CONSERVATION

An Emerging Role of Zoos to Conserve Biodiversity

Roughly one in seven threatened terrestrial vertebrate species are held in captivity, a resource for ex situ conservation efforts.

D. A. Conde,[1]* N. Flesness,[2] F. Colchero,[1] O. R. Jones,[1] A. Scheuerlein[1]

At the October 2010 meeting of the Convention on Biological Diversity (CBD) in Nagoya, Japan, delegates discussed a plan to reduce pressures on the planet's biodiversity. Key targets include expanding coverage of protected areas, halving the rate of loss of natural habitats, and preventing extinction of threatened species (*1*). For species whose habitat is severely threatened, however, the outlook is so bleak that the International Union for Conservation of Nature (IUCN), the U.S. Endangered Species Act, and the CBD (Article 9) recognize that in situ conservation actions (i.e., in the species' natural habitat) will need to be combined with ex situ approaches, such as captive breeding in zoos, aquariums, and so on (*2*, *3*).

Captive breeding may be the only short-term practical conservation option for species confined to dwindling habitats (*4*). However, captive breeding is absent or plays a minor role in the policies of most governments, conservation organizations, and multilateral institutions. To shed light on the state of captive breeding and its potential to contribute to conservation goals, we estimate the number of threatened species already held in captivity.

Captive Breeding

Although ecosystem health should be a conservation priority, a recent evaluation of the status of the world's vertebrates (*5*) noted that captive breeding played a major role in the recovery of 17 of the 68 species whose threat level was reduced [e.g., Przewalski's wild horse (*Equus ferus przewalskii*) (*6*), black-footed ferret (*Mustela nigripes*) (*7*), and California condor (*Gymnogyps californianus*) (*8*)]. Captive breeding has the potential to maintain targeted populations as an "insurance policy" against threats like disease or pressure from nonnative species [e.g., egg predators on islands (*9*)] until reintroduction into the wild is possible. A striking example is the increase of amphibian collections in zoos (*10*) as a response to chytridiomycosis, a fungal infection responsible for precipitous global amphibian population declines (*11*).

Captive breeding for reintroduction has downsides. Sociopolitical factors can determine the success of programs. For example, reintroduction of Arabian oryx (*Oryx leucoryx*) in central Oman was hampered by poaching, partly because local communities were insufficiently involved in conservation efforts (*12*, *13*). Furthermore, captive breeding is costly, and technical difficulties can arise such as hybridization [breeding among different species (*14*), e.g., if current cryptic species are managed as one species, but are later split into several species according to new taxonomic information]. The ability of individuals to learn crucial skills that allow them to survive in the wild (e.g., fear of humans or predators) may be compromised. In many cases, these difficulties have been overcome by creative and species-specific measures. For example, it was feared that Puerto Rican parrots (*Amazona vittata*) would be unable to escape predators in the wild, but this problem was solved with a prerelease aviary-based stimulation and exercise program (*15*). Because ex situ conservation programs can be challenged when called into action at the last possible moment with only a few remaining individuals of a species, captive breeding should not simply be seen as "emergency-room treatment." It is a tool that should be considered before the species has reached the point of no return.

Counting Threatened Species in Captivity

We used the International Species Information System (ISIS) database to estimate the number of threatened species already held in captivity. ISIS is an organization that holds the most comprehensive information on animals held in zoos and aquariums worldwide, with records of ~2.6 million individuals shared among ~800 member institutions (*16*). From the IUCN Red List of Threatened Species (*17*), we obtained the threat category of each terrestrial vertebrate species represented in ISIS (*18*). [See supporting online materials (SOM) for details.]

One-quarter of the world's described bird species and almost 20% of the mammal species are held in ISIS zoos (table S1). Only 12% of the described reptile species are represented and 4% of amphibians. Our primary focus is on species of conservation concern; for mammals, roughly one-fifth to one-quarter of threatened (*19*) and Near-Threatened species are represented in ISIS zoos (see the figure) (table S1). With the exception of Critically Endangered species, which only have a 9% representation (tables S1 and S2), the picture is similar for birds. For amphibians, the representation of threatened species is much lower (~3%); this is a concern because amphibians are a highly threatened group, with 41% of described species listed as threatened or Extinct in the Wild (EW) (*5*). The IUCN threat-level assessment for reptiles has not been completed, so our results should be interpreted with caution, but of the 1672 species already evaluated, zoos hold 37% of threatened and 18% of Near-Threatened species.

Overall, zoos and aquariums hold roughly one in seven threatened species (15%), but it is important to consider also the number of individuals held. Although individual zoos might not have large populations of a particular species, collectively, zoos hold sizable populations of certain species, including highly threatened ones (see the figure). Zoos, as a global network, should strive to ensure that their populations of threatened species can survive in the long term. However, each zoo may make a larger conservation contribution by specializing in breeding a few at-risk targeted species, rather than aiming to increase its species diversity, as specialization increases breeding success (*4*).

Ultimately, success of conservation actions depends on the extent to which birth and death rates permit populations to survive in the wild (*8*). Population viability analyses (PVAs) are used to forecast the probability of population extinction for conservation programs (*20*), but these require parameterization with data on age-specific birth and death rates (*21*). Adequate data from natural environments are often unavailable, especially for threatened species (*20*). The zoo network has large long-term data sets, including data such as average litter size, interval between successive litters, and age at maturity, which could be used to fill these gaps. Of course, zoo data should be used with caution because they

[1]Max Planck Institute for Demographic Research, Rostock 18057, Germany. [2]International Species Information System, Eagan, MN 55121, USA.

*Author for correspondence: conde@demogr.mpg.de

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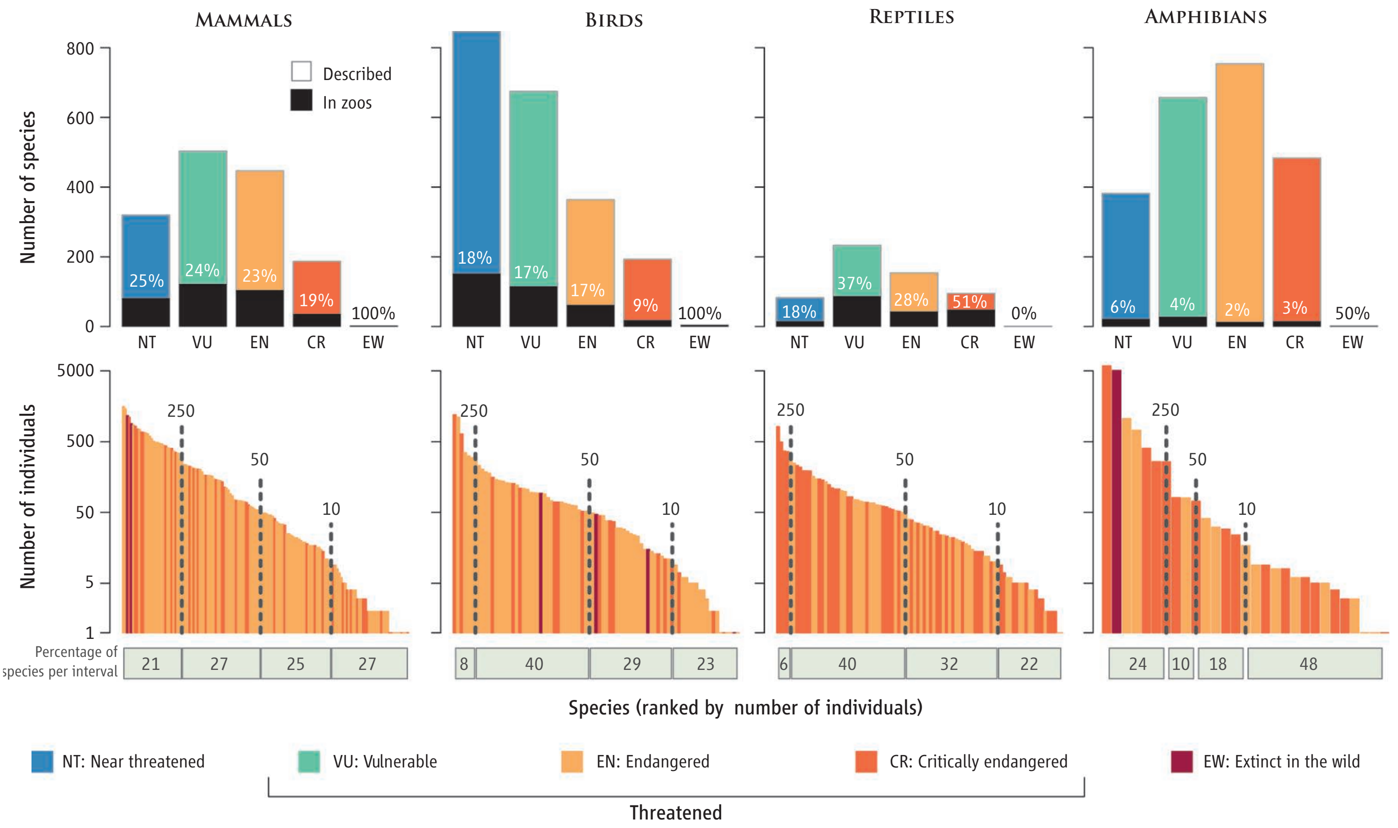

Endangered species in zoos. (**Top**) The number of species with IUCN status, globally described (color bars) and in ISIS zoos (black bars). (**Bottom**) The number of individuals in ISIS zoos for species listed by IUCN—for mammals (142 species), birds (83 species), reptiles (90 species), and amphibians (29 species). The vertical broken lines show the boundaries by 250, 50, and 10 individuals. The large numbers of individuals classified as Vulnerable and Near Threatened are omitted for clarity. See SOM for details.

do not necessarily reflect the situation in the wild, such as population flexibility in the face of changing conditions.

Despite their current and potential contributions to species conservation, ISIS zoos are concentrated in temperate regions, whereas most threatened species are tropical (*5*, *22*) (fig. S1). This mismatch between the areas where captive populations are held and their native range poses a challenge for implementation of effective conservation actions. Acclimatization to a new home is likely to be faster for animals raised in conditions similar to those where they are to be released. This is one reason that it is suggested that captive breeding be done in the country of the species' origin (*2*).

There are large parts of the world with high biodiversity value, yet whose zoos are not well represented in a global network (fig. S1). Given the importance of having data available for design of conservation programs, policy-makers must encourage and facilitate the participation of zoos from regions with high levels of biodiversity threat in global networks, such as ISIS and the World Association of Zoos and Aquariums (WAZA).

The potential for zoos to contribute to conservation is not a new concept for the zoo community. Zoos and aquariums have developed conservation projects in the wild, alongside research and education programs (*23*). For example, members of WAZA collectively spend ~U.S. $350 million per year on conservation actions in the wild, which makes them the third major contributor to conservation worldwide after the Nature Conservancy and the World Wildlife Fund global network (*24*). Given the scale of the biodiversity challenge, it is vital that conservation bodies and policy-makers consider the potential that zoos as a global network can provide.

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Supporting Online Material

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