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COMMENTARY

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Recovered after an extreme bottleneck and saved by ex situ management: Lessons from the Alagoas curassow (*Pauxi mitu* [Linnaeus, 1766]; Aves, Galliformes, Cracidae)

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Abstract

A pivotal debate on biodiversity conservation is whether the scarce budgets must be invested in critically endangered taxa or in those with higher chances to survive due to larger population sizes. Addressing the fate of extremely bottlenecked taxa is an ideal way to test this idea, but empirical cases are surprisingly limited. The reintroduction of the extinct-in-the-wild Alagoas curassow (*Pauxi mitu*) by Brazilian scientists in September 2019 added to the two other known cases of survival to bottlenecks of only two or three individuals. We exploit the reasons why this species has survived, and we report how investments to rescue the Alagoas curassow resulted in the protection of many other taxa, suggesting that in the face of the dramatic number of extinctions expected for the Anthropocene, integration must prevail over a choice.

KEYWORDS

budget, conservation, critically endangered taxa, extreme bottleneck definition, population viability, reintroduction, resources investment

One of the key corollaries of conservation sciences is that species that have passed through severe bottlenecks have higher chances of extinction due to demographic and genetic issues (Frankham et al., 1999; Peery et al., 2012). This has posed a debate of whether the limited resources available for conservation should be invested in more viable taxa, that is, with more individuals (Baillie & Butcher, 2012; McCarthy et al., 2008). If the disappearance of the critically endangered taxa is just a matter of time, such investments in management are a waste of time and money. However, this is a theoretical thought based on very few empirical elements. Addressing the effectiveness of conservation of species that have been through extreme reductions in population size is an ideal way to test this idea because if these organisms can be rescued, it means that the possibilities of recuperation of other critically endangered taxa cannot be neglected. Although the term "extreme bottleneck" has been increasingly used to refer to drastic population reductions, it still

lacks a formal definition (see, for instance, Ledig et al., 1999 and Pedersen et al., 2017), and here we define extreme bottlenecks as those in which for at least one of the sexes only one individual remained, meaning that all of the descendants are related to full- or half-sib levels.

The reintroduction of the Alagoas curassow (*Pauxi mitu*; Figure 1), an extinct-in-the-wild bird, on September 25, 2019, provided a rare opportunity to address the fate of extremely bottlenecked taxa. This species is the largest endemic forest-dwelling bird to the Atlantic Forest of Northeastern Brazil and due to intense deforestation and overhunting, it once was one of the most threatened animal species on Earth (Silveira et al., 2004). The last reliable record in the wild was in 1979 when five individuals were captured for captive breeding. The current population present in captivity descend from only three of these animals (one male and two females; Costa et al., 2017; Silveira et al., 2004). After a problem of hybridization caused by the lack of pedigree control, in 2008, a wide genetic monitoring program started, and subsequently applying an analyses framework that involved diagnostic morphological and molecular markers, a pure group of individuals was identified within the population with a high level of certainty, which permitted the genetic reconstruction of the captive breeding program (Costa et al., 2017).

Two other bird species have recuperated from extreme genetic bottlenecks, the Mauritius kestrel (*Falco punctatus*) and the Chatham Island black robin (*Petroica traversi*). Pesticide contamination, mainly from 1948 to 1970, led the population of the island-endemic Mauritius kestrel to drop to only one breeding pair in 1974 (Jones, 1994), from which all current population is thought to descend (170–200 individuals; BirdLife International, 2020a). For the island-endemic black robin also, the current population of 230 individuals descends from only one viable pair that has reproduced in the wild between 1979 and 1982, as a result of habitat destruction and the introduction of alien species (BirdLife International, 2020b; Weiser et al., 2018). The survival of Alagoas curassow can be attributed to five main factors: (i) the rescue of the last remaining individuals just before species extinction; (ii) the correct reproductive management in captivity; (iii) the fact that founder individuals were not related, as evidenced by an effective population size similar to the number of founders (three; Davanço, 2012); (iv) a rapid demographic expansion, with the second generation presenting 19 individuals, which permitted the genetic variability of the founders to pass to the subsequent generations; and (v) a long-term genetic monitoring program that contributed to avoiding further genetic variability losses. It resulted in moderate genetic variability, with two to five alleles per microsatellite loci (3.0 ± 0.78), in contrast to 2 to 14 alleles per loci (4.36 ± 3.27) in the closely related razor-billed curassow, *Pauxi tuberosa* (Costa et al., 2017).

FIGURE 1 First Alagoas curassow to be released in a 1000-ha Atlantic Forest fragment from Northeastern Brazil, with a telemetry backpack, 40 years after the species became extinct in the wild (Photo: Larissa Fernandes) [Color figure can be viewed at wileyonlinelibrary.com]

Today the captive population of the Alagoas curassow has reached about 100 individuals, and the first three pairs were reintroduced into the wild in September 2019. Despite the still small number of individuals and the lack of knowledge about the behavior of the species in nature, the reintroduction was conducted, and the data gathered in the wild will bring to light important information that will retrofit the conservation plan for the species. This is a breakthrough for conservation, as this is the first extinct-in-the-wild vertebrate to come back to nature in South America. Reintroductions of other large frugivorous birds, such as other galliform and tinamous, are planned in the forthcoming years in an effort of rewilding the almost empty forests of the region. The birds are closely monitored, and two males and one female were found dead due to unknown causes. A radio-tracked male with more than 5000 recorded GPS locations is actively exploring the forest fragment almost one year after releasing, using trees for roosting and feeding on natural fruits. The survival suggests that birds descending from generations in captivity are apt and able to return to their natural habitat with little training, and more adult individuals will be released in 2021/2022.

The main lesson provided by the Alagoas curassow and by the Mauritius kestrel and the black robin is that they retained their intrinsic potential to thrive, despite passing by the worst situation that a surviving species could be through. In the case of the Alagoas curassow, breeding centers one more time proved to be pivotal in saving threatened species, and the synergism with universities and nongovernmental organizations proved to be successful. Although their long-term adaptation capacity to a changing world could be questionable, levels of genetic variability can be small also in many nonendangered species, that is, certain insular organisms (Robinson et al., 2016). Many taxa today listed as extinct never were a target to conservation management plans (such as the recently extinct Alagoas foliage-gleaner, *Philydor novaesi*; Pereira et al., 2014), and the empirical evidence presented here suggests that at least part of these extinctions could have been avoided. The decision to choose between investing money to avoid other species to become critically endangered or to recover the most critical ones is certainly oversimplistic and the example of the Alagoas curassow also could shed light on this paradox. During more than 40 years, different actors

were involved in the recuperation of this species, including aviary owners, ecologists, geneticists, veterinarians, and also members of governmental and nongovernmental organizations that together created more than 3000 ha of private conservation units aiming to guarantee the existence of habitats for the reintroduction of the Alagoas curassow in the most threatened habitat in the New World. Once the Atlantic Forest of Northeast Brazil concentrates the highest numbers of endangered taxa in South America, many other vanishing species have been or could be protected in the areas designated to Alagoas curassow. Then, species with different levels of risk must be included in conservation managers' agenda, and with the devastating number of taxa expected to face the verge of extinction during the Anthropocene, integration must prevail over choice.

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ETHICS STATEMENT

This study was reviewed and approved by the Ethics Committee on Animal Experimentation of Instituto de Biociências da Universidade de São Paulo.

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