

The Scientific and Practical Limitations of De-Extinction

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Abstract

The acceleration of global biodiversity loss has increased interest in de-extinction (also known as resurrection biology) as a modern solution to address species loss. Through a synthesis of current genetic, ecological, and ethical literature, this paper evaluates the feasibility of de-extinction from scientific and practical lenses. It argues that despite its theoretical appeal, de-extinction is currently constrained by three major limitations: (1) technical barriers to the cloning of ancient DNA, CRISPR gene editing, and somatic cell nuclear transfer; (2) the impossibility of replicating extinct phenotypes, which are shaped by lost environmental conditions; and (3) the extensive cost and resource consumption required by de-extinction versus methods relating to the proactive conservation of threatened, yet non-extinct species. Given these significant challenges, this paper suggests that funding and research should largely be redirected away from

de-extinction projects and towards applied conservation genetics like genetic rescue of endangered populations. This reallocation would be a more ethical, practical, and ultimately impactful strategy for addressing the ongoing Holocene extinction.

Keywords: De-Extinction, Resurrection Biology, Conservation Genetics, Biodiversity Crisis, Crispr, Cloning, Ecological Restoration

According to a paper published in the Hastings Center Report, a peer-reviewed bioethics journal, approximately three of Earth's species go extinct [1]. We are currently in the sixth global mass extinction, and for the first time, humans are solely responsible. Because of deforestation, pollution, accelerated climate change, and the exploitation of vulnerable species, humans are driving biodiversity loss. In the journal Proceedings of the National Academy of Sciences, extinction rates are described as "highly unusual as Earth's history" and even implying the future "loss of entire [communities of organisms]" [2]. The cumulative loss of each additional species destroys entire ecosystems critical to humans' wellbeing. As a result, reestablishing global biodiversity has become a significant priority in the scientific community. Resurrection biology has subsequently emerged as an important new technological field. This modern research, known as de-extinction, aims to reintroduce extinct species into current habitats. Technologies related to de-extinction are still very new and in need of significant development. The current complications of these technologies must therefore be addressed through a scientific lens. This way, the feasibility of de-extinction can be determined as it

pertains to the current biodiversity crisis. Despite its theoretical appeal, the successful implementation of resurrection biology is currently restrained by three major scientific limitations: barriers to gene editing and cloning technologies, the impossible nature of replicating extinct phenotypes, and the relative inefficiency of resurrection biology compared to other biodiversification methods. Human well-being is dependent on ecosystems that maintain high biodiversity. Since the current mass extinction destroys these systems, identifying the most efficient means of restoration is urgent. However, another paper published in the Hastings Center Report notes that even advanced “genomic-based conservation tools [...] have significant limitations” [3]. In this way, analyzing these limits to de-extinction can help scientists determine this potential solution’s worth when it comes to addressing the problem of ecosystem collapse.

The first barrier to the success of resurrection biology is challenges related to cloning and gene editing. According to *Zoologica Scripta*, a zoology journal published on behalf of the Royal Swedish Academy of Sciences, genome reconstruction is almost impossible with current technology because genetic material from long-extinct species currently only exists in very damaged pieces [4]. Since resurrection biology is largely reliant on the duplication of ancient cells, the damaged nature of most ancient DNA makes it difficult to create viable cells for organism cloning. Similarly, the *Journal of Heredity* claims that despite advances, existing technologies that edit these partial genomes into the complete DNA needed to clone cells face many obstacles and are notoriously inefficient [5]. The most famous genome editing tool is CRISPR, and even though its Nobel prize winning process splices ancient genetic sequences into a new cell, the tool is very error-prone. The result of successful CRISPR gene editing can even be naturally reversed by the cell if the host cell perceives the genetic changes to be threats [4]. The reality is that a well-publicized invention in this field earned a Nobel Prize while still having many large caveats to its function.

This demonstrates that large limitations to gene editing remain; thus there are difficulties in de-extinction through the cloning of ancient genes. In terms of ultimately creating a cloned cell based on ancient species DNA, a surrogate then needs to be found to turn the duplicated cell into a full organism. This process is called somatic cell nuclear transfer (SCNT). Unfortunately, according to a paper coauthored by Dr. Rhiannon Bolton, a researcher at the University of Oxford, SCNT is rarely compatible “even with closely related species” [6].

After a clone of the extinct species can be initially birthed through the womb of a similar but non-extinct species, as seen with the famous Dolly the sheep, there are often a multitude of complications post-birth like “immune issues” and the creation of “healthy cell membranes” [6]. Therefore, drawbacks persist in cell transfer and the safe use of surrogates. While surrogates are often the only prevalent option for recreating long-extinct species, the complications both pre- and post-birth show the importance of avoiding extinction in the first place. Cloning and gene-editing technologies are relatively modern, prone to error, and restricted by significant complications, limiting their effective use in the current field of resurrection biology.

Even if these technical difficulties can be overcome, the impossibility of replicating extinct phenotypes remains a challenge. A phenotype, which involves the combination of an organism's physical form and behavior, isn't determined solely by genetics. As explained in the highly regarded scientific magazine *Quanta*, development and survival skills are shaped by

environmental interaction in addition to genetics, meaning DNA editing alone isn't enough to assure that a species would behave as it would have prior to extinction [7]. For example, a genetically resurrected woolly mammoth would not behave or even look identical to the genetically identical Ice Age-era woolly mammoth. Modern lab conditions for organism resurrection, as well as the alteration of Earth's ecosystems, may not only result in different upbringing conditions but also ultimately different behavior altogether from these artificially resurrected organisms. If an organism's behavior can't be accurately predicted, the relevance of de-extinction is then called into question. The behavior of certain species is critical to balancing biodiversity in their respective ecosystems. Engaging in the process of de-extinction is accompanied by unknown ecological risks and could ultimately do little to improve global biodiversity. This solution is therefore constrained by the unknown impact of resurrecting a species back into today's world.

These significant constraints cumulatively result in the overall inefficiency of resurrection biology when compared to other conservation strategies. Amidst a mass-extinction crisis with limited global resources, conservation science needs to direct its effort and funding primarily towards actions with the highest probability of success. From this perspective, de-extinction fails the necessary efficiency to merit its use as a primary method of conservation. *Functional Ecology*, a peer reviewed ecological journal, directly questions its utility in the context of conservation, arguing that the large-scale investment required to fund a single de-extinction project could instead be diverted to fund the protection of entire habitats [8]. Resources would then be directed toward preventing the extinction of dozens of currently threatened species rather than riskily attempting to resurrect a long-extinct species.

De-extinction is similarly critiqued by Desalle, a researcher with the American Museum of Natural History, who argues that the modern and innovative appeals of de-extinction can distract from the more critical work of saving non-extinct species. From his viewpoint, gene editing could have "a bigger role in conservation genetics" versus resurrecting lost species [1]. This perspective characterizes de-extinction as a field of technology that, while intriguing, is at odds with the current conservation needs of our world. Overvaluing de-extinction could lead to public perception that species are expendable and can easily be reacquired with technology, which is not the case. Focusing efforts and financial resources on conservation is not only more likely to find success but encourages a global-minded perspective.

Despite having theoretical potential, the implementation of resurrection biology is currently prevented by limitations relating to technology, replicating phenotypes, and conservation efficiency. A better solution is to divert funding from de-extinction toward conservation genetics, such as using CRISPR to genetically rescue endangered species. This would create functional proxies of these species to improve their ecological impact without the complexities of obtaining extinct DNA. Another *Functional Ecology* paper argues that the ultimate goal shouldn't be recreating the past, but to "restore the overall function of an ecosystem" through the development of these ecological proxies [9]. This way, new biotechnology could be applied in less risky ways and have a more immediate positive impact on global biodiversity. Therefore, both scientists and lawmakers are left with the responsibility to prioritize strategies that best address the extinction crisis with the reliable tools currently available.

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