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Review article

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Conservation priorities for global amphibian biodiversity

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Abstract

Amphibians are the most threatened vertebrate group on Earth, with 41% of species classified as globally threatened. In this Review, we discuss important conservation developments, population trends and International Union for the Conservation of Nature (IUCN) conservation status assessments for amphibians worldwide. Between 1980 and 2004, 482 species declined in conservation status, and 306 species declined in conservation status between 2004 and 2022. By contrast, the conservation status of 35 species improved between 1980 and 2004, and 86 species improved in conservation status between 2004 and 2022. Improvements have been associated with effective habitat protection and improved management practices. Tools such as the Threatened Amphibian Landscapes have been instrumental in informing decision-making and allocation of limited resources. Notable advances and successes in amphibian conservation rely on established protocols, and the monitoring of their efficacy through the IUCN Red List Index and the Green Status of Species. Although examples of genuine improvement in species' conservation status provide optimism, improved cooperation across conservation guidelines (such as the Threatened Amphibian Landscapes or the Kunming-Montreal Global Biodiversity Framework (KM-GBF)), landscapes, and diverse organizations is necessary to meet the KM-GBF targets relevant for the future of amphibian conservation.

Sections

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Introduction

Even though amphibians have indispensable roles in ecosystems (Box 1), they are the most threatened group of vertebrates[1] and receive substantially less conservation attention[2,3] than other groups. Amphibians represent 25.2% of all threatened vertebrates on the International Union for the Conservation of Nature (IUCN) Red List, but receive only 3.4% of the funding allocated for vertebrates[4–6]. With 37 amphibian species already declared Extinct (EX) and another 185 species considered Critically Endangered (Possibly Extinct) (CR(PE)), their survival demands urgent action[7].

Amphibian conservation and research priorities have shifted since the amphibian biodiversity crisis was first identified[8]. Threats such as UV radiation and acid rain that were once widespread concerns are now only regionally and temporally restricted concerns[9–11]. However, other threats have escalated globally, particularly habitat loss and degradation, climate change and infectious diseases[7,12–14]. Additionally, changes in population dynamics[11] and the description of more than 1,500 new species over the past decade[15] underscore the need for a thorough re-evaluation of conservation priorities to safeguard global amphibian biodiversity. Evidence-based 'action plans' are being developed at an increasing rate, at both global and local levels[16]. These action plans can target ecosystems[17,18], genera (such as *Atelopus*[19]) and species (such as the Critically Endangered (CR) *Leptodactylus fallax*[20] or the Endangered (EN) *Mantella cowanii*[21]), and provide crucial support for amphibian conservation. The resulting frameworks provide direct guidance for setting conservation priorities in the coming decades.

Although some losses cannot be remediated, conservation actions based on sound scientific evidence generally have positive effects[22–25]. The removal of primary threats often provides sufficient support to help these species to withstand other pressures[8,26]. For example, removing invasive fish has enabled the survival of the CR spotted tree-frog (*Litoria spenceri*), and the recovery of populations of the Vulnerable (VU) Iberian frog (*Rana iberica*), despite the presence of secondary threats[27,28]. In limited cases, new populations of species once considered possibly extinct have been discovered. For example, 37% of 'lost' *Atelopus* spp. have had new populations discovered[29]. Although these rediscoveries could indicate some level of persistence, they do not necessarily represent recoveries; they more probably reflect increased targeted field efforts, improved survey methodologies and a deeper understanding of species' ecology, rather than inherent species resilience or the result of effective conservation actions. In fact, populations of more than 100 *Atelopus* spp. have shown no evidence of true recovery in the two decades following the severe declines reported in the 1990s (ref. [30]), underscoring the urgent need for more targeted and sustained conservation actions[31].

In addition, some amphibians might be more resilient than previously suggested[32], or might persist without human interventions. Striking examples include rapid phenotypic and genetic adaptation[33,34], such as the evolution of resistance to disease[35–38], adaptation to novel landscapes[39,40] or conditions[41], and colonization of anthropogenic habitats[42] such as agricultural wetlands (for example, rice paddies)[43]. This resilience can enhance conservation efforts, demonstrating the value of maximizing the adaptive potential of populations.

Here, we review the state of conservation priorities for global amphibian biodiversity, highlighting the conservation efforts that have resulted in improvements in the conservation status of species. We identify the main threats (habitat loss and degradation, climate change, infectious diseases, ecotoxicology and over-exploitation) and discuss how these threats can be mitigated. Conservation interventions across species, landscape and global scales are all important elements of amphibian conservation, but further integration with the Kunming-Montreal Global Biodiversity Framework (KM-GBF) (particularly under Target 4) is needed. New data streams and modelling technologies, as well as innovative solutions such as genetic intervention and pathogen remediation, will drive effective conservation programmes going forward.

Threats and conservation status

We first discuss the threats to amphibians, their geographic distribution and the extent to which conservation statuses have changed over time.

Box 1 | Ecological roles and ecosystem services supported by amphibians

Ecologically, amphibians are indispensable[238]. They are key nodes in food webs (as both predator and prey), are efficient energy converters[239,240] and represent a large proportion of the vertebrate biomass[241]. In addition, they facilitate nutrient cycling between aquatic and terrestrial systems[242–244] and enhance soil aeration and productivity[245]. Their decline triggers cascading biodiversity losses, affecting predators and ecosystem stability[246]. Many ecosystem roles remain unknown, highlighting the unforeseen risks of losing any species.

Amphibians also provide ecosystem services (meaning that they provide benefits that support human activities). One important ecosystem service is agricultural pest control[247]; in Brazil alone, pest control by anurans accounts for US$1.18 billion in successful crop harvests, with amphibians consuming up to 300 million individual crop pests annually according to estimates in research that have not been peer-reviewed[248]. Furthermore, amphibians control disease vectors; because they are efficient consumers of disease vectors such as those responsible for malaria or dengue[249–251], the absence of amphibians can lead to an increase in malaria[250]. Other ecosystem services associated with amphibians include landforming[252], supporting nutrient dynamics[246] and facilitating energy flow across different habitats including from aquatic to terrestrial environments[253,254]. Aspects of amphibian biology have led to important advances in medicine and technology, including biological glues[255], novel antibiotics[256], Wi-Fi algorithms[257], cold tolerance mechanisms[258] and physiology in space[259].

Beyond these monetary or utilitarian benefits, amphibians also possess intrinsic worth and cultural value[260]. Historically and currently, humans have relied on amphibians for food[261,262], for hunting practices[263] and as bioindicators[264]. Culturally, amphibians feature prominently in symbolism worldwide, in ancient (for example, Egyptian and Greek[261,265]) and contemporary (for example, East Asian[238]) civilizations.

Finally, distinctive species serve as effective conservation flagships, generating ecotourism revenue (for example, in Madagascar and Costa Rica) and funding protection efforts[266,267], exemplified by the Chile Darwin's frog[238]. Protecting amphibians is thus vital for maintaining healthy ecosystems, human health, cultural heritage and economic benefits.

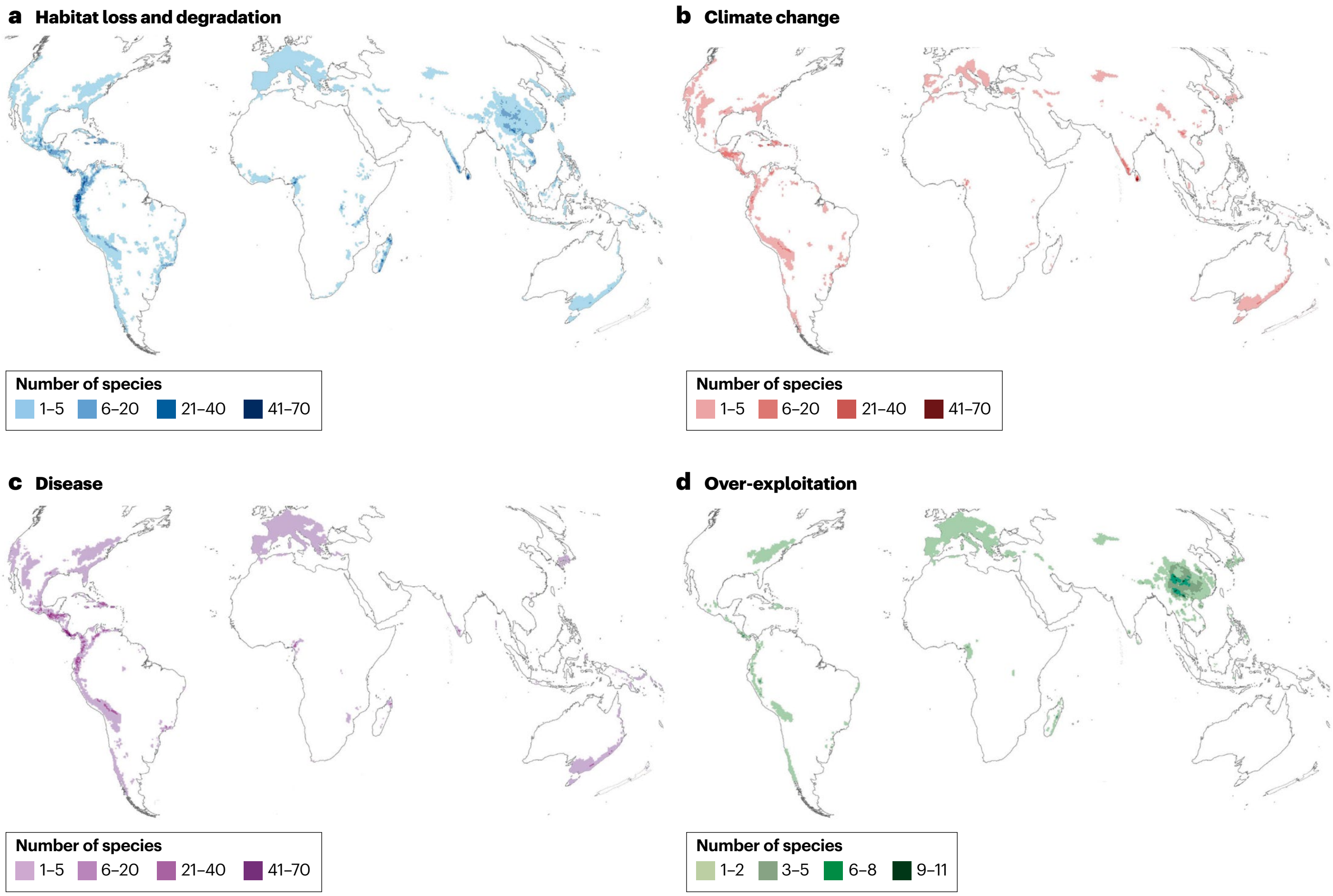

Fig. 1 | The four major threats to threatened amphibians. The number of species affected by each of four main threats mapped globally. **a**, Habitat loss and degradation affects 2,684 species. **b**, Climate change affects 845 species. **c**, Disease affects 880 species. **d**, Over-exploitation affects 257 species. Data in all parts are derived from the second Global Amphibian Assessment (GAA2)[7].

The discussion is primarily based on the results of the second Global Amphibian Assessment (GAA2)[7,44], coordinated by the Amphibian Red List Authority of the IUCN Species Survival Commission (SSC) Amphibian Specialist Group.

Threats

Major threats to amphibians can be divided into those that are relatively well understood and documented, such as habitat loss and degradation and over-exploitation, and those that are more complex, such as climate change and disease[45] (Fig. 1). The threat affecting the highest number of threatened species is habitat loss and degradation, with agriculture affecting 77% of species, timber and plant harvesting affecting 53%, and infrastructure development affecting 40%. Climate change and disease rank equal second in affecting the highest number of species, each affecting 29% of threatened species[7], and are considered intractable threats[46]. Fourth comes over-exploitation (such as use for food and the pet trade), affecting 8% of threatened species[47,48].

Even among the better-understood threats, there are still unknown variables and multifaceted impacts that are threshold-dependent and situation-dependent. For example, habitat loss and degradation resulting from common land-use changes such as agriculture, cattle-raising, urbanization, deforestation, silviculture and selective logging have different impacts on amphibian richness, although they all lead to decreases in community richness[13,49] (Supplementary Fig. 1). Shifts in suitable habitats[50–53] and ecological niches driven by phenological changes due to climate change[54,55] can interact synergistically with other threats such as diseases and habitat loss[46,56–58]. Finally, these threats vary in their influence on different life stages and ecosystems, necessitating a refined understanding and nuanced response to guide effective conservation[59].

Although broad threatening processes are generally well documented, greater specificity and comprehensive synthesis are needed to assess their magnitude, identify conservation actions for mitigation and communicate these findings effectively[16]. This is especially true for caecilians, as their threats remain under-reported[60].

Distribution of threatened species

A total 2,873 out of 8,011 amphibian species were listed as threatened (CR, EN and VU) on the IUCN Red List of Threatened Species[7] at the time of the GAA2, completed in 2022. Salamanders are particularly at high risk of extinction, with 60% of species globally threatened, compared with 39% of frogs and 16% of caecilians[7]. Threatened amphibians are

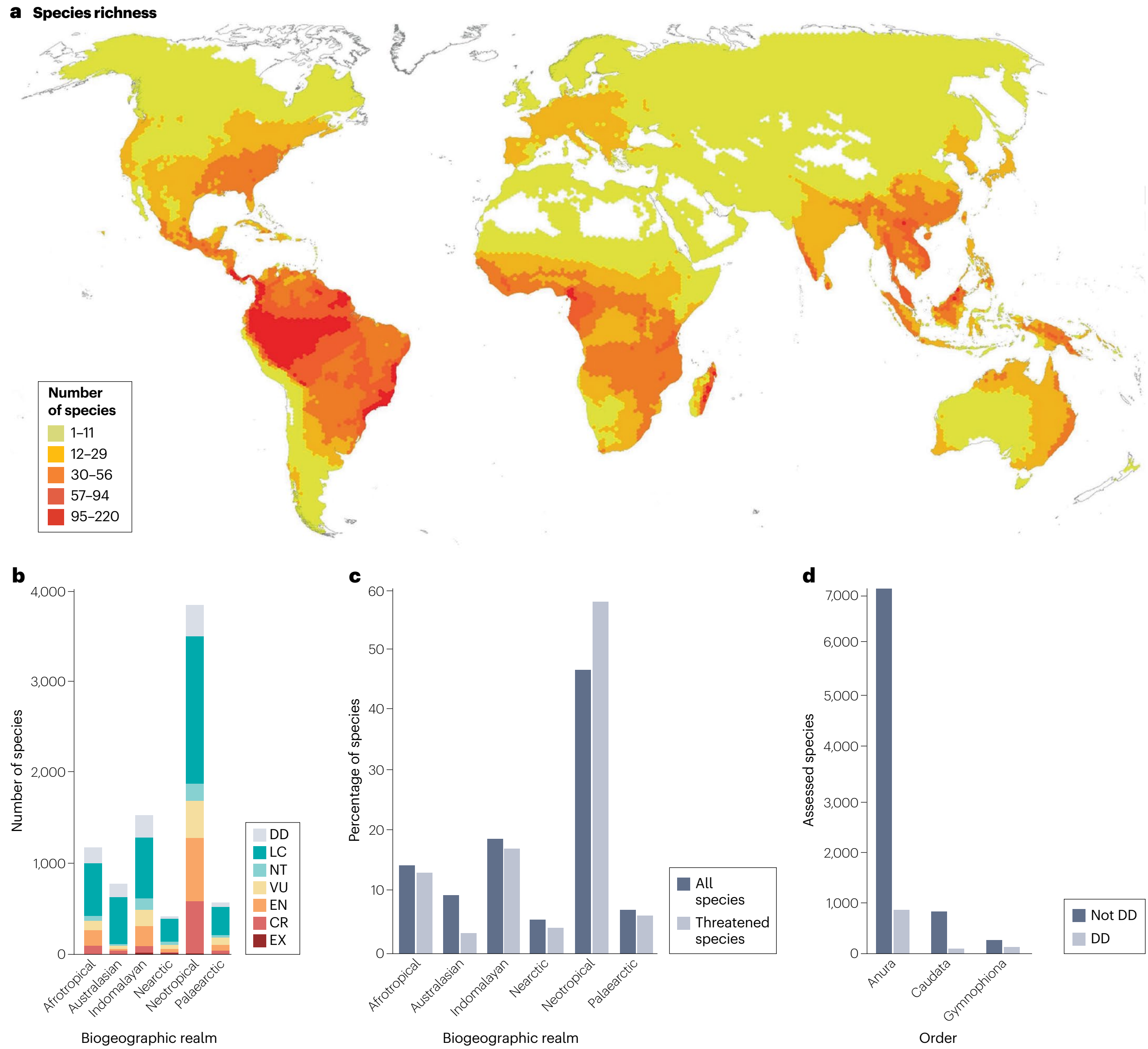

Fig. 2 | Distribution of amphibian species. a, Global distribution of amphibian species richness. **b**, Number of threatened and non-threatened amphibian species in each biogeographic realm, with different colours denoting the International Union for the Conservation of Nature (IUCN) Red List categories. **c**, Percentage of all species (dark grey) and threatened species (light grey) in each biogeographic realm. **d**, Number of Data Deficient (DD) species (light grey) and non-DD species (dark grey) that have been assessed by the IUCN: 11% of assessed Anura, 6% of assessed Caudata and 44% of Gymnophiona are DD. LC, Least Concern; NT, Near Threatened; VU, Vulnerable; EN, Endangered; CR, Critically Endangered; EX, Extinct.

concentrated in global biodiversity hot spots, including the Caribbean islands, Mesoamerica, Tropical Andes, Atlantic Forest of southern Brazil, mountains and forests of western Cameroon and eastern Nigeria, Eastern Arc Mountains of Tanzania, Madagascar, Western Ghats of India, Sri Lanka, central and southern China, and the Annamite Mountains of Vietnam[7] (Fig. 2a).

Effectively addressing threats requires comprehensive data on species distributions, ecology and population trends. However, the lack of capacity in some amphibian-rich but resource-poor regions[16] results in knowledge gaps, making it difficult to accurately assess species' vulnerability and implement targeted conservation measures[61]. In the GAA2 (ref. 7), 909 species were listed as Data Deficient (DD), lacking sufficient data to determine their conservation status, including 44% of caecilians[7,48] (Fig. 2d). This data insufficiency, combined with a high rate of new species descriptions (approximately 150 per year globally) and many species yet to be described[62], creates challenges in keeping up with conservation status assessments and implementing timely conservation actions.

The Red List Index and status changes

The IUCN Red List Index (RLI) is a measure of the average extinction risk of a group of species; an RLI value of 1.0 indicates that all species are of Least Concern (LC), whereas an RLI value of 0 indicates that all species are EX. The most recent RLI for amphibians reveals a continuing decline in their conservation status: the RLI value was 0.76 in 1980, 0.74 in 2004 and 0.73 in 2022. Salamanders, direct developing species, and species occurring in the Neotropics have the lowest RLI values, making them the most threatened groups[7].

Changes in conservation status over time are one way to measure the success of conservation actions. Hereafter, 'uplisting' refers to movement to a higher extinction risk category (for example, from EN to CR), whereas 'downlisting' refers to movement to a lower extinction risk category (for example, from EN to VU). It is important to note that 1980 and 2004 categories used here are back-cast based on data derived from an analysis performed as part of the GAA2 (ref. 7). This backcasting method uses the information in the current Red List assessments in combination with additional knowledge on threatening processes, habitat decline trends and conservation actions (and in some cases further expert consultation) to determine whether a genuine change in the Red List category of a species is likely to have occurred between 1980–2004 and 2004–2022. In the absence of notable evidence suggesting a genuine change, the GAA2 Red List category was assumed to be the same for previous time periods.

A total of 120 species have been downlisted since 1980, with a large number of downlistings in countries such as Costa Rica, India and Malaysia[7]. The majority (51%) of these downlistings were attributed to enhanced habitat protection through the establishment of effective protected areas and/or improved management practices (Fig. 3). The additional 57 downlistings were attributed to reductions in the rate of population decline caused by the chytrid fungus pandemic (driven by the pathogens *Batrachochytrium dendrobatidis*)[63]. A few of these species seem to have survived the disease outbreak by evolving resistance to *B. dendrobatidis*[36]. However, most populations have not recovered from disease-driven declines[7,64]. With fewer than 2% of amphibian species being downlisted since 2004, it is evident that investments in amphibian conservation must be substantially increased to reverse the ongoing extinction crisis (Fig. 3).

A total of 722 species were uplisted at least once since 1980. Uplistings were primarily attributed to disease and habitat loss from 1980 to 2004, and attributed to ongoing and projected effects of climate change (39% of uplistings) and habitat loss and degradation (37%) from 2004 to 2022. Although disease is the primary cause of uplisting for 23% of species between 1980 and 2004, it remains the leading factor driving species into the highest extinction risk categories in 2022 (ref. 7). The number of CR species increased from 588 in 1980 to 798 in 2022. Additionally, the number of species considered CR(PE) rose from 24 to 185, and confirmed extinctions from 23 to 37 over the same period[7] (Fig. 4). The number of uplistings varies across amphibian families (Supplementary Fig. 2).

The majority of threatened species were neither uplisted nor downlisted between 1980 and 2022; specifically, 7,214 out of 8,011 species (90%) did not experience a category change over either time period (Fig. 4). However, this lack of change does not necessarily indicate that the population of each of these species remained stable. Importantly, as of June 2025, only five threatened species show an increasing population trend, as opposed to 2,281 threatened species with decreasing population trends. Downlistings remain rare, and decreasing population size remains the most common population trend.

Conservation interventions

Given the substantial ongoing declines of amphibian species, conservation attention has turned to threat mitigation and various other interventions across multiple scales (species, landscape and global), which are discussed in this section.

Importance of interventions

Despite widespread threats and extinction rates for amphibians soaring hundreds of times above background rates[65], amphibian conservation interventions have been effective in reversing some declines[66,67]. There were 482 species uplisted from 1980 to 2004, and 306 from 2004 to 2022, while during the same periods, conservation actions have resulted in 23 species (of 35 in total) being downlisted from 1980 to 2004, and 40 (of 86 in total) from 2004 to 2022 (Fig. 4). However, these interventions must be massively increased[68], as large-scale conservation actions to reverse multiple declines at the ecosystem level are either inefficient or require substantial long-term investments[69]. In addition, common and widespread species provide ecological services so should not be overlooked for conservation interventions, even though their geographic ranges, population sizes or declines do not meet the thresholds for threatened categories[70].

Large-scale proactive interventions, such as reforestation and the establishment of large, effective protected areas, are crucial in reversing the decline of some populations and their ecosystems[71]. For instance, in the Amazonian rainforest, habitat protection and restoration positively affected hundreds of species[72]. However, implementing large-scale conservation efforts comes with challenges, particularly in identifying the most effective areas for protection. General indices such as biodiversity 'hot spots' do not always align with amphibian genetic diversity and endemism[73,74]. Furthermore, although the number of protected areas has increased over the past 10 years, the number of unprotected amphibian species has also risen. Many of these unprotected species are classified as DD[75], highlighting the gaps in the ability to adequately protect all species. Furthermore, protected areas can often be ineffective at protecting species whose primary threats are disease and climate change. Therefore, other proactive interventions are required for effective amphibian conservation.

Proactive conservation interventions such as habitat creation and restoration can effectively support colonization and subsequent occupation[13,69] when conservation planning is conducted pre-emptively[70]. Small-scale interventions are effective at protecting subpopulations in specific habitats[67] and can also be successful in preventing extinctions for micro-endemic amphibians (species restricted to a very small area). As a result, one of the most promising developments is the demonstration that micro-reserves, ranging from a few hundred square metres for *Alytes obstetricans* in Spain[76] to a few square kilometres[77], are effective for protecting populations of some amphibians[77]. Another targeted, amphibian-focused approach is to prioritize the 50 focal areas designated as Threatened Amphibian Landscapes and covering 71% of all threatened amphibians[44], ensuring that conservation interventions are directed where they are most needed.

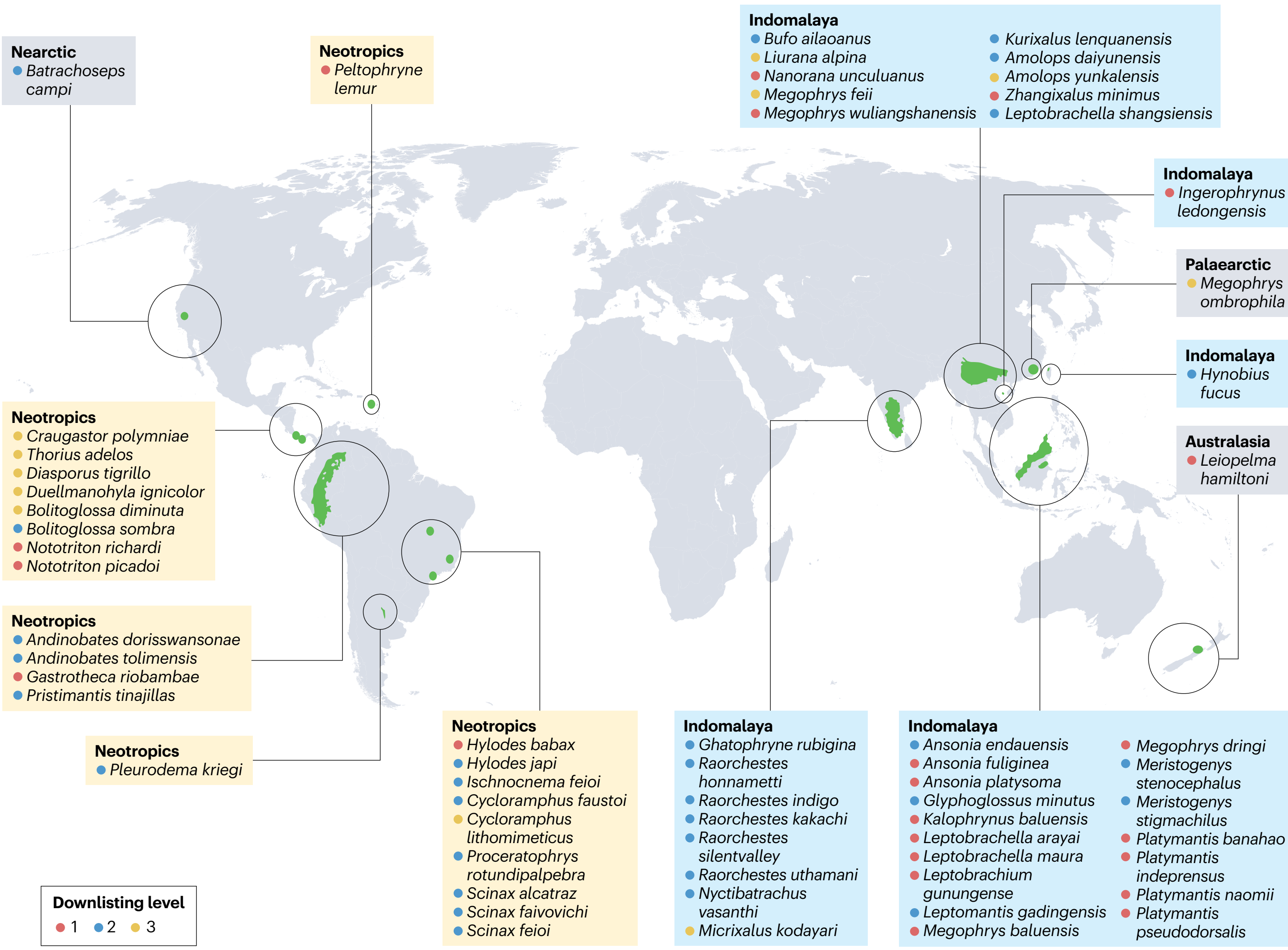

Fig. 3 | Key International Union for the Conservation of Nature (IUCN) status downlistings. Since 1980, 63 species downlistings, some from back-cast categories, have been attributed to conservation practice. Downlisting level 1 (red) indicates an improvement of one category, level 2 (blue) indicates an improvement of two categories and level 3 (yellow) indicates an improvement of three categories. Green areas on the map show locations of downlisted species. The back-cast data are derived from the analysis for the second Global Amphibian Assessment (GAA2)[7], as defined in 'The Red List Index and status changes' in the main text.

Conservation interventions across scales

Conservation interventions are needed across scales from the species level to the landscape level, so that multiple threats can be mitigated in a coordinated and effective way, especially given the limited resources available (Table 1; Supplementary Table 1). Thus, conservation planning is critical and should be guided by existing processes and frameworks established to support biodiversity[78–81]. Interventions must focus on preventing further population declines, maintaining genetic diversity and restoring connectivity[82]. Here, we review conservation interventions effective for amphibians at the species, landscape and ecosystem, and global levels (Box 2). For instance, solutions developed to address climate change-related risks – such as microhabitat creation[83], water management[23,84,85], habitat restoration, including improving the connectivity of aquatic habitats[86–89], and biobanking and cryopreservation[90] – have impacts across different scales.

Species level. Conservation interventions at the species level can be implemented in various ways[16], starting for instance with the deployment of artificial structures used as shelters[91]. However, most actions are influenced by making resources accessible, and the overall complexity of the task[92]. A review of conservation action plans for a broad range of species found that declines in threatened species slowed and eventually reversed with positive recovery trends of recovery within 15 years, and projected outcomes show that it would have been far worse without the planning interventions[93]. As a result, species-specific or multispecies action plans for amphibians are strongly recommended[81].

An increasingly used species management tool is translocations, defined as the human-mediated movement of living organisms from one area with release in another[94]. Translocations include the movement of wild individuals to a new site, release of captive-bred individuals and headstarting, where eggs or larvae are brought into captivity to decrease the mortality of these vulnerable life stages, and then released into the wild once mortality is likely to be lower[95]. Where there have been substantial declines in a species' population or geographic range, translocations can be used to re-establish populations that have become locally extinct, or to bolster population viability and increase the rate of species recovery, thereby limiting periods of extinction vulnerability[96]. Best practice guidelines have been developed for amphibian translocations[97], and should be followed to ensure success[95].

The effectiveness of amphibian translocations varies[98–104], with different reviews finding success rates ranging from 22% to 50%[103,104] and a high proportion of unknown outcomes[99,103,104]. Translocation failures are typically explained by dispersal from the release site, lack of suitable habitat, low founder numbers and poor release design[99,104–106]. The lack of post-release monitoring also hinders the ability to assess the outcome of many amphibian translocations[95,99,103,104]. Decades of monitoring might be required to establish translocation efficacy in species with slow life histories[95,107,108]. However, monitoring can be challenging to implement, particularly for cryptic species[106,108]. Genetic approaches, including non-invasive surveillance approaches such as environmental DNA (eDNA)[109,110], have not been widely implemented for evaluating translocation success in amphibians, but have been used successfully in species such as guppies[111].

Conservation breeding is also a widely used conservation strategy[112]. Ex situ programmes can aid species recovery, primarily by providing animals for translocations[113,114]. The targeted use of conservation breeding for amphibians was advocated by the IUCN in 2005 (ref. 115), and its application has increased over the years[116]. The IUCN's 2024 Amphibian Conservation Action Plan (ACAP)[16] continues to emphasize the importance of ex situ management as a conservation tool for amphibians. However, ex situ efforts must be paired with in situ conservation actions to ensure long-term success and sustainability.

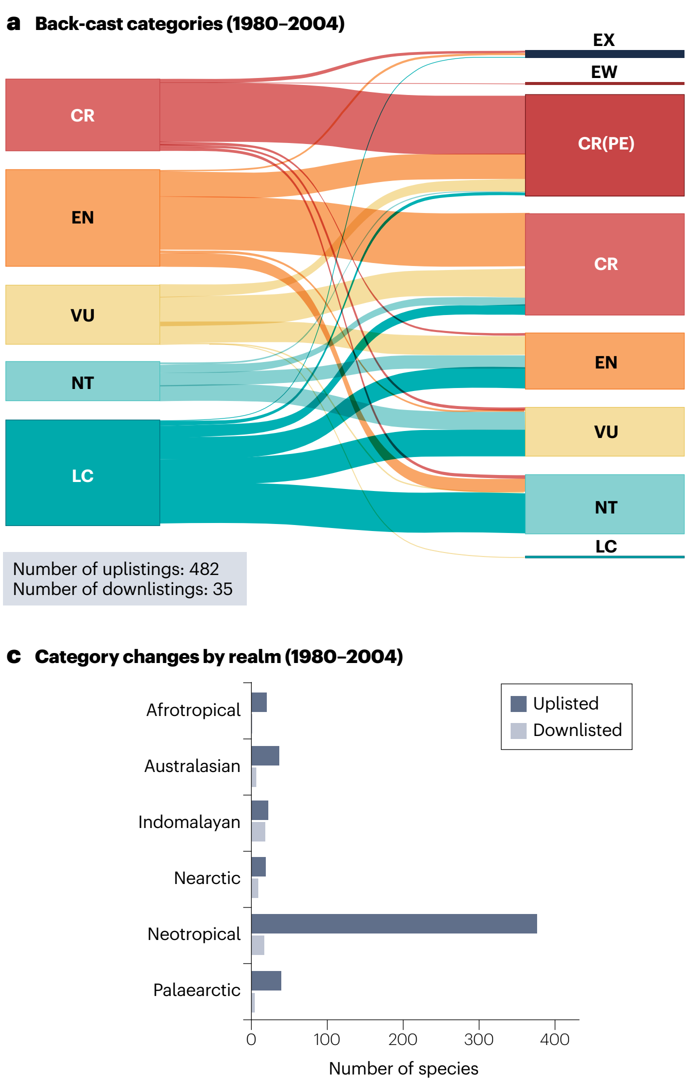

Fig. 4 | Temporal and regional variation in threat status. **a**, Category changes from 1980 to 2004 using backcast categories from the second Global Amphibian Assessment (GAA2) (517 species). **b**, Category changes from 2004 to 2022 using backcast categories from the GAA2 (392 species). International Union for the Conservation of Nature (IUCN) Red List categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (Possibly Extinct) (CR(PE)), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC). **c**, Biogeographic realm of uplistings and downlistings from 1980 to 2004. **d**, Biogeographic realm of uplistings (black) and downlistings (grey) from 2004 to 2022.

Table 1 | Threats and corresponding mitigation actions

Broad mitigation actions	Scale	Reclassified mitigation actions
1. Residential and commercial development		
Assisted reproduction and movement, with habitat management and restoration	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
		Human-assisted migration (40 studies)
	Landscape	Clear vegetation (9 studies)
		Control invasive species (29 studies)
		Create refuges (24 studies)
	Ecosystem	Engaging local communities (20 studies)
		Restore habitat connectivity (2 studies)
		Retain buffer zones (16 studies)
2. Agriculture and aquaculture		
Integrated species recovery, habitat management and community-based policy support	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
	Landscape	Clear vegetation (9 studies)
		Control invasive species (29 studies)
		Create refuges (24 studies)
		Use prescribed fire or modifications to burning regime (21 studies)
		Exclude domestic animals or wild hogs by fencing (5 studies)
		Manage grazing regime (7 studies)
	Ecosystem	Engaging local communities (20 studies)
		Habitat conservation (149 studies)
		Raise awareness (11 studies)
		Use legislative regulation to protect amphibians (7 studies)
3. Energy production and mining		
Assisted reproduction and habitat management	Species	Artificial reproductive technologies (21 studies)
	Landscape	Clear vegetation (9 studies)
4. Transportation and service corridors		
Enhance species recovery and reduce road impacts through assisted reproduction, translocation and habitat modification	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
		Translocation of amphibians (88 studies)
	Landscape	Clear vegetation (9 studies)
		Install barrier fencing along roads (10 studies)
		Modify gully pots and kerbs (1 study)
		Modify vegetation to create a more suitable habitat (31 studies)
		Use signage to warn motorists (1 study)
5. Biological resource use		
Support species recovery and movement while securing habitats and reducing exploitation pressures	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
		Human-assisted migration (40 studies)
	Landscape	Control invasive species (29 studies)
		Create refuges (24 studies)
		Exclude domestic animals or wild hogs by fencing (5 studies)
		Install barrier fencing along roads (10 studies)
		Leave standing deadwood, snags, woody debris in forests (11 studies)
	Ecosystem	Restore habitat connectivity (2 studies)
		Retain buffer zones (16 studies)
		Reduce impact of amphibian trade (1 study)

Table 1 (continued) | Threats and corresponding mitigation actions

Broad mitigation actions	Scale	Reclassified mitigation actions
6. Natural system modifications		
Promote species recovery and reduce threats through habitat modification and public awareness	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
	Landscape	Clear vegetation (9 studies)
		Install barrier fencing along roads (10 studies)
	Ecosystem	Raise awareness (11 studies)
7. Invasive and other problematic species, genes and disease		
Implement species recovery and habitat conservation with disease control and ecological threat reduction	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
		Reduce competition from native amphibians (1 study)
	Landscape	Clear vegetation (9 studies)
		Control invasive species (29 studies)
		Create refuges (24 studies)
		Exclude domestic animals or wild hogs by fencing (5 studies)
		Treatment for disease (35 studies)
	Ecosystem	Habitat conservation (149 studies)
		Manage grazing regime (7 studies)
		Reduce the risk of disease transmission (6 studies)
8. Pollution		
Support species recovery and improve habitat quality through targeted management and chemical use reduction	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
	Landscape	Clear vegetation (9 studies)
		Control invasive species (29 studies)
		Create refuges (24 studies)
		Exclude domestic animals or wild hogs by fencing (5 studies)
		Reduce pesticide or fertilizer use (2 studies)
9. Climate change and severe weather		
Facilitate species recovery and assisted movement while enhancing habitat complexity	Species	Artificial reproductive technologies (21 studies)
		Captive breeding (63 studies)
		Human-assisted migration (40 studies)
	Landscape	Leave standing deadwood, snags, woody debris in forests (11 studies)

The nine threat classifications are from the Threats Classification Scheme (Version 3.3) used by the IUCN Red List of Threatened Species (https://www.iucnredlist.org/resources/threat-classification-scheme). The number of studies supporting specific mitigation actions are reported in parentheses, based on information from the Conservation Evidence Database (www.conservationevidence.com). In several cases, we combined multiple small actions from Conservation Evidence into a new classification under 'Reclassified mitigation actions'. For details of reclassification, refer to Supplementary Table 1.

Conservation breeding can be an effective stopgap in the face of urgent threats[116] for the 10% of amphibians that are CR and face a high probability of extinction before meaningful threat mitigation can occur[117]. In such circumstances, a viable ex situ population can prevent extinction, allowing for reintroduction once threat levels in their native habitats have been reduced or eliminated[113]. One example of such a success is the Valcheta frog (Box 3). A standard evaluation process, the Amphibian Ark's Conservation Need Assessments[118], has been developed specifically for assessing the need for conservation breeding support for amphibian species. To date, 424 amphibian species have been identified through this process as being in need of ex situ rescue through conservation breeding[117], with programmes established for 20% of these species[119].

Future directions for amphibian conservation interventions could involve pre-release anti-predator training[120], restoring skin microbiomes[121], enhancing natural defences through dietary supplementation or probiotics and acclimating individuals in wild mesocosms before release[122], to increase survival rates[120–122].

Conservation interventions at the species level can also be integrated with larger scales. For instance, a framework called the Integrated Biodiversity Assessment Tool[123] (IBAT) aims to help decision-makers to access critical information for the conservation

Box 2 | How conservation efficacy is measured

The effectiveness of conservation actions can be assessed through several approaches and across multiple scales. For a conservation action to be deemed effective, it must not only secure the species' survival and reduce its extinction risk but also promote recovery to achieve the long-term viability and functionality of the population[268,269]. At the species level, the efficacy of conservation can be evaluated by an improvement in the International Union for the Conservation of Nature (IUCN) Red List category or an improvement in the recovery score using the IUCN Green Status of Species (GSS). The GSS measures how conservation actions have influenced the current status, what might happen if these actions cease and how a species' status could improve with continued conservation efforts[270]. Unlike the IUCN Red List, which often requires substantial changes in population size, trend or range to shift between categories, the GSS is sensitive to incremental improvements.

At the taxon level, the Red List Index (RLI) tracks changes in the overall extinction risk of groups of species, whereas the Green Status of Species Index (GSSI) tracks the average recovery scores of species groups across multiple time points. These indices provide insights into whether global efforts are making progress towards or away from recovery goals. Although the RLI and GSSI reflect global trends in extinction risk and recovery, respectively, the Living Planet Index (LPI) complements these by focusing on population trends of vertebrate species across terrestrial, freshwater and marine ecosystems, providing a broader perspective on biodiversity trends. These three indicators (RLI, GSSI and LPI) are integral to the post-2020 Kunming-Montreal Global Biodiversity Framework (KM-GBF). The RLI has been adopted as the headline indicator for Goal A, Target 4 of the KM-GBF; an index based on the GSS has been adopted as an indicator for multiple elements of the KM-GBF; and the LPI has been included as a component and complementary indicator in two goals and four targets of the KM-GBF[159,160].

At a finer scale, project management tools (such as the Conservation Measures Partnership[271]) can be used to guide the design, management, monitoring and adaptation of conservation projects towards having lasting outcomes, and the most effective use of available resources. Monitoring of the target species is essential for assessing the effectiveness of specific conservation actions. This monitoring can be achieved through tracking metrics such as population size or distribution, among other indicators. Efficient and effective monitoring strategies should have clearly defined objectives, use the most appropriate method (which can include the use of new technologies) and provide feedback into decision-making processes (reviewed elsewhere[171]). When assessing the efficacy of an action aimed at reducing a specific threat, it can be more efficient to monitor the threat directly compared with monitoring the species. For example, efforts to reduce an invasive predator can be evaluated by measuring the introduced species itself, but it is essential to link these actions to measurable changes to the target species to verify that addressing the threat positively affects the species, ensuring that assumptions about these relationships are correct[235].

Although directly linking conservation interventions to changes in the status of a species or population can be challenging, such attempts are crucial. Sutherland et al.[272] provide a thorough assessment from the available scientific evidence, highlighting conservation interventions that work for multiple taxa under specific threat, including amphibians[66]. With increased knowledge and evidence, future efforts will be better informed, leading to more effective conservation actions for amphibians and other taxa.

A review by Langhammer et al.[22] used meta-analysis to evaluate whether conservation actions, such as protected area creation and management, yield better outcomes compared with no action. The study found that, broadly speaking, conservation efforts improved the state of biodiversity or at least slowed declines in approximately two-thirds of cases. Specifically, interventions targeting species and ecosystems such as invasive species control, habitat loss reduction and restoration, protected area establishment and sustainable management have been shown to be highly effective, demonstrating large effect sizes. This provides the strongest evidence to date that conservation actions are successful and underscores the need for transformational scaling up to meet global biodiversity targets. These findings are particularly promising for amphibian conservation, as they highlight the importance of interventions tailored to the needs of species and their habitats.

of species. The IBAT draws from three global databases (the IUCN Red List of Threatened Species, the World Database of Key Biodiversity Areas and the World Database on Protected Areas) to provide an integrated assessment of a specific area. This tool is supplemented by the Species Threat Abatement & Restoration Metric (STAR), designed to reduce threats of global species extinctions and guide protected area establishment.

Landscape and ecosystem levels. At the landscape level, direct interventions are frequently implemented to address specific threats[124]. For example, manipulating the hydroperiod can improve water availability and breeding conditions for aquatic species, supporting their development and survival[84,85,125]. Conservation actions that manipulate the hydroperiod typically include habitat creation and enhancement[126–128], often through artificial methods[129–132]. Notably, pond creation can support high larval densities, boosting population sustainability[133,134]. Another important aspect of landscape-level conservation is the rehabilitation of breeding habitat, which can include improvement of connectivity[132,133,135–137], re-vegetation of the habitat[138] and cattle exclusion in agricultural areas[139,140], particularly in buffer zones[141] (Table 1). For instance, fencing farm dams to exclude livestock and allow regeneration of the vegetation resulted in greater amphibian abundance than in non-fenced farm dams, especially in areas where water quality, vegetation cover and topographic wetness were already adequate for amphibians[140].

Other amphibian conservation approaches at the landscape level include spraying water in the habitat to reduce evaporative loss, a method with demonstrated positive effects for direct developing species[2]. In addition, antifungal and environmental chemical treatments (such as sodium chloride[142–144]) can be applied in some aquatic environments to eliminate pathogens including the chytrid fungus[145]. However, chemical treatments are likely to have unintended effects on other species within the ecosystem, and should be tested before widespread application. Approaches that manipulate temperature could also provide viable alternatives against chytrid infections as the chytrid fungus is sensitive to high temperatures[146,147].

Changes in environmental policies, particularly regulations addressing agricultural or other pollutants, have benefited amphibians. For example, the decline in acid rain and subsequent increase in pH resulted in an increase in amphibian populations in lakes in Norway[148]; in Mexico, the filtration of ammonia and nitrates (combined with fish exclusion) resulted in weight gain in axolotl[149]; and the discontinuation of herbicides and pesticides by farmers increased populations of the Taipei frog (*Hylarana taipehensis*)[150]. Although the harmful effects of pollutants are well documented[124], the broader ecological effects of their removal on populations require further study. Although such interventions generally yield positive outcomes, not all threats can be mitigated by blanket bans and regulations[151,152].

At the ecosystem level, area-based approaches (protected areas and Other Effective Area-based Conservation Measures) can provide protection for assemblages or communities[153], but connectivity is essential for the long-term resilience of amphibian species and the persistence of community assemblages. Although amphibians are generally less mobile than other vertebrate groups, many travel considerable distances between breeding and non-breeding habitats, relying on different habitat types throughout their life history[154,155]. Breeding habitat restoration coupled with the creation of movement corridors between protected areas has been effective for increasing populations in entire amphibian assemblages (Box 3). Additionally, buffer zones around breeding habitats should be maintained, with a recommended minimum buffer distance of 30 m to protect vital water resources[154]. In terms of protection of non-breeding terrestrial habitats, buffer zones are dependent on species' life history, and terrestrial buffer zones are recommended to be at least 400 m around wetlands[154,155]. Thus, landscape-level conservation interventions are essential for tackling complex ecological challenges and maintaining ecological processes across multiple scales, necessitating collaboration among a diverse network of entities (local communities, conservation organizations, governments), often extending beyond jurisdictional boundaries[156].

Global scale. Given that the over-exploitation of amphibians (use for food and the pet trade) is affecting 8% of species[7], global policies to prevent trade have been considered. Specifically, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates the trade of 381 taxa listed at the species level across three appendices (https://checklist.cites.org/). Although adopting

Box 3 | Two case studies of conservation successes

These cases highlight the outcomes of conservation interventions directed either for focal species or for an entire amphibian assemblage.

The Valcheta frog, *Pleurodema somuncurense*

The Valcheta frog is an Argentinian micro-endemic species, restricted to 1.8 ha of the headwaters of the Valcheta stream in Patagonia[273]. The species is threatened by introduced trout, livestock farming and dam construction. This species had disappeared from at least two of the nine known sites in its former range. In 2016, it was assessed as Critically Endangered (CR)[274].

Following the development of a species Conservation Action Plan[275], an ex situ species assurance population was established in 2015 at La Planta Museum, Buenos Aires[276]. Habitat restoration began in 2017 in sites formerly occupied by the species. This restoration involved fencing to exclude livestock, removal of the trout and restoring natural stream flow with the removal of sections of a dam. As a result, the riparian and aquatic vegetation rapidly recovered, and the original stream width was restored[277]. At sites close enough to existing populations, frogs began to be recorded where trout had been eradicated.

Reintroduction trials commenced in 2017 (ref. 139) and by 2021, 200 froglets and 5,500 tadpoles, all captive-bred, had been released to four separate restored sites where the natural re-establishment of populations was unlikely to occur[16]. Post-release monitoring has confirmed breeding at the reintroduced sites, achieving population densities at least as great as those in other wild populations[139] (Rodrigo Calvo, personal communication). This example is the first use of reintroduction as a conservation tool for amphibians in Argentina.

Habitat restoration in Rwanda for amphibian conservation

Rwanda is home to 935 wetlands making up 10.6% of the country's area. Of these, 53% have been converted to agriculture, primarily for rice farming, whereas the remaining 47% is still mostly covered by its native vegetation[278,279]. The increasing human population in Rwanda requires increasing use of wetlands for agriculture, which has degraded natural vegetation[280,281] and resulted in the local extirpation of some wetland biodiversity, including amphibians[282]. The Rwandan government, through the Rwanda Environmental Management Authority, is actively investing in wetland rehabilitation to restore degraded habitats for wetland-dependent species. A model example of rehabilitated wetlands includes the Nyandungu Urban Wetland Eco-park, which supports eleven amphibian species, all widespread generalists[283]. Additionally, five more wetlands are slated for rehabilitation in the city of Kigali.

Sixty-two amphibian species are known to occur in Rwanda, 14 of which are being used as targets for monitoring, with those best adapted to cultivated wetlands now being used as potential indicators of wetland disturbance[284]. Surveys conducted in 2023 show that wetlands in Rwanda undergoing restoration still harbour species typically found in disturbed wetlands[283], although some areas contain a mix of both habitat-specific and disturbed wetland species. This persistence of disturbance-tolerant species has raised concerns about the potential of amphibians as indicators of the effectiveness of wetland rehabilitation.

Rugezi wetland, the only recognized Ramsar site in Rwanda[279] among 62 proposed Ramsar sites, harbours species of national conservation concern as identified in the national International Union for the Conservation of Nature (IUCN) Red List including *Afrixalus orophilus* (nationally Endangered), *Hyperolius lateralis* (nationally Vulnerable) and *Ptychadena chrysogaster* (nationally Vulnerable), despite their Least Concern (LC) categorization based on the global IUCN Red List[284]. Hence, rehabilitating wetlands provides natural habitats for amphibians and maintains populations that cannot survive elsewhere, including habitat specialists.

sustainable practices is needed for some species, a complete ban on commercial trade does not benefit all species[157]. For example, the listing of all glass frogs (Centrolenidae) in CITES Appendix II (CoP19 Proposal 38) had unexpected consequences, such as limiting research on the group, despite the benefits of halting the legal trade. Nuanced, species-specific policies should balance conservation with scientific and management considerations. When carefully implemented, policies targeting specific taxa can not only mitigate threats but also support species recovery, as demonstrated by the successful conservation efforts for the *Hoplobatrachus* genus in India following their listing in CITES appendix II[158].

The KM-GBF[159] has 22 targets for conservation action by 2050, many of which align with amphibian conservation priorities[160]. Target 4, which aims to "halt species extinction, protect genetic diversity, and manage human–wildlife conflicts", stands out as the most relevant, and in addition aims to "ensure urgent management actions to halt human-induced extinction of known threatened species and for the recovery and conservation of species, in particular threatened species, to significantly reduce extinction risk", which has the greatest potential to eliminate extinction risks in amphibians[161]. Achieving this ambitious target by 2030 will require the establishment of designated protected areas or threat elimination programmes for all 2,875 threatened amphibian species[48]. These protected areas have the potential to ensure long-term access to suitable habitats for all species, and also incorporating thermal refugia to address climate change[162]. The '30x30' target (Target 3) overlooks the complexity of addressing only the two main threats to amphibians, habitat loss and climate change[7], due to the synergetic impact of the threats, and limits the reach of the target as the "maintenance and restoration of the genetic diversity within and between populations of native, wild and domesticated species to maintain their adaptive potential"[159] is not included. Achieving these targets, therefore, requires actions that are encompassed by the other targets of the framework, aligning amphibians with other taxa[161]. This approach has been highlighted by the Global Species Action Plan for all species[163] and the ACAP for amphibians[16].

Importantly, targets are not binding, and experience with the Aichi Biodiversity Targets has shown that they tend to guide, but do not drive, conservation actions[164]. As a result, more actionable frameworks – such as the integration of Target 3, to protect 30% of land and water areas by 2030 (ref. 165), and the IUCN Red List of Ecosystems[166] into conservation plans – could offer tangible, short-term guidance for effective conservation efforts.

Promising opportunities

Although some efficient conservation actions have been taken, much work remains to reduce the threat status of amphibian species. This section focuses on conservation interventions that are known to work but need to be scaled up to make a significant contribution to amphibian conservation. We also highlight future opportunities that still need to be explored and developed.

Advances in data collection and analysis

In the past decade, advances in machine learning methods have enabled predictive modelling and classifying vast amounts of data[167], including the identification of species and detection of individuals in images, audio or environmental samples. Robust sampling design and modelling frameworks are now able to account for imperfect detection[168–170], improving the investigation of population trends, community dynamics, range shifts and demographic rates (see ref. 171 for a comprehensive review). Genomic analyses (including population genetics, genome assembly and transcriptomics) enable understanding of the genetic basis of traits that affect fitness and identify genetically vulnerable populations[5]. Hardware innovations, software development and the use of open-source remote sensing software improved the ability to analyse spatial data from the global level to the local level and process satellite images at higher resolutions[172,173]. Improved data collection, however, comes with the challenge of maintaining, processing and analysing large and complex datasets[174]; and amphibian genomes being among the largest vertebrate genomes is adding to this challenge[5].

The use of eDNA and automated acoustic monitoring as indirect survey methods has risen in the past decade[171]. eDNA enables thorough assessments of amphibian communities[175–177], rediscovery of 'lost' amphibian species (species not seen in more than 10 years)[178], and increasing detection of elusive and cryptic species from water, soil and faeces samples[179,180]. Other emerging applications of eDNA and metabarcoding include detecting parasites, diseases and microbiomes, and assessing diet from faecal samples[181–183]. Other technological advances include tracking devices such as low-cost lightweight GPS data loggers, Passive Integrated Transponder tags, micro radio transmitters[184,185], DNA sequencers that work in the field[5], and autonomous recording units such as data loggers, acoustic devices and camera traps[186–188].

Genetic intervention and pathogen remediation

Genetic intervention strategies, such as genetic rescue[189], synthetic biodiversity conservation[190] and targeted genetic intervention[191], remain largely untested in amphibians, although studies on their effectiveness are currently underway[25,192]. Evidence from other taxa indicates that genetic rescue is most effective when the primary threat is low genetic diversity[193]. By contrast, targeted genetic intervention is designed to promote adaptation to persistent threats such as climate change or disease. The first successful demonstration of targeted genetic intervention in amphibians was in California's mountain yellow-legged frogs (*Rana muscosa* and *Rana sierrae*), where translocating individuals from chytridiomycosis-resistant populations improved survival rates after 1 year[194]. Although not yet trialled in amphibians, genetic rescue has been successful in numerous other taxa including Florida panthers[195], mountain pygmy possums[196] and European adders[197].

Although genetic intervention holds great promise for use in amphibians, it should be evaluated on a case-by-case basis to identify any unintended consequences such as genetic incompatibility, outbreeding depression and introduction of maladaptive alleles[25,191,192]. Amphibians, particularly those with restricted ranges, might be at great risk of negative outcomes from genetic interventions due to the high genetic structuring found within their populations. For example, between-population crosses of Bibron's toadlets (*Pseudophryne bibronii*) exhibited lower fitness than within-population crosses, indicating potential genetic incompatibility between populations and suggesting that the genetic rescue might not be a viable approach for this species[198].

Genetic intervention approaches can now leverage advancements in genomics and genetic engineering, enabling highly targeted interventions such as targeted genetic intervention and genetically informed translocations for genetic rescue[5]. New initiatives, such as the Amphibian Genomics Consortium, further accelerate these efforts by expanding genomic resources and fostering cross-disciplinary collaborations[5]. Additionally, these methods can use biobanked material to restore lost genetic diversity[90,199], as demonstrated in species such as the black-footed ferret[200].

Genetic interventions should be used in synergy with other fields of research, such as disease ecology and physiology, to enhance their success[201]. For example, experimental evidence suggests that it is possible to harness the thermophilic behaviour of some species by providing shelters that increase their body temperature and enable them to clear chytrid fungus infections[202]. This knowledge should be further incorporated into mechanistic modelling approaches that can include critical temperatures to understand geographic areas where species can be sheltered from chytrid infections[203,204]. Other avenues of research are also on the brink of major developments. For example, laboratory experiments have shown the potential for prophylactic treatment of aquatic larvae using chytrid metabolites[205] and longer-term immunity to chytrid fungus might be achieved by vaccination[25,206] or manipulating the skin microbiome[207].

Improved cooperation and inclusive conservation

For conservation efforts to expand and become more effective, conservation must be an integrated, planned and multidimensional process to provide equitable distribution of its benefits. For instance, at the UN Convention on Biological Diversity's COP 16 summit in Colombia in November 2024, an agreement was reached for large companies to pay for the use of digital genetic information, if it yields profits[208]. Similarly, biodiversity credit markets, if they are designed and operated effectively, could help to generate private-sector funds for biodiversity and amphibian conservation[209].

Amphibians are rarely included in stand-alone species conservation programmes due to their perceived lack of charisma[210], and biodiversity conservation projects typically target charismatic species of mammals and birds[6,211–213], especially in developing countries[214]. However, the importance of amphibians in aquatic ecosystems and food webs[215] makes a strong case to include amphibians in major conservation initiatives. For example, the diet of the leopard cat (*Prionailurus bengalensis*) includes amphibians such as the declining *Nanorana vicina*, a frog endemic to the Hindukush–Himalayan region, and *Microhyla okinavensis*, endemic to the Ryukyu Islands[216,217]. Furthermore, the lack of consensus on the total number and composition of amphibian species in countries such as Uganda[218] or Nepal[219,220], or the need for timely conservation action in countries where amphibian species composition is well established, such as in the Republic of Korea[221], reflect the need for better inclusion of amphibians in conservation efforts, and especially in area-based conservation programmes that can protect amphibians. Additionally, biodiversity conservation must also be linked with economic regulations that indirectly affect the habitat of species. For example, the rice production compensation programme of the World Trade Organization has resulted in a decrease of suitable habitat for the Korean tree-frog *Dryophytes suweonensis* through changes in human behaviour[222], a fact that needs to be integrated into conservation programmes to compensate for this change. Hence, true diversity, equity and inclusion in conservation actors require broadening efforts to encompass often-overlooked taxa such as amphibians, across all fields of knowledge.

Conservation should be conducted in collaboration with local institutions and provide them with the possibility to lead projects[4,223] (as well as local zoos and aquaria, because amphibians benefit from both in situ and ex situ conservation projects[224,225]). The emphasis on local involvement and leadership is key for conservation success[226]. Multilateral collaboration from different institutions and different countries will also enable the development of more effective policies for the conservation of amphibians and other species. For example, Chile and Argentina have established a binational conservation strategy to protect the threatened Darwin's frogs (EN *Rhinoderma darwinii* and CR *Rhinoderma rufum*)[227]. Similarly, numerous institutions in multiple countries collaborated to develop the 'Mountain Chicken Recovery Plan' to protect *L. fallax*[20].

Summary and future directions

Amphibians are experiencing a biodiversity crisis more severe than any other vertebrate group, yet conservation efforts remain disproportionately underfunded and amphibians remain understudied. We have provided a comprehensive global synthesis of amphibian conservation, examining their current status and threats, highlighting conservation successes and offering evidence-based recommendations for actions. Although conservation interventions have led to measurable improvements for some species, these successes must be scaled up dramatically to reverse ongoing declines. Key opportunities lie in addressing habitat loss, leveraging genetic and genomic tools, improving global collaboration, and integrating amphibians into broader conservation and policy frameworks such as the KM-GBF.

An important next step is to reduce the funding gap for amphibian conservation. Improving capacity for grant-writing and project management is thus necessary to start closing this gap, although not sufficient given the number of species in need of conservation. When funding is obtained, grants are often insufficient, and funding cycles are usually limited to short-term grants, which are restrictive in terms of achieving meaningful and lasting influence. Recommendations from the ACAP include increasing the number of applications for amphibian projects, including through improved collaboration, and with a focus on themed approaches and multispecies or landscape-level scales. Habitat loss is the biggest threat to amphibians, yet relatively little funding has been directed to amphibian-specific habitat protection. Prioritization of key amphibian areas, such as Key Biodiversity Areas, Alliance for Zero Extinction sites and Threatened Amphibian Landscapes[44], is critical for targeted conservation and in directing such efforts. Collaborative projects aimed at applied conservation and threat mitigation are comparatively more likely to be successful in securing funding. Sustainable financing models, such as biodiversity credits, species bonds and the integration of biodiversity-based economic opportunities, such as ecotourism, will also be vital to achieving amphibian conservation targets.

Looking forward, the use of conservation introductions to establish populations outside their current or former known range as habitats shift due to the impacts of climate change may also need to be considered for amphibian species and populations[94,95,97,228]. Although some support this approach, there has been some debate in the literature about the suitability of conservation introductions as a conservation tool. Concerns include potential negative consequences on source populations and recipient ecosystems, as well as genetic risks, disruption to co-adaptation, and uncertainty in climate change predictions and subsequent species responses making predictions of success difficult[229–233]. Therefore, conservation introductions should not be undertaken lightly, and alternative methods such as creating suitable microhabitats within the current range should also be considered. Although models have been applied to establish future climatically suitable sites and suggest management strategies for some amphibian species[234–237], to our knowledge, conservation introductions have not yet been applied in practice to a threatened amphibian. If this approach is to be trialled, success will require a good understanding of suitable climate and habitat needs for appropriate release sites to be identified, for the potential risks to be adequately assessed and mitigated, and for existing translocation guidance to be applied in all cases[94,97].

Ultimately, reversing amphibian declines will require coordinated efforts across species, landscape and ecosystem levels. Interventions must be tailored, inclusive and data-informed, with an emphasis on scaling up proven strategies such as habitat restoration, disease mitigation and proactive conservation breeding. Building capacity, improving funding mechanisms and embracing emerging technologies, such as eDNA, remote sensing and genetic intervention, will be crucial for securing the future of amphibian biodiversity.

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