Classic Debate Camp
LD Brief

November - December 2026

Resolved: De-Extinction Is Unethical

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A Message From the Authors

Hello ya'll! We're excited to put out a brief for what is the first competition topic of the year for many of you! We are happy to be sharing this brief with our campers and any other LD competitors who happen to come across it. Classic Debate Camp believes in accessibility and equity in debate resources, and we have developed this brief with those values in mind.

While our aim in writing this brief was to provide you with critical analysis and comprehensive understanding of this topic, our staff decided to take a slightly different approach with this brief than we have in the past. This time, we chose to focus a little more on evidence and a little less on topic analysis, so you'll find a good number of high-quality cards in key argument categories on both sides of the topic. But even though we have already cut the cards, you should read the evidence closely - the original sources ideally - and re-cut the cards to fit your arguments. We welcome any feedback from the debaters using this brief, so please email us if you have thoughts you want to share with us!

We are hopeful that this brief will inspire each of you to dig deeper, consider the complex implications of this topic, and develop well-evidenced and unique cases. Feel free to reach out to us with any questions about any of the materials in this brief! Our contact information is listed below.

Best of luck in your tournaments!

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Topic Analysis by Callista Martin[1]

Introduction

For a lot of debaters, this topic will seem pretty similar to the Rewilding topic for Nov/Dec 2025. However, I want to warn against assuming you can only make arguments you've made previously. This topic opens up discussions of our responsibility to fix past mistakes, the costs and funding de-extinction could bring to more than just conservation, and what role we play in creating or destroying life on this earth. There are a lot of very interesting ways to approach this topic, and if you debated last year, I encourage you to try out a new approach to how you debated conservation. While there are some differences, topics like invasive species, biodiversity loss, and climate resilience will come up again, and you should be prepared to both argue and rebut those arguments. In my topic analysis I'll go over general information to know, burdens of the Aff and Neg, examples of cases I'd make for this topic, and some basic framework ideas separate from the cases.

General information

First, what actually is de-extinction? The best explanation I've seen is that 'De-extinction is the process of creating an organism which is – or greatly resembles – a member of an extinct species.'[2] That means that the end goal is to create an organism that is close to or an exact replica. The reason why the definition includes the words 'greatly resembles' is because there is debate on whether or not de-extinction is truly possible. A lot of the methods used may bring back an extremely similar version, but not the exact version of what may have existed in the past. This is partially because we may not have the complete genetic code of some of these animals, or because the methods used aren't meant to totally replicate the animal, but instead just bring back core traits that distinguished it from today's animals.

There are a couple approaches to de-extinction.[3] The first is back-breeding, or breeding only the organisms that have high amounts of ancestral DNA to get more and more of that DNA in the offspring. This is currently being used to bring back the predecessor of modern cattle, aurochs. The second approach is cloning, also known as somatic cell transfer, which makes identical copies of an organism through using a preserved nucleus and a surrogate animal. If you've heard of Dolly the sheep, that was how she was cloned. The issue with this is that it may not work on older extinct species, or species that we can't get this kind of nucleus from and implanted. The last approach is genome engineering, which adds or replaces sections of DNA to get specific extinct phenotypes to show up in animals. For example, if there are no blue footed ravens, then

[1] Callista Martin is an NSDA Alum and an instructor at Classic Debate Camp. She competed in Washington state in traditional LD.
[2] Lucia Martinelli et al"De-Extinction: A Novel and Remarkable Case of Bio-Objectification." Croatian Medical Journal, https://doi.org/10.3325/cmj.2014.55.423
[3] Stephen D. Turner, Anna Keyre, Andrew Pask, Beth Shapiro. "De-Extinction Technology and its Application to Conservation." https://academic.oup.com/jhered/article/117/5/959/8262805#573397764

we could insert the DNA sequence into a raven without the phenotype to get a blue footed raven. This is currently being used to try and revive the almost extinct black footed ferret, as when a population gets too small, the genetic pool becomes extremely limited and makes them susceptible to disease and defects.[4]

If you want to have a definition debate, you could claim that only cloning is actual de-extinction, or that you're only doing genome sequencing, but I personally think incorporating all three will lead to the most productive debates. If you like debating topicality you can certainly find evidence claiming that only specific methods lead to true de-extinction. The safest move would be to avoid claiming a specific method for de-extinction, and to focus more on the ethics side instead of the definitions.

Burdens

I think it's very important to note that this topic doesn't have the word should or ought. It's not asking if we should do de-extinction, it's only talking about the ethicality of it. This means that you can agree that there are better alternatives, but that doesn't make it un-ethical to do de-extinction. For Aff, you can prove the unethicality of de-extinction in various ways. Things you will have to make clear as the Aff/Neg.

> **Aff**: Is it unethical in theory or in practice?
>
> **Aff**: Is it unethical because it focuses too much on humans? Or because it will have a bad impact on humans?
>
> **Aff**: Are you claiming that every instance is unethical, or that it's unethical as a general principle?
>
> **Neg**: Are you arguing that it's ethical or just amoral (not good or bad)?
>
> **Neg**: Are you arguing that it's ethical in all circumstances or just specific cases?

Once you're able to answer these questions, you'll be able to have a much more coherent narrative throughout your case.

Example Case Ideas

Aff/Neg Kant

First, for those of you who want a very clear way to define whether or not something is moral, Kant's categorical imperatives are a great way to do that. There's a couple different formulations of the categorical imperatives, and the two that are relevant are the universality formula and the humanity formula.

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[4] Sergei Kliver et al "Chromosome-length genome assembly and karyotype of the endangered black-footed ferret" https://pmc.ncbi.nlm.nih.gov/articles/PMC10848218/

Kant's first universality formula states that we must "act only according to that maxim whereby you can at the same time will that it should become a universal law." Basically, we are morally obligated to act in a way that we could logically want everyone to act. For example, picking leaves off of a tree is bad, because if everyone picked leaves off that tree, the tree would have no leaves.

Kant's second humanity formula is "Act in such a way that you always treat people whether in your own person or in the person of any other, never merely as means, but always at the same time as an end." Basically, you cannot use people merely as means to an end. You treat people as mere means when you use them for your own purposes without regard for their own interests. Treating someone as an end requires treating their goals as if they were a part of your goals. If you aren't aware of their goals, you must then treat them with the respect and dignity every human deserves. For example, buying a cup of coffee doesn't violate the formula because the employee chooses to work there, and you're paying them. If you forced them to make you coffee though, that would be violating the humanity formula.

If you want to be able to apply this to animals and not just humans, I'd recommend looking into Kristine Korsgaard works on Kant.[5]

If I wanted to use Kant on Aff, I'd use a value of morality or dignity, then Kant's humanity formula, but adapted to include animals for the criterion. Contentions would be that de-extinction violates animal rights and that it weakens human responsibility to initially care for our environment.

On Neg, you could use morality for the value and Kant's universality formula on the criterion. The contention could be our responsibility to fix our mistakes. Essentially because we destroyed these species, we need to fix our mistakes, as it's immoral to do otherwise.

Consequentialism/Util

For a more consequence-based case, I think you probably could do a consequentialist structural violence framework. Essentially de-extinction worsens climate change, and climate change disproportionately affects marginalized communities. You could do this on either side as long as you have good evidence that de-extinction affects climate change. Or you may be able to do an mitigating structural violence framework with the idea that these specific animals will devastate low income communities, kind of like how rewilded wolves were bad for farmers.

You could also do a utilitarianism-based case (but please cite a philosopher for the definition and give real warrants!). The contentions for a util Aff could be that it destabilizes ecosystems and causes disease risks. The contentions for a util Neg could be that it stabilizes ecosystems and tech benefits spillover into other industries.

Other

If you want to look into more frameworks, I'd look into Taoism, Leopold's land ethic, or biocentrism. All of those have interesting angles of approach for this topic.

Best of luck, and I hope this topic analysis will be helpful for your tournament season!

[5] https://www.thephilosopher1923.org/post/on-the-value-of-people-and-animals

Topic Analysis by Greta Wedel[6]

Background and General Topic Analysis

My first thought when I saw this topic announced by NSDA was *fun.* Indeed, this topic is somewhat of a welcome departure from the policy and political philosophy topics that we often see. It sits at a unique intersection of disciplines – applied ethics, environmental philosophy, and science. And it's worth noting that the uniqueness of the topic doesn't come from its rigor or critical nature – it's a byproduct of the area of focus and resolution structure itself. That said, this topic is also broad and can lend itself quite heavily to extinction-level debates, which brings its own set of challenges in terms of preparation and case strategy.

Before I delve into the case-level analysis, I want to note that this topic, like all LD topics, carries weight. For many of us, de-extinction might feel like an almost humorous scientific absurdity taken from the likes of *Jurassic Park.* In recent decades, however, de-extinction has transformed from a myth of science fiction to a reality of modern science. These are real procedures being pursued by real companies, with real money, on real animals. Indeed, the animals used in the development and testing of these procedures are alive, and they have welfare interests. It is also true that these practices stand to have real impacts on real communities who have developed acute and unique relationships with the land, including indigenous peoples. I encourage all of you to do the work to understand the science behind these processes accurately, and to take your arguments and your opponents' arguments seriously.

This resolution presents a fairly straightforward question: Is de-extinction ethical? It is worth noting that this topic does not specify the *process* of de-extinction, meaning that it leaves room to debate both the impacts resulting from the pursuit of de-extinction, as well as the impacts caused by de-extinction itself. Unlike a typical "ought" resolution, this topic does not identify an actor, government or otherwise, meaning debate is focused largely on the theoretical implications of the process itself on an ethical or humanitarian level, not the implications for a specific country or actor.

This essay is intended to advise debaters in their approach to this topic. Given the heavily theoretical nature of this topic, I will begin by discussing the definitional contours of the topic before moving on to framing, burdens, and some approaches to consider on both sides (in terms of both the constructive debate and framework debate).

[6] Greta Wedel is an NSDA alumni and former Lincoln-Douglas competitor from Colorado, as well as a past instructor at Classic Debate Camp. Greta attended NSDA national tournament to compete in LD in 2021, 2022, and 2023, and she championed the Colorado State Tournament in 2023.

Defining De-Extinction

For some background – "de-extinction" is an umbrella term for scientific efforts to artificially produce life that mirrors that of extinct species. There are a few main methods for de-extinction:

1. **Back Breeding:** Back breeding, or selective breeding, is a process that has been used by scientists for centuries to resurrect diluted or extinct traits in the genetic lineage of a given species. As a de-extinction approach, back-breeding has a limited scope; it can work well when there is an existing non-extinct species that closely resembles the extinct species, but as extinct species become increasingly removed from those that remain alive, the process becomes increasingly difficult and lacks predictability.
2. **Cloning:** Cloning is a scientific process that aims to produce genetically identical copies of biological life. The process generally involves somatic cell nuclear transfer (SCNT) in order to generate an identical gene sequence to the donor's non-reproductive cell. It is worth noting that cloning requires intact living cells, making it a suitable de-extinction process for species near extinction, but not for long-extinct species.
3. **Genome Editing and Synthetic Genomes:** Genetic editing is a process by which scientists can alter a living organism's genome by deleting, replacing, inserting, or otherwise altering components of its DNA sequence. Through these small changes, scientists can bring about changes in physical traits. Genome editing technology can create hybrids between existing and extinct species through the insertion of extinct DNA into the nucleus of a live, reproducing cell. The resulting organism, then, is not identical to either the extinct or existing species, but instead a genetic combination of the two.

I anticipate that definitions will matter a great deal with this topic, as the manner in which de-extinction is defined will either broaden or narrow the viable impacts that either debater can argue. Both sides ought to be conscious when choosing their definitions in order to ensure that those definitions do not exclude any arguments presented in the case.

It is also worth noting that scientists and general critics alike have argued that the "hybrid" or "proxy" species created by processes like genome editing may or may not qualify as the original extinct species. Whether the animal produced by these processes is the extinct species itself or whether it is a proxy is a debated question, and I expect that the best debaters may consider the ways they can leverage this ambiguity to their advantage, whether it is to limit or expand the scope of the debate.

Framing, Scoping, and Burdens

This resolution presents the broad question of whether de-extinction practices are morally wrong. As said above, it does not provide an actor, and further, does not provide a given scope in which to argue impacts. As a result, the framing of burdens and scope is of critical importance. It is not worth your time to try to argue every contour of this topic, as it is a broad one; indeed, the best

debaters will likely use observations and definitions to strategically limit the ground for argumentation and create better clash.

For the Aff, the general burden is straightforward – prove that de-extinction is unethical. For the Neg, it's slightly more interesting. Neg debaters do not have to prove that de-extinction is ethical; instead, they simply have to prove that it's not unethical. This is a permissibility burden, and it's significantly lower than the former. Neg debaters may argue that the practice is permissible or even beneficial based on certain effects, or they may argue that the blanket statement nature of the resolution suffers from overextended miscategorization, as ethics depend on circumstances. Insofar as this is true, it may also be advantageous for the Neg to expand the definition of de-extinction to include practices that are critical to modern conservation efforts, including genetic rescue, biobanking, and genetic engineering for conservation.

The resolution can be taken as a matter of general principle under which both sides are required to prove that de-extinction is either unethical or ethical as a matter of principle, meaning in the majority of cases. This is likely the fairest framing of the round, given that it allows for there to be one-offs or exceptions on both sides. Oftentimes, I find that judges tend to prefer general principle framing when it's posited against a more heavily scoped or uneven framing observation from the other side; however, that's not to say skewed framing cannot work because it certainly can if argued correctly.

The Aff may choose to frame the resolution as a universal statement, meaning that they must prove de-extinction in all cases is unethical. This strategy, however, is likely not particularly effective in the large majority of cases as it creates the largest possible burden for the Aff debater. On the flip side, it may be advantageous for the Neg to try and impose a universal burden on the Aff, though judges will often disregard this scoping in favor of a more balanced approach if one is proposed in order to bolster fairness and accessibility in the debate.

In terms of Fiat – this resolution assumes that de-extinction is possible, meaning it is relatively useless for any debater (Neg or Aff) to spend time arguing about the practicality of the process. That said, debaters may still make arguments as to what qualifies as de-extinction based on the real-world capabilities of science.

Now, while it's not worthwhile to attempt to prove de-extinction is impossible or improbable, that does not mean that debaters cannot argue the real-world implications of the process. As with many normative statement resolutions, this topic is primed for plan or quasi-plan debate, in which debaters define what qualifies as de-extinction or argue the ethicality of a specific type of de-extinction.

For example, the Neg may provide an observation at the top of the case that scopes the debate to a single example. By that, I mean that if Neg proves a specific type or use of de-extinction is ethical, they win the round. Now, while people may contest whether this kind of scoping is

abusive, it's certainly common, and it may be a viable strategy depending on how it's framed. The Aff similarly may also choose to take a single-example approach in which they limit their argument to a specific type of de-extinction and argue that that instance is unethical. With a broad resolution like this, debaters may be well off attempting to scope the round this way, as it can narrow the grounds for debate and thereby lead to a cleaner round with better clash.

The real-world impacts of de-extinction processes, including economic and ecological effects as well as ripple effects in terms of innovation, are certainly fair ground for debaters on this topic. Debaters should be aware that rounds may include odd clashes, including heavy theory against pragmatic or policy arguments, and ought to prepare accordingly. Insofar as rounds may be varied or include heavily mismatched approaches, impact weighing also becomes increasingly important. Debaters ought to familiarize themselves with how to weigh deontological impacts against consequential ones and vice versa, as I find it highly likely that these kinds of debates will arise frequently with a topic like this one.

Perspectives on the Resolution

Given that the resolution lacks an actor, the question of whose interests matter in this topic is up to you (the debater). As a result, I believe it's potentially advantageous to consider selecting what I would call a "perspective" for argumentation. This means selecting an actor or group of actors that are involved in the process of the resolution or are affected by its impacts and building a case based on that perspective. Below, I will provide a list of potential perspectives to consider:

- **The Animals:** This perspective concerns the interests of the de-extincted animals, surrogate mothers, and other animals involved in processes like genetic engineering or cloning.

- **The Ecosystem/Environment:** I believe that this will likely be the most frequently used perspective on this topic, as it carries heavy weight and spans strong arguments on both sides of the flow. The ecosystem approach examines biodiversity, ecological functions, and the risks associated with introducing artificially produced animals and organisms into natural ecosystems.

- **Humanity (General):** The humanity approach spans a broad array of topics, including justice and restitution for human-caused extinction, the interests of specific communities including indigenous peoples (see below), and potential epidemiological and resource effects.

- **The Economy/Science:** This approach situates de-extinction in the context of the greater scientific economy, which predominantly involves arguments about the innovations, spinoffs, and greater technological and scientific impact associated with the pursuit of de-extinction.

- **The Conservation Community:** This approach examines the impact of de-extinction on still-existing species. The Aff may argue that de-extinction threatens the continued existence of certain species, while the Neg may posit de-extinction as a viable conservation tactic for critically endangered populations.

- **Indigenous Peoples:** This approach focuses on the impact de-extinction practices may have on indigenous communities, either on the Aff through arguments about ecological risk and failure to include indigenous voices, or on the Neg through arguments about the potential of de-extinction to restore and sustainably maintain culturally relevant relationships between indigenous populations and native animal populations.

While not exhaustive, this list ought to give debaters some general ideas of the stakeholders involved in this topic. Cases can certainly be inclusive of the perspectives of multiple stakeholder groups, but on a broad topic like this one, it's often advantageous for debaters to be selective about which stakeholders to focus on in their arguments, as it generally makes impact weighing cleaner and easier.

Affirmative Strategy and Framework Recommendations

The burden of the affirmative is simple – affirm the resolution. With a topic like this one, it's important to focus on the actual scope of the resolution and fulfill the affirmative burden. While arguments can be made that de-extinction creates certain risks or may bring about negative consequences, the presence of negative consequences does not inherently mean something is unethical, unless, of course, the framework says so. That is ultimately the requirement of the Aff framework in this resolution; it must define the ethical contours of the arguments in case, allowing them to be weighed against other impacts. Below, I will discuss some of the predominant case approaches that I see for the Aff, as well as thoughts regarding frameworks:

The Animal Rights Approach

One of the most intuitive and potentially interesting Aff cases to explore on this topic is the animal welfare approach. The argument is based on the understanding that de-extinction requires the artificial creation of sentient beings. This approach can be either consequential or deontological in nature, or a case may adopt a mixed approach in which debaters present both a consequential and deontological contention under a flexible framework.

On the consequential level, an Animal Rights case may focus on how de-extinction might intervene in existing environments and negatively impact native animal populations. De-extinction involves the artificial creation of essentially new species. While these animals may mirror species that have gone extinct, it is worth noting that no de-extinction process has actually been proven capable of creating exact copies of extinct species. These species are, then, assumed

to be either (1) studied in confinement for scientific gain or (2) reintroduced into natural habitats. There are consequential arguments to be made on both sides, including the infringement on animal rights that can occur through the forced reintroduction of foreign species into the ecosystem.

The deontological dimension of this particular approach is, in my opinion, the more interesting of the two. This argument would focus on the impact of the actual process of de-extinction. It's relatively well established that de-extinction processes involve what some might call significant suffering as well as high rates of failure. Both cloning and gene editing require a great deal of trial and error, which means failed pregnancies, deformed and/or non-viable animals, and the heavy reliance on surrogate mothers. On the far end of the theoretical spectrum, I do think there is potential to make a viable feminist argument here; however, given that this is a trad-focused brief, I'm not going to spend time delving too deeply into that contour of the topic.

Frameworks that suit this topic may have flexibility to be applied both deontologically and consequentially, and can include spins on minimizing suffering, respect for sentient life, or otherwise more closely tailored theories.

The Util Case

Despite being a relatively unique topic which does lend well to heavily theoretical debate, I do think there is a strong and viable utilitarian angle for the Aff. It is worth noting that there are many scales and dimensions to the potential consequences of de-extinction – those impacts could range from local (ex., impacts of species reintroduction on agriculture and food production) to national (ex., degradation of conservation efforts) to global (ex., ecological collapse or epidemiological outbreaks). This breadth in potential arguments creates a unique problem for the Aff – you're spoiled for choice. That is to say, I believe that the strongest util approaches by Aff will narrow in on a specific theme (epidemiological risk, ecological impacts, economic impacts, etc.) and build a well-thought-out case around that area. While it can be appealing to cover as much ground as possible, I have seen that cases that bite off too much often do too little on the linkchain level, and on a heavily theoretical and broad topic like this one, that can be a massive risk.

The Moral Hazard/Conservation Efforts Case

Oxford Languages defines a moral hazard as a situation where one party takes more risks because another bears the cost. This framing, in my opinion, has an incredibly interesting application for this topic. I believe that there is a strong argument to be made that the process of de-extinction lowers the perceived risk of causing extinction in the first place. By lowering the cost of extinction, de-extinction may effectively have a reverse impact on conservation efforts.

There is a strong intuitive component to this approach – if policymakers believe that true extinction is no longer a risk, the need for effective conservation efforts and ecological maintenance drops, including negative impacts on anti-poaching and habitat protection efforts.

This approach is effective because it can (1) provide a unique angle on the case that spans economic, political, and ecological categories, and (2) exists as a clear turn to one of the most predominant negative arguments.

The weak point of this case is evidence – de-extinction is a relatively new process and likely not successful enough consistently to have played out as a moral hazard *yet.* In order to build this case, debaters will need to draw on proxy examples and construct clear, critical link chains to establish the risk of moral hazard. That is to say, it's not enough to say this will happen; you have to prove it.

The Ecological Impact Case

The ecological impact case will likely be one of the most frequently seen on this topic. I want debaters to remember, however, that this case fits more than one mold. Not every ecological impact case will be the same, and not every one of them is equal.

I believe that there is a unique and interesting argument to be made on the theoretical level about the impact of de-extinction on human relationships with nature. In some ways, the pursuit of de-extinction represents a human desire to move beyond nature's boundaries – to reverse death. Instead of pursuing restorative processes that reverse or limit the behaviors that have led to anthropogenically caused extinction, humanity has instead found a way to reverse the natural consequences of what it has done. On a topic that posits *ethics* as the qualifier in the resolution, I think that this argument could certainly hold weight.

On the other hand, arguments can also be made on a more practical level regarding the impact of de-extinction on existing animal species and environments. The evidence for this concept is ripe – even beyond limited examples of de-extinction, debaters can draw on past instances of non-native species reintroduction, forced migration, or other human intervention to establish their case.

The Indigenous Rights Case

This is the most critical-theory-oriented of the cases that I have discussed, but I certainly do think it could be an interesting strategy (and it's one of my personal favorites). This case focuses on the scientific process of de-extinction (and how de-extinction practices were developed) and argues that, because native voices have been largely ignored or excluded from conversations surrounding de-extinction, de-extinction is structurally violent towards indigenous peoples.

I know that may sound complicated, and in a lot of ways it is, but to break it down as best I can in a brief – the culturally critical relationship between native peoples and the natural environment and the shared impact of colonialism on both morally mandates the inclusion of indigenous voices in discussions surrounding de-extinction. It follows that the exclusion of indigenous voices in the discussions surrounding the development and application practices is another instance of structural violence and exclusion.

Negative Strategy and Framework Recommendations

The burden of the negative in this case is, as established above, to prove that de-extinction is not unethical. This does not mean that the Neg must prove that the process IS ethical. Below, I will discuss some of the predominant case approaches that I see for the Neg, as well as thoughts regarding frameworks:

The Restorative Justice Case
This case is going to be a common one on this topic, but similarly to the ecological rights case above, please try to remember that just because a lot of debaters pursue this topic does not mean it can't be done well and uniquely.

I see two potential approaches to this case, the first one being the more general one of the two, focusing on the relationship between humans and the environment. This argument posits, then, that the pursuit of de-extinction processes represents a form of ecological reparations from humanity to animal communities and environments. De-extinction serves as a way to reverse the harm done to animal populations by anthropogenic impacts like climate change, poaching, and pollution. This case is interesting and certainly gives the Neg a degree of moral impact, which is beneficial against highly intuitive or appealing morality-focused Aff cases. That said, this approach generally only works when limiting the resolution to human-caused extinctions, so the Neg should spend some time on scoping.

The other way I can see this case being done is through a structural violence angle, in which a debater focuses on the potential for de-extinction processes to restore native relationships with the land and thereby act as a form of reparations to native peoples for the impact of colonialism. It is well-evidenced that colonialism brought about a great deal of harm to untouched natural landscapes and native ecological systems. Similarly, history recognizes the nature of strong and sacred Indigenous relationships with the land across societies from North America to Australia to Latin America. Colonialism, then, not only impacted native peoples directly through disease spread and violence, but also on a cultural and identity level through the destruction of sacred relationships and practices.

I believe that there is an interesting argument to be made about the potential for de-extinction processes to serve as a form of postcolonial reparations, though I believe that this argument is in some ways predicated on the need for indigenous peoples to be involved in conversations and decisions about de-extinction. The Neg needs to be careful when scoping this approach, as I do think there is a strong Aff turn regarding the ontological impact of the exclusion of indigenous voices from these scientific conversations (see above).

The Util Case

As for the Aff, I do think there is a strong and viable util approach on the Neg. In my opinion, the greatest area of consequential argumentation for the Neg is conservation. While de-extinction may have many impacts, including economic ones (see below), its most appealing and perhaps most impactful potential lies in the area of ecological restoration.

This case can focus on the potential for de-extinction and associated processes such as genetic engineering, biobanking, and development of disease resistance, to serve as forms of effective ecological restoration. This case does link directly to the definitional strategy I discuss two sections prior (selecting a broad/inclusive definition), so be careful about scoping.

The Economics & Innovation Case

This case focuses primarily on the economic, scientific, and technological impact of de-extinction practices. This argument focuses on the innovation-economy contours of de-extinction, arguing that there have been developments including new genetic engineering technologies, improved understanding of diseases and genetic mutations, better potential for development of disease resilience, and scientific improvements to conservation efforts (ex., biobanking) which have resulted from the pursuit of de-extinction technologies.

While there is certainly ground for this argument, I do think it avoids many of the theoretical contours of the topic and may lead to uneven or clunky clash. Debaters ought to be conscious to still be able to respond to unique and critical theories when pursuing this approach.

Final Remarks

This topic has the opportunity to be as simple or creative as you choose to make it. As always, I urge you all to read a lot, think even more, and get to know this topic as well as you can. Develop arguments that are unique, intellectually deep, and compelling – just because an approach is uncommon is not a reason not to run it. At the end of the day, this topic is what you make of it, so make it something fun that you can be proud of. Happy Prepping!

Evidence Section Foreword

The remainder of this brief is focused on evidence in key argument categories, including definitions, affirmative case evidence, and negative case evidence. Much of this evidence aligns with the cases and strategies discussed in the two analyses, but some of it does extend beyond into other categories. As always, we urge you to not take these cards at face value. Yes, they've been found and cut for you, but as debaters, you should always take the time to read the original source, understand what the card is saying, and tailor the cut to the needs of your case!

Definitions

Britannica definition of de-extinction

Rogers 25 [Kara Rogers is the senior editor of biomedical sciences at Encyclopædia Britannica "de-extinction, , https://www.britannica.com/science/de-extinction. 13 Jul. 2025]

de-extinction, the process of resurrecting species that have died out, or gone extinct. Although once considered a fanciful notion, the possibility of bringing extinct species back to life has been raised by advances in selective breeding, genetics, and reproductive cloning technologies. Key among those advances was the development in the 1990s of a technique known as somatic cell nuclear transfer (SCNT), which was used to produce the first mammalian clone, Dolly the sheep (born 1996, died 2003).

Definition of what methods are considered de-extinction

Turner 25. [Stephen D. Turner, Anna Keyre, Andrew Pask, Beth Shapiro. "De-Extinction Technology and its Application to Conservation." American Genetic Association. Journal of Heredity. https://academic.oup.com/jhered/article/117/5/959/8262805#573397764 September 24, 2025.]

De-extinction can be understood as a continuum where at one end lies an organism whose genome, phenotype, and ecological role are indistinguishable from the original and, at the other, a functionally equivalent proxy of the extinct species that is capable of restoring lost ecological functions (IUCN 2016; Shapiro 2017; Novak 2018). De-extinction can proceed via different paths. Selective back-breeding, for example, is being used to restore the ancestral traits that defined aurochs, the wild ancestor of domestic cattle (Stokstad 2015). Back-breeding, however, takes many generations and requires living relatives that preserve the targeted extinct traits. Another approach is somatic cell nuclear transfer (SCNT) or 'cloning', which creates an identical copy of an extinct organism from a cryopreserved nucleus by inserting it into an enucleated egg of a suitable surrogate. This approach was used for the bucardo and to de-extinct the gastric brooding frog (Novak 2018). Cloning, however, requires an intact frozen cell, and this approach may not be possible for birds and reptiles due to the inability to access the nucleus at the stage required. A third approach, genome engineering, alters the genome of a living organism to add or replace DNA sequences with the goal to engineer extinct phenotypes. Each of these approaches can lead to restoration of traits that defined the extinct species in a living surrogate (Fig. 1).

Conservation definition of de-extinction

IUCN SSC 16 [International Union for Conservation of Nature, Species Survival Commission, The Species Survival Commission is a science-based network of thousands of volunteer experts from almost every country in the world, all working together toward achieving the vision of "a just world that values and conserves nature through positive action to both prevent the loss and aid recovery of the diversity of life on earth." "IUCN SSC Guiding Principles on Creating Proxies of Extinct Species for Conservation Benefit" https://portals.iucn.org/library/efiles/documents/Rep-2016-009.pdf May 18 2016]

The prospect of species "de-extinction", defined as the process of creating an organism that resembles an extinct species (but see Note on Terminology below) has moved from science fiction to plausibility within the last decade, but has been debated widely only within the last few years. The increasing public profile of species "de-extinction" has been driven in part by rapid advances in the technical capacity to read and

manipulate genetic code. The discussion around revival of extinct species has shifted from “could we?” to “should we?” As with almost any new technology, enthusiastic endorsement needs to be balanced against significant concern over any possible harmful consequences.

Bio technical definition of de-extinction

Martinelli et al 24 [Lucia Martinelli MUSE – Science Museum, Trento, Italy, Markku Oksanen Department of Behavioural Sciences and Philosophy, University of Turku, Turku, Finland, Helena Siipi Department of Behavioural Sciences and Philosophy, University of Turku, Turku, Finland"De-Extinction: A Novel and Remarkable Case of Bio-Objectification.” Croatian Medical Journal, vol. 55, no. 4, Aug. 2014, pp. 423–27, https://doi.org/10.3325/cmj.2014.55.423 Accessed 15 Oct. 2026."]

De-extinction is the process of creating an organism which is – or greatly resembles – a member of an extinct species (1). Contemporary biotechnology offers various promising alternatives for achieving this purpose, including the techniques that have already been applied to preserving endangered species (2). De-extinction requires an in-depth study of the biophysical conditions where the species can live and reproduce in relation to other species – including humans – and adapt to the environmental changes. In any case, risk and harm evaluation on the impact of the “re-birth” of species is necessary. There is a number of crucial ethical issues concerning de-extinction. They include the meanings of concepts such as “nature,” “species,” “evolution,” “biodiversity,” “death,” and “wildlife” in relation to human behavior and human impact on nature (3). In 2013, de-extinction became popular through press and public events; the National Geographic devoted a cover story to this topic and presented various possibilities and scenarios about the most suitable candidates. The Revive & Restore network, with the support of TED and in partnership with the National Geographic Society, convened the TEDxDeExtinction conference bringing together conservationists, genetic technology practitioners, scientists, and ethicists (http://www.ted.com/tedx/events/7650). Because the revival of extinct animals inspires imagination (4), de-extinction has been a topic of science fiction novels, such as John Brosnan’s Carnosaur (1984) and Michael Crichton’s Jurassic Park (1990) and their film adaptations.

Affirmative Evidence

Animal Rights

General Ideas:

- Cloning harms animals
- Treats animals as pets for humans
- Medical issues
- Treat animals as mere means
- Dodo bird for profit, not restoration

Cloning inflicts unnecessary harm on animals and fails to achieve its goals simultaneously

Ibtisham et al 16 [Ibitsham "Animal Cloning Drawbacks An-Overview." Journal of Dairy, Veterinary & Animal Research, vol. 3, no. 4, June 2016, https://doi.org/10.15406/jdvar.2016.03.00087. Accessed 16 Oct. 2026.]

One barrier to the practical use of techniques involving somatic cell nuclear transfer is the low possibility of cloned embryos; only a few percent of reconstructed oocyte are always able to develop.[43] Up-to now success rate if cloning of intra species is 1%[44] despite use of healthy and synchronize recipient in addition to it good quality of embryo used. In most mammalian species, assessment of embryo morphology remains the method of selection for variety of practicable embryos earlier to transfer. It is the most realistic and clinically useful way to assess of embryo viability.[14] But still most of cases significant loss of pregnancy is reported in early developmental stages approximately at the age of 30-90days of gestation[45] due to failure of placental membrane and reduce placental vessel development,[39] it is reported that Early first trimester pregnancy rates are less than 1/2 that normally expected, embryonic loss is very high and near about 80% miscarry by second trimester in addition late gestation high level of chances to develop placental and fatal abnormalities then normal.[7] The main cause of third trimester losses are hydroallantois and fetal hydrops, usually attributed to inadequate placentation.[16] It is also present in literature that loss of clone foetus is also due to hypoxic condition because in cloned animal number of placentome is less which able to exchange less nutrient from dam to foetus and make a unfavourable condition for development of foetus.[15]

De-extinction is inherently wrong - it considers animals objects to be used solely for the entertainment of humans

Martinelli et al 14 [Martinelli, Lucia, et al. "De-Extinction: A Novel and Remarkable Case of Bio-Objectification." Croatian Medical Journal, vol. 55, no. 4, Aug. 2014, pp. 423–27, https://doi.org/10.3325/cmj.2014.55.423. Accessed 16 Oct. 2026.]

The organisms born from de-extinction procedures are bio-objects, since they are "living beings […], and yet at the same time […] objects that can be used, controlled, and traded for human purposes" (19). These organisms carry various crucial features we attribute to bio-objects. As "boundary crawlers" (20), they cross borders between natural and artificial, death and life; extinction and still existing; past and present. Moreover, questions rise concerning their identity (7,21) since live specimens of extinct species may not be quite the original species; and if so, what kinds of techno-social processes would determine their identity? For all these peculiarities, re-created organisms definitely appear to be "out of place," a feature often associated with bio-objects (22,23). This feature is most obvious in re-created organisms that live their whole life "out of nature" in zoos, laboratories, or even in touring exhibitions. Yet, for many re-created organisms this may be the only feasible possibility. Ecosystems are constantly evolving and changing, and it may be difficult

to find suitable niches for the re-created organisms (24). For many extinct species, (human caused) changes in the living environment were the cause for extinction, and their native range can no longer provide them a suitable living environment. Thus, we can say that also in their native range, they would be out of place in the sense of their environment being unsuitable for them. Thus, re-creating these kinds of organism destines them to be out of place. However, if extinct species would be adaptive and able to modify a habitat to become suitable to them, as suggested for the woolly mammoth in Siberia (25), it would be possible to see de-extinction as a process that can contribute to putting species back into their places.

Horrific and unnecessary medical problems are a key aspect of de-extinction's cloning technology

Odenbaugh 23 [Odenbaugh, Jay. "Philosophy and Ethics of De-Extinction." Cambridge Prisms: Extinction, vol. 1, no. e7, Jan. 2023, https://doi.org/10.1017/ext.2023.4. Accessed 16 Oct. 2026.]

The first argument against de-extinction concerns animal welfare (Kasperbauer, 2017; Browning, 2018; Browning]

and Veit, 2022). It is morally wrong to cause a sentient being unnecessary suffering. De-extinction will cause unnecessary suffering. Therefore, it is morally wrong to recreate and resurrect species. As a case in point, consider the bucardo cloned and born in 2003. Due to its deformed lungs, it lived for a brief time in tremendous pain (Cohen, 2014). De-extinction could lead to "miscarriage, stillbirth, early death, genetic abnormality and chronic disease" as the result of cloning (Browning, 2018, p. 789). And these are just the beginnings of the ethical issues since there are others regarding rearing and reintroducing these animals. However, conservation always involves a balance between protecting and restoring species and the welfare of individual organisms. For example, in places such as New Zealand endemic biodiversity is protected from predatory mammals through multi-kill traps and aerial poisons (Butler et al., 2014). Our obligations to conserve and restore biodiversity can be outweighed by conservations of animal welfare, but the extent to which there can be "compassionate conservation" is an active debate in conservation practice.

De-extinction promotes human hubris not animal welfare

Sandler 14 [SANDLER, RONALD. "The Ethics of Reviving Long Extinct Species." Conservation Biology, vol. 28, no. 2, Dec. 2013, pp. 354–60, https://doi.org/10.1111/cobi.12198. Accessed 16 Oct. 2026.]

There now appears to be a plausible pathway for reviving species that have been extinct for several decades, centuries, or even millennia. I conducted an ethical analysis of de-extinction of long extinct species. I assessed several possible ethical considerations in favor of pursuing de-extinction: that it is a matter of justice; that it would reestablish lost value; that it would create new value; and that society needs it as a conservation last resort. I also assessed several possible ethical arguments against pursuing de-extinction: that it is unnatural; that it could cause animal suffering; that it could be ecologically problematic or detrimental to human health; and that it is hubristic. There are reasons in favor of reviving long extinct species, and it can be ethically acceptable to do so. However, the reasons in favor of pursuing de-extinction do not have to do with its usefulness in species conservation; rather, they concern the status of revived species as scientific and technological achievements, and it would be ethically problematic to promote de-extinction as a significant conservation strategy, because it does not prevent species extinctions, does not address the causes of extinction, and could be detrimental to some species conservation efforts. Moreover, humanity does not have a responsibility or obligation to pursue de-extinction of long extinct species, and reviving them does not address any urgent problem. Therefore, legitimate ecological, political, animal welfare, legal, or human health concerns associated with a de-extinction (and reintroduction) must be thoroughly addressed for it to be ethically acceptable.

Plans to bring back the dodo emphasizes de-extinction's focus on profit over genuine environmental progress

Ogden 23 [Ogden, Claire. "Why Bother Bringing Back the Dodo?" The Ethics Institute, Feb. 2023, https://cssh.northeastern.edu/ethics/why-bother-bringing-back-the-dodo/. Accessed 16 Oct. 2026.]

It's clear that the potential for new spin-outs is part of why venture capitalists are excited about de-extinction. But the flow of money toward biotech might be subtly reshaping how we think about conservation: Is it about leaving things alone, or modifying species—like Colossal intends to do—so they can survive a world that humans have created? The flow of resources into this sector may change the sorts of conservation practices people engage in, says Ronald Sandler, professor of philosophy and director of the Ethics Institute at Northeastern University in Boston. "There's a new set of potential tools here, a new set of possibilities and opportunities," Sandler says. What isn't clear is whether these new tools actually address why we're in the middle of a mass extinction event, or if they just dangle a technological panacea for the problem, which is that humans are consuming much more of the world's resources than they should. "There's a risk of losing sight of what the real problem is that really needs to be solved," Sandler says.

Tradeoffs

General Ideas:

- Steals attention
- Costs a lot of money
- Current biodiversity preservation comes first
- Steals political attention

Empirics from New Zealand and New South Wales indicate that de-extinction efforts would decrease net biodiversity due to trade-offs with species conservation

Bennet et al 17 [Spending limited resources on de-extinction could lead to net biodiversity loss; Nature Ecology & Evolution; 01 March 2017; Joseph R. Bennett, Richard F. Maloney, Tammy E. Steeves, James Brazill-Boast, Hugh P. Possingham & Philip J. Seddon; Dr. Joseph R. Bennet PhD is a Professor of Ecology at Carleton University; https://www.nature.com/articles/s41559-016-0053]

There is contentious debate surrounding the merits of de-extinction as a biodiversity conservation tool. Here, we use extant analogues to predict conservation actions for potential de-extinction candidate species from New Zealand and the Australian state of New South Wales, and use a prioritization protocol to predict the impacts of reintroducing and maintaining populations of these species on conservation of extant threatened species. **Even using the optimistic assumptions** that resurrection of species is externally sponsored, and that actions for resurrected species can share costs with extant analogue species, public funding for conservation of resurrected species would lead to fewer extant species that could be conserved, suggesting **net biodiversity loss**. If full costs of establishment and maintenance for resurrected species populations were publicly funded, there could be substantial sacrifices in extant species conservation. If conservation of resurrected species populations could be fully externally sponsored, there could be benefits to extant threatened species. However, such benefits would be outweighed by opportunity costs, assuming such discretionary money could directly fund conservation of extant species. Potential sacrifices in conservation of extant species should be a crucial consideration in deciding whether to invest in de-extinction or focus our efforts on extant species. Technological advances are reducing the barriers to resurrecting extinct species or their close genetic proxies, allowing de-extinction to be considered as a biodiversity conservation tool1,2. Arguments in favour of de-extinction include necessity, driven by the rapid rate of species and habitat loss3,4, an ethical duty to redress past mistakes, as well as potential technological and ecological knowledge that could stem from de-extinction programmes. Counter-arguments include high risk of failure due to difficulties of cloning for some species6, technical risks inherent in re-introductions7–9, loss of culture in resurrected animal species8, and lack of remaining habitat for some species10,11, as well as negative consequences for extant species, including reduced incentive for traditional conservation12, and ecological impacts of introducing long-absent or genetically modified species12. The relative cost versus benefit for biodiversity is fundamental to the debate surrounding de-extinction. Assuming species are resurrected to be released into former habitats, the cost of de-extinction includes the process of producing initial founder populations, translocating individuals, then monitoring and managing new wild populations. If conservation funds are re-directed from extant to resurrected species, there is risk of perverse outcomes whereby net biodiversity might decrease as a result of de-extinction12,13. Although private agencies might fund the resurrection of extinct species out of technical or philanthropic interest, the subsequent ongoing management of such species (many of which would face the same threats that made them extinct) would fall on government agencies, as commonly occurs with extant threatened species. Alternatively, if private agencies are willing to provide new funding for post de-extinction management, there could be additional benefits to species sharing habitats or threats. Here, we test the potential impact of establishing and sustaining wild populations of resurrected extinct species (or proxies of such species) on the conservation of extant species. Specifically, we use long-term conservation programmes for extant analogue species in New Zealand (NZ) and the Australian state of New South Wales (NSW), to infer potential conservation actions for resurrected species, and predict the impact of resurrected species programmes on conservation of extant species. We use these datasets because they contain detailed prescriptions and costs of actions designed to achieve population recovery for most of the extant threatened species requiring specific management actions in either jurisdiction. We estimate the net number of extant species that can be conserved, using the following scenarios: (1) establishment and maintenance of resurrected species become the burden of government conservation programmes, and (2) establishment and maintenance of resurrected species populations are funded externally using non-public resources. In

Scenario 1, the use of government resources on resurrected species results in less funding for extant species programmes, but provides potential benefits for species that share actions with resurrected species. In Scenario 2, there are also potential benefits to extant species conservation programmes through shared conservation actions. However, there are potential opportunity costs, if private agencies use resources they could otherwise have used on conservation of extant species. Our analysis assumes that species would be resurrected to be re-introduced into their former habitats, rather than for other potential reasons, such as research or public displayBecause little is known about the costs of producing viable initial populations of resurrected species, we do not consider this in our analysis, and assume it is covered by a private agency. Instead, we focus on the long-term cost of conservation for resurrected species, assuming that such species would have small founder populations that require conservation actions similar to those required for extant threatened species. Although there is considerable uncertainty regarding the necessary conservation actions for many extinct species should they be resurrected7, we assume that such species would share many actions with closely related extant species that share habitats, threats and ecological roles. Therefore, from among the endemic, fully extinct species of our study areas, we chose focal extinct species whose taxonomy, range, habitat, life history and threats were similar to an extant threatened analogue species. Among 70 recently extinct (AD 1000 to present) species in NZ, we found 11 for which we could assign reasonable analogues (Supplementary Table 1). For NSW, we considered 29 recently extinct species, and found 5 with reasonable extant analogues. Our inferred conservation programmes for the extinct species (assuming they were resurrected), were the same as for their analogue extant species, with the addition of captive breeding and translocation costs, based on average costs of captive breeding and translocation from extant species of the same taxonomic group (for example, bird, amphibian). Although cost and shared actions were not criteria for choosing our focal species, our chosen group represented a broad range in terms of estimated costs and the number of extant species with shared actions (Supplementary Table 1). Note that using analogues in this way probably underestimates the cost, along with the risk of failure, and that we have assumed that actions could be completely shared between resurrected and extant analogue species. It is unlikely that an effective conservation programme for a resurrected species would completely share actions with that of an extant species. Our analysis also includes the largely untested assumption that technical barriers to creating initial populations of these species can be overcome6,14. Thus, our results should be regarded as optimistic in favour of the net benefits of resurrected-species conservation programmes. To assess the potential influence of resurrected species on extant species conservation, we incorporated the proposed programmes for resurrected species into threatened species project prioritization protocols developed for the New Zealand Department of Conservation and the NSW Office of Environment and Heritage (see 'Methods' for details). Costs of shared actions (for example, predator control that benefits several species sharing a site) were shared among prioritized species recovery projects. Thus, if private funding covers the cost of actions for a resurrected species, the cost of the same actions for any other species (including the resurrected species' analogue) would also be covered, potentially allowing more species to be conserved within a given budget. In Scenario 1, where resurrected species become the burden of governments, we subtracted the budgets for resurrected species conservation programmes from realistic baseline budgets for NZ (NZD$30 million15,16) and NSW (AUD$4.65 million17), and set the cost of any specific actions that were shared in location and time with other species (for example, predator fence on a shared habitat patch) to zero. We compared the number of extant species that could be prioritized for funding in this scenario with the number of extant species that would normally be prioritized with the same baseline budget. We did this for each resurrected species considered individually (cost of only one focal species subtracted), as well as all resurrected species (11 for NZ and 5 for NSW) considered together. For Scenario 2, where resurrected species programmes are entirely externally sponsored, we determined potential benefits for conservation of extant species by setting the cost of any shared actions between resurrected and extant species to zero, and re-ran the

*** FIGURE OMITTED***

Number of extant species prioritized for conservation for different de-extinction scenarios. a,b, Mean differences in the number of extant species prioritized versus the baseline number of prioritized species when considering extant species only (vertical dashed line), for New Zealand (a) and New South Wales (b). Red bars represent Scenario 1, where conservation of resurrected species becomes the responsibility of government. Yellow bars represent Scenario 2, where conservation of resurrected species is externally sponsored. Blue bars represent the number of extant species that could be prioritized for conservation if funding for conservation costs of resurrected species could instead be applied to extant species. Thus, they represent the opportunity costs associated with Scenario 2. Error bars represent standard errors. Note that the Scenario 1 costs for two species in NSW were higher than the set government budget, so mean differences could not be measured (N/A).]

prioritization algorithms with our baseline budgets. To determine the opportunity cost associated with this scenario, we added the cost of actions for resurrected species' sponsorship programmes to the baseline budget for extant species prioritization, then determined the number of species that would be prioritized for conservation if such funding could be used on extant instead of resurrected species. For both NZ and NSW species, the number of extant species that could be prioritized for conservation was generally lower in Scenario 1, where resurrected species become the burden of the government (Fig. 1, red bars). This suggests a potential long-term net loss of biodiversity if conservation efforts are shifted towards resurrected species. For NZ, there were potential net gains associated with a single resurrected species, Coenocorypha chathamica. This is because the conservation prescription for this species contained many shared actions with 39 extant species that inhabit its former habitat on Chatham Island. Shared costs for some of these species allowed more to be prioritized than in the baseline scenario. However, for NSW the estimated conservation costs for two extinct species are greater than the most recent baseline budget estimate, suggesting that the government budget would have to be drastically increased if conservation of either species were publically funded. Given that the NZ and NSW algorithms are designed to efficiently conserve species using limited resources, and to account for shared costs, it is possible that the impact of government payment for resurrected species programmes could be greater in other jurisdictions where spending is less efficient. In Scenario 2, where the conservation costs of resurrected species are covered by an external agency, lowered costs of shared actions would allow more extant species to be prioritized for conservation (Fig. 1, yellow bars). However, the potential biodiversity benefits are outweighed by the opportunity costs of not applying the same funding to extant species (Fig. 1, blue bars). For both scenarios, including the costs of all resurrected species together amplified the results (Supplementary Table 2). For example, government-funded conservation for all 11 focal extinct species in NZ would sacrifice conservation for nearly three times as many (31) extant species. External funding for conservation of the five focal extinct NSW species could instead be used to conserve over eight times as many (42) extant species. It is probable that including the costs of producing viable initial

populations of these species would greatly increase our estimates for the sacrifices in extant species conservation. The costs for such programmes are difficult to project, but they are likely to be substantial. A programme aimed at using stem cell technology and surrogates to prevent the extinction of the northern white rhinoceros (which would have fewer technical hurdles than resurrecting species from only preserved materials) has been estimated to cost several million dollars2. In addition, our analyses make the generous assumption that we would have perfect analogues for the extinct species, such that conservation programmes for resurrected and extant species would share costs. Breeding and husbandry of resurrected species before and after reintroduction could well be more expensive and more prone to failure than for extant [endangered] species, because we typically know less about the behaviour and physiology of extinct species. Reintroduction of locally extirpated species would likely have considerably lower risk and costs, given better knowledge of the ecology and physiology of such species. Debates regarding the merits of de-extinction tend to centre on either ethical or biological arguments. Ethical arguments often focus on the potential of de-extinction to right past wrongs, versus the 'moral hazard' arising from diminished motivation to conserve extant species, if it is assumed that extinctions can be reversed some time in the (potentially distant) future12. Biological arguments often focus on the relative benefit to biodiversity. For example, there may be conservation gains through applying technical lessons learned in the process of attempting de-extinctions4. There could also be gains through restoration of ecosystem processes that were provided by the extinct species18. For example, extinct 'ecosystem engineers', such as woolly mammoths or passenger pigeons, could potentially be resurrected in attempts to restore their lost functional roles19. In addition, resurrected species could act as 'flagships' to promote conservation5, and potentially increase resources for management of extant threatened species. However, there is considerable risk in assuming that resurrected species would fill these intended roles. Resurrected ecosystem engineers would be introduced into environments that have been much altered by humans, and they could fail to thrive in these new circumstances7,19. Resurrecting populations large enough for such species to fill their former roles could also prove very challenging19. Conversely, there may be biodiversity losses if resurrected species become invasive or spread disease12,20,21. Experience with extant iconic species also suggests a high risk that iconic species resurrected as 'flagships' could draw resources away from programmes for extant species22, or even create self-reinforcing biases whereby the public profile of resurrected species and resources spent on them would synergistically increase, at the expense of non-iconic extant species23. More fundamentally, de-extinction could lead either to biodiversity gains via resurrection of the extinct species themselves and shared conservation actions with extant species, or to losses through missed opportunities to allocate resources to extant species. Conservation resources are scarce24, necessitating careful allocation of funds25. Our analysis strongly suggests that resources expended on long-term conservation of resurrected species could easily lead to **net biodiversity loss**, compared with spending the same resources on extant species [conservation]. If the risk of failure and the costs associated with establishing viable populations could also be calculated, estimates of potential net losses or missed opportunities would probably be **considerably higher**. Given this considerable potential for missed opportunity, as well as the risks inherent in assuming a resurrected species would fulfil its role as an ecosystem engineer or flagship species, it is unlikely that de-extinction could be justified on grounds of biodiversity conservation. NATURE ECOLOGY & EVOLUTION 1, 0053 (2017) | DOI: 10.1038/s41559-016-0053 | www.nature.com/natecolevol ARTICLES Methods Focal extinct species were chosen based on taxonomic relatedness as well as having ranges, habitats, threats and life-history strategies shared with extant analogue species. We chose fully extinct species (not just locally extirpated) that went extinct after AD 1000, assuming that feasibility of resurrection (for example, availability of genetic material, knowledge of life history and physiology) would be prohibitively low for species that went extinct before this time. However, we did not assess the availability of genetic material in our focal species, nor consider the feasibility or cost of producing viable initial populations. Species conservation projects and prioritization algorithms. Species conservation projects for all species in the NZ and NSW datasets (including the analogue species) were determined using information gathered from threatened species experts (> 100 experts for NZ, ~250 for NSW). The projects include the specific actions (including specific location, timing and cost) considered necessary to ensure ~95% probability of each species' persistence over 50 years. The prioritization algorithms rank species by the cost-effectiveness of their conservation projects, using the following equation: = × E B S i i i C i where Ei is the cost effectiveness of the conservation project for species i; Bi is the benefit of the project to the species, defined as the difference between estimated probabilities that a species will be secure in 50 years with and without the project; Si is the estimated probability of success for the conservation project; and Ci is the total cost of all actions for the project, across all sites. The NZ algorithm uses an additional parameter that estimates a species' evolutionary distinctiveness (see ref. 15 for details). Costs of actions are shared among prioritized species recovery projects. For example, the cost of predator control at a site that benefits two prioritized species sharing the site is reduced by 50% for each of the two species. The algorithm begins with all species ranked, then eliminates the lowest-ranked species sequentially until the set first-year budget is reached. As species are removed from the ranks, cost sharing is updated for the remaining species. Species that are no longer prioritized no longer share costs with those that remain. Additional details regarding the algorithm are given in refs 15,26.

Meta-analysis confirms that biodiversity loss contributes significantly to infectious disease risk

Rohr et al. 16 [A meta-analysis on global change drivers and the risk of infectious disease; Nature; Michael B. Mahon, Alexandra Sack, O. Alejandro Aleuy, Carly Barbera, Ethan Brown, Heather Buelow, David J. Civitello, Jeremy M. Cohen, Luz A. de Wit, Meghan Forstchen, Fletcher W. Halliday, Patrick

Heffernan, Sarah A. Knutie, Alexis Korotasz, Joanna G. Larson, Samantha L. Rumschlag, Emily Selland, Alexander Shepack, Nitin Vincent & Jason R. Rohr; 2016; Jason Rohr is a professor of ecology and public health at Notre Dame University; https://www.nature.com/articles/s41586-024-07380-6]

Anthropogenic change is contributing to the rise in emerging infectious diseases, which are significantly correlated with socioeconomic, environmental and ecological factors1. Studies have shown that infectious disease risk is modified by changes to biodiversity2,3,4,5,6, climate change7,8,9,10,11, chemical pollution12,13,14, landscape transformations15,16,17,18,19,20 and species introductions21. However, it remains unclear which global change drivers most increase disease and under what contexts. Here we amassed a dataset from the literature that contains 2,938 observations of infectious disease responses to global change drivers across 1,497 host–parasite combinations, including plant, animal and human hosts. We found that biodiversity loss, chemical pollution, climate change and introduced species are associated with increases in disease-related end points or harm, whereas urbanization is associated with decreases in disease end points. Natural biodiversity gradients, deforestation and forest fragmentation are comparatively unimportant or idiosyncratic as drivers of disease. Overall, these results are consistent across human and non-human diseases. Nevertheless, context-dependent effects of the global change drivers on disease were found to be common. The findings uncovered by this meta-analysis should help target disease management and surveillance efforts towards global change drivers that increase disease. Specifically, reducing greenhouse gas emissions, managing ecosystem health, and preventing biological invasions and biodiversity loss could help to reduce the burden of plant, animal and human diseases, especially when coupled with improvements to social and economic determinants of health. Database of infectious disease studies The database resulting from our literature search includes 972 studies and 2,938 observations of global change drivers on disease or parasitism from 1,006 parasite taxa, 480 host taxa and 1,497 host–parasite taxa combinations (Fig. 1 and Extended Data Fig. 1). Each continent except for Antarctica was well represented with data from field studies across the global change drivers (Fig. 1g). In contrast to many meta-analyses, we had reasonable coverage of studies within low- and middle-income countries (LMICs; that is, more than 20 field studies in the LMICs per driver), except for chemical pollution and introduced species (6 and 3 field studies in the LMICs, respectively; Fig. 1g). Nevertheless, there were still less data available for LMICs, highlighting the need for additional research in these countries.Each observation in the database contains information on the associated global change driver and host and parasite taxa and traits (for example, human versus non-human parasite), and whether it was derived from freshwater, marine, or terrestrial systems and laboratory or field studies (Fig. 1, Extended Data Figs. 2 and 3 and Supplementary Table 2). Moreover, each response variable was classified as a host end point, which captures host symptoms or consequences of infection (disease presence, disease severity, survival, growth and reproduction) or a parasite end point, which captures parasite pressure in hosts (parasite prevalence, incidence, intensity, abundance, survival, growth and richness). Hedge's g and log response ratio effect sizes were calculated from each study, with positive and negative effect sizes representing increases and decreases in disease, respectively. The exception was for studies on introduced species, for which decreases and increases in parasites or disease in the native host received negative and positive values, respectively, but the opposite was true for non-native hosts because a reduction in disease in non-native hosts and an increase in native hosts were both deemed to be potentially detrimental (further discussion is provided in the Methods and Supplementary Information 1). Comparing among global change drivers Among the global change drivers, habitat loss/change caused significant reductions in disease, while chemical pollution, climate change, introduced species and biodiversity change increased disease responses or disease-related harm, in order of increasing magnitude. These patterns were similar using Hedge's g and log response ratios (Figs. 2 and 3 and Extended Data Fig. 4) and we therefore focus on Hedge's g hereafter. Biodiversity change was associated with a 393% greater increase in disease compared with chemical pollution, a 111% greater increase in disease compared with climate change and a 65% greater increase in disease compared with introduced species (Fig. 2). Importantly, we found no evidence that effect-size patterns among global change drivers could be explained by differences in variances or sample sizes among global change drivers (Extended Data Fig. 5), extreme values (Extended Data Fig. 6a), or publication (Extended Data Fig. 6b–d) or time-lag (Extended Data Fig. 6, Supplementary Data 1 and Supplementary Information 2) biases. Comparing among subcategories of drivers Next, we evaluated global change driver subcategories (Fig. 3). Consistent with previous studies3, the loss of pre-existing biodiversity was associated with significantly greater increases in infectious disease outcomes (857% more) [infectious disease outcomes] compared with natural biodiversity gradients (for example, latitudinal or elevational gradients in species richness; Fig. 3). Enemy release (that is, the notion that introduced species leave many of their parasites behind in their native range) reduced infectious diseases in introduced species, but had weaker effects compared with biodiversity loss (39% weaker). Mean temperature and carbon dioxide similarly increased disease but had weaker effects compared with biodiversity loss (55% and 62% weaker, respectively) and enemy release (26% and 38% weaker, respectively). Urbanization decreased infectious diseases, perhaps because urban development is associated with improved water, sanitation and hygiene for humans, and habitat loss for many parasites and their non-human hosts18. Specifically, helminths, protists and arthropods were all negatively associated with urbanization, whereas viruses were non-significantly positively associated with urbanization (Extended Data Fig. 7a). Furthermore, disease was reduced in urban settings compared with in rural and peri-urban settings, whereas there were no differences in disease along urbanization gradients or between urban and natural settings (Extended Data Fig. 7b). Similarly, the effect of forest fragmentation on disease depended on the type of fragmentation being compared, but the effect of deforestation on disease did not depend on the type of land-use conversion (Extended Data Fig. 7c). All of the other subcategories had non-significant effects on disease (Fig. 3). Given the limited funds for infectious disease management, these results suggest that controlling or mitigating biodiversity loss, introduced species and climate change might be particularly important for infectious disease control. Context dependencies Understanding context dependencies is also crucial for properly targeting limited resources for disease control. Although the ideal approach would have been to

compare global change drivers in a single model-selection analysis that considered the correlations among all independent variables and their interactions, this approach was not possible due to missing combinations of variables (Methods and Supplementary Table 2). We circumvented these statistical limitations using two approaches. First, we tested for two-way interactions between each global change driver and host and parasite taxa and various traits of hosts, parasites and studies. Second, to account for the covariances among predictors and to identify the most parsimonious combinations of predictors, we fit models with all possible combinations of main effects of host, parasite and study factors for each global change driver separately (Methods and Supplementary Data 1). We then qualitatively assessed the consistency in the results between these statistical approaches. Importantly, these analyses can reveal both when there are and are not context dependencies. For example, there were many consistent patterns across global change drivers. For several global change drivers, parasite versus host end point was an important moderator in either the two-way interaction (Fig. 4a) or model selection (Fig. 4b) analyses and, in each case, parasite end points were as sensitive or more sensitive to the global change drivers compared with host end points (Extended Data Fig. 8a and Supplementary Table 3). Given that parasite abundance can change profoundly without changes in symptoms or disease, especially for hosts that have tolerance (that is, ameliorating the damage that infection causes) rather than resistance (that is, 'fighting' the parasite directly) defence strategies28,29, it is unsurprising that parasite end points, which are capturing parasite abundance, are more sensitive to global change factors than host end points, which are capturing host symptoms or consequences of infection.

Meta-analysis reveals that conservation efforts are extremely effective

Langhammer 24 [The positive impact of conservation action; SCIENCE; 2024; Penny F. Langhammer1,2*, Joseph W. Bull3-5, Jake E. Bicknell4, Joseph L. Oakley6, Mary H. Brown1, Michael W. Bruford7,8† , Stuart H. M. Butchart9,10, Jamie A. Carr11-13, Don Church1, Rosie Cooney14,15, Simone Cutajar16, Wendy Foden13,17-19, Matthew N. Foster1, Claude Gascon20, Jonas Geldmann10,21, Piero Genovesi22-24, Michael Hoffmann25,26, Jo Howard McCombe27,28, Tiffany Lewis29, Nicholas B.W. Macfarlane30, Zoe E. Melvin27,31, Rossana Stoltz Merizalde32, Meredith G. Morehouse33, Shyama Pagad34, Beth Polidoro25,35, Wes Sechrest1, Gernot Segelbacher8,36, Kevin G. Smith37, Janna Steadman4, Kyle Strongin38, Jake Williams39, Stephen Woodley40, Thomas M. Brooks41-43; As Chief Program Officer, Dr. Penny Langhammer oversees all Re:wild programs across the world. She is responsible for developing and implementing Re:wild's strategy through both regional and cross-cutting programs. Penny also leads our work in several global partnerships including the Key Biodiversity Areas, Forests for Life, and Red List Partnerships. In her role, Penny serves as the programmatic conduit to the Executive Team and Board of Directors https://www.science.org/doi/10.1126/science.adj6598]

Main Text: Ongoing and dramatic declines in global biodiversity, and the associated negative consequences for human well-being, are among the most pressing contemporary risks to society (1). Governments have thus adopted goals to tackle biodiversity loss and its drivers: 20 Aichi Biodiversity Targets in the Strategic Plan for Biodiversity 2010-2020 through the Convention on Biological Diversity, and now 4 goals for 2050 and 23 targets for 2030 in the 2022 Kunming Montreal Global Biodiversity Framework (GBF) (2). Similar targets are echoed in the 17 Sustainable Development Goals (3). More than $121 billion is invested annually into biodiversity conservation worldwide (4). Yet despite this, none of the Aichi Targets were fully met (1). It could be concluded that responses to the ongoing biodiversity crisis are either insufficient, ineffective, or both (5, 6) and that the targets established in the new GBF will also likely not be achieved. However, such conclusions are premature: conservation interventions could represent progress, and be at least partly effective, even if global policy targets have not yet been achieved in full. There is consequently a need for a robust evaluation of policy targets, and an assessment of whether conservation interventions are working – that is, having positive impacts and providing better outcomes than the absence of interventions – as governments start committing resources and implementing the GBF. Robust impact assessment using a counterfactual approach (7) reveals that conservation action has prevented extinctions (8) and reduced extinction risk (9) for species across taxonomic groups compared with an absence of conservation action. There has been an increase over the last decade in studies evaluating the impact of specific conservation actions, from global to local scales, using counterfactual comparisons, including for protected areas (10), payments for environmental services (11), invasive alien species (IAS) eradications (12), and sustainable management of ecosystems (13). Other studies have undertaken meta-analyses or systematic reviews, but only for individual conservation actions (14–16). Similarly, the Conservation Evidence website (17) provides a compendium of evidence for the effectiveness of a wide range of individual conservation interventions. However, since conservation actions started over a century ago, there has been no comprehensive meta-analysis of the impact of conservation across the full suite of conservation actions and intervention types, multiple levels and metrics of biodiversity, and over time. Such an assessment is critically needed to inform implementation of the GBF. Here we conduct a meta-analysis of the impact of a wide range of conservation interventions globally. Meta-analysis provides a powerful and informative method to summarize results from multiple studies and accounts for unequal precision among studies in the calculation of effect sizes. We evaluate the impact of conservation actions that address direct pressures on biodiversity, promote restoration and recovery of populations and habitat, and aim to safeguard the environment across different levels of biological organization, compared with outcomes expected without intervention. Specifically, we consider seven intervention types aiming to tackle the direct drivers of environmental degradation: establishment and

management of protected areas; other measures to reduce habitat loss and degradation (including policy and restoration); sustainable use of species; sustainable management of ecosystems; control of pollution; eradication and control of invasive alien (and problematic native) species; and climate change adaptation. These classes of intervention were identified based on the strategies of the intergovernmental environmental agreements, especially the nine Aichi Targets in Strategic Goals B and C of the Strategic Plan for Biodiversity 2011-2020 (Table S1), aligned in turn to the targets of the GBF and Sustainable Development Goals 14 (Life Below Water) & 15 (Life on Land). We consider impacts on biodiversity at ecosystem, species, and genetic levels. We conducted a Rapid Evidence Assessment (see Methods) and meta-analysis of studies published in English that present a counterfactual-based analysis of the impact of conservation actions over time (18). Our literature search yielded 1,445 studies (published papers) spanning spatial scales from local to continental, and more than a century (1890-2019) (Table S2; Fig. S1). Of these, we retained only studies that contained temporal data, where we could express outcomes as effect sizes generated from the 'rate of change under the intervention' compared with 'rate of change under a counterfactual scenario' (19), yielding 186 studies that were included in our meta-analysis (Table S3). Using a rate of change to calculate the effect size allowed us to assess conservation actions over different time scales, avoiding premature conclusions based on study duration. Where studies measured change in biodiversity using more than one metric (e.g. different species), each was treated as a distinct trial nested within that study, totaling 665 trials across the dataset. Our comprehensive dataset shows the variable outcomes of conservation outcomes. As such, interventions that generate gains in the state of biodiversity compared with a counterfactual in which biodiversity declines, stays the same, or improves to a lesser degree than the intervention, reveal absolute positive impacts of conservation action (Fig. 1a). Relative positive impacts of conservation action result when biodiversity declines, but the intervention slows the decline compared with the counterfactual (Fig. 1b). Conversely, relative negative impacts of conservation action occur when biodiversity improves, but the counterfactual reveals greater improvements than the intervention (Fig. 1c). Absolute negative impacts of conservation action result when biodiversity declines following the intervention while it improves, stays the same, or declines to a lesser degree in the counterfactual (Fig. 1d). These four categories are mutually exclusive. Results We find that in the majority of cases, biodiversity conservation works. Our meta-analysis shows that the 'Overall' impact of conservation is positive and significant (mean Hedges' g [± 95% CI] = 3.24 [2.95 – 3.52], $p<0.001$), indicating that, conservation interventions yield beneficial outcomes for biodiversity compared with the outcome in the absence of an intervention (Fig. 2a). We also show that conservation actions can yield positive impacts in both an absolute and a relative sense (Fig. 1). In two-thirds of trials, conservation either improved the state of biodiversity ("absolute positive impacts", 45.4%), or at least slowed declines ("relative positive impacts", 20.6%). However, in one-fifth of trials, biodiversity under the intervention declined more than no action ("absolute negative impacts", 20.6%), while in a smaller number of cases biodiversity improved in both the intervention and counterfactual, but the counterfactual revealed greater improvements ("relative negative impacts", 11.6%). There was no difference between intervention and counterfactual for 1.8% of trials. Moreover, we find that the effect sizes of some individual interventions are high in magnitude and positive, indicating a substantial positive impact of those actions on the whole. All types of intervention assessed that had more than five trials showed a significant positive effect compared with a counterfactual (Fig. 2a; Fig. S2) – eradication and control of invasive alien and problematic native species (7.07 [6.1–8.04], $p<0.001$), sustainable management of ecosystems (5.70 [4.66–6.74], $p<0.001$), habitat loss reduction & restoration (5.58 [4.5–6.7], $p<0.001$), and establishment and management of protected areas (1.41 [1.03–1.78], $p<0.001$). The impact of efforts towards sustainable use of species is inconclusive (2.07 [-0.71–4.84], $p=0.15$), with large confidence intervals possibly related to the small number of studies (Nstudies=5, Ntrials=7). There were too few studies assessing the impact of interventions of pollution control or climate change adaptation to analyze separately (each had five or fewer trials) but these were included in the calculation of the Overall effect size. Likewise 'Other' studies that did not fit into one of the seven key intervention categories (e.g. food supplementation (Nstudies=1), culling of diseased individuals (Nstudies=1), and captive breeding and release (Nstudies=5)) were only included in the calculation of the Overall effect size (categorized as "Other" in the Figures). Studies focused on the impact of controlling problematic native species were combined with studies on IAS given the similarity of the interventions involved. The impact of actions targeting different levels of ecological organization are positive and significant, with the greatest impact shown for actions targeting species (3.56 [3.14–3.97], $p<0.001$), followed by ecosystems (2.88 [2.46–3.29], $p<0.001$), and then genetic diversity (3.84 [1.35–6.32], $p=0.002$), which had wide confidence intervals because there were few studies (Fig. 2b). In terms of geographic breakdown, effect sizes were positive and significant on all continents (Table S4). Our dataset also shows that effect sizes are positive and significant across each of the differing approaches to measuring the impact of an intervention (Table S5). The timespan of datasets analyzed in the different studies was highly variable, with the shortest being 1 month and the longest 110 years (median=4.7, mean=7.4) (Fig. 3). These date back to 1890, and show a trend that studies mainly focused on protected areas until the 1990s, but after this, diversified to a wider range of interventions. Studies with a longer duration were not significantly more likely to show more beneficial or detrimental impacts of conservation actions than shorter studies (Fig. S3). Meta-regression of effect sizes against year of publication (Fig. 4) indicated that more recent studies were more likely to show a positive effect of conservation action, although the low R2 shows that other factors influence effect sizes, as would be expected (because many factors in addition to the intervention determine effect sizes). Half of the studies that met our meta-analysis inclusion criteria (95/186) were conducted in Western Europe, North America, Australia, and New Zealand (Fig. 3). Of the seven intervention types examined, the largest proportion focused on terrestrial and marine protected areas (38%) and the eradication and control of invasive alien and problematic native species (25%). Fewer studies evaluated other conservation actions for ecosystems (e.g. restoration, habitat conservation policy, sustainable management), for species (e.g. sustainable use, reintroductions), and for genetic diversity (e.g. supplementation, supportive breeding; Table S3). Our results remain largely unchanged in sensitivity analyses designed to test the impact of different methodological considerations (Fig. S4), including: imputing the rate of change when it was zero in either the intervention or counterfactual; nesting trials within studies; and undertaking a supplemental literature search. Cumulative meta-analysis revealed that effect sizes stabilize after the addition of studies published from approximately 2011 onwards (Fig S5), and in assessing publication bias, the symmetrical nature of our funnel plots (Fig. S6), combined with a Fail-safe N of 1,280, led us to conclude that any publication bias in our dataset is minimal. Discussion We have shown that across a full suite of conservation actions and intervention types, multiple levels and metrics of biodiversity, and over a century of action, conservation has improved the state of biodiversity – or at

least slowed its decline – compared with no conservation action. Our calculated effect sizes are often large and positive, meaning that the outcomes from conservation actions are substantially better than no action at all. Among the different conservation actions evaluated in our study, the eradication, control and management of I[nvasive]A[lien]S[pecies] showed the largest impact of conservation action (as highlighted by the largest effect size in our intervention groupings), followed by actions to reduce habitat loss and degradation, sustainable management of ecosystems, and protected areas (Fig. 2a). IAS eradication and control has generated some of the most striking conservation successes reported to date, particularly on islands (20, 21). There were numerous studies evaluating the impact of IAS control and eradication that were excluded from our meta-analysis because they report data for only one time point, but these tend to also show a positive impact. Although few in number, studies assessing actions to reduce habitat loss and degradation, including restoration, did show positive results (Fig. 2a) consistent with global analyses (22, 23). Efforts to ensure sustainable management of ecosystems, particularly on land, also generally increased native species abundance and habitat cover (Fig. 2a). These results are consistent with global analyses of sustainable management of ecosystems under agriculture and forestry (24, 25). Protected areas have been shown to be effective in reducing conversion of natural land cover (10), terrestrial habitat loss (15), coral loss (26), tropical forest fires (27), species extinction risk (28), and in increasing biomass and density of marine organisms (14, 29). Protected area effectiveness varies geographically, in terms of their effectiveness in preventing deforestation (30) and reducing anthropogenic pressure (31). Poor performance of protected areas often results from shortfalls in human and financial capacity (32, 33), while protected area downgrading, downsizing and degazettement presents another major challenge in some regions (34). However, our results concur that while their effectiveness is not universal (31), protected areas are an important tool for achieving conservation outcomes (Fig. 2a). The impacts of efforts to address unsustainable use of species in the ocean and on land were mixed (Fig. 2a), but the number of studies meeting the criteria for inclusion in our meta-analysis was small (Nstudies=5). Across our dataset, 137 trials (21% of cases) provide examples in which conservation interventions were not only associated with a negative rate of change, but performed more poorly than counterfactuals for biodiversity state. Eradicating and controlling invasive alien and problematic native species can negatively impact non-target species through incidental damage or mortality, or meso-predator release, and this explains the negative impacts observed for this group of papers. For example, in the United States, application of herbicides to invasive alien plants harmed native forbs (35), and in India, physical removal of invasive alien algae caused further spread and establishment elsewhere (36) (Fig. 1). Protected areas can show negative impacts if there is poor enforcement and insufficient resourcing, leading to higher rates of resource extraction, poaching, or agricultural expansion compared with counterfactual areas (37), or if protection increases the abundance of both predators and the target species in a no-take marine protected area (38). These unintended outcomes emphasize the importance of evidence. More and better counterfactual studies are needed for a wider range of conservation interventions and geographic regions. Particular gaps include assessments of pollution control, climate change adaptation, sustainable use of species, habitat loss reduction (beyond protected areas), actions targeting species and genetic diversity, and conservation actions in the Global South. The finding that contemporary studies were more likely to show a positive effect of conservation actions (Fig. 4) may be due to increases in funding and project-level resources, more targeted interventions, or indeed, that conservation practice is improving over time as lessons are learned from previous failures, and methods are improved. These same factors may help explain the larger effect sizes of more rigorous experimental/quasi-experimental study designs (Table S5), since their application (particularly quasi-experimental) tends to be more recent. That the relationship between effect size vs. study duration (Fig. S3) showed no general trend in direction indicates that valuable insights can be gained even for studies that are short in duration, provided the study design is appropriate. This further underscores the necessity of counterfactual evaluation and meta-analysis to assess conservation impact. Overall, global conservation efforts have helped to slow declines in biodiversity, and could eventually bend the curve of absolute biodiversity loss (39). Quantifying and evidencing the relative biodiversity outcomes (typically gains) of conservation is crucial, to contextualize and explain declining state indicator and increasing response indicator trends. While the state of biodiversity is declining across the globe in absolute terms, conservation actions work most of the time – the challenge is now to expand these to the scale necessary to reverse the global biodiversity crisis. That is, conservation interventions are working, but there are simply not enough conservation actions implemented, or in the right places. Realizing the highly ambitious vision of the GBF not simply to slow declines of biodiversity by the end of the decade, but to reverse them (2), will require ongoing assessment of the impact of specific conservation interventions, to inform adaptive management with evidence. Even more importantly, however, it will require substantially scaled-up funding and commitment for implementation of demonstrably effective conservation interventions – a real transformational change – which in turn depends on increased political will and investment. Such an increase in conservation action and associated outcomes will require expanded implementation and significant additional investment across many sectors of society, particularly beyond the traditional conservation sector. Meeting global biodiversity conservation targets to reduce the extinction risk of all species and safeguard sites of international biodiversity importance was estimated to cost around $80 billion annually over a decade ago (40). A comprehensive global conservation program would require an investment of $178-524 billion annually (4), much of it focused in highly biodiverse countries. Although high, these costs are dwarfed by the value that biodiversity provides to society through the delivery of ecosystem services (41). Thus, conservation actions are investments rather than payments – and, as our study demonstrates, they are typically investments that yield genuine, high-magnitude positive impacts.

Ecological Collapse

General Ideas:

- Extinct environments don't exist
- Invasive species
- Kills current biodiversity

Evolutionary discontinuity and temporal separation make de-extinction efforts liable to disrupt ecosystem dynamics

Robert et al. 16 [De-extinction and evolution; British Ecological Society; Alexandre Robert, Charles Thévenin, Karine Princé, François Sarrazin, Joanne Clavel; 2016; Alexandre Robert is a Professor of demography, population dynamics, demo-genetics, conservation genetics, general ecology, conservation biology, bio-statistics, statistics for small samples and capture-mark-recapture at Centre d'Écologie et des Sciences de la Conservation (CESCO)https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2435.12723]

Evolutionary constraints on the local success of de-extinction projects Discontinuity of biological processes A first difference between de-extinctions and other types of conservation translocations (although shared with cloning of extant species) is the discontinuity or breakdown of some molecular, cellular, behavioural and ecological processes. Such discontinuity is mainly related to the non-genetic transmission of a proportion of the heritable biological and cultural information (Danchin et al. 2011), which might be disrupted by cloning protocols (Tsunoda & Kato 2002; Shapiro 2017). This includes epigenetic make-up, vertically transmitted symbionts, physiological effects and cultural transmission. Such discontinuities are potentially associated with demographic problems. For example, somatic cell nuclear transfer protocols can be associated with epigenetic drift of the embryonic genome, leading to developmental constraints on the clones, and potential post natal mortality (Loi, Galli & Ptak 2007). Recent ecological research also showed that imperfect vertical transmission of symbionts can affect population dynamics (Yule, Miller & Rudgers 2013). Other examples include missing parental effects, such as antibodies transmission or behavioural care, which are likely to affect juvenile survival and, in turn, population dynamics. Initial genetic diversity and evolutionary resilience In most conservation translocations, the number of translocated individuals determines the extent of demographic stochasticity occurring during the establishment phase of the population's dynamics and thus influences success (Robert et al. 2015). From a genetic viewpoint, the initial number of individuals partly determines the initial genetic variation and subsequent short-term genetic deterioration and lack of adaptability (Robert, Couvet & Sarrazin 2007). Numbers of released individuals in reintroduction programmes typically range from a few tens to a few hundred individuals, and empirical reintroduction surveys suggest that there is a positive relationship between the number of released individuals and programme success (Wolf et al. 1996), yet the potential contribution of genetic effects to this pattern has not been clearly established. One peculiarity of de-extinction with respect to initial genetic variation is that initial numbers of individuals and initial genetic variation can be completely decoupled in cases the operations are based on, for example multiple clones from a single source (see Steeves, Johnson & Hale 2017). Although it has been suggested that new genomic editing techniques 'should be able to restore heterozygosity pretty easily in living genomes' (Brand 2014), the amount of initial genetic variation is likely to remain an important issue in de-extinctions. Evolutionary resilience refers to both the ability of populations to persist in their current state and to undergo evolutionary adaptation in response to changing environmental conditions (Sgró, Lowe & Hoffmann 2011). Low genetic variation can affect evolutionary resilience through reduction in population fitness due to increased inbreeding and drift loads (Keller & Waller 2002) and through reduced adaptability to future environmental changes (Lankau et al. 2011). A population founded with the genetic material from only one or a few individuals will experience similar genetic problems as any natural or captive population experiencing a severe bottleneck, in turn reducing its ability to adapt to changing environments (Frankham et al. 1999). Even assuming that genomic editing can be used, not only to fill gaps, but also to capture a significant fraction of the genetic variation of closely related, extant species, this would necessitate the use of hundreds of distinct individuals of the extant species to avoid such bottleneck effect. On the positive side, although low genetic variation has been shown to increase the extinction risk, there are some documented cases of populations that have persisted over long periods of time at extremely small population sizes prior to recovery (e.g. Groombridge et al. 2000), and both conservation translocation and invasive species literatures provide examples of viable populations founded with very few individuals (Taylor, Jamieson & Armstrong 2005). Furthermore, the science of conservation translocation provides concepts and tools (i) to minimize the loss of genetic variation of captive populations before release into the wild (Lacy 1989) and (ii) to maximize post-release survival and population growth through optimal release methods (Hardouin et al. 2014) and through continuing and adaptive management (Swaisgood 2010). Finally, the persistence of small populations is a general concern in conservation biology, and more research on this issue will provide benefits beyond the field of de-extinction.

For example, rapid progress in breeding and genetic technologies associated with the de-extinction research may also be applied to the conservation of extant endangered species based on cloning, for example to target under-represented genetic lines (Holt, Pickard & Prather 2004) or mitigate the effects of demographic stochasticity. Evolutionary divergences Like seed banks or cryogenic zoos, de-extinction raises the issue of evolutionary freezing (Simmonds 1962), which might imply strong divergence between the target species and its target environment. Such evolutionary divergence is primarily a matter of time. The times since extinction of the twenty de-extinction candidate species proposed following the TEDxDeExtinction conference (see Seddon, Moehrenschlager & Ewen 2014) range from a few years to more than 10 000 years, which means that, in some cases, several hundreds or thousands of generations might have elapsed since the original extinction (see Table 1). As a comparison, in the case of reintroductions, times between local extinction and the planned release range from a few years to a few 100 years (Fig. 1). Thus, although the time scales of de-extinction and reintroduction largely overlap, the temporal horizon envisaged for some 'deep de-extinction' projects (as coined by Sandler 2014) is likely to be several orders of magnitude longer than for any reintroduction project.Although the effect of the time since local extinction on the success of reintroduction programmes has, to our knowledge, not been formally, empirically assessed, Osborne & Seddon (2012) recently pointed out that the longer this time, the greater the chance th[e]at suitable habitat will no longer be available. The environment is continually changing at different rates and scales, and humans are main drivers of these changes (Corlett 2015; Hofman et al. 2015). The main human drivers of rapid evolutionary responses are harvesting (Uusi-Heikkilä et al. 2015), invasive species (Mooney & Cleland 2001), habitat degradation (Macnair 1987) and ongoing climate change (Hof et al. 2011). Thus, in many regions of the world, conditions under which a 200-year-old tree established are likely to be quite different to those existing today (Sgró, Lowe & Hoffmann 2011), and the ecological context of a species that went extinct even only 100 years ago, such as the passenger pigeon (Ectopistes migratorius), has changed dramatically (Sherkow & Greely 2013; Peers et al. 2016). These dramatic environmental changes can be associated with particularly strong and rapid selection, as many populations have the capacity to respond to, for example, climate change within a time frame of tens of years (Hendry, Farrugia & Kinnison 2008). Such adaptive changes are generally considered much more rapid than non-adaptive changes (Stockwell, Hendry & Kinnison 2003), and most phenotypic differences observed among natural populations are likely adaptive (Hendry et al. 2010). Thus, recent temporal environmental changes and associated contemporary evolution are likely to generate strong levels of divergence between the environment and a de-extinct population that has not had the opportunity to adapt to (i) human-induced environmental changes, (ii) biotic changes in response to these changes, or (iii) biotic changes in response to the original extinction of the target species.

Disease Risk

General Ideas:

- Bioweapon development
- Prion disease
- Neurological disorders
- Vulnerable to current illness

De-extinction introduces diseases to native species

Genovesi and Simberloff 20 [Piero Genovesi Institute for Environmental Protection and Research and Chair IUCN SSC Invasive Species Specialist Group, Rome, Italy, Daniel Simberloff Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, USA, "“De-extinction” in conservation: Assessing risks of releasing “resurrected” species" https://www.sciencedirect.com/science/article/abs/pii/S1617138120300844?utm_source 6 May 2020]

Biodiversity is decreasing at an alarming rate, and it is therefore important to set ambitious targets and to explore innovative tools, such as de-extinction, to protect and recover species. However, it is also essential that risks associated with innovative tools, such as release of proxies for extinct species into the wild, be carefully evaluated. Risks associated with such releases parallel those for introducing non-native species or re-introducing locally extinct species and include the possibility that the proxy becomes invasive and affects native species, communities, or ecosystems through predation, competition, browsing, hybridisation, facilitation of spread of diseases, and various ecosystem-level impacts such as changed hydrology or fire regimes. It is essential that such risks of releasing a proxy be subjected to rigorous application of advances in risk assessment science. However, the substantial limits of risk assessment methods for such species must be recognized, and the safety of existing native species and substantial maintenance of existing ecosystem functions should be privileged over potential benefits of releasing a proxy for an extinct species when the reliability of these assessments is limited, as is especially likely when the proxied species is long extinct. Quantifying potential costs and benefits of indirect effects of releasing a proxy – such as lessened public concern for biodiversity loss or increased interest in conservation based on a “resurrected” charismatic species – do not appear tractable with current risk assessment methods.

De-extinction can revive viruses that native species have

Genovesi and Simberloff 20 [Piero Genovesi Institute for Environmental Protection and Research and Chair IUCN SSC Invasive Species Specialist Group, Rome, Italy, Daniel Simberloff Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN, USA, "“De-extinction” in conservation: Assessing risks of releasing “resurrected” species" https://www.sciencedirect.com/science/article/abs/pii/S1617138120300844?utm_source 6 May 2020]

De-extinction also carries health risks both to other species and to humans. All organisms have some level of infection with micro-organisms or parasites, and the release of a species, especially following some inevitable period of captivity before release, could spread a disease. Furthermore, new associations with pathogens not previously encountered might make a proxy a novel vector for disease. There is also a limited but not negligible risk that de-extinction would resurrect endogenous retroviruses residing in the genome of the target species, with health risks that are impossible to evaluate. It is relevant that introduction of non-native species often entails a lag time of decades or even a century before they spread and become invasive (Crooks, 2011). The complex and interacting negative effects of introduced species on biodiversity, human health, cultural values, and ecosystem services may first become evident decades after introduction, when the project will be considered completed.”

Empirically, de-extinction brings species into a disease-fulfilled environment that has killed them before

Richmond et al 16 [Douglas J. Richmond, Mikkel-Holger S. Sinding, M. Thomas P. Gilbert, published in Zoologica Scripta, Royal Swedish Academy of Sciences., "The potential and pitfalls of de-extinction" https://onlinelibrary.wiley.com/doi/10.1111/zsc.12212 27 September 2016]

Secondly, we must consider the disease angle. This relates to both the susceptibility of the de-extinct form to modern diseases and parasites, with which it stopped co-evolving at time of extinction (Seddon *et al*. **2014**), and whether the de-extinction form could represent a vector of disease to other species (including livestock; Cohen **2014**; Seddon *et al*. **2014**). An extreme example of susceptibility is the Christmas Island rat (Rattus macleari, Box 2), whose extinction appears to have been caused by an infectious disease (Wyatt et al. 2008). Therefore, bringing this species back (with an aim of rewilding) would require equipping it with immunity to the trypanosome that likely led to its demise.

As the de-extinction method of choice for the rat would most likely be via genome editing of the brown rat (*Rattus norvegicus*), it is possible that this could be achieved by maintaining some of the immune genes of this species rather than replacing with those of the Christmas Island rat. The brown rat has established itself on Christmas Island (Armstrong **1992**) so it appears that it is equipped with the required immunity for survival here. If the brown rat is used as a surrogate, the individual should also obtain antibodies for resistance during gestation. The more we alter the species, the less its creation will be viewed as a de-extinction, however. A trade-off exists between maintaining the integrity of the original species, and creating a species that is able to survive and function well in today's ecosystems. We must therefore decide how important the label of de-extinction is, and carefully consider what the real objectives of the process are, in order to decide whether these compromises are acceptable

Limit Human Authority

General Ideas:

- Humans don't have the right to play god
- Domination of nature
- Domination of others
- Human intervention worse

De-extinction removes the independence, and therefore value of nature's existence without humans

Cohen 14 [Shlomo, Shlomo Cohen is an academic researcher from Agricultural Research Organization, Volcani Center. The author has contributed to research in topics: Tomato yellow leaf curl virus & Plant virus. The author has an index of 14, co-authored 16 publications. "The Ethics of De-Extinction" https://r.jordan.im/download/ethics/s11569-014-0201-2.pdf 27 July 2014]

Defying the anthropocentrism that dominated traditional ethical theories, certain environmental philosophies have advocated the inherent worth of nature and all living things, regardless of their instrumental utility as resources for humans. In Aldo Leopold's influential formulation, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" ([7]: 224– 225). Accordingly, the primary ethical argument for deextinction is its potential contribution to the environment—specifically, to promoting biodiversity. This argument for de-extinction must surmount two challenges, however. It may be argued that de-extinction lacks positive ecological value either in principle or all things considered. Let us examine these in turn. The first objection is that de-extinction cannot be ecologically valuable in principle. Before considering the philosophical argument, I shall briefly mention a parallel opposition from biology. It can be argued that extinction is absolutely normal, the necessary mirror phenomenon of speciation (an estimated 99.9% of species have disappeared) ([8]: 3–4); de-extinction is therefore naively wrongheaded. The answer to this is the combination of two facts. The first is that the staggering current rate of extinction strongly suggests that the biological world is experiencing the sixth major extinction event in its history [9]. Up to 50% of species according to one prediction will be lost in the first half of the 21st century [10]. The second is that this historical extinction is predominantly human-triggered, expressing an ever-increasing use of the world's resources by an expanding human population (major processes include habitat destruction, fragmentation, and degradation, pollution, overexploitation of species, introduction of invasive exotic species, and increased spread of disease [11,in recent decades global warming has increasingly altered species' habitats beyond survival ranges [13]). Extinctions caused by human encroachment do not fit in the natural turnover of species based on the survival of the fittest. "Natural extinction typically occurs with transformation, either of the extinct line or related or competing lines. Artificial extinction is without issue. One opens doors; the other closes them. Humans generate and regenerate nothing; they only dead-end these lines" ([14]: 724). In light of all this, we may suppose that reintroducing species extinct by humanity to enhance biodiversity can be ecologically beneficial. The philosophical argument against performing deextinction for nature's sake is the following. If nature has intrinsic value, this value must entail independence (autonomy) from human purpose, activity and interest. Humans cannot restore natural intrinsic value, since all restoration is, qua human creation, artifactual—the precise antonym of the natural. An artifact's value is instrumental to the human purpose in creating it; it hence, ipso facto loses all intrinsic value [15]. Relatedly, Bernard Williams spoke of a "paradox" when "we have to use our power to preserve a sense of what is not in our power" ([16]: 240). One cannot manipulate nature in order to preserve its autonomy; yet only as autonomous is it intrinsically valuable. If correct, this would undermine the ecological value of de-extinction. In response, we must analyze the sense of autonomy presupposed by this criticism. Since autonomous nature is taken to be conceptually opposed to that of artifact, we shall examine the relevant senses of artifact. Three senses can be extracted from pertinent criticisms.Being the result of human involvement.

De-extinction is immoral in a world where we dominate all other species

Vogt and Zwicker 15 [Kristiina Vogt is a professor of ecosystem management and founder (and co-coordinator) of the Forest Systems and Bioenergy program at the University of Washington. She has conducted research in Iceland, Malaysia, Mexico, Brazil, Belize, Indonesia and in Alaska and Puerto Rico as well as within the continental US. Professor Vogt has authored or co-authored eight books and published over 150 refereed articles. Samantha Zwicker is a master's student at the University of Washington in the School of Environmental and Forest Sciences, where she is researching ecology and conservation in coupled human-environment systems. She is a member of Xi Sigma Pi Forestry Honor Society, a term member of the renowned Explorers Club, and the co-founder and President of the nonprofit Hoja Nueva., "De-extinction in an Anthropogenic World" https://humansandnature.org/conservation-extinction-kristiina-vogt-samantha-zwicker/ March 11, 2015]

We live in the Anthropocene, an era characterized by widespread extinction and landscapes that are less habitable for most large mammals. Over 25 percent of terrestrial mammals are now in decline and 66 percent of top carnivores—creatures with profound ecological roles—are threatened with extinction. As habitat is fragmented and destroyed, wildlife across the world are left with both less and lower quality habitat and lack the resources necessary for survival. De-extinction is an option under consideration as the world undergoes this mass extinction event—the sixth such event in Earth's history. However, if there is currently no room for the magnificent Bengal Tiger or African Elephant, why are we considering bringing back Woolly Mammoths?

Earth's landscapes have undergone vast changes since the beginning of time; however, humans have left an unnaturally large ecological footprint over the last two hundred thousand years, especially since the industrial revolution of the eighteen hundreds. Humans, motivated by fear and competition for resources, were responsible for most of the eradication of the Pleistocene megafauna. Now we occupy almost every corner of this earth and have an impact, often direct, on every ecosystem on Earth. Given that human history reflects an ongoing struggle to coexist with top predators and share the landscape with large mammals, the idea of de-extinction seems irrational. It is ironic that humans are fascinated with recreating animals that they have spent a considerable amount of time killing off.

Despite the irrefutable significance of predators and large mammals to ecosystem function, we seem to want to be the only predators in place. We will allow species to co-exist with human communities only as long as they are not a danger to us or our livelihoods. If the animals are dangerous to humans, they are removed into safe zones, such as zoos or animal parks, where there is a boundary that keeps us separated from them.

For instance, many farmers and ranchers were (and are) against the reintroduction of wolves. Following the loss of legal protection from the endangered species list, wolves were killed by the thousands in the Midwest and in Eastern Washington. This gruesome elimination of wolves took place despite the fact that the number of wolves (especially in Washington) was so small that there were (and continue to be) grave concerns regarding the genetic robustness and survivability of these populations. A similar example is the Black Bear: due to shrinking habitat, bears are moving into human-dominated areas all over the country to find food. The Black Bear is becoming more comfortable and acclimated to human landscapes; bears have been photographed in backyards and trashcans on numerous occasions. Humans are responsible for the bears's loss of food and habitat, but our response to bears entering human-inhabited areas has been less than understanding; more than 1,600 bears were killed in the state of New Jersey alone, over a four-year period. Perhaps before we bring back species that we have driven to extinction, we should re-consider how we might co-exist with the species that currently share—and increasingly seek to share—human-dominated landscapes. Furthermore, we need to consider that large carnivores (and other species under consideration for de-extinction, such as the Passenger Pigeon) require a large land base to survive, which means they would be highly vulnerable to a world characterized by shrinking habitats.

What has changed in popular opinion such that present conservation problems are not as much of a concern as past extinctions? Have we found new locations where species that are dangerous to humans may live without impacting society? If so,

do these locations retain ecological conditions conducive for de-extinct species to survive and live long, self-sustaining lives? Or will humans need to continuously regulate these habitats to ensure the survival of de-extinct species? If we need to continuously manage such habitats to ensure species survival, it behooves us to keep in mind that we face considerable challenges maintaining landscapes to support species that are currently endangered or recovering from the brink. Moreover, who would determine which species are brought back and which landscapes would be selected for their habitat? Who will monitor and manage these species? So many unanswered questions should give us pause.

If we are able to answer these questions and provide complex ecosystems and landscapes for the continuous survival of each recreated species, then we should undertake de-extinction. However, the more likely scenario is that de-extinction will be practiced simply because it is new and cool; and the vast majority of these recreated species will end up in zoos and parks.

Despite countless arguments against de-extinction, or resurrection biology, there is nonetheless increasing support for some forms of it. In addition to reviving extinct species, advanced cloning technology could be used to save threatened and endangered animals and introduce greater genetic variability into small populations at risk of inbreeding. Most importantly, there is a potential for this miraculous process to increase awareness and support for current conservation efforts.

While resurrecting Woolly Mammoths and Tasmanian Tigers will undoubtedly come with risks and high costs, rewilding and refaunation of existing species on a more controlled, local level could provide enormous ecological benefits with fewer uncertainties. For instance, a combination of captive breeding and cloning could be used to reestablish populations of species extinct in the wild, like the Northern White Rhinoceros, or critically endangered carnivores, such as the Amur Leopard.

Ultimately, the use of de-extinction technologies is an ethical decision. We caused the extinction of countless animals over the course of our existence, so isn't it our responsibility to bring them back if we can? This particular rationale does not address the fact that many species, globally, are struggling to survive today, especially megafauna including wolves, cats, elephants, rhinos, and bears. Their habitat areas continue to shrink, and only 13 percent of ecosystems worldwide are under some protected status. Currently, protection is needed for millions of species and landscapes, including many yet to be discovered or described. What is our response—and our responsibility—with respect to these challenges?

The survival of species ultimately depends on our decisions. Millions of dollars and immense amounts of resources are funneled toward recreating ancient ice age ecosystems, such as the Pleistocene Park in Siberia. Yet, a mere one million dollars diverted from these projects could buy over 120,000 acres of Amazonian rainforest, which is vulnerable to invasion and deforestation. This land supports countless species of flora and fauna—many that will be lost before they are ever even found—in need of study and protection.

It is astonishing that technology has advanced to the point where we discuss bringing animals back from extinction. However, what we need to consider is not what we could do, but rather what we should do. Are we going to use our technology and resources for good—to mitigate our mistakes and shape a sustainable future—or continue a vicious cycle that is both unbalanced and unnatural?

We don't have the right to play god through de-extinction

Minteer 17 [Ben A. Minteer holds the Arizona Zoological Society Endowed Chair in the School of Life Sciences at Arizona State University. His work explores the intersection of environmental ethics, ecology, and conservation, especially the impact of global environmental change on our understandings of environmental responsibility. "The Perils of De-extinction" https://humansandnature.org/the-perils-of-de-extinction/ July 4, 2017]

Lurking within some of the more fervent pro-de-extinction arguments is an even more troubling moral and cultural vision, however: a view of humans as all-powerful creators and the presumptive governors of planetary life. It's telling, I think, that Brand has resurrected and slightly revised his familiar motto from the Whole Earth Catalog in his pitch for de-extinction: "We are as gods and HAVE to get good at it."[13]

Interestingly, Brand considers himself a "Pragmatist" in environmental and conservation matters; the subtitle of his most recent book is "An Eco-Pragmatist Manifesto." But a truly authentic Pragmatism (i.e., that late nineteenth and early twentieth century school of American philosophy

led by William James and John Dewey, among others) is distinguished not by Brand's aggressively anthropocentric view of the universe, but by the recognition of our own fallibility and the contingency of experience and by a sense of human limits in nature. It's an outlook that, in Dewey's work, required the careful adaptation to and cooperation with natural forces as much as it necessitated adjustment and transformation of them. Brand's intellectual mooring is therefore not Pragmatism. Instead, it's a twenty-first century spin on Prometheanism: a celebration and justification of human creation, power, and the control of nature in the engineering age.

Apparently, this Promethean ability to create also licenses the creator to destroy. Consider how de-extinction advocate Subrat Kumar (a biologist writing in the journal Nature) responds to worries that revived species could become destructive forces if and when they are eventually released into ecosystems: "Any species that we bring back," he writes, "could be engineered to be eliminated easily should it pose a problem."[14] It's a remark notable, perhaps, for its frankness (and for its tin ear toward animal and environmental ethics), but I think this cavalier view toward life flows quite naturally from the philosophical commitments of the de-extinction movement that at times bleeds through all the high-minded conservation rhetoric.

"A new species would bless me as its creator and source; many happy and excellent natures would owe their being to me." [Frontispiece to the revised 1831 edition of Mary Wollstonecraft Shelly, Frankenstein; or the Modern Prometheus] (Image: Wikimedia)

Hard Choices in the Anthropocene

De-extinction, then, fails as a conservation ethic. But I think it also collapses as a conservation strategy. Even if we could get past its myriad ethical, cultural, and philosophical challenges (spoiler alert: I don't think we can), it is difficult to see how it could ever play a significant role in the conservation of (extant) vulnerable species or the protection of ecological systems. It will do very little, for example, to address the current crisis of global biodiversity decline and habitat fragmentation and destruction. That's not to say that some of the technologies at the core of the idea don't have scientific value for conservation; the study of ancient DNA to understand ecological and evolutionary processes, for example, is certainly relevant to contemporary conservation science.[15] But de-extinction can't be considered a plausible conservation approach, despite the desire of Brand and others to make it one. It's only a curio.

High-tech fantasies like de-extinction will certainly not do much to address the ratcheting up of the rate of current global species losses—perhaps more than one thousand times the background or "normal" rate of extinction. It's a distressing statistic that has led many biodiversity scientists to suggest that we may be in the middle of a sixth mass extinction on Earth, an event on par with the disappearance of the dinosaurs.[16] But it isn't only the quickening extinction trends that are troubling. It's also the wider pattern of population declines and decreases in abundance of individuals within them. This has prompted some scientists to refer to the current moment as the "Anthropocene defaunation," a term that captures the full sweep of human-driven species decline as well as the impacts of these losses on the healthy functioning of ecosystems.[17]

The numbers are alarming (there's that doom and gloom again). According to the 2014 Living Planet Index report authored by the World Wildlife Fund and the London Zoological Society, on average vertebrate species populations have declined 52 percent since 1970.[18] A new analysis performed by the journal *Nature* has found that 41 percent of all amphibians, 26 percent of mammal species, and 13 percent of birds currently face extinction, with considerably higher percentages at risk in the future if current threats, from climate change and habitat loss to species exploitation, continue unabated.[19]

Responding systematically and effectively to the global conservation challenge demands an extraordinary effort and by all accounts an unprecedented one. Hard decisions will have to be made. For example, in many cases intensive and aggressive conservation actions will be required to protect biodiversity in the coming decades. These might even include translocating vulnerable populations outside their historical ranges to novel habitats deemed more suitable as the climate changes, a controversial practice called managed relocation (a.k.a., "assisted colonization" or "assisted migration"). It's a radical departure from the traditional preservationist approach, which emphasizes the protection of species in their historical habitat and, in general, the minimization of human manipulation of ecological communities.[20]

As we go down this more interventionist path, however, we need to ensure that our aggressive efforts to conserve do not evolve into a "save species at any cost" philosophy. If we end up sacrificing other important environmental and moral values, such as the respect for nature's wildness and a sense of human proportion on the landscape, we will have lost something vital in our conservation ethic as we tighten our grip on the ecological and evolutionary wheel. Conservation in the Anthropocene must be a balancing act between the pragmatic need for action and the moral wisdom of ecological restraint.

We aren’t qualified to play god - intervening by adding/removing species ends in horrible animal abuse

Bai 08 [Nina Bai, Journalist for Discover that focuses on science and tech news "To Fight Croc-Killing Toads, Australians Turn to "Cane Toad Golf"", Nov 20, 2008]

A new report suggests that as much as 77 percent of the crocodile population along the Victoria River has now perished from toad poisoning. In yet another example of the "solution to one problem becomes an even bigger problem" doctrine, cane toads were purposely introduced to the region as a pest-control measure for beetles in the sugar cane fields. But sure enough, the toads soon became pests themselves, to the point where volunteer groups are trying to stop the toads' spread across the continent. One community has been promoting "cane toad golf"—basically whacking the toads with golf clubs.

De-Extinction Fails

General Ideas:

- Not the same species
- Don't recreate environment
- Animals die fast

Cloning for de-extinction leads to negative health impacts for cloned animals

Browning 19 [Browning, H. School of Philosophy, Australian National University "Won't Somebody Please Think of the Mammoths? De-extinction and Animal Welfare." https://doi.org/10.1007/s10806-018-9755-2 1 January 2019]

In the first instance, there are issues surrounding the cloning technology used in both SCNT and genetic engineering. These will not be a problem for back-breeding projects, though this method will face a few problems of its own.

So far, the use of cloning has been problematic for animal welfare, with cloned animals showing rapid aging, ongoing health problems and premature death. "Cloned animals suffer from impaired health, including placental abnormalities, foetal overgrowth, prolonged gestation, stillbirth, hypoxia, respiratory failure and circulatory problems, malfunctions in the urogenital tract, malformations in the liver and brain, immune dysfunction, anaemia, and bacterial and viral infections" (Gamborg 2014, p. 6). Fiester (2005) outlines the different ways in which cloning procedures can have negative impacts on animal welfare—through the suffering inherent in the cloning procedure, gestational problems with surrogates, ongoing health of cloned animals and the future suffering cloned animals might endure through research, housing etc. These procedures are associated with miscarriage, stillbirth, early death, genetic abnormality and chronic disease. As the success rates (in terms of live birth) for even the most effective programs are only 5–12%, this creates a lot of excess donor procedures and surrogate pregnancies. As cloned foetuses show a higher than average birth weight, caesarian deliveries are also often necessary. Those offspring that are delivered alive show huge mortality rates, due to conditions such as developmental abnormalities and lung, heart and liver problems. The US Humane Society has advocated for a ban on these procedures due to the high incidence of welfare problems.

De-extinction fails as the criteria of success is unclear

Shultz 16 [David Shultz bachelor's degree in immunology and infectious disease from Penn State University and a master's degree in science journalism from Boston University "Should we bring extinct species back from the dead?" https://www.science.org/content/article/should-we-bring-extinct-species-back-dead?referrer=https%3A%2F%2Fwww.google.com%2F 26 Sep 2016]

If scientists engineer an Asian elephant to have small ears, extra fur, and more body fat by swapping in mammoth DNA, is it still an Asian elephant? "If you're willing to accept something that is an elephant that has a few mammoth genes inserted into its genome and therefore is able to make some proteins that mammoths might, we're probably closer to that," says Beth Shapiro, author of *How to Clone a Mammoth: The Science of De-Extinction* and an evolutionary biologist at UC Santa Cruz specializing in ancient DNA.

The passenger pigeons project faces similar questions. Novak wants to resurrect the bird using its closest living relative, the band-tailed pigeon, but how many genes need to be swapped to constitute success is

somewhat arbitrary. "The two genomes are 97% the same. That 3% has built up over many millions of years and the majority of it is noise," he says. "So the actual differences are much likely a smaller portion—probably within the realm of several thousand mutations. What we want to find is the key 20 or 100 mutations that affect the traits that are most important."

There's also a divide as to what constitutes a de-extinction success for the scientists versus the public. Genetically coaxing to behave like their extinct relatives might restore the ecosystem's lost function, Novak says. But is that good enough to count? "I don't think anyone in the world is really going to call it de-extinction unless the bird looks right."

Even if researchers can pinpoint and transfer those key mutations (a daunting task), DNA is only half the battle. From there it's a matter of getting the hybrid cell to grow in a surrogate, hoping all the genes work harmoniously together, bringing the hybrid to term, and hoping it acts like the extinct species even though it was raised by a modern relative. If all that goes right, you still need the hybrids to mate and give birth to fertile offspring. "I think the hardest part is getting developmental biology to go," says Philip Seddon, a conservation biologist at the University of Otago, Dunedin, in New Zealand and the lead author on a recent report by the International Union for Conservation of Nature (IUCN) that issued guidelines for de-extinction research

Negative Evidence

Stabilize Ecosystems

General Ideas:

- Maintain genetic diversity
- Undo recent extinctions
- Save native species
- Restore ecological functions

De-extinction accelerates recovery of key ecosystem processes

Jepson 25 [Dr Paul Jepson is Senior Research Fellow in Conservation Practice at the Environmental Change Institute, University of Oxford. "De-extinction beyond species: Restoring ecosystem functionality through large herbivore rewilding" *Camb Prism Extinct*, 2025 Jan 13th, https://pmc.ncbi.nlm.nih.gov/articles/PMC11895704/]

A growing body of rewilding science investigates the relationship between the functional effects of megafauna, natural (ecosystem) processes, and the ecosystem services and societal benefits derived from the recovery of ecosystem integrity. Despite their frequent mention in the scientific literature, natural processes remain poorly theorised and classified. These processes involve the movement or transfer of energy, materials, or organisms within ecosystems, driving functions and dynamics that influence ecosystem condition, recovery, resilience, and long-term evolution. While natural processes encompass a wide range of interactions—such as photosynthesis, predation, and pollination – a land-mark paper by Perino et al. (2019) posited that improvements in three higher-order natural processes, namely dispersal, random disturbance and trophic cascades would support and accelerate the recovery of complex ecosystems. The authors emphasised the central role of large herbivores in the recovery of these processes.

Building on this, scientists and rewilding practitioners have demonstrated how restored are large herbivore populations drive the recovery of key ecosystem processes such as nutrient cycling, seed and nutrient dispersal, permafrost cooling (albedo effect), and soil and hydrological processes (see, e.g., Cromsigt et al., 2016; Macias-Fauria et al., 2021; Kristensen et al., 2022). The interactions between their functional effects, embodied energy and resources, and natural processes create emergent properties leading to complexity (e.g. via niche creation) and structures (e.g. scavenger ecologies, Rewilding Europe/Ark Nature, 2017).

Rewilding draws attention to the downgrading legacy of large herbivore extinctions on ecosystem integrity and the opportunity to reverse this decline through de-domestication pathways. The state of ecosystem integrity directly correlates with the quality and quantity of ecosystem services, which provide societal benefits such as hazard reduction, pollution control, and human well-being. Many of these benefits result from joint production processes involving both ecosystem and human inputs, mediated by new institutional frameworks such as markets for environmental credits. De-domesticated cattle and horses, at various stages on the ‘wilding’ pathway, are helping create ecosystem assets that sequester carbon (Burrell et al., 2024), reduce the risk of extreme flood and wildfire events (Jepson et al., 2018; Johnson et al., 2018), and contribute to rural regeneration through ecotourism (Hall, 2019).

In the context of rewilding and NbS, the purpose of large herbivores de-extinction via de-domestication pathways is to revive ecosystem processes and functions, thereby enabling ecosystems to recover their integrity and capacity to provide ecosystem services and benefits for society This shifts the moral imperative of de-extinction from redemption for past human-induced extinctions to creating opportunities for co-developing ecosystem assets together with non-human life forms. Rewilding offers a compelling policy rational for de-extinction and addresses criticisms that it is hubristic (Odenbaugh, 2023), risks diverting resources from urgent conservation priorities (Bennett et al., 2017), or undermines conservation efforts by providing a perceived 'offset' for environmental damage (Sandler, 2013).

De-extinction of keystone species/tech

Brand 13 [Stewart Brand is an American project developer and writer, best known as the co-founder and editor of the Whole Earth Catalog. Other organizations he has founded include the WELL, the Global Business Network, and the Long Now Foundation."The Case for Reviving Extinct Species" March 11, 2013 https://reviverestore.org/why-revive-extinct-species/]

Useful science will also emerge. Close examination of the genomes of extinct species can tell us much about what made them vulnerable in the first place. Were they in a bottleneck with too little genetic variability? How were they different from close relatives that survived? Living specimens will reveal even more.

Techniques being developed for de-extinction will also be directly applicable to living species that are close to extinction. Tiny populations can have their genetic variability restored. A species with a genetic Achilles' heel might be totally cured with an adjustment introduced through cloning.

For instance, the transmissible cancer on the faces of Tasmanian devils is thought to be caused by a single gene. That gene can be silenced in a generation of the animals released to the wild. The cancer would disappear in the wild soon after, because the immune animals won't transmit it, and animals with the immunity will out-reproduce the susceptible until the entire population is immune.

Some extinct species were important "keystones" in their region. Restoring them would help restore a great deal of ecological richness.

Woolly mammoths, for instance, were the dominant herbivore of the "mammoth steppe" in the far north, once the largest biome on Earth. In their absence, the grasslands they helped sustain were replaced by species-poor tundra and boreal forest. Their return to the north would bring back carbon-fixing grass and reduce greenhouse-gas-releasing tundra. Similarly, the European aurochs (extinct since 1627) helped to keep forests across all of Europe and Asia mixed with biodiverse meadows and grasslands.

The passenger pigeon was a keystone species for the whole eastern deciduous forest, from the Mississippi to the Atlantic, from the Deep South clear up into Canada. "Yearly the feathered tempest roared up, down, and across the continent," the pioneer conservationist Aldo Leopold wrote, "sucking up the laden fruits of forest and prairie, burning them in a traveling blast of life."

Such animals can also serve as icons, flagship species inspiring the protection of a whole region. The prospect of bringing back the aurochs is helping to boost the vibrant European "rewilding" movement to connect tracts of abandoned farmland into wildlife corridors spanning national boundaries.

Funding

General Ideas:

- Generates interest
- Not enough focus now
- Publicity helps all

De-extinction brings in new funding

Hunt 25 [Katie Hunt writes about science for CNN Digital based in London. She was previously a senior digital producer in Hong Kong, where she led coverage of China. "Scientists say they are close to resurrecting a lost species. Is the age of de-extinction upon us?" https://www.cnn.com/2025/01/16/science/colossal-de-extinction-funding-resurrection-science Jan 16 2025]

The age of de-extinction may soon be a reality.

Advances in genetic engineering and synthetic biology are making resurrecting animals once lost to this world a tangible prospect. The organizations and companies at the forefront of de-extinction efforts are promising success — and surprisingly soon.

Those efforts just got a boost. Colossal Biosciences, the biotech company behind plans to revive the woolly mammoth, dodo and Tasmanian tiger, announced Wednesday it has raised an additional $200 million in investment, bringing its total funding to $435 million. That hefty sum grew from an initial $15 million in 2021 when entrepreneur Ben Lamm and Harvard University geneticist George Church founded the Dallas-based company.

Within a decade or less, the world may see approximations of creatures only known from black-and-white photographs, taxidermy museum exhibits, and fossilized skeletons, with the ultimate goal of restoring the fauna to their natural habitat.

Advocates say resurrecting extinct animals is attracting new investors with deep pockets to conservation. The scientific field pushes the boundaries of biotechnology in a way that will make it possible to save other species on the brink and offers a promising way to better protect and preserve present-day ecosystems, ultimately making them more resilient to the climate crisis.

Skeptics, however, argue the efforts are an underscrutinized pet project of millionaires, whose money could be spent more effectively elsewhere. Detractors also assert that scientists will only ever be able to engineer unsatisfactory imitations of extinct animals. Raising and breeding such creatures, some experts warn, could imperil living animals used as surrogates and the ecosystems into which resurrected individuals might ultimately be released.

"Who doesn't want to see a dodo? Good God, I do. A mammoth. I mean, wow, amazing," said Melanie Challenger, the deputy co-chair of the Nuffield Council on Bioethics in the United Kingdom.

De-extinction does not take away funding from conservation movements

Selçukoğlu and Kaykı 25 [Alper Kaan Selçukoğlu, Deha Kaykı, scholars studying at Istanbul University. "Rethinking De-Extinction Criticism: A Multi-Dimensional Model for Prioritizing Revivable Species under Funding Controversies" https://www.biorxiv.org/content/10.1101/2025.07.16.665200v1.full#sec-28 July 18, 2025.]

This study set out to examine whether the rise of de-extinction initiatives has affected the financial landscape of conservation biology. Our findings show no evidence that de-extinction projects are taking resources away from traditional conservation. Instead, they contribute additional funding, mainly from private investors, thereby increasing the total funding available for conservation. This challenges the common claim that money spent on de-extinction would be better used for

protecting existing species. Our data show that the money going into deextinction comes from completely different sources. It is largely funded by private individuals and organizations interested in technological breakthroughs, who would likely not invest in classical conservation projects. In other words, these are new funds that would not have gone to conventional conservation anyway. Redirecting these funds to traditional conservation is not just unlikely; it also overlooks that these investors are motivated by technological innovation, and their support expands rather than replaces existing conservation efforts.

While our results suggest that de-extinction projects currently do not take resources away from traditional conservation, this does not guarantee that future developments will have no financial impact. Moreover, it remains unclear what level of funding would be required for the reintroduction, management, and long-term monitoring of resurrected species in the wild. These downstream costs, which could include habitat restoration, ongoing veterinary care, and potential conflict mitigation, are difficult to estimate at present and represent an important area for future research.

De-extinction draws funding from different sources than typical conservation, and is used to diversify investment into conservation

Carvalho 25 [Rodrigo Béllo Carvalho, Department of Biology, Stanford University, "Corrigendum to "Between Hype and Hope: De-extinction is a tool, not a panacea for the biodiversity crisis" https://www.sciencedirect.com/science/article/pii/S0006320725003635 September 2025]

Concerns about funding are important and merit careful consideration. Notwithstanding, the portfolio currently sponsoring de-extinction initiatives suggests a more complex picture. Given de-extinction's interdisciplinary nature, spanning paleogenomics, animal science, synthetic biology, and bioinformatics, funding can be sourced from agencies supporting both basic and applied science. This includes sectors like public health, veterinary medicine, technological innovation, and even data science—areas in which traditional conservation projects usually do not primarily rely on (Bakker et al., 2010; Echols et al., 2019). Media visibility and speculative appeal undoubtedly play a role in attracting investments to de-extinction; however, this same visibility can also unlock new funding channels that would otherwise remain untapped to biodiversity efforts. Importantly, while de-extinction differs in both scope and philosophical grounding from traditional conservation, the growing participation of start-ups, companies, and philanthropists suggests that it can draw from new, alternative streams of private venture capital (Donlan, 2014; Saul, 2025)—rather than competing with public funds allocated to conservation. Frequently, de-extinction projects may even amplify funding or infrastructure that supports related conservation goals, including habitat restoration and species protection (Colossal Inc., 2025c; Revive and Restore, 2025). If thoughtfully managed, this diversification could supplement rather than cannibalize traditional conservation funding, much like how cooperation, instead of competition, fosters resilience in ecological systems. To realize this potential, however, clear boundaries and robust policy safeguards are critical to ensure that public resource allocation aligns with long-term conservation priorities

Adapt to Change

General Ideas:

- Changing climate is bad now
- Plants/animals that lived in heat can be brought back
- Still have some ecosystems rather than none

Extreme damage to human communities and ecosystems is imminent as we far overshoot 1.5 degrees but adaptation is still possible

UNEP 26 [United Nations Environment Programme. "UNEP: World Set to Cross 1.5°C Global Warming, but Can Still Limit, Adapt to and Return From Higher Temperatures." UNEP - UN Environment Programme, 14 Oct. 2026, www.unep.org/en/news-and-stories/press-release/unep-world-set-cross-15degc-global-warming-can-still-limit-adapt-and.]

UNEP: World set to cross 1.5°C global warming, but can still limit, adapt to and return from higher temperatures Report puts best-case scenario peak temperature rise at 1.8°C; others suggest over 2°C Above 1.5°C, climate impacts and risks of tipping points intensify with every fraction of a degree 'Overshoot, peak and decline' pathway best remaining option to help vulnerable nations and communities cope and return to below 1.5°C Nairobi, 2 September 2026 – Global temperature rise is set to cross 1.5°C, likely within the next few years, pushing climate risks and impacts to increasingly dangerous heights, but it is still possible to bring temperatures down and achieve global goals in the Paris Agreement, according to a new UN Environment Programme (UNEP) report. The report, Limiting Overshoot, identifies an 'overshoot, peak, and decline' pathway as the best remaining option to minimize the magnitude and duration of this overshoot and try to return to below 1.5°C as soon as possible. "This summer's scorching heat, raging wildfires and deadly floods are a warning of what lies ahead. We must make the overshoot above 1.5 degrees as small and short as possible. That demands an overshoot of ambition" said UN Secretary-General Antőnio Guterres. This pathway would minimize peak temperature rise through immediate and sustained cuts to greenhouse gas emissions, including methane, on the road to net-zero, and bring down temperatures through long-term net-negative emissions, with carefully governed Carbon Dioxide Removal (CDR) – the process of removing carbon from the air and storing it through afforestation or other means – an essential part of the mix. At the same time, following this pathway would involve adaptation actions that reduce vulnerability to the current, expected and unexpected impacts of climate change on societies, communities and economies – although there will likely be limits to adaptation and irreversible impacts, especially if peak temperatures are not minimized. The report stresses such a pathway would reduce risks and impacts, make adaptation less difficult and expensive, and increase the chances of lowering temperatures. "There are no good outcomes if we remain above 1.5°C. Across the globe, extreme heatwaves are already proving that climate impacts will strike faster, hit harder, and last longer - costing more lives and causing deeper disruption," said Inger Andersen, Executive Director of UNEP. "Now is the time we must double down on climate action. We can – and must – get on the right path. By cutting greenhouse gas emissions, strengthening resilience and adaptation, and ensuring exceedance of 1.5°C is as small and short as possible." Devastating impacts The most optimistic scenario will see temperature rise peak at 1.8°C above pre-industrial levels, above the goal of limiting warming to 1.5°C set by the Paris Agreement. Most other scenarios predict higher peaks. Above 1.5°C, risks and impacts will intensify with every extra fraction of a degree and every year. Anticipated impacts include intensified extreme weather, ecosystem loss, and submersion of Small Island Developing States and low-lying coastal cities. Severe damage to human health, food security, water supplies, nature, cities, infrastructure, and economies is expected. The report warns that the likelihood

of crossing irreversible tipping points increases with the magnitude and duration of higher temperatures. These include the destabilization of major ice sheets, degradation of the Amazon rainforest and disruption of the Atlantic Meridional Overturning Circulation (the system of currents that moves warm surface water north and cold deep water south, playing a key role in regulating the climate). Some impacts may emerge abruptly, while others will accumulate over time. Considering the scale of the risks and the co-benefits of climate interventions such as a rapid transition away from fossil fuels to renewable energy – improving air quality and public health, lowering energy costs and increasing access to electricity – the report urges accelerated, collective and global action to get on an overshoot, peak and decline pathway. How quickly and strongly this action happens will define the shape and trajectory of the pathway. Conditions for success Strong political will and multilateralism, effective policies, inclusive governance, and finance are all important enabling conditions for action – and equity and justice must underpin all responses. Countries with greater responsibility for climate change should act the fastest with the greatest ambition. The report also finds that mitigation and adaptation, which are mutually reinforcing, must advance together, while being responsive to emerging risks. Interventions that achieve both mitigation and adaptation goals – such as nature-based cooling – should be prioritized. Adaptation set up now forms the foundation for efforts to come, but it must become transformational and responsive to evolving non-linear and abruptly arising risks – including those that will harm mitigation efforts. The report emphasizes that net-zero is a milestone towards net-negative, with CDR needed in addition to, not instead of, sustained reductions in greenhouse gas emissions. However, CDR can only contribute credibly to a return below 1.5°C if peak warming remains well below 2°C and all residual emissions are reduced. Strong governance frameworks for CDR will be critical to allow responsible deployment and manage implications for environmental integrity, equity, scale. Responding to a changed future Years of inaction mean that even if a return to below 1.5°C is secured, irreversible losses and permanently changed conditions are certain. Many communities may be forced to relocate or change livelihoods, while societies will face the challenge of re-adjustment. This raises issues of justice, power, and political legitimacy, which will require new, inclusive governance arrangements to resolve difficult issues. This report is a reminder that an overshoot, peak and decline pathway is a next generation climate frontier, but one which cannot be left unattended to for the next generation to tackle. Immediate action is required for such a pathway to remain possible.

De-extinction creates species that are more resistant to stress, creating resilient keystone species and improving genetic diversity, protecting carbon sinks

Church 13 [Church, George. “George Church: De-Extinction Is a Good Idea.” Scientific American, 20 Feb. 2024, www.scientificamerican.com/article/george-church-de-extinction-is-a-good-idea.]

In its June issue Scientific American published an essay stating emphatically that reanimating species such as woolly mammoths from surviving DNA is a bad idea. This dismissal is too hasty. The idea has merit and is worth discussing with an open mind—and with multidisciplinary viewpoints. The goal of reanimation research is not to make perfect living copies of extinct organisms, nor is it meant to be a one-off stunt in a laboratory or zoo. Reanimation is about leveraging the best of ancient and synthetic DNA. The goal is to adapt existing ecosystems to radical modern environmental changes, such as global warming, and possibly reverse those changes. Ecosystems that depend on “keystone species” have lost the species diversity they once had because some species no longer fit. As environmental change occurs, ancient diversity may be needed again. For instance, 4,000 years ago the tundras of Russia and Canada consisted of a richer grass- and ice-based ecosystem. Today they are melting, and if that process continues, they could release more greenhouse gas than all the world's forests would if they burned to the ground. A few dozen changes to the genome of a modern elephant—to give it subcutaneous fat, woolly hair and sebaceous glands—might suffice to create a variation that is functionally similar to the mammoth. Returning this keystone species to the tundras could stave off some effects of warming. Mammoths could keep the region colder by: (a) eating dead grass, thus enabling the sun to reach spring grass, whose deep roots prevent erosion; (b) increasing reflected light by

felling trees, which absorb sunlight; and (c) punching through insulating snow so that freezing air penetrates the soil. Poachers seem far less likely to target Arctic mammoths than African elephants. "De-extinction" is not a novel idea. Medical researchers have resurrected the full genomes of the human endogenous retrovirus HERV-K and the 1918 influenza virus. Insight into these reanimated species could save millions of lives. Several other extinct genes, including for mammoth hemoglobin, have been reconstructed and tested for novel properties. Moving from these few genes to most of the 20,000 or so in a bird or mammalian genome may not be necessary, and even if it is, it may not be hard to do. The costs for a variety of relevant technologies are low—and dropping. Breeding animals and raising them until there are sufficient numbers to release into the wild is an ambitious undertaking, but the expense should be comparable to breeding livestock or preserving other endangered wildlife. These costs could be reduced if we used genetic means to improve the species we revive—boosting their immunity and fertility and their ability to draw nutrition from available food and to cope with environmental stress. Aside from bringing back extinct species, reanimation could help living ones by restoring lost genetic diversity. The Tasmanian devil (aka Sarcophilus harrisii) is so inbred at this point that most species members can exchange tumor cells without rejection. A rare transmissible cancer spread via facial wounds is driving the species toward extinction. Reanimating ancestral, diverse Sarcophilus histocompatibility genes, which govern tissue rejection, could save it. Similar arguments could be made for amphibians, cheetahs, corals and other groups. Ancient genes could make them more tolerant of chemicals, heat, infection and drought. Reanimation is not a panacea for ecosystems at risk. Preventing ongoing extinction of elephants, rhinoceroses and other threatened species is critically important. By all means, we must set priorities for allocating finite conservation resources. But it is a mistake to look at this issue as a zero-sum game. Just as a new vaccine can free up medical resources that would otherwise be spent on sick patients, reanimation may be able to help conservationists by giving them powerful new tools. That this is even a possibility is reason enough to explore it seriously.

Healthy ecosystems are key to mitigating climate change - without them we release sequestered carbon and accelerate warming

UN 23 [United Nations. "Biodiversity - Our Strongest Natural Defense Against Climate Change | United Nations." United Nations, www.un.org/en/climatechange/science/climate-issues/biodiversity.]

Biological diversity — or biodiversity — is the variety of life on Earth, in all its forms, from genes and bacteria to entire ecosystems such as forests or coral reefs. The biodiversity we see today is the result of 4.5 billion years of evolution, increasingly influenced by humans. Biodiversity forms the web of life that we depend on for so many things – food, water, medicine, a stable climate, economic growth, among others. Over half of global GDP is dependent on nature. More than 1 billion people rely on forests for their livelihoods. And land and the ocean absorb more than half of all carbon emissions. But nature is in crisis. Up to one million species are threatened with extinction, many within decades. Irreplaceable ecosystems like parts of the Amazon rainforest are turning from carbon sinks into carbon sources due to deforestation. And 85 per cent of wetlands, such as salt marshes and mangrove swamps which absorb large amounts of carbon, have disappeared. How is climate change affecting biodiversity? The main driver of biodiversity loss remains humans' use of land – primarily for food production. Human activity has already altered over 70 per cent of all ice-free land. When land is converted for agriculture, some animal and plant species may lose their habitat and face extinction. But climate change is playing an increasingly important role in the decline of biodiversity. Climate change has altered marine, terrestrial, and freshwater ecosystems around the world. It has caused the loss of local species, increased diseases, and driven mass mortality of plants and animals, resulting in the first climate-driven extinctions. On land, higher temperatures have forced animals and plants to move to higher elevations or higher latitudes, many moving towards the Earth's poles, with far-reaching consequences for ecosystems. The risk of species extinction increases with every degree of warming. The Earth is feeling the heat. In the ocean, rising temperatures increase the risk of irreversible loss of marine and coastal ecosystems. For instance, 14 per cent of the coral from the world's coral reefs was lost between 2009 and 2018, mostly due to climate change, and further warming threatens to destroy almost all remaining reefs. photocomposition: a turtle swimming in the oceanphotocomposition: a turtle swimming in the oceanphotocomposition: a turtle swimming in the ocean Overall, climate change affects the health of ecosystems, influencing shifts in the distribution of plants, viruses, animals, and even human settlements. This can create increased opportunities for animals to spread diseases and for viruses to spill over to humans. Human health can also be affected by reduced ecosystem services, such as the loss of food, medicine and livelihoods provided by nature. Why is biodiversity essential for limiting climate change? When human activities produce greenhouse gases, around half of the emissions remain in the atmosphere, while the other half is absorbed by the land and ocean. These

ecosystems – and the biodiversity they contain – are natural carbon sinks, providing so-called nature-based solutions to climate change. Protecting, managing, and restoring forests, for example, offers roughly two-thirds of the total mitigation potential of all nature-based solutions. Despite massive and ongoing losses, forests still cover more than 30 per cent of the planet's land. Peatlands – wetlands such as marshes and swamps – cover only 3 per cent of the world's land, but they store twice as much carbon as all the forests. Preserving and restoring peatlands means keeping them wet so the carbon doesn't oxidize and float off into the atmosphere. Ocean habitats such as seagrasses and mangroves can also sequester carbon dioxide from the atmosphere at rates up to four times higher than terrestrial forests can. Their ability to capture and store carbon make mangroves highly valuable in the fight against climate change. Conserving and restoring natural spaces, both on land and in the water, is essential for limiting carbon emissions and adapting to an already changing climate. About one-third of the greenhouse gas emissions reductions needed in the next decade could be achieved by improving nature's ability to absorb emissions. Is the UN tackling climate and biodiversity together? Climate change and biodiversity loss (as well as pollution) are part of an interlinked triple planetary crisis the world is facing today. They need to be tackled together if we are to advance the Sustainable Development Goals and secure a viable future on this planet. The Earth is feeling the heat. Governments deal with climate change and biodiversity through two different international agreements – the UN Framework Convention on Climate Change (UNFCCC) and the UN Convention on Biological Diversity (CBD), both established at the 1992 Rio Earth Summit. Similar to the historic Paris Agreement made in 2015 under the UNFCCC, parties to the Biodiversity Convention in December 2022 adopted an agreement for nature, known as the Kunming-Montreal Global Biodiversity Framework, which succeeds the Aichi Biodiversity Targets adopted in 2010. The framework includes wide-ranging steps to tackle the causes of biodiversity loss worldwide, including climate change and pollution, and should work in synergy with the Paris Agreement. "Delivering on the framework will contribute to the climate agenda, while full delivery of the Paris Agreement is needed to allow the framework to succeed," said Inger Andersen, the head of the UN Environment Programme. "We can't work in isolation if we are to end the triple planetary crises." At COP15 in December 2022, governments met in Montreal, Canada, and agreed on the new framework to address biodiversity loss, restore ecosystems and protect the rights of Indigenous Peoples, who suffer disproportionately from biodiversity loss. "Indigenous Peoples, people of African descent, and local communities are guardians of our nature," said the UN Secretary-General. "Their traditional knowledge is a living library of biodiversity conservation. They must be protected. And they must be part of every biodiversity conversation." At the meeting, the parties also adopted the Multilateral Mechanism on the fair and equitable sharing of benefits arising from the use of digital sequence information on genetic resources. In November 2024, at COP16 in Cali, Colombia, countries reached a historic consensus, including on the functioning of a fund, known as the Cali Fund, aimed at mobilizing new streams of funding for biodiversity action worldwide and boosting the implementation of the framework. The Cali Fund was launched in Rome, Italy, in February 2025 on the margins of the resumed session of COP16. It is set to receive contributions from private sector entities making commercial use of data from genetic resources, with the aim to raise an additional $200 billion each year by 2030 to close the global biodiversity finance gap. "Those profiting from nature cannot treat it like a free, infinite resource. They must step up and contribute to its protection and restoration," the UN Secretary-General said.

Even if de-extinction doesn't directly revive species, it supports gene editing tech that protects existing endangered species

ERS Genomics 26 [ERS Genomics. "CRISPR for Conservation: Exploring Species Preservation and De-Extinction | ERS Genomics." ERS Genomics, 29 July 2026, www.ersgenomics.com/knowledge/crispr-for-conservation-species-preservation-de-extinction.]

CRISPR/Cas9 offers a potential solution to biodiversity loss — from reviving extinct species like the dire wolf and woolly mammoth to protecting endangered animals such as the black-footed ferret and reef-building corals. According to the IUCN red list, there are over 16,000 endangered animals, almost 10,000 of which are critically endangered. Beyond this, countless animals have gone extinct, harming ecosystems and biodiversity across the world. CRISPR/Cas9 offers a potential solution to this. Through gene editing technology, there is an avenue to restore extinct species and to provide endangered animals with the tools to prevent further extinction. CRISPR is a precise gene-editing tool that allows scientists to target and modify specific genes. This technology relies on a guide RNA, which locates the specific DNA segment, and the Cas9 protein, which cuts the DNA in that spot. Through that, scientists have the ability to alter portions of DNA in living organisms. More specifically, they can use this ability to modify genes to re-create extinct species or to provide currently endangered species with the genetic tools to protect them. De-Extinction Through CRISPR, it is now possible to restore previously extinct species. To implement this, scientists must find preserved portions of the animal's DNA, often in a fossil, in order to sequence their genome. Following this, they will identify a living animal with a similar genome and will compare the genetic difference. Finally, with CRISPR, the living cells will be modified in order to recreate the genome of the extinct species. Scientists will be able to target the specific genes in need of modification with the Cas9 protein, allowing them to form an embryo from genetically modified cells. Through this, they can re-create extinct species (Shapiro, 2015). One prominent example of de-extinction today focuses on the dire wolf. In 2024, Colossal Laboratories & Biosciences was able to successfully create two dire wolf pups, named Romulus and Remus. This was followed up by the birth of a subsequent dire wolf in early 2025. To achieve this, scientists extracted and sequenced DNA in cells from a fossilised dire wolf's ear lobe. Then, they selected 14 genes in gray wolf cells, the closest living ancestor, which accounted for the bulk of the differences between the current gray wolf and the dire wolf. With the use of CRISPR, they were able to modify these genes into those of the dire wolf, creating an embryo. Dog surrogates were selected to carry those embryos, and from there, the dire wolves were born (Ilic, 2025). Beyond the dire wolf, the woolly mammoth may also be recreated through CRISPR. Although it went extinct around 4,000 years ago, it may be possible for a new woolly mammoth to come into existence under CRISPR. Currently, Colossal is working to recreate the woolly mammoth genome from the Asian Elephant, its closest living ancestor. As of right now, the woolly mammoth is in a late editing stage. This means that the genome of the animal has been largely recreated, but the final steps are still in progress (Tibbets, 2022; Turner et al., 2025). Currently, the project has a target completion date of 2028. In the future, the ability to achieve de-extinction through CRISPR presents countless possibilities. This technology has enabled the revival of thousands of species that were once thought to be permanently dead. Even now, projects are in place to revive the dodo bird, Tasmanian tiger, bluebuck, and more. In the future, many more animals could be recreated, revolutionising the way we view extinct species. However, it is also important to understand that de-extinction through CRISPR has been met with controversy. Many scientists have criticised the work, arguing that these projects do not truly represent extinct animals, but they instead are merely genetically modified living animals. While de-extinction certainly brings forth a wealth of possibilities, it is important to determine whether they are truly bringing back animals, or if it is simply an illusion. Endangered Species

Beyond extinct animals, CRISPR presents avenues to protect endangered species. This gene editing technology has the ability to target and modify specific genes within animals to help them withstand environmental or other external pressures (Tibbets, 2022). For instance, the black-footed ferret is classified as severely endangered with only 300 to 500 individuals left in the population. This animal is highly susceptible to the sylvatic plague, a disease that was spread by non-native fleas. However, CRISPR has the potential to rectify this. Through the use of CRISPR, scientists hope to create a genetic vaccine, meaning that they will permanently alter the genome of the black-footed ferret. This will provide both them and all of their descendants with resistance to the disease (Livieri et al., 2022). To implement the vaccine, researchers plan to test the genome of the domestic ferret, which is able to resist the disease unlike the black-footed ferret. This will allow them to identify the particular genes that create immunity to the disease within the domestic ferret, but not the black-footed ferret. With the help of this data, scientists will alter the ferret's DNA with CRISPR to provide it with the same immunity, helping the black-footed ferret survive the plague and avoid extinction (Tibbets, 2022). Similarly, researchers have found that CRISPR could have an impact on coral conservation. Over 40% of coral species have been classified as endangered, and rising temperatures are a major contributing factor. When the ocean becomes too warm, coral will expel the algae that they rely on, leading them to turn white, also known as coral bleaching, and placing them at risk of starvation (Cleves et al., 2020). However, researchers

have found that mutating the HSF1 gene in coral with CRISPR would limit its ability to survive during extreme temperatures. This indicates that the HSF1 gene is one of the primary genes that contributes to coral heat resistance. With this knowledge, scientists opened up a world of possibilities. This will allow for future testing of coral genes to develop a further understanding of their heat tolerance. It also will allow scientists to potentially modify this gene to produce a more heat-resistant coral, helping it to survive climate change (Cleves et al., 2018; Cleves et al., 2020). In the future, CRISPR will continue to open gateways to preserve endangered species. CRISPR can modify specific genes in animals beyond just the black-footed ferret and coral, and this will allow scientists to help animals become stronger and better able to resist threats in an ever changing world. As a result, CRISPR can play a major role in improving conservation worldwide. Conclusion Evidently, CRISPR presents a unique opportunity to address extinct and endangered species. Through its ability to accurately identify and modify genes, CRISPR makes it possible to test the functions of specific genes and to create changes to recreate and preserve extinct species and endangered species.

Climate change is devastating - it puts billions of people at risk and every tenth of a degree that we prevent is critical

Cabot 23 [Cabot, Cyrielle. "'Every Tenth of a Degree Matters': UN Climate Report Is a Call for Action, Not Despair." *France 24*, 22 Mar. 2023, www.france24.com/en/environment/20230322-every-tenth-of-a-degree-matters-un-climate-report-is-a-call-for-action-not-despair. Accessed 3/28/25.]

[[Note: Author Creds translated from original French where possible Journalist trained at CELSA, I write for the written press and the web. I am particularly interested in international news, with a focus on Thailand and the rest of Southeast Asia. I also follow environmental issues closely. National Institute of Oriental Languages and Civilizations (Inalco)National Institute of Oriental Languages and Civilizations (Inalco) Bachelor's degree, SiameseBachelor's degree, Siamese Sep 2020Sep 2020 Registered in Siamese license since September 2020.Registered in Siamese license since September 2020. CELSA Paris-Sorbonne logo CELSA Paris-SorbonneCELSA Paris-Sorbonne Master in Information and Communication with a specialization in Journalism, JournalismMaster in Information and Communication with a specialization in Journalism, Journalism 2014 - 20162014 - 2016 Lycée Fénelon, ParisLycée Fénelon, Paris Hypokhâgne, Khâgne specialty history-geography]]

'Every tenth of a degree matters': UN climate report is a call for action, not despair The latest report by the UN's climate advisory panel has once again highlighted the need for urgent action against human-induced climate change, noting that the tools to prevent climate catastrophe already exist. While hopes of limiting global warming at 1.5C are rapidly fading, climate experts stress that "every additional tenth of a degree matters" to mitigate the already dire consequences of our planet warming. Issued on: 22/03/2023 - 16:57 5 min A polar bear is seen on ice floes in the Franz Josef Land archipelago, in the Arctic Ocean. A polar bear is seen on ice floes in the Franz Josef Land archipelago, in the Arctic Ocean. © Ekaterina Anismova, AFP By: Cyrielle CABOT ADVERTISING The 36-page "summary for policymakers", a synthesis of nine years of research by the Intergovernmental Panel on Climate Change(IPCC), is a stark reminder that the devastating impacts of climate change are hitting faster than expected – and that failure to take decisive action could make some of those consequences irreversible. "Humanity is on thin ice – and that ice is melting fast," UN Secretary-General Antonio Guterres warned on Monday as he presented the report's key findings. "Our world needs climate action on all fronts – everything, everywhere, all at once." The IPCC report says our planet is on course to reach 1.5 degrees Celsius above pre-industrial levels – considered a safer limit to global warming – in little over a decade. Its dire warning comes just eight years after the COP21 climate summit in Paris made the 1.5C threshold a beacon for climate policies. "Since the Paris Accord, the stated objective of states has been to keep global warming well below 2C above pre-industrial levels – and to step up efforts to limit it to 1.5C," says Wolfgang Cramer, a research director at the Mediterranean Institute of Marine and Terrestrial Biodiversity and Ecology (IMBE). "This overall objective provided a horizon and a specific target for climate policies," adds Cramer, who co-authored the IPCC's last major report in 2022. "But when you look at the current trajectories and the poor efforts mustered by governments, it does indeed appear highly unlikely that we can meet that second target." The figures speak for themselves. The IPCC says greenhouse gas emissions would need to be slashed by 45% by 2030 for there to be any chance of capping global warming at 1.5C. That would mean annual cuts equivalent to the one witnessed at the height of the Covid-19 pandemic in 2020, when the world's economies ground to a halt. As things stand,

humanity is well off the mark. According to the IPCC's projections, our planet is on course for global heating of 2.5C by the end of the century if governments stick to their emissions pledges – and 2.8C if they stick to current policy. The planet's 'fever' While the outlook is dire, it should not be cause for fatalism and inaction, experts caution. "Our actions right now will determine the extent of global warming in the long run. The objective is to ensure it remains as low as possible," says Cramer, for whom the 1.5C target "is already too high" to avert major consequences for the planet. "We're currently at 1.2C and already we are bearing the consequences, with an increase in heatwaves, droughts and flooding," he explains. SCIENCE05:04 SCIENCE © FRANCE 24 To understand the significance of each fraction of a degree, Cramer draws a parallel with a human suffering from fever. Add one degree Celsius to the normal body temperature of 37C and the person will feel unwell and have headache. Add 2C and the suffering increases. At 3C it becomes dangerous, particularly if the person is vulnerable. The same goes for our planet, Cramer adds. "The consequences will differ at each degree and in different parts of the world: they will be most severe in places that are most vulnerable," he says. "1.5C will always be better than 1.6C, which will always be preferable to 1.7C. Every tenth of a degree matters." Biodiversity under threat The consequences of this global "fever" are increasingly evident, starting with the extinction of biodiversity. In 2015, the year of the Paris Accord, the Bramble Cay Melomy, a small rodent that lived on a speck of land off the coast of Papua New Guinea, became the first known mammal to go extinct as a result of human-caused climate change. "Scientists have shown that its disappearance was caused by rising sea levels submerging its habitat," Camille Parmesan, a climate and biodiversity expert at the CNRS research centre, told FRANCE 24 in an interview in December. "We have also documented the disappearance of 92 species of amphibians, killed because of the proliferation of a fungus that developed as a result of climate change modifying ecosystems," Parmesan added. >> 'Humanity is bullying nature – and we will pay the price,' WWF chief tells FRANCE 24 Corals are another obvious casualty. At 1.5°C, 70% to 90% of reefs could disappear. At 2°C, the figure rises to 99%. Experts at the UN-backed biodiversity agency IPBES say more than a million species are currently threatened with extinction, with climate change becoming the "most significant" menace. "The more it increases, the more ecosystems are disrupted, with consequences for wildlife," an agency report stated in 2021. Extreme weather "Each additional degree will translate into increasingly frequent and severe weather events, with ever greater consequences for the 3.3 billion people who live in vulnerable areas," adds Cramer. For several years now, scientists have been investigating links between climate change and extreme weather events, a field known as "attribution science". Their findings confirm that heatwaves, floods and hurricanes are increasing in intensity, magnitude and frequency as a result of global warming. Research has thus established that climate change made the devastating heatwave that hit India and Pakistan in March and April last year thirty times more likely. In this context, "decision makers should also focus their efforts on slowing down global warming" – in addition to curbing it, says glaciologist Gerhard Krinner, one of the authors of the latest IPCC report. "The faster climate change takes place the less time people will have to adapt," he explains. "This in turn will increase the risk of severe shortages, famines and conflicts." Tipping points Both experts flag the danger of reaching "tipping points" that would be extremely difficult to reverse, such as a destabilisation of the Antarctic ice cap. While the likelihood of catastrophic ice-sheet melting is currently still low, "it increases as the planet warms and there is a real risk of the rise in sea levels accelerating dramatically at between 1.5C and 2C", Cramer warns. Daily newsletter Receive essential international news every morning Subscribe Should the Antarctic's permafrost come to melt, it would release vast amounts of greenhouse gases trapped under the ice, in turn further warming the planet and accelerating ice melt. Other examples of tipping points include the Amazon rainforest turning to savannah and Greenland's ice cap melting. Each of these scenarios can be avoided, the experts insist, provided there is a political will to do so. "We now have multiple solutions that are readily available to slow down and limit climate change," says Cramer, for whom "the obstacle is no longer innovation – but politics". " Today's efforts will make all the difference in the long term," adds Krinner. "We can still [to] spare ourselves those extra tenths of a degree."

Tech Spillover

General Ideas:

- Helps for cancer research
- Helps for gene therapy
- Helps for other conservation efforts

Genome-engineering technologies applicable to de-extinction could restore lost genetic diversity and strengthen traditional conservation efforts to prevent future extinctions

Oosterhout 25 [Oosterhout, Cock, Supply, Megan A., Morales, Hernan E., Birley, Thomas, Totayah, Vikash, Jones, Carl.G, Whitford, Harriet L., Tollington, Simon, Ruhomaun, Kevin, Groombridge, Jim J. University of Kent "Genome Engineering in Biodiversity Conservation and Restoration." . https://www.nature.com/articles/s44358-025-00065-6. 2025 Date accessed 10/17/2026.]

28 Introduction We are in the UN's Decade on Ecosystem Restoration, yet over 46,000 (28%) of the 166,061 species in the IUCN Red List of Threatened Species are at risk of extinction1. Recent global analyses highlight that genetic diversity is being lost at alarming rates, with direct consequences for population resilience and biodiversity conservation2. Humans are currently changing ecosystems at a pace that exceeds the rate of natural habitat transitions during glaciation cycles3. The pace of change is more comparable to that observed during tectonic and volcanic activities, which have sudden environmental impacts that have led to mass extinctions4. Present-day species are facing this extreme challenge hampered by an ecological and evolutionary disadvantage. Habitats have been destroyed and fragmented, obstructing migration of threatened species to more habitable environments. Furthermore, genetic diversity of species has been in decline for decades if not centuries. Direct and indirect effects of human activities have decimated the population size of many species, leading to a loss of genetic diversity that compromises their long-term viability and evolutionary potential5–7. In recent decades, conservation biologists have saved numerous species from extinction, often against remarkable odds8–10. Traditional conservation approaches focus on demographic recovery through habitat protection and restoration, predator and alien species control, supplementary feeding, and captive breeding programs11,12. While such "first aid" conservation efforts have successfully prevented many immediate extinctions8, it cannot restore genetic diversity that has been lost from the species' living gene pool. Long-term sustainability of biodiversity depends on a combination of traditional conservation strategies, as well as biobanks and technological advances. Genome engineering can be considered "second aid", and it involves the restoration of damage incurred by genomic erosion, including the recovery of lost genetic diversity, reduction of the genetic load, and increase of the evolutionary potential of threatened populations. In this Perspective, we discuss the benefits, challenges and ethical considerations of genome engineering in biodiversity conservation, and we propose an approach for its implementation into conservation practice (Figure 1). By combining traditional conservation with advances in genomics-informed conservation, assisted reproductive technology, and genome engineering, we can now consider reintroducing lost genetic variation from preserved specimens into threatened populations (Figure 2). To ensure the long-term survival of threatened species in our rapidly changing environment, we must embrace new technological advances alongside traditional conservation approaches13. Saving species from extinction past and present Throughout evolution, species have avoided extinction by hybridizing with closely related species and subspecies14. Deep time reticulation in phylogenetic trees suggests that such interspecific gene flow might be more common in nature than previously thought, and that it is an important contributor to evolutionary rescue15,16. Our own genome bears the sign of 1–4% of DNA inherited from Neanderthal ancestors, which have enabled adaptation to new environments, including cold climates, increased UV exposure, increased hypoxia, and novel pathogens17,18. Genetic exchanges between species are fundamental to adaptive evolution19,20. Some species possess viable zoo populations that serve as "insurance populations," indeed around 90 species considered extinct in the wild persist in ex-situ facilities21. Zoos that are members of the European Association for Zoos and Aquaria (EAZA) and the Association of Zoos and Aquaria (AZA) collectively manage over 1000 species through their breeding programs. However, this represents only a small portion of species at risk of extinction. Moreover, captive bred populations face various challenges, such as inbreeding, genetic drift, adaptation to captivity, accumulation of harmful mutations in the benign environment, emerging infectious diseases, and logistical challenges22. Conservation biologists have long recognized these challenges, establishing biobanks and cryopreservation facilities to preserve genetic diversity23,24. Natural history museums worldwide house over 2 billion specimens collected over centuries that too contain valuable genetic diversity25,26. This preserved DNA could improve the viability of threatened species, but until recently, we lacked the tools to study and utilize this genetic diversity. Conservation genetics

has developed rapidly in the past 50 years. It has its roots in a theoretical population genetics framework dating back a century, and it is now starting to employ cutting- edge genomic tools for species preservation and restoration27–30. This development mirrors broader advances in genetic technologies, from early molecular markers to whole-genome sequencing, and genome engineering. Understanding evolutionary genetic processes – from the erosion of diversity in small populations, to new strategies for increasing the speed and effectiveness of genetic rescue – has become essential for effective biodiversity conservation31– 35. Following a “first aid” approach, species that have faced severe population size decline may require “second aid” conservation to counter genomic erosion and improve their evolutionary potential36. The remaining genetic variation may be insufficient to prevent local extinctions of subpopulations. The loss of evolutionary significant units (ESUs) and habitat fragmentation limits effective gene flow and the adaptive evolutionary response of metapopulations. The genetic health of the population is, however, rarely assessed during the first phase in conservation. Yet, we know that genetic diversity is necessary for the long-term survival and adaptability of species31–35 with some arguing that genetic data should be included in the IUCN Red List assessments37. Additionally, the IUCN Red List assesses extinction risk over a comparatively short timeframe (3 generations or 10 years, whichever is longer), and it therefore ignores the long-term risk of extinction due to genomic erosion. Genomic erosion Timing is critical. Many species face an ongoing "drift debt" – a slow but steady erosion of genetic diversity that continues to threaten declining species, even after population sizes stabilize or partially recover38,39. Genomic erosion compromises the evolutionary potential of populations35,40,41. Due to the drift debt, loss of genetic diversity will continue for many decades even after habitats are protected and populations increase42. Genomic erosion also affects genetic load. During population recovery, purifying selection removes the most deleterious alleles, but less harmful variants may increase in frequency due to drift43. Loci become more homozygous not only due to inbreeding, but also because the frequency of some deleterious alleles increases. Inbreeding and drift lead to a conversion of masked load into realized load, resulting in inbreeding depression44. Fixation of harmful genetic variants can lead to a gradual loss of fitness and population viability. This so-called drift load is not rapidly redressed via new compensatory mutations in small populations, which have a limited capacity of evolutionary rescue through natural means45. Genomic erosion puts additional pressure on the population on top of any external threats that led to its initial population decline43. Assessing extinction risks without evaluating the genetic health of populations may create a misleading sense that all conservation efforts have been completed. Traditional conservation management has helped many species to recover demographically after a severe bottleneck, and in recognition of such conservation success, these species are often down-listed on the IUCN Red List and in the Species Directory of the Endangered Species Act (ESA). Some conservation geneticists are concerned by such down-listings, arguing they are premature, and that the species are still at considerable risk of extinction5,38,46. Their concern is that without the intense conservation support, the down-listed species are at risk of a decline due to a drift debt caused by ongoing genomic erosion and conversion of genetic load. See Box 1 for case studies in genomic erosion. Genetic rescue The goal of genetic rescue is to increase individual fitness and population viability by introducing new alleles into the population, thereby increasing genetic diversity and reducing realized load47,48. Gene flow has large and consistent benefits49, and nearly half of reintroductions of captive-bred animals into the wild were considered to be successful50. Nevertheless, implementation of genetic rescue has historically been limited by concerns about outbreeding depression, loss of local adaptation, and various cultural and legislative barriers51. Evaluation of these risks and formulation of guidelines for genetic rescue51,52 have somewhat alleviated these fears. With recent improvements in bioinformatics and analysis tools, genomics data can be used to select optimal individuals and populations for genetic rescue, increasing genetic diversity while limiting the number of potentially harmful variants47,53. See Box 2 for case studies in genetic rescue. Museum collections, biobanks and cryopreservation facilities 23,24 contain potentially important sources of genetic variation for genetic rescue, enabling the reintroduction of recently lost genetic variants. Museum collections also provide a catalog of historical genetic variants that provides a baseline on past genetic diversity25,26. With the advances in the extraction and analysis of DNA from museum specimens, it is now possible to evaluate historical genetic diversity to inform conservation strategies54. Furthermore, biobanks are able to preserve high- quality specimens. Facilities such as the biobanks of the European Association of Zoos and Aquaria (EAZA), the San Diego Zoo's Frozen Zoo55, Nature's SAFE, and the Smithsonian's National Zoo and Conservation Biology Institute56, provide critical resources, including living cell lines, reproductive materials, and cryopreserved tissues that could be used to augment genetic rescue with genome engineering. While this perspective primarily focuses on animals, similar challenges and opportunities exist for plants, where genome editing is increasingly recognized as a valuable tool for conservation57. Genome engineering for genetic rescue Genome engineering offers a complementary solution to recover lost genetic diversity and replace harmful variants in a targeted way, providing much-needed “second aid” conservation to make species more resilient against future environmental change (Figure 3). However, this technology is not a silver bullet, and it may benefit only a subset of species. In particular, it could help recover the viability of species that lack immunogenetic variation critical for defence against emerging infectious diseases. In addition, the vital rates of threatened species that have fixed harmful genetic variants after a bottleneck could be improved by this technology. Moreover, it could improve the adaptive potential of species threatened by rapid climate change in the future58. ! As with any novel approach, these technologies must be implemented with caution. Risks such as unintended off-target genetic modifications, ecological repercussions of engineered organisms (e.g., gene flow to non-target populations), and ethical dilemmas surrounding intervention in natural systems (e.g., altering species traits and ecological roles) must be carefully evaluated. To mitigate these risks, genome engineering efforts must align with clearly defined conservation goals that are evaluated and agreed upon by all stakeholders. Transparency, robust risk assessments, and inclusive engagement with conservation practitioners, ecologists, ethicists, and local communities will be essential to ensure these technologies are applied responsibly and effectively (Figure 1). Genome engineering should be viewed as a complementary tool that can be applied not only when traditional conservation genetics and other approaches prove insufficient, but also when it offers enhanced efficiency, cost-effectiveness, or the opportunity to avoid removing wild individuals for captive breeding. In this way, it serves as a strategic option to optimize conservation outcomes while minimizing potential ecological disruptions. For many species, cost-effective and well-established methods are adequate for addressing conservation challenges. We acknowledge that genome engineering is not a standalone solution but rather an emerging complementary tool to traditional conservation strategies. Genome engineering primer Recent advances in genome engineering technologies, particularly CRISPR-Cas9 and related complexes, have opened new possibilities for genetic rescue and biodiversity conservation. These foundational technologies have been thoroughly reviewed elsewhere59–64. These tools offer unprecedented precision in genetic modification (see Box 3). The continuing evolution of these technologies, from simple gene knockouts to precise base changes and large sequence insertions, provides conservation biologists with an expanding toolkit for addressing genetic challenges in threatened species65. When combined with

advances in genomic sequencing, bioinformatics, computer modelling, and our understanding of evolutionary genetics, these tools offer promising new approaches for species conservation, particularly in cases where traditional methods alone are insufficient to ensure long-term survival[66]. We can learn from evolution to engineer genomes of endangered species, helping them to cope better with future threats of genetic drift, inbreeding, and environmental change. Some species are able to rapidly recover from a population crash, whereas others are much more vulnerable to drift and inbreeding[5,31]. With modern genome engineering it is possible to change the genomic architecture to make vulnerable species more tolerant to genetic drift, inbreeding, and imminent threats such as disease and environmental change. Targets for genome engineering Introducing immunogenetic variation Genome engineering can introduce beneficial variants that help populations cope with specific threats, particularly emerging infectious diseases. The American chestnut (Castanea dentata) demonstrates how engineering disease resistance can restore a species: researchers successfully introduced an oxalate oxidase gene from wheat to create blight-resistant trees that can coexist with the fungal pathogen that nearly drove the species to extinction[67,68]. Genome modifications that introduce heterospecific DNA to gain disease resistance are common practice in crops[69]. Genome modifications could help other species threatened by (re)emerging infectious diseases, in particular species that lack (or have lost) immunogenetic variants that offer tolerance or resistance to disease. Examples are amphibians affected by chytrid fungus, where research has identified potential target genes involved in skin integrity and immune response[70]. Similarly, Tasmanian devils (Sarcophilus harrisii) that are impacted by facial tumor disease could potentially benefit from genome engineering, given that a genome-wide association study identified rare candidate regions associated with disease resistance[71]. The critically endangered orange-bellied parrot (Neophema chrysogaster) has lost immunogenetic diversity at Toll-like receptor (TLR) genes critical for pathogen defense[72]. Contemporary populations show reduced TLR allelic diversity compared to their ancestors, with particularly concerning losses in genes linked to bacterial infection resistance. Identifying and restoring immunogenetic diversity that has been lost from the historical gene pool could improve the long-term viability of vulnerable species like the orange-bellied parrot, which is predicted to become extinct by 2038. Introducing climate adaptive genetic variation Climate change presents another critical challenge where genetic rescue augmented with genome engineering could help threatened species adapt to rapidly changing conditions. The IPCC report warns about increased intensity and frequency of temperature extremes which threaten biodiversity loss in most ecosystems[73]. Genome editing techniques could help increase the adaptive potential of species by introducing heterospecific DNA from species already adapted to these conditions, in a more intentional process than cross-breeding. By widening the environmental envelope of keystone species, genome engineering could potentially improve the resilience of the most vulnerable ecosystems. One of the many challenges is whether we can scale-up these techniques to provide sufficient genetic diversity to enable an adaptive evolutionary response to rapidly changing selection pressures. Corals exemplify this potential: by introducing heat tolerance genes identified in resilient coral species, we might enhance the survival prospects of vulnerable reef ecosystems facing warming oceans[74–77]. Additionally, large-scale comparative genomics projects like Zoonomia[78] and the Bird 10K Genomes Project[79] can help identify target variants for both disease resistance and climate adaptation. These targets can be further validated through genome-wide association studies and analysis of model organisms[80]. Reducing genetic load Deleterious mutations that have become fixed through genetic drift can no longer be purged from the population by natural selection[43]. Such drift load is particularly high in species with large ancestral population size that underwent a small bottleneck or founder event[81]. Genome engineering can reduce this drift load by replacing fixed mutations with ancestral wild-type alleles. Using genome engineering to replace harmful alleles has been successfully achieved in model systems[82,83] and recently the FDA approved the first CRISPR therapy to treat an inherited disease[84]. Modern computational methods and bioinformatics techniques can identify high- impact deleterious mutations that are prime candidates for editing, allowing researchers to prioritize variants likely to have the largest impact on fitness[44,47]. An example of using genome engineering for genetic rescue to incorporate historical variation from museum, biobank, or other ESU samples is shown in Figure 2. Consequences of genome engineering The introduction and spread of edited variants through the population could lead to genetic erosion through hard selective sweeps, i.e., the localised reduction of genetic diversity around the targeted locus due to genetic hitchhiking[85] (Figure 4). Moreover, providing additional targets for strong positive selection risks reducing the effective population size (Ne) by increasing the variance in lifetime reproductive success, which erodes diversity at a genome-wide scale[86]. Furthermore, Hill–Robertson interference can reduce the efficacy of purifying selection against other (slightly less) harmful variants[87], which may reduce the efficiency of purging of genetic load. The cost of selection is less in larger populations and during population size expansion because it takes longer for the beneficial edited variant to become fixed in the population (Figure 4). This allows for more recombination, which helps to preserve genetic diversity. The inadvertent negative consequences of genome engineering can be minimized when it is combined with conventional conservation actions. The restoration of habitat and increase of carrying capacity can lead to population growth, which reduces genomic erosion caused by the additional selection pressures associated with the introduction of novel beneficial variants. Computer simulation models can help assess the benefits and risks of targeting specific variants, allowing for informed decision-making before implementing genomic engineering and genetic rescue programs. Societal, economic, and bioethical dimensions Genome engineering is accompanied by ethical, technical, and regulatory challenges that must be considered to ensure that such genetic rescue efforts are socially and ethically acceptable and scientifically sound. Public perception, ecological risks, and policy considerations all play roles in determining how these technologies can be deployed in conservation efforts. Public perception and societal attitudes Public support is necessary for the success of conservation initiatives involving genetic engineering because this new technology risks altering practices, concepts, and values in conservation[88]. Studies have shown that public attitudes towards such interventions vary across stakeholder groups and are strongly influenced by perceptions of environmental benefits and risks[75,89]. While conservation professionals and scientists generally perceive lower risks and greater benefits, public acceptance often depends on trust in regulatory institutions and clear communication about potential outcomes[88]. Research on genetic rescue projects like that

aimed at restoring the American chestnut has demonstrated that early engagement with stakeholders and transparent discussion of both benefits and limitations is essential for building public support89. Funding and equitable access considerations We argue that knowledge and techniques developed for genome modification can now be applied to save threatened species from extinction. A common concern is that funding for genetic engineering in species restoration projects may divert resources away from actual conservation efforts90,91. No genetic rescue intervention (engineering or otherwise) makes sense without ecosystem restoration and species protection. Critics argue that investing in high-tech solutions could undermine support for conventional strategies, which remain critical for biodiversity conservation65,88,90,92,93. However, funding for genome engineering and species restoration often originates from distinct sources specifically targeting technological innovation, such as private donors, biotechnology firms, or grants focused on scientific advancements. These funds are typically non-fungible and would not otherwise be redirected to conventional conservation efforts94. Genome engineering complements rather than replaces traditional conservation measures. By restoring genetic diversity, it can enhance population fitness and adaptive capacity (Figure 3), amplify the success of habitat restoration and captive breeding, and create a more optimistic outlook on species recovery, serving as a beacon that encourages broader conservation initiatives like habitat restoration. We argue that rapid developments in genome engineering technologies are transferable, and that they should be applied to avoid extinction. As such, genome engineering can become a transformative and inclusive tool for biodiversity conservation and restoration, enhancing the resilience and viability of species by providing much-needed "second aid". It is important to acknowledge the disparities in access to these new technologies. Many conservation laboratories rely on microsatellite and other lower- cost tools and may perceive the promotion of genome editing as a dismissal of these foundational methods. Transparent communication and equitable collaboration are necessary to avoid marginalizing practitioners without access to expensive technologies.

De-extinction research directly generates transferable technologies that advance conservation and help prevent future extinctions

Turner 25 [Stephen D. Turner, Anna Keyre, Andrew Pask, Beth Shapiro. “De-Extinction Technology and its Application to Conservation.” American Genetic Association. Journal of Heredity. https://academic.oup.com/jhered/article/117/5/959/8262805#573397764 September 24, 2025.]

2: Conservation benefits from de-extinction research The technologies being developed as part of de-extinction research have immediate utility in conservation biology, offering new pathways for genetic rescue, disease resistance, and ecosystem restoration (IUCN 2016, 2019b, 2019a; Lean 2024; Macfarlane et al. 2022; Novak 2018). These advances create opportunities for "de-endangerment," which is broadly using biotechnology to enhance genetic diversity, bolster pathogen resistance, and improve the resilience of threatened species across both animal and plant kingdoms (Yin et al. 2024; Marx 2025). De-extinction projects provide opportunities to study the long-term effects of multiplex gene editing, epigenetic stability, and physiological integration in controlled environments. Longitudinal data on health, development, immune function, and behavior from early generations of genomeedited species in managed care can establish baselines that inform future conservation applications while ensuring animal welfare (IUCN 2016). This rigorous monitoring de-risks applications in threatened species by providing carefully documented case studies of how edited genomes function in vivo over time. The high public profile of de-extinction projects catalyzes broader conservation efforts, attracting new funding and inspiring collaborative efforts among scientists, policymakers, and communities (Donlan 2014; Jones 2014; Bloom 2024; Nature Biotechnology 2025). This creates a conservation flywheel (Fig. 2) where technological advancements and heightened public engagement mutually reinforce biodiversity preservation efforts. The following sections examine how deextinction technologies can supplement traditional conservation programs, highlighting candidate species that may benefit from these innovations (Table 3). 3.1. Genetic rescue and increasing genetic diversity Genetic diversity is the cornerstone of population resilience and adaptive potential, yet ongoing rapid loss of this diversity (Shaw et al. 2025) compromises long-term evolutionary viability (Kardos et al. 2021; Matthews et al. 2024). When species experience severe bottlenecks, genetic erosion and accumulation of deleterious mutations—known as genetic load—reduces both the immediate fitness of individuals and the population’s adaptive potential (Grossen and Ramakrishnan 2024). In many threatened species, such losses are so pronounced that, even after demographic recovery, the risk of extinction persists due to diminished genetic variability. Such populations can become trapped

in extinction vortices in which reduced fitness and increased inbreeding further decreases effective population size (Bosse and van Loon 2022). Table 3. Candidate conservation projects benefitting from the potential application of technologies developed for de-extinction. Species IUCN Threat Status Technology Conservation benefits Black-footed ferret (Mustela Endangered Somatic cell nuclear transfer (SCNT) Genetic diversity: Restores 3x genetic diversity seen in current populations from nigripes) cryopreserved tissue; Combats inbreeding depression. Chytrid-susceptible amphibians (e.g. Critically endangered (e.g. the Transgenic modification Multiplex Disease resistance; Engineered antibody and antifungal peptide expression; Pseudophryne spp.) Corroboree Frog) genome editing with CRISPR-Cas9 Targets immune response pathways. American chestnut tree (Castanea Critically endangered Transgenic modification Disease resistance; Introduces blight-resistant oxalate oxidase (OxO) transgene dentata) from wheat. Reef-building corals (e.g. Acropora Varies (e.g. Acropora spp. CRISPR-Cas9 gene editing, Environmental stress resilience; identify natural gene variants in existing coral and spp.) endangered or critically endangered) assisted/directed breeding their microbiomes that confer tolerance to increasing water temperatures. Northern quoll (Dasyurus Endangered CRISPR-Cas9 gene editing of Toxin resistance; Introduces heritable bufotoxin resistance; Enables quolls to act hallucatus) ATP1A1 as natural biocontrol agents for invasive cane toads. Northern white rhinoceros Critically endangered Induced pluripotent stem cells Resurrects genetic diversity from cryopreserved cell lines; Prevents progression (Ceratotherium simum cottoni) (iPSCs) and IVF from functional extinction to total extinction. Pink pigeon (Nesoenas mayeri) Vulnerable; Critically Depleted* Multiplex genome editing with Increase genetic diversity to reduce genetic load; introduces genetic variation from CRISPR-Cas9 sequenced museum samples, reducing genetic load and genomic erosion. Red wolf (Canis rufus) Critically endangered Somatic cell nuclear transfer (SCNT) Genetic rescue: Adds 25% new founder diversity from three novel cell lines; from blood-derived endothelial Provides a non-invasive cloning platform for biobanking and population progenitor cells supplementation; Enhances capacity for rewilding and long-term species persistence. Genetic rescue seeks to bolster adaptive potential by reintroducing lost alleles and reducing inbreeding effects (Whiteley et al. 2015). The pink pigeon of Mauritius (Nesoenas mayeri) exemplifies both the challenges and potential of this approach The pink pigeon has faced significant population declines due to habitat destruction and invasive species (Jones and Swinnerton 1997). Despite recovering from a population of fewer than 10 individuals to several hundred, the species suffers from extensive runs of homozygosity and high genetic load (Jackson et al. 2022). Pink pigeons are also susceptible to trichomonosis, further threatening its long-term survival (Bunbury et al. 2008). Genome engineering offers targeted reintroduction of lost genetic variants from museum specimens and cryobanked tissues, potentially correcting harmful mutations and restoring alleles that confer fitness benefits (van Oosterhout et al., 2025). The functionally extinct northern white rhinoceros (C. simum cottoni) illustrates genetic rescue using only cryopreserved material. With only two females remaining, biobanked semen and tissue samples retain genetic variation absent from the living population. Advanced ART, including iPSC derivation and in vitro embryo production, are being developed to harness this preserved genetic diversity for creating new individuals (Hildebrandt et al. 2021; Wilder et al. 2024). The black-footed ferret (Mustela nigripes) presents a compelling genetic rescue success story. Having started from only seven reproductively viable individuals, the captive breeding colony established by the U.S. Fish and Wildlife Service faces the potential of severe inbreeding (Tibbetts 2022; Novak et al. 2024). In 2020, a black-footed ferret called 'Elizabeth Ann' was born following SCNT using blackfooted ferret cells biobanked in 1988, representing a lineage that was not present in the captive population (Fritts 2022; Novak et al. 2024). While Elizabeth Ann was unable to reproduce, another individual, Antonia, was cloned from the same biobanked sample and has so far produced two healthy kits, marking the first time a cloned endangered species produced offspring (U.S. Fish and Wildlife Service 2024). This achievement demonstrates how archived genetic material can reintroduce critical variation and reduce genetic load in bottlenecked populations (Wisely et al. 2015). Research on dire wolf de-extinction has generated parallel benefits for the critically endangered red wolf (Canis rufus). Today only around 20 red wolves survive in the wild and all descended from 14 individuals captured to establish a breeding population in the 1970s (vonHoldt et al. 2022a; vonHoldt et al. 2022b). The dire wolf de-extinction project led to development of SCNT protocols refined for canids and novel pluripotent cell line technologies enabling production of two litters of 'ghost wolf' pups—clones of animals that remain part of a wild population of red wolves with some admixed coyote ancestry from coastal Louisiana where the founders of the captive red wolf population were captured. As red wolves are gray wolf—coyote hybrids, integrating ghost wolf ancestry into the red wolf breeding program could increase the diversity of preserved red wolf genomic ancestry and alleviate challenges of fitness decline in small populations due to limited genetic diversity. 3.2. Disease resistance and climate resilience Emerging infectious diseases and climate change are rapidly altering ecosystems, prompting conservationists to explore innovative genetic interventions to bolster species resilience. These challenges often interact, creating compound threats that traditional conservation approaches struggle to address effectively. 3.2.1. Pathogen resistance through genome engineering Chytridiomycosis, caused by the chytrid fungus, devastates amphibian populations globally (Kilpatrick et al. 2010). Researchers at the University of Melbourne are engineering chytrid resistance into Australia's critically endangered Corroboree Frog (Pseudophryne spp.), by engineering transgenes expressing antibodies and antifungal peptides in amphibian skin (University of Melbourne 2024). This approach targets the infection mechanism directly, offering hope for species facing imminent extinction from this pandemic pathogen. Similarly, invasive species can introduce novel toxins that native predators often cannot tolerate. Australian cane toads have devastated endangered northern quoll (Dasyurus hallucatus) populations since 1935, as these marsupials lack physiological defenses against bufotoxin. Recent breakthrough work introduced bufotoxin resistance into marsupial cell lines using genome editing, achieving > 45-fold increased resistance (Ibri et al. 2024). This proof-of-concept demonstrates that genetic engineering can create resilience to toxic invasive species while potentially providing a dual benefit, in that resistant quolls could help control cane toad populations through increased predation. 3.2.2. Climate adaptation and forest restoration Climate change intensifies the need for species that can adapt to rapidly shifting environmental conditions. Targeted genome editing offers promising avenues for developing climate-resilient traits, as demonstrated in forest tree studies showing increased heat and drought tolerance (Cao et al. 2022). The American chestnut (Castanea dentata) is a striking example of successful restoration through pathogen resistance engineering. Once a keystone tree species in eastern North American forests, American chestnuts were functionally eliminated by the invasive fungus, Cryphonectria parasitica, which causes chestnut blight. Researchers developed blight-tolerant American chestnut trees by introducing an oxalate oxidase transgene from wheat that breaks down the pathogen's toxic compounds (Powell et al. 2019). This approach enables the tree and fungus to coexist and avoids creating selective pressure for pathogen resistance, providing an evolutionarily stable solution (Powell et al. 2019). This success provides a model for restoring other disease-affected species. 3.2.3. Marine ecosystem resilience Ocean warming and acidification threaten coral reefs, which provide billions in economic value through fisheries, tourism, and coastal protection while supporting immense biodiversity (Birkeland 2015). Rising sea temperatures trigger mass bleaching events and structural degradation, threatening both the ecological functions and the economic benefits these ecosystems provide (Henley et al. 2024). Ocean warming can lead to mass bleaching events when symbiotic algae are expelled

from coral tissues (Hughes et al. 2018). Genome engineering approaches could introduce or enhance heat tolerance genes identified in resistant coral species, potentially increasing susceptible populations' resilience to rising temperatures (van Oppen and Oakeshott 2020; Selmoni et al. 2024). Complementary strategies targeting coral microbiomes offer additional pathways for enhancing thermal tolerance and ecosystem stability (Epstein et al. 2019). While these individual-level interventions address specific threats to target species, de-extinction technologies also enable broader ecosystem-scale restoration through the reintroduction of keystone species and management of ecological interactions. 3.3. Ecosystem restoration and resilience De-extinction technologies offer transformative potential for ecosystem restoration by reestablishing keystone species and managing ecological interactions that promote habitat recovery and biodiversity enhancement. These approaches extend beyond species revival to address fundamental ecosystem processes and community dynamics. 3.3.1. Trophic cascades and keystone species restoration The Yellowstone wolf reintroduction demonstrates how restoring apex predators can trigger powerful trophic cascades that reinvigorate ecosystem processes (Ripple et al. 2025). Gray wolf (C. lupus) reintroduction to Yellowstone National Park reduced elk herbivory pressure, leading to increased riparian willow biomass and beaver habitat restoration, ultimately reversing erosion and water table disruption (Hobbs et al. 2024; Ripple et al. 2025). This natural experiment demonstrates how single-species interventions can generate landscape-scale ecological recovery. Such restoration efforts align with natural climate solutions that emphasize ecosystem protection for carbon capture and storage. Some estimates suggest that species such as elephants, bison, wolves, and whales contribute to ecosystem carbon storage on the order of gigatons annually (Schmitz et al. 2023). 3.3.2. Genetic tools for invasive species management Invasive species remain major obstacles to ecosystem restoration and were implicated in extinctions like the dodo in Mauritius, where introduced rats disrupted native communities (Fair et al. 2023). Reintroducing species into ecosystems dominated by non-endemic invasive species is unlikely to succeed without addressing these fundamental alterations to ecosystem structure. Genetic technologies offer distinct approaches to invasive species management and biological control (Teem et al. 2020). RNA interference (RNAi), for example, has emerged as a promising biocontrol method for invasive species (Willow et al., 2022). RNAi works by introducing double-stranded RNA molecules that match target genes, leading to their degradation and effectively silencing gene expression. In invasive species control, this can disrupt essential physiological pathways (such as metabolism, reproduction, or digestion) ultimately reducing survival or fertility. However, RNAi typically acts in a limited way: locally and transiently. Another potential approach, gene drives, bias inheritance patterns to spread genes and associated traits rapidly through populations. These approaches show promise for suppressing and even eradicating invasive rodents on islands, where native species are especially vulnerable (Burgess et al. 2021). CRISPR-based gene drives have also demonstrated potential for reducing populations of insect disease vectors, such as mosquitoes that transmit malaria to birds, people, and other species (McFarlane et al. 2018; Samuel et al. 2020). 3.3.3. Integrative conservation approaches The methods being developed and refined in de-extinction research, from ecological restoration via reintroduction of keystone species to genetic strategies for invasive species management, represent valuable additions to the conservation toolbox. By integrating lessons from successful rewilding initiatives with genome editing technologies and advanced reproductive techniques, conservationists can develop more holistic strategies that restore ecosystem functionality while safeguarding biodiversity. However, success requires careful consideration of modern ecological contexts and potential unintended consequences of genetic interventions. 3.4. Public engagement in conservation In addition to the technological advances described above, deextinction serves as a powerful catalyst for public engagement in conservation biology, in particular when it is presented as a complementary approach to more traditional conservation strategies. The prospect of resurrecting iconic species captures public imagination in ways that transcend traditional conservation messaging, creating new opportunities for funding, education, and international collaboration. 3.4.1. Wonder and public imagination De-extinction's ability to evoke awe and curiosity creates a "wonder factor" that serves as a gateway for broader public engagement (Rohwer and Marris, 2018; Sherkow and Greely 2013). Media coverage highlighting technological aspects may attract audiences not typically engaged in conservation issues. Some stakeholders may view reviving species lost to human activities as a form of ecological restoration. This narrative aligns with growing public interest in synthetic biology and genetic engineering, positioning de-extinction as a tangible application of cutting-edge science for environmental benefit. A 2023 Australian Broadcasting Corporation survey, for example, found that nearly 70% of respondents supported deextinction and reintroduction of the thylacine, demonstrating strong public enthusiasm for reviving lost species (Zoe Kean and Lucie Cutting 2023). In its de-extinction guidelines, the IUCN acknowledges that successful de-extinction and restoration 'could provide a strong rationale for the preservation or restoration of habitat, and might be a means to reconnect people with the natural world in ways that could translate to conservation awareness beyond just the proxy' (IUCN 2016). By making abstract concepts like biodiversity loss more concrete and actionable, de-extinction narratives humanize complex conservation challenges through charismatic species (Valdez et al. 2019). 3.4.2. Funding dynamics and institutional support The heightened visibility of de-extinction projects demonstrably affects conservation funding. High-profile initiatives attract philanthropic investments and corporate partnerships that might not otherwise support traditional programs (Jones 2014). This 'halo effect' extends beyond de-extinction itself, as funders develop increased interest in supporting broader ecosystem protection measures (Molhuizen et al. 2025, 13). However, this landscape requires navigation to avoid resource imbalances or perceptions of de-extinction as a technological 'quick fix' for biodiversity loss (IUCN 2016; Valdez et al. 2019). Well-structured engagement initiatives can mitigate this risk by explicitly highlighting the high costs of biodiversity loss, thereby positioning de-extinction technologies within existing conservation frameworks rather than as competitors to them. 3.4.3. International collaboration and policy innovation De-extinction's transnational nature accelerates international cooperation in conservation governance. Reviving species from disparate biogeographic histories necessitates collaborative frameworks for genetic resource sharing, habitat restoration, and risk assessment. The IUCN's deextinction guidelines exemplify how these challenges spur policy innovation, creating precedents for managing emerging biotechnologies in conservation contexts (IUCN 2016). These collaborations often expose gaps in existing regulatory architectures. For instance, debates about de-extinction have prompted reevaluations of the Cartagena Protocol's applicability to resurrected species, driving discussions about modernizing international biosafety agreements (Valdez et al. 2019). The technical demands foster unprecedented data sharing networks between geneticists, ecologists, and conservationists across borders. 3.4.4. Educational opportunities De-extinction's narrative power is particularly effective in STEM education, with opportunities to inspire new generations of conservation biologists. Integration into curricula provides multidisciplinary teaching opportunities combining genetics, ecology, and ethics. Museums and zoos capitalize on this interest through exhibits using de-extinction themes to explain broader concepts like trophic cascades and habitat connectivity. This educational synergy emphasizes de-extinction's capacity to function as both a scientific tool and a cultural touchstone, bridging the laboratory research and public engagement with biodiversity while making threats like climate change and habitat fragmentation more relatable to diverse audiences. 4. Outlook De-extinction research has evolved from a speculative concept to a frontier of applied biotechnology, generating innovations that extend far beyond species revival. The genome engineering, advanced assisted reproductive technologies, and ecological modeling tools developed for de-extinction are providing new pathways for genetic rescue, species resilience, and ecosystem

restoration. As these technologies mature, their integration into mainstream conservation will offer transformative approaches to biodiversity preservation. Significant technical challenges remain. Fully reconstructing extinct genomes, developing reproductive strategies for functionally extinct species, and ensuring successful rewilding require continued innovation. Priority areas include refining genome editing precision and efficiency, optimizing cloning, and exogenous development protocols, and enhancing AIdriven ecological modeling for reintroduction planning. The field must also balance the compelling narrative of species resurrection with urgent protection needs for currently endangered species. The most immediate application of deextinction technologies lies in using genetic interventions to prevent species from reaching extinction. This proactive approach avoids the complex challenges of ecosystem reintegration that extinct species face. The future of de-extinction will be shaped by interdisciplinary collaboration across genomics, reproductive biology, conservation science, and ecological restoration. As genome editing becomes more precise and cost-effective, and as aART techniques advance, conservation applications will become increasingly feasible. AI and environmental monitoring advances will enable robust assessment of how reintroduced species interact with modern ecosystems, ensuring contributions to long-term ecological resilience rather than isolated scientific achievements. While it will be critical both to maintain a clear vision for how de-extinction technologies can serve conservation goals and to maintain a balance between technological ambition and ecological responsibility, de-extinction is increasingly understood as an emerging branch of conservation biology—one that complements and expands the existing toolkit.

De-extinction associated advances in bio-technology have created real world progress in cloning efficiency and has expanded genetic rescue capabilities for endangered species

Knecht 26 [Laura Knecht, Anthony Mastracci IV, Riley Harbert, Fatima Charles, Laura L. Kuperman-Yao, Tyler Miyawaki, Gregory L. Gedman, Kathleen M. Provich, Jason Herrick, Linda Lay, Alba Ledesma, Steve Metzler, Dennis Milutinovitch, James B. Papizan, Parker Pennington, Lexie Russell, Kerry Ryan, Kanokwan Srirattana, Kailtin Steiger, Darya A. Tourzani, Kelcey Walker, Rafael V. Sampaio, Sven Cocklandy, Ban Lamm, Matt James, Shawn Walker, Beth Shapiro, James Kehler. “Radi Derivation of cloning-competent cells from peripheral blood advances conservation biobanking.” Journal of Heredity. 25 June 2026. https://doi.org/10.1093/jhered/esag048. Date accessed 10/17/2026.]

Establishing viable cell lines from endangered species is essential for conservation, yet traditional fibroblast derivation from skin biopsies faces challenges including contamination risk and extended culture timelines. Here, we demonstrate that endothelial progenitor cells (EPCs) and pericytes isolated from peripheral blood represent robust alternatives to fibroblasts for biobanking. Compared to canid fibroblasts, canid blood-derived cells exhibit 2- to 3-fold faster doubling rates (15 to 20 h vs. ~35 h for fibroblasts) and reduced time to banked cell lines (1.5 to 2 wks vs. 3 to 4 wks for fibroblasts). Proteomic profiling of 32 canonical markers confirmed EPCs and pericytes represent distinct populations with lineage-specific molecular signatures. Optical genome mapping demonstrated equivalent genomic stability across cell types with no detectable structural variants or aneuploidies. Finally, interspecific somatic cell nuclear transfer (iSCNT) experiments confirmed both EPCs and pericytes generate viable canid embryos with efficiency meeting or exceeding fibroblasts.As a proof of concept for conservation cloning, iSCNT embryos made with gray wolf blood-derived cells had a 15% implantation rate following embryo transfer and resulted in six viable fetuses. These findings support integrating blood-derived cell banking into conservation programs, which enables opportunistic genetic preservation during standard management activities and expands options for genetic rescue through assisted reproductive technologies.

** Paragraph Break **

This study demonstrates that EPCs and pericytes isolated from peripheral blood are a robust alternative to dermal FBs for conservation biobanking and iSCNT. Blood-derived cells exhibit 2 to 3-fold faster doubling rates (15 to 20 h vs. >35 h for FBs) and reduce the timeline for generating banked cell lines from 3 to 4 wks to 1.5 to 2 wks (Figs 1 and 2). Combined with genomic stability equivalent to tissue-derived cells (Fig. 5) and demonstrated viability for generating cloned embryos across three mammalian genera (Fig. 7), blood-derived cells offer practical advantages for accelerating genetic rescue efforts. The primary advantages of peripheral blood over skin biopsies are the initial cell propagation length and ease of acquisition during existing veterinary workflows. While FB derivation from skin is well-established, the small

tissue fragments typical of dart biopsies may prolong the culture time due to limited starting material. Peripheral blood offers a more abundant starting material, which may mitigate the risks associated with sample degradation or contamination,both factors relevant in field-based collection where laboratory proximity varies. The sterile, closed-system collection of blood in anticoagulant tubes contrasts with the microbial burden inherent to skin surfaces. The consistency of blood-derived cell doubling rates may facilitate standardized biobanking workflows across diverse conservation programs. Whole blood samples are already routinely collected with anticoagulants for genomic studies and non-viably frozen in the field without cryoprotectants for DNA extraction. With advanced planning, blood collection protocols could preserve options for both immediate genomic analysis and future cell line establishment, maximizing the value of each sampling event. This dual-purpose approach is particularly relevant for cryptic, nocturnal, or otherwise difficult-to-sample species where opportunities for biological sample collections are rare. Molecular and functional characterization confirms distinct cell populations Comprehensive proteomic profiling established that EPCs, pericytes, and FBs are biologically distinct populations with lineage-specific molecular signatures (Fig. 6). FBs exhibited elevated ECM production markers (COL1A1, COL3A1, FAP), pericytes showed high abundance of adhesion and vascular remodeling proteins (ITGB5, ICAM1, MMP14, MCAM), and EPCs expressed endothelial-associated markers (ENG, CDH5, PDGFRA) along with canonical EPC markers (CD34, PECAM1, SELE, NOS3) detected exclusively in EPCs (Fig. 6, Table S1). The statistical significance of expression differences (Log10(P-value) > 2.8) and consistency across biological replicates confirm that blood-derived cultures yield distinct cell types rather than heterogeneous mixtures. For practical biobanking characterization without mass spectrometry, morphological assessment combined with doubling rate measurements provides reliable first-pass identification (Figs 2 and 3). EPCs consistently display cobblestone morphology and ~15-h doubling times, while FBs show spindle morphology with >35-h doubling times. Pericytes exhibit intermediate characteristics with FB-like morphology but faster doubling (~20 h). Functional assays further distinguish cell types within 24 h: tubule formation on ECM occurs exclusively in EPC cultures, while differential uptake of fluorescently labeled LDL versus acetylated-LDL distinguishes EPCs from pericytes (Fig. 4). These species-agnostic methods should enable biobank curators to characterize cell lines from taxonomically diverse samples as collections expand to under-represented vertebrate lineages. Both EPCs and pericytes support viable iSCNT outcomes Our iSCNT experiments demonstrate that blood-derived cells generate viable embryos with efficiency comparable to or exceeding traditional FB donors. In gray wolves, both pericytes (19% implantation) and EPCs (11% implantation) contributed to viable fetuses, with the combined rate (15%) exceeding prior published wolf iSCNT rates using FBs (0.8%) (Kim et al. 2007). Collectively, these results indicate that cell source (blood versus tissue) and specific blood-derived cell type do not compromise cloning outcomes. Current limitations and opportunities for optimization The stochastic emergence of either EPC-dominant or pericyte-dominant cultures from blood samples presents both a challenge and an opportunity. In our study, replating the total buffy-coat fraction resulted in primary colonies of both cell types adhering to traditional cell culture substrates and media optimized for EPC derivation and expansion.Both cell types formed primary colonies in a similar time window and could be dissociated, replated, and grown rapidly. While admixture of both cell types in cultures cannot be ruled out without single-cell analyses, the formation of cultures appeared stochastic with either EPCs or pericytes forming the predominant cell type in individual cultures. Selective enrichment may be achievable through substrate modification, growth factor supplementation, or differential adhesion protocols, enabling targeted derivation based on intended downstream applications. Both EPCs and pericytes participate in angiogenic signaling and repair and provide cell models for studying pathophysiological processes like atherosclerosis, making such optimization valuable for future studies beyond conservation applications. Future work will be necessary to optimize derivation success for different species. Species-specific body size, hematocrit, and circulating EPC/pericyte frequency are likely to influence blood volume requirements, and establishing taxon-specific guidelines would improve collection success rates while minimizing physiological stress to sampled individuals. In addition, robust field-to-lab workflows that maintain both cell viability and genomic quality would maximize the utility of opportunistic sampling, particularly for endangered species where repeated sampling is not always feasible. Integration with conservation strategies and existing biobanking infrastructure The choice between blood and tissue sampling should ultimately be guided by species-specific factors, including restraint safety, veterinary access, and protocol success rates. Blood sampling and viable cell propagation provides a complementary approach to biobanking to intervene in species with compressed timelines facing precipitous population declines. Recent successes introducing cloned historically underrepresented founders into black-footed ferret and Przewalski's horse populations (Novak et al. 2024; Novak et al. 2025b) illustrate how biobanked cells restore genetic variation unavailable through conventional breeding. Here we demonstrate how blood-derived cells can also be used to expand the pool of individuals to be biobanked before unique genotypes are lost. Integration of blood-derived cell lines with existing repositories such as the Frozen Zoo requires no additional steps. Blood-derived cells can be processed using standard cryopreservation protocols and stored under identical conditions as tissue-derived lines. Unlike the technical demands of generating and biobanking stem cells (Hutchinson et al. 2024), blood-derived cells can be processed using standard cryopreservation protocols and stored under identical conditions as tissue-derived lines. Ultimately, however, the success of any biobanking-to-cloning effort depends on co-development of Assisted Reproductive Technologies (ARTs). The iSCNT results reported here were only possible because of established ART protocols in domestic dogs, emphasizing that cloning advances depend on robust foundational reproductive biology research (Cowl et al. 2024; Hildebrandt and Holtze 2024). Finally,the selection of genetically valuable individuals for cloning should be performed in coordination with local and international community members invested in the propagation of endangered species and populations (Gray et al. 2023; Novak et al. 2025a). Support for international and Indigenous groups advocating for in situ and ex situ conservation efforts is a critical parallel need alongside biobanking and cloning efforts (Bolton et al. 2022; Hayah et al. 2025). By integrating blood-derived cell collection into routine management activities, conservation programs can opportunistically capture genetic diversity during standard veterinary procedures, expanding options for genetic rescue when traditional reproductive technologies cannot achieve sufficient genetic diversity. The minimal infrastructure requirements make this approach accessible to field programs with limited resources, broadening the pool of individuals and species represented in global biobanking efforts.

Fill Info Gaps

General Ideas:

- Understand previous extinctions
- Help see adaptation to climate
- See role in ecosystem

De-extinction could be revolutionary for our knowledge of evolutionary biology

Richmond et al 16 [Douglas J. Richmond, Mikkel-Holger S. Sinding, M. Thomas P. Gilbert, Richmond is a researcher at the University of Copenhagen, Mikkel works for the Greenland Institute of Natural Resources, and Marcus Thomas Pius Gilbert is an evolutionary biologist. His work is highly cited, and influential in the fields of palaeogenomics, evolutionary genomics and evolutionary hologenomics. He is currently the director of the University of Copenhagen's Center for Evolutionary Hologenomics. "The potential and pitfalls of de-extinction" https://onlinelibrary.wiley.com/doi/10.1111/zsc.12212 Sept 27 2016]

A further argument that has been presented in support of de-extinction is that humans have caused the extinctions. Human hunting of megafauna and environmental impacts of human activity is considered to be one of the main drivers of global Holocene megafauna extinctions (Zimov *et al*. 1995; Miller *et al*. 1999; Alroy 2001; Fisher 2009; Gill *et al*. 2009). During this time frame, anatomically modern humans spread to most of their present range, and as they did, human presence generally correlated with extinctions (Burney & Flannery 2005; Sandom *et al*. 2014; Surovell *et al*. 2016). As Neolithic societies established and eventually became industrialised, global human populations modified increasing areas of the planet's surface, and hence virtually all ecosystems are today affected by human enterprise, causing wide ranging and accelerating extinction (Thomas *et al*. 2004; Harnik *et al*. 2012; Keith *et al*. 2015). The further back in time extinctions took place, the more difficult it is to determine the extent of the role humans played however, and early megafauna extinctions are especially hotly debated (Burney & Flannery 2005, 2006; Wroe *et al*. 2006; Lorenzen *et al*. 2011; Sandom *et al*. 2014; Willerslev *et al*. 2014). Nevertheless, there are many cases where it is absolutely certain that humans exterminated a species. These may be perceived by some to be ethically wrong acts which we as a species have a duty to right. Integrated in this line of thought is the idea that there is an order within nature which we are independent from, and that human-mediated extinctions are unnatural. Whether humans should be viewed as components of past or present ecosystems, and whether man-made de-extinction is more justified than man-made extinction is an ethical debate which is out of scope of this paper. However, setting ethics aside, and focusing on functionality, it has been reasoned that the introduction of extinct species could be useful to preserve and restore ecosystems. It is in humanity's best interest to maintain an environment that is functionally useful to society and aesthetically pleasing, supporting the range of ecosystem services required for us to thrive (DeFries *et al*. 2004; Zhang *et al*. 2007), and the introduction of keystone species may boost ecosystem function and stability. Species introductions in modern nature management are generally viewed as acceptable if the species was exterminated from the ecosystem, and its reintroduction is believed to be needed to complete the previous system (Duffy 2003; Svenning *et al*. 2016). Bringing back extinct species may also further our knowledge of evolutionary biology and our understanding of the breadth of possibilities for physiological functioning of animals that existed in different time periods and climates. Extinct genes could also be potentially used to improve livestock (FAO 2016).

De-extinction allows us to study further the factors that contributed to species extinction, and aid conservation efforts

Miyatsu 25 [Rose Miyatsu, Director of Communications, UC Santa Cruz Genomics Institute "Ancient DNA research aids de-extinction efforts and reveals surprising dire wolf ancestry" https://news.ucsc.edu/2025/04/dire-wolf-genome/ 4/14/25]

"Ancient DNA is notoriously difficult to work with because it is often fragile and degraded, but paleogenomics has made tremendous leaps forward in the past 20 years, leading to the recent groundbreaking achievement of the world's first de-extinction with the birth of Colossal's dire wolves," Shapiro said. "This amazing feat was possible because of Colossal's strong partnerships with academic institutions, like UC Santa Cruz, that have pioneered work in this field."

On April 11, a team of researchers from Colossal, UC Santa Cruz, Form Bio, and academic collaborators from around the globe, released a preprint of some of the research that the team conducted on ancient dire wolf genomes. The new study introduces an improved method for reconstructing ancient genomes, using the Minigraph-Cactus pipeline and Giraffe tool developed at the UC Santa Cruz Genomics Institute. This new method allowed the team to discover a surprising ancestry.

Researchers knew from fossil remains that dire wolves were larger than modern gray wolves, with stronger jaw muscles that likely helped them specialize as hunters of large Ice Age mammals. The new study reveals that these distinct features come from a surprising mix of two ancient canid groups. Roughly two-thirds of the dire wolf genome seems to originate from an ancestor of wolves and coyotes, while the remaining third comes from an ancient lineage related to South American dogs. This finding suggests that the dire wolf arose through interbreeding between distantly related lineages approximately 4 to 5 million years ago.

Interbreeding between species to create an entirely new species is known as "hybrid speciation," and scientists believed it to be an extremely rare way for evolution to work. These new findings about the ancestry of the dire wolf, combined with an earlier finding co-authored by UC Santa Cruz about the evolutionary origins of the Columbian mammoth, suggest that it might be more common than we thought.

Understanding the dire wolf's evolutionary history contributes to our knowledge of the factors that may have contributed to their eventual extinction, which could have benefits for conservation. Shapiro and Colossal's CEO, Ben Lamm, have argued that the technologies they are developing in the process of de-extinction will help rescue endangered plants and animals from a global extinction crisis that threatens to wipe away 30-50% of the world's species in the next 25 years. The advanced paleogenomic techniques employed in this study also provide a roadmap for future research on other extinct species that will offer insights into broader patterns of evolution on Earth.

"Our newest paper builds on decades of ancient DNA research to present an improved method for reconstructing ancient genomes, which allowed us to discover a surprising evolutionary history hidden in dire wolf DNA," Shapiro said. "I'm excited to see what else it will allow us to discover in the future, and how this new knowledge will help us to conserve earth's amazing biodiversity."

De-extinction technology can create tech for curing diseases and bringing back entire evolutionary branches

Pilcher 16 [Helen has a PHD in Cell Biology from London's Institute of Psychiatry She writes for the likes of Apple News, Science Focus, BBC Wildlife and The Guardian, and appears on podcasts, radio and TV shows. "Why Extinction Doesn't Have to Be Forever Anymore" https://www.nbcnews.com/storyline/the-big-questions/why-extinction-doesn-t-have-be-forever-anymore-n696106 Dec. 15, 2016]

Studies by de-extinction pioneer Ben Novak from the University of California, Santa Cruz have shown that in their time, passenger pigeons drove the regeneration of their native north American forests. By toppling trees, breaking boughs and fertilizing the forest floor, they turned stagnant, closed canopy woodland into a sunlit, fertile nursery where plant and animal life flourished.

Bring the passenger pigeon back, the argument goes, and it could resume its role as ecosystem engineer, sculpting the landscape and boosting overall levels of biodiversity. Similarly, if the woolly mammoth was returned to Siberia, it's thought it could change the scraggy, sparse Arctic tundra into lush, fertile grasslands of its prehistoric heyday. De-extinction, advocates argue, is of value because it could help repair ailing ecosystems.

Along the way, think of what could be learned. Bring back the gastric brooding frog; understand how it stopped secreting stomach enzymes in order not to digest its young, and it could lead to new treatments for stomach ulcers. And because the gastric brooding frog was genetically, physiologically and evolutionarily distinct from anything living today, its de-extinction would return not just a twig to the tree of life, but an entire missing limb.

Critically, the same methods being developed to bring back extinct animals — assisted reproduction, stem cell biology and gene editing — can equally be applied to living species that are in trouble. In the U.S., pro-de-extinction outfit Revive and Restore are hoping to use these techniques to save the endangered black-footed ferret, a feisty north American mustelid under threat from disease and inbreeding. Meanwhile, researchers in Europe are developing stem cell science to try to save the northern white rhino, a gentle African giant of which there are just three individuals left. De-extinction isn't just about bringing back the dead, it's about helping the living, too.

Sometimes, science needs its rallying points. Making a mammoth, for example, could be a 'man on the moon' moment for biology, a point of inspiration and wonder for generations to come. It could teach us to value the natural spaces we still have, and instill in us a desire to protect the flora and fauna that live there.

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