of these species for human consumption, especially in Asia. Declines caused by habitat loss are important in most families, and “enigmatic” declines have had a particularly major impact in the Bufonidae (29). Some very small families, such as Rheobatrachidae, Rhinodermatidae (Darwin’s frogs) and Cryptobranchidae (giant salamanders) also have high proportions of “rapidly declining” species.

The wide variation between families in the number and proportion of “rapidly declining” species is confounded by the non-random geographic pattern of declines (Table 1, Fig. 1). Families that are endemic to regions where “enigmatic” declines have taken place tend to be more susceptible to serious declines. If “enigmatic” declines spread to other regions, especially in Africa and Asia, then it is likely that some other families will prove to be susceptible to declining rapidly (29).

The findings of the GAA confirm earlier suspicions that rapid and poorly explained declines in amphibian populations are taking place in addition to the typical causes of biodiversity loss, including habitat loss and over-exploitation (which are also serious for amphibians) (5, 10). Most extinction rate models are based on predicted habitat loss, either as a result of direct human activity (30–31) or climate change (32). Because these models do not take account of “enigmatic” declines of the type affecting amphibian species, they underestimate the current extinction rate in amphibians. For a species facing an “enigmatic” decline, the only conservation option currently available is captive breeding, but many of the species affected are hard to maintain in *ex situ* conditions. Unless these declines are quickly understood and reversed, hundreds of species of amphibian can be expected to go extinct over the next few decades.

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Supporting Online Material

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Materials and Methods

Fig. S1

Tables S1 to S7

Appendix S1

References

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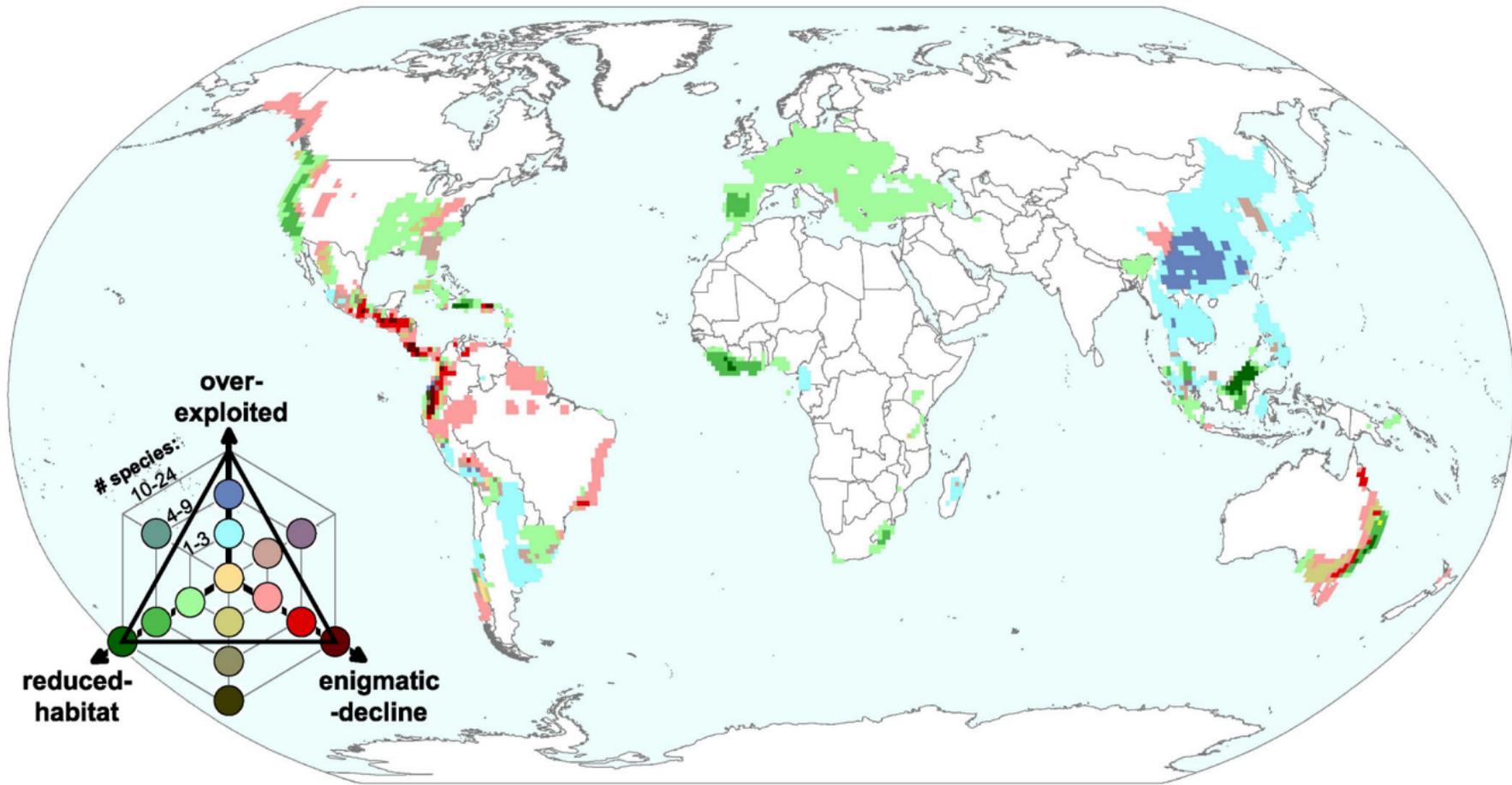
Include this information when citing this paper.

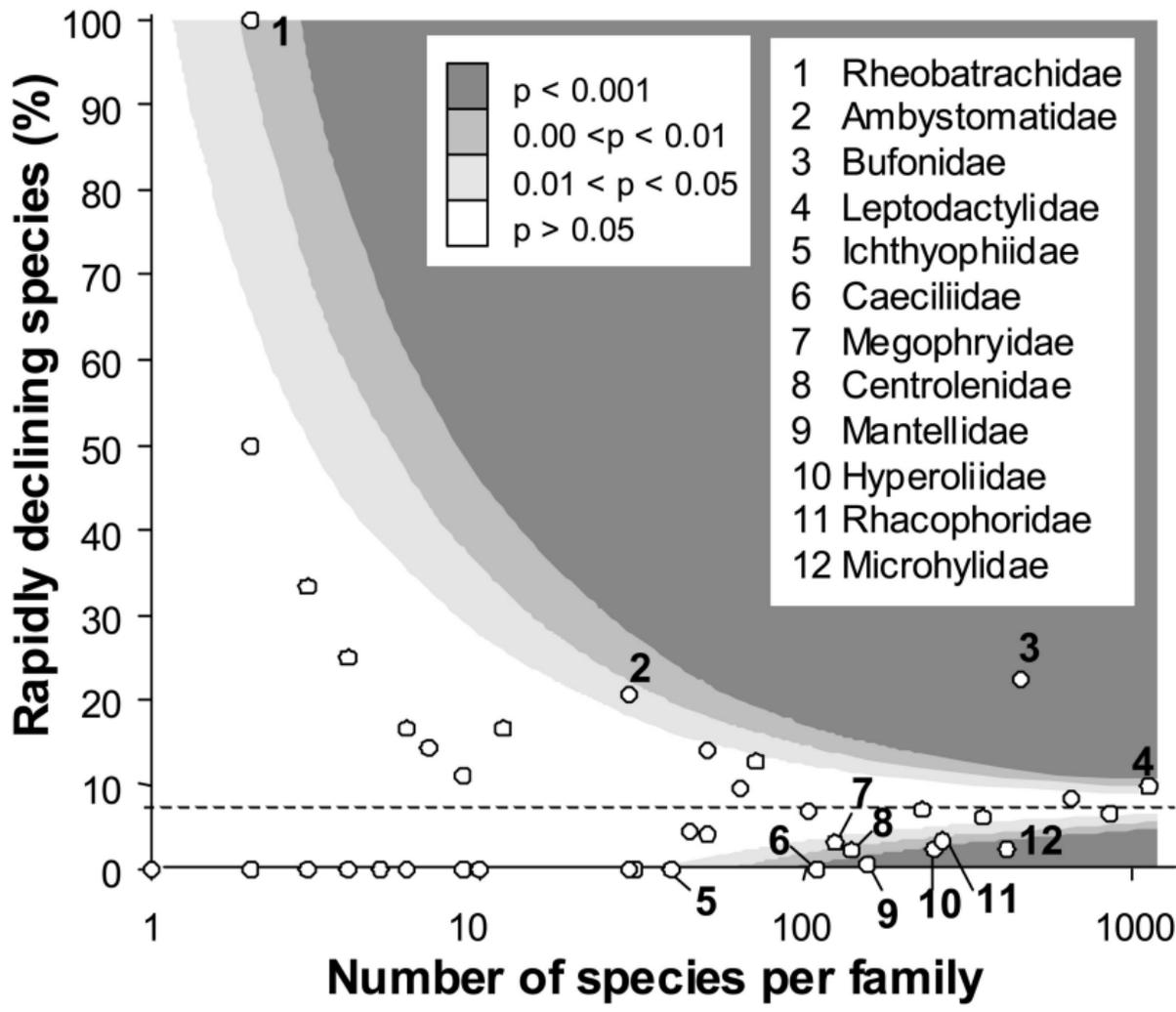
Fig. 1. Geographical pattern of the dominant cause for rapid decline (*I*₅) in amphibian species: “over-exploited” (shades of blue); “reduced-habitat” (shades of green); “enigmatic-decline” (shades of red). Where two threat types overlap in the same 1-degree cell, the color referring to the threat type with the larger number of “rapidly declining” species in that cell is indicated on the map. Intermediate colors are shown in cases of equal numbers of species experiencing two types of decline in the same cell, as shown in the key. Darker colors correspond to higher numbers of “rapidly declining” species of any type (not just of the dominant type in the cell in question).

Fig. 2. Percentage of “rapidly declining” species (*I*₅) per amphibian family in relation to the average across all

amphibians. The horizontal dashed line represents the overall mean percentage of “rapidly declining” species (7.6%).

Fig. 3. Percentages and numbers of “rapidly declining” species (*I*₅) in amphibian families (with at least one rapidly declining species), broken into groups reflecting the dominant cause for rapid decline: over-exploitation; habitat loss; “enigmatic” decline.





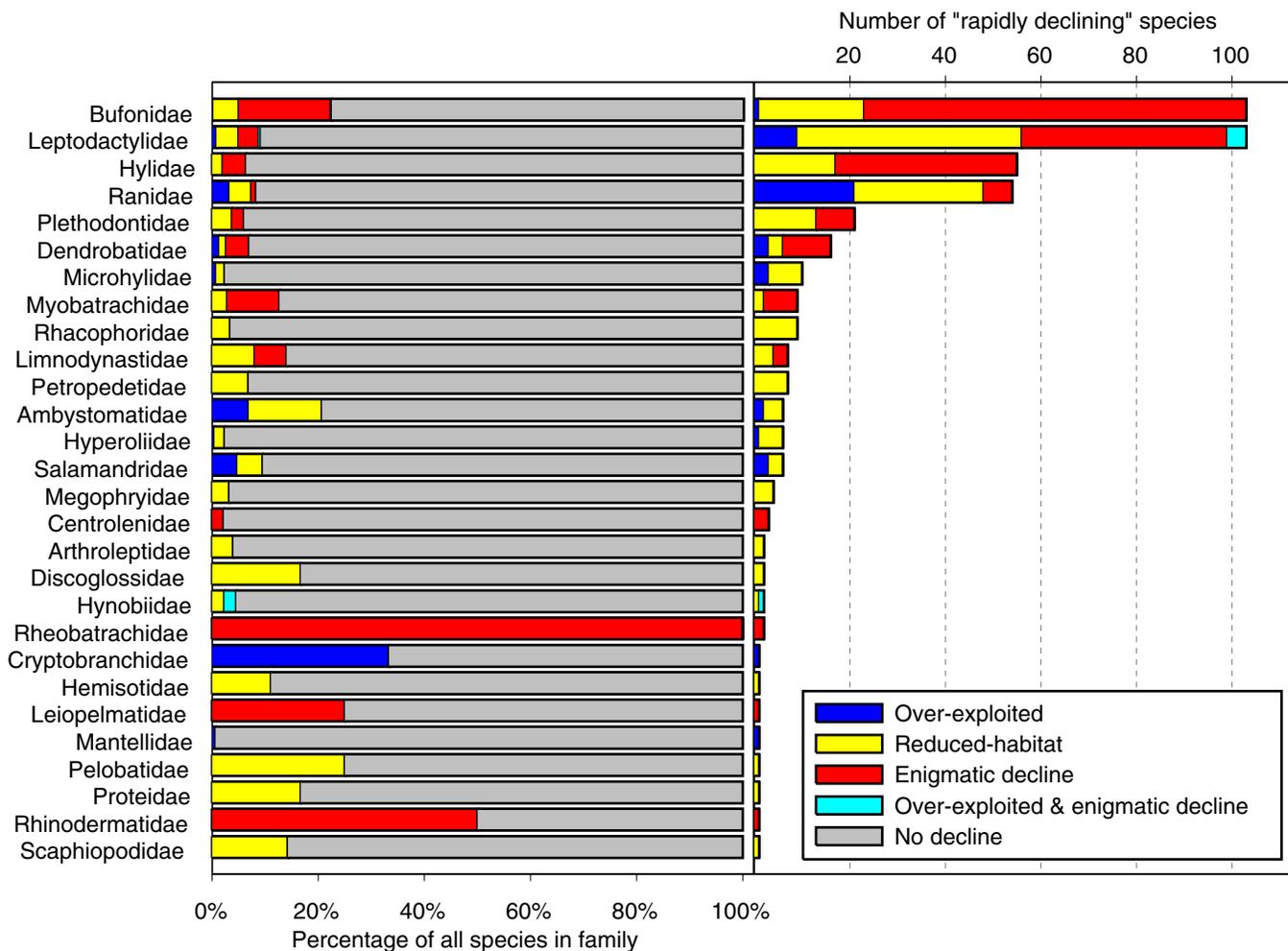


Table 1. Habitat preferences and biogeographic affinities of “rapidly declining” and “enigmatic-decline” amphibians in relation to all amphibian species (15).

Habitat preferences	Total number of species (%)	Number of “rapidly declining” species† (%)	Number of “enigmatic-decline” species‡ (%)
Forest	4,699 (81.8)	365 (82.6)	187 (90.3) ***↑
Savanna	487 (8.5)	7 (1.6) ***↓	0 (0.0) ***↓
Shrubland	814 (14.2)	47 (10.6) *↓	14 (6.8) ***↓
Grassland	953 (16.6)	81 (18.3)	39 (18.8)
Flowing water	2,650 (46.1)	277 (62.7) ***↑	164 (79.2) ***↑
Marshes / swamps	760 (13.2)	43 (9.7) *↓	14 (6.8) **↓
Still water bodies	2,030 (35.3)	107 (24.2) ***↓	28 (13.5) ***↓
Artificial terrestrial habitats	1,304 (22.7)	40 (9.0) ***↓	22 (10.6) ***↓
Tropical lowland habitats	3,392 (59.1)	212 (48.0) **↓	79 (38.2) ***↓
Tropical montane habitats	2,714 (47.3)	251 (56.8) ***↑	155 (74.9) ***↑
Biogeographic realms			
Afrotropical	951 (16.6)	28 (6.3) ***↓	1 (0.5) ***↓
Australasian/ Oceanic	561 (9.8)	36 (8.1)	23 (11.1)
Australia and New Zealand	219 (3.8)	32 (7.2) ***↑	23 (11.1) ***↑
Indomalayan	938 (16.3)	59 (13.3)	1 (0.5) ***↓
Nearctic	331 (5.8)	24 (5.4)	9 (4.3)
Neotropical	2,825 (49.2)	279 (63.1) ***↑	174 (84.1) ***↑
Palaearctic	451 (7.9)	34 (7.7)	2 (1.0) ***↓

†“Rapidly declining” species: those that now qualify for listing in a IUCN Red List Category of higher threat than they did in 1980. ‡“Enigmatic-decline” species: “rapidly declining” species that have shown dramatic declines, even where suitable habitat remains, for reasons they are not fully explained. See text for more details.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ (27). ↑ significantly higher than average, ↓ significantly lower than average.