De-extinction: The Good, The Bad, and The Unknown

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0. Abstract:

De-extinction is a complicated and divisive topic with potential benefits and drawbacks and a great amount of uncertainty. This essay takes a holistic look at the de-extinction debate, discussing the ways in which de-extinction could help our planet and the species that live here as well as the various risks involved in practicing the discipline. Due to the relatively theoretical nature of current de-extinction literature, this essay emphasises the uncertainty in evaluating the benefits and risks of any one de-extinction project.

Benefits of de-extinction are wide-ranging and potentially revolutionary for the protection of our planet. Environmental and conservation benefits, such as restoring unproductive ecosystems to a more biodiverse state and increasing the ability of conservation biologists to protect endangered species, are often emphasised as primary motivations for de-extinction projects. The scientific knowledge learnt through de-extinction has the potential to revolutionise medical science and more philosophical concepts such as feelings of wonder and justice are also emphasised in the literature as benefits of de-extinction.

De-extinction is not without risk, however. Although environmental and conservation benefit is possible, so is environmental and conservation harm due to the uncertainties involved in introducing a 'new' species into an ecosystem. Poor animal welfare is also of great concern as the de-extinction technology is highly inefficient and the raising of animals in captivity has not yet been perfected. Negative ethical consequences of de-extinction could include moral hazard, biocapitalism, and enhanced biases, and negative public perceptions of genetically modified organisms and scientific interference in nature could reduce acceptance for de-extinction. Finally, there are several conflicts between the goals and actions of de-extinction which may suggest that de-extinction is not a viable discipline, at least currently.

1. Introduction:

As discussed in the first essay in this series – De-extinction: The Science behind the Fiction – de-extinction is a biological discipline that utilises techniques from reproductive science, synthetic biology, and genomics to create an organism that contains traits of an extinct species and can fill the ecological role left by extinction, seemingly resurrecting the extinct species. Unsurprisingly, with such a revolutionary concept comes intense debate over how and whether this technology should be used. Some people are excited by the idea of being able to witness a live woolly mammoth and are optimistic about the ability of the products of de-extinction to transform our environment, reducing the burden of the current environmental crises. Others, however, are less enthusiastic about this new discipline and have cited many reasons for their reservations, from financial and environmental costs to animal welfare concerns and more philosophical questions regarding the ethicality of resurrecting the extinct[1]. This essay will take a holistic view of the de-extinction debate, detailing the potential benefits and drawbacks of the discipline. It should be noted that due to the length of de-extinction programs, with some projects estimating time scales of 100 years or more[2], there is little empirical data available for these programs[3]. This means that much of the literature regarding de-extinction is in the form of modelling and educated opinions. There is therefore a great level of uncertainty regarding how much benefit or harm will be produced through de-extinction and this uncertainty should be kept in mind when reaching personal conclusions regarding this topic.

2. Benefits of De-extinction:

2.1. Environmental Benefits:

Major motivations for de-extinction projects are the possible environmental benefits that may be achieved. The extinction of a single species, especially those that had a large or unique role within an ecosystem, could greatly impact the ecosystem, possibly leading to further extinctions and reductions in the biodiversity and productivity of that ecosystem. Reintroducing these extinct species through de-extinction could reverse the damage caused by the initial extinction, benefiting the environment, other species, and ecosystem as a whole[4]. I will now use a woolly mammoth project to demonstrate how de-extinction may be used for environmental benefit.

2.1.1. Woolly Mammoth:

As discussed in the previous essay in this series, the woolly mammoth could be considered the ‘poster child’ of the de-extinction movement. It is the subject of one of the most well-known de-extinction projects, currently being carried out by Colossal Laboratories[5], and is the foundation of much of the de-extinction literature, including that which concerns itself with the environmental benefits possible from de-extinction.

Before their extinction 3400 years ago[6], woolly mammoths were considered ecosystem engineers as they were capable of directly shaping their Arctic environment in ways other species were not[3]. Through their grazing, mammoths created highly species diverse mosaic grasslands which would have had increased nutrient and water cycling meaning that the ecosystem was more productive and drier than it is today. As they travelled great distances, mammoths were also important in the distribution of seeds and nutrients. Their large size meant that they could trample leaves and knock down trees, reducing the amount of unproductive and species-poor woody forests and preventing fires. Finally, due to their great effect on the environment, mammoths were a strong evolutionary selection pressure, so plants evolved defences such as spines in response to their presence. Given how important mammoths were to their environment, it is not a surprise that the loss of these megaherbivores had a profound impact on the ecosystem and the other species that lived there. Loss of aggressive grazing led to the formation of dense forests and increased fires and coevolved plants began to decline[4, 7, 8]. Furthermore, the highly insulating snow present during the winter was no longer being trampled by the large mammoths, causing the permafrost beneath to warm up and begin to melt[9]. This latter point is incredibly important as the Arctic permafrost contains approximately 1.3 trillion tonnes of carbon. If the melting of the permafrost continues, this carbon will be released into the atmosphere, in the form of carbon dioxide and methane, greatly contributing to global warming which itself is an extinction threat to many species, including humans[2]. This desperate situation has not gone unnoticed however, and scientist across the globe, including those involved in de-extinction, are attempting to halt this cataclysmic event.

Sergey Zimov, a conservationist working in Siberia, has set up Pleistocene Park, a nature reserve with the aim of reverting the Siberian environment back to how it was over 10 000 years ago, before the interference of humans[10]. This is being done through the reintroduction of Arctic herbivores such as bison, elk, reindeer, moose and horses which graze on the mosses and shrubs that have grown since their local extinctions, making way for grasses which are more productive and keep the ground cold in the summer. During the winter, these species remove and trample the snow, exposing the permafrost to the air. These actions have led to the permafrost within Pleistocene Park being an average of 2°C colder than outside[9]. This suggests that the actions of Zimov and his team are working and that the reintroduction of species into Siberia may be an effective way to prevent the melting of the permafrost. These effects have been seen without the reintroduction of the woolly mammoth so de-extinction is likely not necessary for this ecosystem transformation project to succeed, however the size of the mammoth is a unique feature that will likely speed up the project. The ability to knock over trees is one that could be vital for large scale transformation of the Siberian tundra into the more diverse mammoth steppe ecosystem so, although some cooling of the permafrost can be achieved without mammoths, it may be necessary to reintroduce these megaherbivores for a more profound and widespread effect[2].

2.1.2. Challenges:

Although there is certainly cause to be optimistic about the environmental benefit that could be achieved through the de-extinction of species such as the woolly mammoth, there are nevertheless challenges that are important to discuss.

2.1.2.1. Species fill ecosystem gaps:

Although the extinction of a species tends to leave an ecological gap within the ecosystem, it is not inevitable that these gaps will lead to the cascade of ecological destruction as detailed for the woolly mammoth. It is possible that the extinction of some species, even functionally unique and important species such as elephants, will open gaps which will then be filled by other species which adapt to their new ecological role. The likelihood of ecological gaps being filled by other species increases as the time from extinction increases so it may be best to focus de-extinction efforts on recently extinct species that left large gaps within their ecosystem that other species have not filled[2].

2.1.2.2. Environmental changes:

If the ecological gap left by the extinct species is not filled, it is likely that the ecosystem and environment will change considerably after the extinction. This may mean that the extinct species is no longer adapted to the current environment and so de-extinction of that species may not yield the desired outcome as the species can no longer complete its ecological role in its native environment. This may lead to environmental damage, as will be discussed later in this essay, or even re-extinction[11]. In the case of the woolly mammoth, the climatic conditions of modern-day Siberia are similar enough to the late-Pleistocene and early-Holocene that mammoths are expected to be able to survive well[10], however the soil has increased in acidity in the millennia since the mammoth disappeared so whether a grassland ecosystem can be fully revived is unknown[4].

2.1.2.3. Scale:

It is unlikely that a single mammoth would be sufficient to restore Siberia to its previous glory. In fact, it is likely that many individuals will be necessary to have any great effect on the wide expanse of land that constitutes the Arctic. This is the case for most de-extinction-for-environmental-benefit projects and is a major challenge as it is expensive and resource and labour intensive to produce just one de-extinct organism. The production of entire herds of mammoths or flocks of passenger pigeons seems unfeasible at present and, as long as it remains so, projects that rely on the production of many individuals may not be possible. As technology develops and knowledge expands, this problem may become less intense, but it is likely that large scale production of resurrected species may remain difficult for the foreseeable future[4].

2.1.2.4. Alternatives to de-extinction:

As shown in the case of Pleistocene Park, it is possible to achieve environmental benefit through the translocation of local extinct species, instead of through de-extinction. Bison, elk, and other large herbivores were moved from their original habitats outside of Siberia and into Pleistocene Park and have been able to have a great impact on the environment there[10]. This suggests that the translocation of living species with similar ecological functions as extinct species into the habitat once occupied by these extinct species may be sufficient to achieve at least some environmental benefit. This alternative to the de-extinction of the extinct species itself is appealing as it is less expensive, time consuming, and risky. There are some species, however, which cannot be simply replaced by a living species. Elephants, for example, are the only living species that can fill the ecological role of the mammoth, however they cannot survive in the cold, hostile conditions of the Arctic and therefore de-extinction methods are needed to produce cold-resistant elephants that can replace mammoths in their native habitat[12]. Similarly, various attempts to replace the bucardo with other species of ibex have not succeed due to the hostile conditions of the bucardos native habitat. Recently, a new species of ibex seems to be surviving within this habitat, but it may be beneficial to use de-extinction techniques to genetically engineer bucardo genes into this species, increasing the likelihood of success[2].

2.1.2.5. Human conflicts:

If large numbers of a resurrected species were reintroduced into human-occupied areas, there is a chance that conflicts could occur, especially as the purpose of the release of this species is to disrupt the environment and restore the original ecosystem [2, 4]. This will be discussed later in this essay but is mentioned here as public opinion is a major challenge for any de-extinction project.

2.1.2.6. Uncertainty:

As mentioned in the introduction to this essay, the precise effect of releasing de-extinct individuals into the wild is unknown. It is possible that the actual effect may be less pronounced than expected or even might be opposite to what is desired[9]. Robust modelling and simulation may provide more accurate projections but the uncertainty over exactly how reintroduced species will affect the environment will remain until release projects are underway.

2.2. Conservation Benefits:

Along with possible benefits to the environment, de-extinction projects have the potential to bring about benefits for endangered species and the discipline of conservation biology. These benefits can be either direct or indirect.

2.2.1. Direct benefits:

2.2.1.1. Genetic enhancement and recovery:

As discussed in the genetic engineering section of the previous essay, the most feasible method of de-extinction is through editing the genome of living species to resemble extinct species. Although the primary objective of this is, in most cases, to produce an ecological proxy of the extinct species and hence resurrect it, the same technique can be used to conserve and protect endangered species. It may be possible to use de-extinction techniques to insert beneficial genes obtained from extinct species or lineages into living species with the objective to increase the living species chance of survival either in its current habitat or in another one. It is this which motivates George Church who wishes to resurrect certain cold-resistant traits found in mammoths and insert them into Asian elephants. These edited mammoths can then be released into Siberia, increasing the geographical range of the endangered species and so enhancing their ability to survive as well as providing the environmental benefits of a resurrected mammoth as detailed in the previous section[2]. In addition to genetic enhancement, it may be possible to increase the genetic diversity within species by resurrecting extinct species and the diversity that they hold. This would be of great benefit for species with low genetic diversity, such as cheetahs, as it could increase adaptability and decrease the likelihood of inbreeding which can reduce the fitness of the population[12].

2.2.1.2. Cryobanking and Frozen Zoos:

Although de-extinction is commonly considered a backwards-looking discipline, concerned with resurrecting already extinct species, it is possible to freeze cells from endangered species, in anticipation of their extinction. These cells can be stored in 'Frozen Zoos' and can be used to revive currently endangered species, after their extinction[13, 14]. This is a highly controversial application of de-extinction technology with some believing that it is essential to 'back-up' endangered species to have a 'second chance'[13] at conserving them and others seeing this as simply a 'distraction'[15] and not true conservation.

2.2.2. Indirect benefits:

2.2.2.1. Increased interest in conservation:

It is possible that de-extinction could increase awareness and interest in endangered species and habitats. For some species, their native habitat no longer exists or is in such a state of disrepair that it is not able to support them. Due to the costs involved in de-extinction, it is likely that those who fund the initial de-extinction will continue to fund the conservation of the habitat into which the resurrected species would be released. De-extinction therefore has the potential to provide indirect benefits on the environment and other species that live in that environment in the form of funds, interest, and awareness[16].

2.2.2.2. Cheaper technologies:

New technologies tend to be very expensive meaning that they cannot be commonly used in disciplines that are underfunded, such as conservation science. With the development of these technologies, however, comes a decrease in price. Technologies such as genome sequencing and editing can be very useful in conservation science. As previously mentioned, genome editing can be used in genetic recovery and enhancement, and genome sequencing can be used in many ways such as estimating population size, understanding familial relationships to avoid inbreeding, and detecting invasive species[17]. Both genome editing and sequencing are necessary components of most de-extinction projects so, as these techniques are used and developed to resurrect extinct species and traits, their price will continue to fall, and they will become available for use by conservationists.

2.2.2.3. Scientific knowledge:

Just as techniques are developed by de-extinction projects, so is our scientific knowledge, some of which could be useful for conservation. The resurrection of the Gastric-brooding frog and subsequent experimentation may provide answers to why it, and many other species of frog, are susceptible to a fungal disease and pave the way to understanding how to treat the disease, protecting endangered species across the globe[2]. Understanding how to successfully breed Ibex in captivity for cloning reasons could increase the success of captive breeding projects for conservation. Husbandry knowledge collected through the captive care and release of passenger pigeons could be essential for the success of conservation programs for endangered bird species. Ultimately, the knowledge acquired through de-extinction programs is likely to be valuable for the conservation of endangered species and is more likely to be acquired indirectly through de-extinction than directly through conservation programs due to more interest and funds being directed towards de-extinction.

2.2.3. Challenge:

2.2.3.1. Conservationist vs. synthetic biologists:

Apart from the possibility for conservation damage, which will be discussed later, a major challenge for de-extinction-for-conservation-benefit is the animosity between conservationists and synthetic biologists. Many conservationists see de-extinction and synthetic biology in general as a ‘waste of time’[2] and a ‘dramatic side-story’[15] when compared to more traditional conservation methods. They are sceptical of whether de-extinction can be considered an effective conservation strategy and are often averse to the risks and uncertainties that come along with any new technology. There is a distinct lack of communication and cooperation between the two disciplines which must work together to achieve the goals of de-extinction[2]. As long as this separation exists, de-extinction cannot progress, and the conservation benefits highlighted throughout this section cannot be realised.

2.3. Scientific Knowledge and Technological Progress:

The scientific knowledge and technological developments acquired through de-extinction can be used more widely than conservation. Although it does take time for new technology to become accessible to less funded disciplines such as conservation[2], its development in disciplines that are of greater interest to the public and private donors, such as de-extinction, means that development will occur quicker and so the time until the technologies are more widely available should be less.

2.3.1. Human health and medicine:

Human health and medicine can benefit from de-extinction in several ways. Firstly, it is possible that extinct plants may have unique medicinal properties so their resurrection could be highly beneficial[18]. Secondly, the development of embryology techniques[19] and the de-extinction of the Gastric-brooding frog specifically[20] could be useful for humans as it may provide more efficient reproductive techniques and technologies. Next, the stem cell reprogramming required for cloning may be adapted for humans to give rise to regenerative and personalised medicine. Finally, disease modelling may be achieved through genetic engineering and stem cell research, providing more accurate information regarding the timeline and stages of a disease[19].

2.3.2. Environmental sustainability and protection:

Genetic engineering has the potential to increase the sustainability of farming practices as well as producing innovative ways of protecting our planet, for example through the production of plastic eating bacteria[19].

2.4. Aesthetic Value:

An advantage of de-extinction may be its production of aesthetic value in the form of 'awe' or 'wonder'. It is commonly assumed that if an individual were to witness an animal that looks like a woolly mammoth or acts like a passenger pigeon, they would be filled with a great wonder and happiness that would provide personal fulfilment and perhaps increase support for conservation[2, 16, 18, 20]. There are some who believe that the artificiality of de-extinct species negates this aesthetic value[21] and that these feelings of wonder are not sufficient to justify de-extinction if harm is likely to be caused[20]. Nevertheless, the aesthetic value of de-extinct species is possibly the strongest advantage of de-extinction for the public and should be emphasised to increase public support for de-extinction.

2.5. Justice:

The final argument for de-extinction that I will discuss is that of restorative justice. It is believed by some that humans have a moral obligation not to cause the extinction of any species[21] so, in situations where it is believed that humans did cause the extinction of a species, it is our moral duty to resurrect them[16]. However, de-extinction as a form of justice has been challenged in several ways.

2.5.1. Challenges:

2.5.1.1. Do species have rights?

For something to be owed justice for a supposed wrong, it must be something which can have rights in the first place. A generally accepted definition of a 'right-bearer' is something that has 'conscious aims or desires and therefore interests'[21]. Whether a species as a whole has rights is a highly contentious topic with some believing that, as actions may be taken for the 'good of the species' rather than the 'good of the individual' such as in the cause of self-sacrifice for increased species fitness, a species is an entity which can have interests and therefore is deserving of rights[21], and others believing that species are too heterogeneous to be 'goal directed' and hence are not owed rights or justice[22, 23].

2.5.1.2. Do we owe debts to extinct species?

If we agree that species do have rights and deserve justice for wrongs committed against them, does this duty extend to extinct species? Some believe not as they believe that a condition of having interests, and therefore rights which can be impinged, is life. As extinct species are dead, some believe that they do not qualify as having interests and so do not experience being wronged, and therefore cannot be owed justice for these wrongs[23].

2.5.1.3. Who is to blame?

If we do owe a debt of justice to extinct species, who should be held accountable for the wrong of extinction and made to follow through on this debt? As the individuals who caused the extinction are likely no longer alive, the accountability falls on current humans, however this is problematic as is it fair or acceptable to attribute actions committed by long dead humans to those who live today and do not have any direct relation to those who committed the actions? Furthermore, is there a moral difference between extinctions caused by hunting for survival, as would have been the case for the woolly mammoth, and extinctions caused by hunting for sport, as would have been the case for the passenger pigeon? Finally, it may be uncertain whether humans were the sole cause of extinction so there may not be any debt owed in the first place[16].

2.5.1.4. Duties to living species:

As they are currently living and we have a direct effect on their survival, it could be said that we have a greater duty to living species than extinct species. Where there is a choice between funding de-extinction and the conservation of living species, living species should be prioritised[23].

2.5.1.5. Duties to humanity:

It is commonly believed that the highest duty of humanity should be to humanity. Therefore, where there is a choice between using limited resources for the de-extinction of an extinct species or research into the justification of said de-extinction, and the survival of humanity, humanity should be prioritised[16]. It should be noted that de-extinction of culturally or economically significant species could be beneficial to certain human communities so duties to extinct species may not be in opposition to duties to humanity[20].

2.5.2. Alternative to de-extinction:

Due to the various challenges lodged against de-extinction-for-restorative-justice, it may be beneficial to explore alternative options for providing justice to extinct species which do not involve difficult political debates and potential harm to other species. Reparative justice may be given through the reformation of practices to reduce the number of extinctions in the future and through the protection and restoration of ecosystems to reduce the impact of extinction on other species and the environment. Although de-extinction can be used in the carrying out of this latter point, as described earlier in this essay, it is likely unnecessary[22]. Reparative justice is likely to work alongside conservation goals[18] so may be a viable alternative to provide justice to extinct species while also making sure that protections are in place for living species and maintaining relationships with indigenous communities[23].

3. Drawbacks of De-extinction:

3.1. Environmental Harm:

Although a strong motivation for pursuing de-extinction is to provide benefit to the environment, it is also possible that the risks and uncertainties involved in this discipline may inadvertently cause environmental harm. Indeed, a survey concluded that experts believe that de-extinction may cause more damage than benefit to the environment[18].

3.1.1. Invasive species:

When a species is a reintroduced into an environment, even if it is their indigenous habitat, there is a risk that it may become invasive. An invasive species may threaten other species through competition[18] and may generally disrupt already fragile ecosystems, as was seen when starlings were released in North America[2]. As the purpose of de-extinction is usually to disrupt the environment to restore valuable ecological interactions[2], it may be difficult to ensure that resurrected species are able to do their 'job' whilst remaining non-invasive. These problems become more profound when a species is released or spreads into an area that it was not originally native to[11, 24]. These new environments will likely be unprepared for these species and so any disruption to the ecosystem may be more greatly felt. The management of invasive species is developing[2, 26] and 'exit strategies' such as euthanasia are commonly developed within the planning stage of any project[26] so this may become less of a problem in the future.

3.1.2. Increased disease risk:

Another risk associated with de-extinct species is that they may be carriers of disease for both other species within the ecosystem and humans[22, 27]. As there has been no recent coevolution between the de-extinct and other species, any new pathogens brought into an ecosystem may have disastrous consequences for the other species that have not developed defences towards it. Most de-extinction candidate species are unlikely to pose health risks and only those released into the wild will be a general risk to the environment, but this is a factor to be considered when assessing a species suitability for de-extinction. Furthermore, some believe that there is a risk of resurrecting pathogens during the de-extinction process. This is generally not believed to be a substantial issue as it is necessary for pathogen cells to be intact for them to be resurrected, a feat not yet seen[1].

3.1.3. Uncertainty over interactions:

Similar to the risk of invasiveness, the uncertainty regarding the precise interactions the de-extinct species will have with its environment is a major problem with de-extinction. As the behaviour of a resurrected individual will be based on their developmental environment as well as their genes[2], it is likely that a de-extinct species will be different to its extinct counterpart, especially when it comes to learned behaviours and social structures. These differences may lead to the de-extinct species not performing the same ecological function as the extinct form. Furthermore, the habitat, even if it is technically the native environment of the species, is likely to have changed since the extinction. All of this means that the interactions between the de-extinct species and its environment are likely to be different and unexpected[28]. This risks environmental damage and should be assessed in the early stages of project development, though there is likely to always be some uncertainty regarding the environmental interactions of the de-extinct species[1].

3.2. Conservation Harm:

Although de-extinction has the potential to provide benefit to the conservation of endangered species, some people, especially conservation practitioners, believe that the reintroduction of extinct species, or even the research to create them, may damage conservation efforts.

3.2.1. Diverting funds:

One of the most common arguments against de-extinction is that some of the already meagre funding allocated to traditional conservation work may be diverted to the newer and more exciting de-extinction projects. De-extinction research, genetic engineering, reintroduction, and post-release management are all currently extremely expensive[13] and if the funding for these projects comes from conservation budgets it is likely that the ability of conservationists to protect endangered species and environments will be dramatically reduced. However, it is unlikely significant amounts of funding for de-extinction projects will come from conservation budgets. De-extinction projects typically have two phases: a resurrection phase and a release phase. The resurrection phase involves all of the technological research and experimentation required to actually produce de-extinct individuals. The release phase involves the release and maintenance of these individuals in the wild. The resurrection phase is likely to be the most expensive stage of the project due to the time and resources required to develop the technologies and produce a genetically engineered individual. Funding for this phase is likely to come from private donors who have interests in the development of new synthetic biology technologies and the resurrection of extinct species[29]. This is an entirely different demographic to those who fund traditional conservation efforts so, instead of diverting funds, de-extinction is likely to increase conservation funding by attracting new people. The release phase may be less expensive than the resurrection phase due to the techniques and methods being highly developed already, but there is still a need for considerable funds, and it is likely that the release of de-extinct individuals will be more expensive than the reintroduction of living species due to potential long-term management and monitoring and the need to synthetically engineer genetic diversity[13]. It is likely that the funding and resources required to complete the release phase of a de-extinction project will fall on conservationists due to their knowledge and expertise in the field[29]. Therefore, although funding is unlikely to be directly diverted from conservation to produce de-extinct species, it is likely that some compromises will have to be made between the protection of living and de-extinct species in the wild, likely prioritising de-extinct species due to the time, effort, and money that has already been given to them[13].

3.2.2. Diverting attention away from conservation:

The possibility for diverting attention away from conservation comes in several forms. As just mentioned, de-extinct species are likely to be prioritised over living species when it comes to choices over post-release management due to previous investment[13]. The more commonly cited way in which attention may be diverted, however, is through the apparent reversal of extinction reducing the importance of preventing extinction in the eyes of the public and hence reducing interest in conservation efforts. If it is possible to resurrect extinct species, less effort may be exerted to limit the current extinct crisis as any extinctions today can be 'fixed' tomorrow[30]. This is highly problematic as it could cause a reduction in private funding, and possibly even public funding, which will severely limit what conservationists are able to do to protect endangered species. One way to avoid this seeming 'apathy'[30] towards the natural world is to emphasise the fact that no de-extinction technique can produce a 'true de-extinction'[29]. There will always be some differences between the extinct and de-extinct forms and even cloning is not capable of resurrecting a perfect copy of an extinct individual (see De-extinction: The Science behind the Fiction for more information). A final way in which attention may be diverted is in the research laboratory. Some believe that even simply researching de-extinction and the technologies required is a waste of time, resources, and funding which can be better used for traditional conservation research more directly. This can be countered by understanding that most de-extinction projects are 'side-projects' that are funded with whatever money is left after the funding of main projects, usually conservation projects[2]. Additionally, de-extinction technologies have utility outside of de-extinction, as previously discussed, and it is commonly for these other purposes that the technology required for de-extinction is funded and developed[1]. Ultimately, although a valid concern, the diversion of attention away from conservation due to the de-extinction is not an inevitability.

3.2.3. Definition fluidity

With the addition of any new concept to a previously well-understood field comes disruption in the form of how that new concept will fit within the confines of the field. This often leads to the addition or alteration of definitions. Before the development of technologies that could resurrect extinct species, the term 'extinction' was relatively simple to define. A species was declared extinct once all members of that species had died. The declaration of extinction itself was not simple with difficulties making sure that no members of the species were living being of major significance. The definition itself, however, was straightforward and easy to understand and, most importantly, final – once extinct there is no coming back. With the 'invention' of de-extinction, however, this definition has become more confusing. Can a species ever be truly extinct if it is possible to resurrect it? Is the survival of cells in a Frozen Zoo that can be used to produce a fully functioning individual enough to say that a species is not extinct, even if no fully functioning individuals are alive? These questions and more distort what it means for a species to be extinct and endangered which could have catastrophic consequences for conservation. If there is no consensus over how to define extinction, there will be no consensus over the list of species that require protection from extinction. The Red List curated by the International Union for the Conservation of Nature (IUCN) is a list of species thought to be threatened by extinction. It is this list that aids conservation efforts around the world. Any fluidity or distortion of the definition of extinction is likely to complicate the list and hence global conservation efforts. A new term of evolutionarily torpid has been suggested to refer to species that have no living individuals but can be resurrected (i.e. cells exist in Frozen Zoos) with globally extinct referring to cases in which no living individuals or cells exist[3,] but the global acceptance of these terms would require cooperation and communication on a global scale and will also require the redrafting of conservation guidelines, all of which takes time, resources, and money. There does not currently appear to be a consensus over how to define extinction in the era of de-extinction and this does appear to a problem that may cause harm to conservation projects[30, 31].

3.3. Animal Welfare Concerns

Of surprisingly little concern throughout the de-extinction literature is animal welfare. This, in my view, is a mistake and signals to a general apathy towards animal welfare throughout the biological sciences. It is not uncommon for both proponents and detractors of de-extinction to consider the animal welfare risks involved in de-extinction to be similar to those in other research disciplines[22] and thus of little concern and warranting little discussion within the de-extinction debate. Again, I believe this to be in error as the costs and benefits of each practice should be evaluated separately and while some animal suffering may be accepted in some practices if sufficient benefits are likely, the same level of suffering may be deemed unacceptable in other practices if the benefits are less[20]. Animal welfare concerns are raised within three distinct stages of a de-extinction project: cloning, captive rearing, and reintroduction.

3.3.1. Animal welfare concerns with cloning:

As discussed in the previous essay in this series, cloning is an essential part of most de-extinction project but is, at present, highly inefficient and potentially dangerous for both the surrogate mother and the cloned offspring.

3.3.1.1. *Surrogate mother welfare:*

Cloning, especially interspecies cloning which would be the type used for de-extinction, can be incredibly risky for the surrogate mother. I will use the Asian elephant as an example as this is the species that is planned to be used for mammoth cloning and so has been discussed the most in the literature. The highly inefficient nature of cloning means that many embryos are needed to produce a single live clone. This means that many elephants will be required to go through dangerous pregnancies that will likely end in miscarriage[20]. As the Asian elephant is an endangered species, it is likely that there are simply not enough individuals to complete this[2], and even if there were, the possibility of harm in the form of ovarian tumours and the likelihood of a caesarean section being needed to birth the clone makes the use of elephants in this way unethical [16, 20]. Furthermore, as elephants only produce 1 egg approximately every five years, it may be considered unethical to use this egg not to produce more elephants but instead to resurrect the mammoth. It may be theoretically possible to avoid using a surrogate mother altogether using artificial uteri which will allow for the development of a de-extinct clone outside of a body. However, this is not currently feasible, and it is unknown when the technology will become sophisticated enough to develop an embryo to term, completely without the need of a living host[2].

3.3.1.2. Clone welfare:

From the possibly 5-12% of cloning experiments that successfully produce live clones, most of the individuals produced will display chronic health problems and abnormalities possibly leading to premature ageing and death. This appears to be a major animal welfare issue and a strong argument against de-extinction and cloning in general. Is it ethical to produce an animal that is highly likely to live a life of suffering? Furthermore, maternal rejection may occur, especially if the cloned offspring is very different to the surrogate mother, which could lead to social isolation and even poorer outcomes for the offspring[20]. It is likely that, as the technology develops, the success rate of cloning experiments will increase as will the outcomes for the offspring. To develop this technology, however, it is likely that many animals with little chance of a suffering-free life will be born.

3.3.2. Animal welfare concerns with captive rearing:

Due to uncertainties regarding social, behavioural and diet requirements, it is likely that the rearing of de-extinct individuals will be a very challenging stage in any project. It is likely that much trial and error will be involved before the correct rearing techniques are found so any early de-extinct individuals will likely suffer from poor treatment while these techniques are being developed[20]. Furthermore, even if the correct rearing technique is found, it is likely that a captively reared animal will be different to their wild counterparts. It has been observed that the size of organs differs between captive and wild raised animals and captive-raised individuals tend to display different defensive behaviours. Elephants especially survive considerably better in the wild compared to captivity, due in part to their requirements for large social circles. This is particularly problematic for proponents of mammoth de-extinction so it will be necessary to find a way to better raise elephants in captivity before these projects can be successful[1].

3.3.3. Animal welfare concerns with reintroduction:

As only 11% of reintroduction projects are considered successful[20], there are clearly issues in the process of moving individuals from captivity to the wild. It may be that the individuals are not sufficiently prepared for life in the wild and are unable to defend or sustain themselves[2]. If, like elephants, they are unable to thrive when bred in captivity, it is likely that their health will be considerably poorer than their wild-bred counterparts and so their fitness in the wild is likely to be greatly reduced. Additionally, if they do thrive in captivity, they will see a distinct reduction in quality of life when released into the wild which may cause stress or disease, also leading to reduced fitness[20]. Long-term monitoring and management may be necessary to ensure the best outcomes for the de-extinct animals which may divert resources away from other projects leading to welfare issues for other species. It is likely, as with the previous stages, that as techniques are developed and species-specific knowledge is obtained, these welfare concerns will reduce but it may take a great number of generations with many animals destined for poor survival outcomes.

3.4. **Moral Hazard**

A common argument against de-extinction is its potential to become a moral hazard. Moral hazards are defined as actions that have risks that are suffered by anyone other than the one who took the action. In the case of de-extinction, actions taken by people today may have a negative impact on people of the future. As previously discussed, the possibility of resurrecting extinct species may reduce public support for conservation. This is a form of moral hazard as future generations are now responsible for 'fixing' the extinctions that the inaction of today has produced. Furthermore, any reduction in support for conservation today is likely to continue into the future, possibly increasing the environmental biodiversity crisis we are seeing today for future generations, with possibly more dramatic consequences[29].

The mere thought of this new technology is not the only way that de-extinction may become a moral hazard, however. The environmental and conservation harm that de-extinction has the potential to cause will likely cause long-term consequences so it will be the responsibility of future generations to shoulder these burdens and sort them out[29]. Of course, it is not inevitable that such harm will occur, but the uncertainty regarding the long-term consequences of de-extinction has the potential to be perceived as a moral hazard.

Rigorous regulation and in-depth planning of de-extinction may minimise the short- and long-term risks of de-extinction and, as conservation is generally not of high priority to the public, the risk to conservation interest may be less than feared[25]. Nevertheless, discussions on the long-term ethicality of de-extinction are important to have.

3.5. Biocaptialism

A new, but nevertheless important, consideration within the de-extinction debate is that of the commodification of biological materials, such as cells, and their products, such as de-extinct species – biocapitalism. A strong motivation for businesses to become involved in de-extinction is the potential for them to make a lot of money through the patenting of biotechnologies and the de-extinct species themselves, and through the exhibition of these de-extinct species. Although the scientists involved in de-extinction proclaim to be uninterested in this aspect of business[2], the businesspeople heading companies such as Colossal Laboratories are more enthusiastic about the prospect of 'owning' de-extinct species[32]. It is not inevitable that resurrected animals would be eligible for patents but there does appear to be substantial arguments for their eligibility, including their novelty and difference from the original extinct species[33]. The expense of developing de-extinction technologies and carrying out experiments must be funded and the potential for 'ownership' can be highly motivating to those who may fund these projects however, is it ethical to be able to 'own' a species? What may be the future consequences of this? These questions and more are worthy of debate and, as of yet, there are no definitive answers.

Additionally, the ethicality of exhibiting de-extinct species in zoos may be debated. If de-extinct species were made into so-called tourist attractions, great amounts of money could be earned by zoos and local communities[16]. This economic boost could be imperative in persuading local communities to accept de-extinct species and money from tourism could be used to fund the creation of the individuals. Additionally, as detailed previously, animals that survive well in captivity would often see a decrease in quality of life if released into the wild, so keeping these animals in zoos could be better for their health and happiness. However, is resurrection of a species ethical if they are to be kept in zoos? Are the costs of de-extinction justified if environmental and conservation benefits are not achieved? This may be solved by releasing de-extinct species into nature reserves where they can impact the local ecosystem while also being available for tourism[2].

3.6. Enhanced Biases

Throughout this essay I have focussed almost exclusively on the de-extinction of animals. This is due to a bias in the de-extinction literature and research which typically ignores plants, invertebrates, and even marine animals, in favour of large, well-known, and interesting terrestrial vertebrates[30]. This bias is due to three main reasons. Firstly, the list of de-extinction candidate species comes from the list of species known to be extinct. This extinction list is, itself, biased towards species that are easily found, identified, and documented. These species are typically large, physically unique, and terrestrial so the extinction of small invertebrates, similar looking plants, and animals that live in the unexplored seas are often not documented[11]. Secondly, the majority of extinctions that humans have directly caused have been of large and land-based species[4]. If the motivation for de-extinction is justice, it is from this list that candidate species will be selected. Finally, de-extinction requires a great amount of funding and larger, more charismatic species are more able to attract this funding that smaller, less interesting species[11, 16].

Another bias at the heart of de-extinction is a bias towards which species are protected. A fundamental objective of most de-extinction projects is to release a resurrected species into an ecosystem to restore that ecosystem to a more productive state. In doing so, it is highly likely that some individuals will die. This is not considered environmental or conservation harm as this is the planned outcome; the death of some individuals is required for the restoration of ecosystems. There are plans to introduce genetically engineered elephants into Siberia so that they can knock down trees to restore the mammoth steppe ecosystem. This will not just destroy the trees themselves but also disrupt any communities that live there. Plans to clean up large plastic rafts in the North Pacific will destroy a strong ecosystem of invertebrates to produce an environment that can be used by other species. Extinction is an essential aspect of nature, and it is impossible for all species that have ever lived on Earth to exist all at once. This means that, for one species to exist, another must die[32]. Who gets to decide which species should be protected and which should not? In the case of de-extinction, extinct species are prioritised over those currently living. Is this ethical?

3.7. Public Perception:

For de-extinction projects to succeed, the public, especially communities into which the resurrected species will be released, must be supportive. Although the public may benefit from de-extinction in several ways, including economically and through the prevention of environmental collapse, suspicion of new technologies and inconveniences caused by the reintroduction of species may be sufficient to dissuade members of the public from supporting these projects.

3.7.1. Living Modified Organisms:

As genetic engineering techniques will likely be used to create de-extinct species, these species will likely be seen as Living Modified Organisms (LMOs)[34]. The public debate over the benefits and risks of genetically modified organisms (GMOs) has raged for years[29] and this debate is likely to be even fiercer for LMOs due to their more mobile and impactful nature. Concerns over possible environmental and health risks associated with LMOs are not unfounded, as discussed throughout this essay, but various international legislations and local regulations are already in place to regulate LMOs. The IUCN published guidelines on how de-extinction projects should proceed and the risk assessments required for ethical and safe reintroduction[26, 35]. The Convention on Biological Diversity published a protocol on biosafety which, although it wasn't made for de-extinction, could be used to regulate the release of de-extinct species into the wild[34]. This latter Cartagena Protocol has been ratified by 173 of the 198 counties in the world, however the 25 countries that have not approved this protocol includes the United States, Canada, Russia, and Australia[36]. As these four countries are primary 'release areas' for de-extinction projects – specifically the mammoth, passenger pigeon, and thylacine projects – different regulation may be required.

3.7.2. Inconveniences and conflicts:

The public may be less accepting of de-extinct species if they cause inconveniences. For example, it is undeniable that a flock of 1 billion passenger pigeons flying over a city will cause considerable disturbance and inconvenience to the humans that live there. Even if people find this sight fascinating, as Ben Novak believes, the disruption that they cause may outweigh any benefits and so support for their de-extinction may decrease. Additionally, the release of predators near human civilisation may be highly contentious due to fears of harm to humans and livestock[2, 37]. If a de-extinct species become too inconvenient, it is likely to lead to human-animal conflicts reminiscent of the original extinction events[4]. Additionally, to prevent re-extinction, protections will likely need to be put in place prior to the release of de-extinct species, so trading and hunting-for-sport may become tightly regulated, causing economic issues and leading to reduced support for de-extinction.

3.7.3. "Playing God"/ Hubris:

The crime of "playing God" is often one levelled at scientists when they develop new technologies to change aspects of life that were once considered stationary. It relates to the concept of hubris as it is rooted in a fear that we, as humans, do not fully understand the consequences of our actions and therefore should not be taking them[1]. It is these beliefs and emotions that typically determine how somebody will feel or react to a situation so it is necessary to understand that feelings such as hubris may be a primary contributor to somebody's decision to support or not support movements like de-extinction and use this understanding to lead community discussions.

3.7.4. The Authenticity Issue:

Nature is generally valued highly by humans for its positive impact through the reduction of stress and evocation of humility, as well as more abstract concepts such as its wildness and sublimity[2]. As de-extinction involves the release of synthetic, or at least partly synthetic, organisms that exist outside the 'natural order' of nature, the practice of reintroducing resurrected species may devalue nature as the products of de-extinction may not be seen as authentic or 'natural'[23]. There is much disagreement and debate within the literature regarding whether de-extinct species would be eligible for membership of the same species as the extinct form, i.e. whether the de-extinct form is an authentic recreation of the extinct form. Generally, it is believed that a de-extinct species will be different from the extinct species[1] but to what extent and whether this difference is enough to deny it species membership is hotly contested. Whether the fact that humans have a hand in the production of de-extinct species but not in their design is enough to render these organisms unnatural and artificial is also a common debating point[38, 39]. It is beyond the scope of this essay to answer questions on authenticity and naturalness, but it is sufficient to say that some members of the public may see de-extinction as reducing the value of nature and oppose it on these grounds.

3.8. Inherent Contradictions

A final possible argument against de-extinction is the various contradictions at the heart of the movement. De-extinction is not alone in having contradictions between its objectives and its actions as it is possible to find such contradictions in a range of scientific disciplines, but this does not mean that contradictions specific to de-extinction should not be discussed.

3.8.1. Evolutionary distinctiveness vs. need for related species:

For a de-extinction project to be of most use, the species that is resurrected must be functionally and evolutionarily unique. As de-extinction is more costly than the introduction of living species into a new environment, for de-extinction to be justified there must be no living species that can fill the ecological role of the extinct species. This is problematic, however, as the presence of a close living relative is a requirement of all de-extinction methods[1, 11]. It would be very difficult, if not impossible, to find a completely functionally and evolutionarily unique extinct species that has a close enough living relative for de-extinction to be feasible. It is likely that, for this contradiction, feasibility will prevail over justification, with less unique extinct species with close relatives being prioritised, but this adds the question of if a practice is not fully justified, no matter how feasible it is, should it be carried out?

3.8.2. Possible success vs. certainty:

As has been discussed several times throughout this essay, the outcomes and impacts of de-extinction are generally uncertain. It is not known, for example, how a resurrected species will interact with its environment or how the public will react to previously extinct creatures roaming the lands in which they live. These outcomes, although always at some level uncertain, are considerably more predictable if the environment that the de-extinct species will be reintroduced into is similar to the environment the extinct species lived in. This, however, is highly unlikely, especially if a species has been extinct for hundreds or thousands of years. A study of the suitability of North American habitats available for three extinct bird species determined that the most suitable environments for reintroduction, and hence the environments most likely to provide success, are outside the indigenous ranges of the species. If the species were to be reintroduced into their native habitats, there is a high chance that the projects would fail as the environment is not able to adequately support the species. If the species were to be reintroduced into the suitable non-native habitats, the projects would be more likely to succeed but the impacts would be considerably less certain as the interactions between the de-extinct species and their new ecosystem would be unknown[24]. A choice between a higher likelihood of success and a higher amount of certainty may go in either direction, but success may be prioritised due to the costs already incurred in the production of the de-extinct species, given that the uncertainties are minimised as much as possible.

3.8.3. Environmental protection vs. DNA procurement:

As discussed towards the beginning of this essay, a major benefit of the de-extinction of the woolly mammoth is its potential to prevent the melting of the permafrost and therefore protect the world from accelerated climate change as caused by the release of a trillion tonnes of carbon into the atmosphere. For the de-extinction of the woolly mammoth to proceed, however, mammoth DNA must be procured. This DNA must be as undamaged as it is possible for it to be, and the most likely location of this DNA is within bones and hair frozen within the permafrost. To obtain adequate DNA to resurrect the mammoth it is necessary for the permafrost to melt enough to expose the remains, the thing that the de-extinction of the mammoth will try to prevent[40]. It is probable that mammoth remains are held within the upper layers of the permafrost so large-scale thawing is likely not required, but the melting, either natural due to ongoing climate change or manufactured, is still at odds with the objective of the project. Unlike the previous contradictions, there is no choice to be made here, for the environmental protection given by mammoths they must first be produced and to produce them requires environmental destruction. Instead, this contradiction should perhaps signal that alternatives to mammoth de-extinction should be developed to protect the permafrost, alternatives that do not involve the melting of the same permafrost.

3.8.4. Species conservation vs. environmental protection:

The final de-extinction contradiction that I will discuss is one concerning cryobanking. As previously discussed, the storing of living cells within cryobanks or Frozen Zoos is a way in which de-extinction techniques could be used to conserve living species. However, the electrical costs of these cryobanks, and therefore their carbon footprint, is incredibly high. This means that a choice must be made between keeping cells from endangered species frozen for potential resurrection later and protecting the environment from human-induced climate change[40]. In my opinion, the long-term health of the environment should be prioritised over the possibility of resurrecting individual species in the future as it is of benefit to more species across the world and, if the environment has been destroyed, the resurrected species will have nowhere to go. If more sustainable ways of storing cells were developed, this contradiction would become void, but, as it is, this is another way in which de-extinction actions are at odds with its objective and those of conservation and environmentalism in general.

4. Conclusion:

As should have been made clear throughout this essay, de-extinction is a discipline that evokes strong emotions and opinions from scientists and the public alike. To decide whether de-extinction is ‘good’ or ‘bad’, potential environmental, conservation, scientific, aesthetic and ethical benefits must be weighed against potential environmental, conservation, animal, and ethical harm. The word ‘potential’ is important here as the uncertainty of any benefits and drawbacks is a caveat of all de-extinction projects. In my opinion, de-extinction as a concept and discipline is neither good nor bad. The benefits that may be provided by de-extinct species are exciting and there is enough research to be optimistic that at least some of the projected benefits may be realised. On the other hand, the potential harm that could be caused by de-extinction is intimidating. De-extinction has the potential to revolutionise our world if appropriately used, and to destroy it further if not. To maximise the benefits and minimise the drawbacks, it is necessary for rigorous assessments of candidate species to take place before the commencement of any de-extinction project. Every project will be different, and each candidate species will have unique benefits and challenges associated with it. As such, the third and final essay in this series will set out criteria for the selection of de-extinction candidate species and will then assess the suitability of five species currently the focus of active de-extinction projects – the woolly mammoth, the passenger pigeon, the thylacine, the dodo, and the aurochs.

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