

## Should Extinction Be Forever

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Typically the extinction of a species is thought of as an ultimate end by conservation biologists. However, now with the advent of inter-species somatic cell nuclear transfer extinct species can be re-created using a tissue sample from the extinct species and oocytes from a related species. This technology has a long way to go before stable populations of previously extinct species can be created, but we must consider the ethics of re-creating extinct species and the potential consequences of de-extinction, whether positive or negative. Some argue re-creating extinct species could potentially allow for justice for these wronged species and new cultural, research, and ecological value. However, others think this process is too unnatural or hubristic and that it could also detract from conserving extant species and have negative effects on human societies and cultures or ecosystems. Re-creating extinct species may ultimately be an inevitable technological advancement, but we must consider all these issues to make sure de-extinction is pursued in such a way to have net positive effects.

### INTRODUCTION

Typically the extinction of a species is thought of as an ultimate end by conservation biologists; once a species goes extinct failure of conservation efforts cannot be denied. This situation becomes particularly grim considering the current high extinction rate due to human activities. However, species extinctions may be able to be reversed with the advent and progression of cloning technology. But the question remains of whether or not we should attempt to revive extinct species.

De-extinction can be performed by transferring a nucleus from a somatic, or body, cell tissue sample from the extinct species into the egg with the nucleus removed of a related extant, and usually domestic, species (Lanza et al. 2004). The developing embryo can then be implanted into the uterus of a surrogate mother, which is usually the same species as the oocyte donor (Foch et al. 2009). The process of inter-species somatic cell nuclear transfer (iSCNT) could also be applied with a tissue sample from an existing endangered species to create individual organisms in an effort to preserve the species (Piña-Aguilar 2009). Traditional intraspecies cloning could cause accidental deaths of the endangered species due to oocyte removal or pregnancy, and it could be difficult to find surrogate mothers of the endangered species and implant the developing embryos, but iSCNT removes these challenges.

In fact, somatic cells of the gaur bull, a large wild ox on the verge of extinction, were fused with the enucleated oocytes from domestic cows and resulted in the successful production of fetuses (Lanza et al.

2004). The Esfahan mouflon, a species classified by the ICUN as vulnerable, has also been cloned through the process of iSCNT by combining mouflon somatic cell nuclei with domestic sheep oocytes (Hajian et al. 2011). These successes paved the way for trying to revive extinct species.

The bucardo, an extinct wild goat subspecies, was briefly recreated using iSCNT (Folch et al. 2009). Bucardo fibroblasts cryopreserved in skin biopsies were electrofused to enucleated domestic goat oocytes, and then the resulting embryos were cultured and transferred to either Spanish ibex or Spanish ibex and domestic goat hybrid females (Folch et al. 2009). One morphologically normal bucardo female was obtained by caesarean section through this method but died some minutes after birth due to lung defects (Folch et al. 2009). While this attempt at de-extinction was not highly successful, it showed it could be done.

The bucardo very recently went extinct, meaning its DNA has had little time to degrade, but other species that have been extinct for much longer periods of time could also be revived. Scientists were able to extract and culture 25-40 million year old bacterial spores found in the abdomens of extinct bees preserved in amber, thereby reviving this species (Cano and Borucki 1995). An Australian scientist is attempting to revive the thylacine, a dog-like marsupial that went extinct in the 1930s (Archer 2013). These revived species could potentially be useful in scientific research or ecological restoration.

There are serious issues to consider with de-extinction though, and these mainly include the ethics of re-creating any individual organisms, the potential

consequences of introducing populations of re-created species to natural habitats, and the consequences of extinct species re-creation on conservation efforts.

### ETHICAL CONSIDERATIONS

Ethical considerations mostly center on justice for extinct species, the creation of value, the unnaturalness and hubris of recreating extinct species, the ecological consequences of re-introducing revived species, and the potential costs of species re-creation to conservation efforts.

### JUSTICE

Humans have caused over 1200 known extinctions since 1600 and are likely precipitating a sixth mass extinction (Raup 1986). If we can revive extinct species perhaps we have the responsibility to do so as a matter of justice for species wiped out by anthropogenic forces; we could make up for past wrongs by recreating these species (Sandler 2013). However, even if humans did drive a species extinct, the humans alive today are not likely responsible (Cottrell et al. 2013). Can we be held accountable for actions of our ancestors? If not, we are not compelled to re-create extinct species except perhaps of those extinguished in our lifetime.

There is another problem with the justice for extinct species argument. Since species do not have goals or aims, they cannot technically be wronged (Sandler 2013). A species merely exists; this cannot even be said to be a goal. Therefore, it makes no difference to the species if it exists or not and it cannot be wronged by non-existence. The natural world also does not have goals or aims, so it cannot be wronged by the extinction of species (Sandler 2013). The concept of right and wrong is a human construction, and so it cannot be applied to other species and nature, as in nature was wronged by the extinction of species. Humans are a part of nature. Any change we cause may be to the detriment to the Earth as a whole and our own species, but we do not exist outside nature and then impose our will. Things in nature are always changing. The individuals extinguished cannot be given justice by de-extinction because an individual itself could not be revived, even if a clone of it is made (Sandler 2013). Since these extinguished individuals cannot be given justice, restorative justice in which reparation is owed because of wrong done to someone (or something) cannot be provided for extinct species (Sandler 2013). In interpersonal situations in which restorative justice cannot be provided (such as with homicide or slavery), reparative or rehabili-

tative actions are taken to ensure a similar wrong does not occur again, i.e. anti-slavery laws are passed and murderers are isolated from society (Sandler 2013). A reparation and rehabilitation approach could make up for our past wrongs regarding species extinctions; this would entail protecting existing species and preventing more extinctions (Sandler 2013). If de-extinction is not a valuable conservation measure for extant species, de-extinction is not well-justified by the need for justice (Sandler 2013). Humans changed the Earth and ecosystems by prompting species extinctions, and this cannot be undone by recreating the lost species. Thus, true justice cannot be served.

### UNNATURALNESS

Some object to species de-extinction on the grounds that it is too unnatural. De-extinction would require mixing genomic material between individuals of species that could not have hybridized without human intervention (Sandler 2013). The existence of transgenic organisms is not ethically problematic as interspecific hybridization occurs in nature, and it is not ethically problematic that these species would not have come to exist without human intervention since many things would not exist without humans (Sandler 2013). Many of the candidate species for de-extinction would not be extinct without humans. There is only an ethical problem with the physical process of de-extinction if one objects to transgenic biotechnology (Sandler 2013).

### HUBRIS

Some worry that re-creating extinct species is akin to “playing God” and that it represents excessive pride of the human race that could lead to our downfall (Sandler 2013). If we are not careful and release revived species into natural habitats without first studying their ecological roles and niches and how these species might fill new ones upon re-introduction, there could be very detrimental consequences to the environment (Sandler 2013). It would be hubristic to use re-creation of species as a fix in lieu of traditional conservation efforts (Sandler 2013). To assume we know everything about a species and the consequences of its re-creation and re-introduction would be foolish.

Some think transgenic biotechnology endorses the view that we should remake the world to how we like it and that it takes a reductionist stance thereby encouraging viewing ecological systems as only existing to fulfill human needs (Sandler 2013). However, many proponents of de-extinction emphasize the value of species and want to pursue it for ecological restoration (Sandler 2013). There

is no evidence that de-extinction will cause people to value nature less or want to engineer ecological systems to fit their needs (Sandler 2013). It would be hubristic to try to control ecosystems and manipulate them to suit our exact needs, but this is not the goal generally of proponents of de-extinction.

### CREATING VALUE

Another reason suggested for why extinct species should be revived is the re-creation of lost historical and cultural value to human communities (Sandler 2013). However, these relationships probably began to change as species' numbers dwindled and undoubtedly changed with the extinction of the species (Sandler 2013). The lost value cannot simply be re-discovered since the species will enter a changed world (Sandler 2013). There may be some remnants of this cultural value still left, but we cannot expect to return to a previous state with de-extinction.

However, perhaps reviving extinct species could create new value (Sandler 2013). There is scientific value in de-extinction; re-created organisms could be used in novel and innovative scientific research. This was the primary reason for reviving the ancient bacterial species from amber and a large motivator behind the thylacine recreation program since the thylacine was a unique carnivorous marsupial (Archer 2013).

Reviving extinct species could also create new cultural value. Revived species could create revenue through nature-based tourism (Seddon et al. 2014), and this could help create positive associations with the species and lead to value of the species beyond economic incentives. Some human communities may welcome revived species for the prospect of tourism or for some lingering cultural value from when the species existed, but communities may not welcome the re-introduction of certain species, such as predators that can affect livestock (Seddon et al. 2014). Released species can threaten human safety or livelihoods and can indirectly affect ecosystem services important to human societies (Seddon et al. 2014). Re-introduction success can be dependent on support by the local community, especially when there is culture, economic or human health significance (Seddon et al. 2014), so the potential effects to local human communities and responses of community members need to be considered with species revival. De-extinction has the potential to create new cultural value, but it could also deleteriously affect human communities.

From a utilitarian view, re-creating extinct species could be ethical if makes more people happy than not

re-creating species (Cottrell et al. 2013). Reviving extinct species could make the creators happy about their accomplishments, project donors happy about accomplishments they funded, tourists happy to see these extinct organisms, and community members happy to support the species and receive economic benefits from tourism (Cottrell et al. 2013). If recreated species are kept in zoos, there is no damage to ecosystems, except that of constructing and maintaining the zoos, and the money re-created species bring to zoos could help them improve or provide money for research (Cottrell et al. 2013). However, re-creating extinct species may not lead to more happiness for more people if there is too much opposition, either from people outside the local community that object on moral grounds or from local community members that object on practical grounds, or if there are negative ecological consequences or negative consequences to conservation efforts, which would have a deleterious impact on human economies and societies.

### ECOLOGICAL CONCERNS OF RE-INTRODUCTION

The revival of extinct species could be used in ecological restoration via the re-introduction of these species so their ecosystem functions could be reestablished. This would be an attempt to re-create lost value in ecological communities, and there could be positive and negative consequences of re-introducing revived species into natural habitats. These ecological consequences can then affect human societies.

Re-introducing revived species may help return some lost vital ecosystem functions thereby increasing biodiversity and ecosystem health and sustainability, but it may be hard to predict the impact of introducing these species to ecosystems. During the absence of these species, ecosystems may have changed and different species could have evolved or moved in to fill the niche of the extinct species. This could mean the revived species could be competitively excluded, and the costs of introduction would have been a waste. Community structure changes along with significant climatic changes since the extinction event could also prompt the revived species to spread away from its area of re-introduction in an unexpected manner. Thus, re-introducing a previously extinct species could potentially disrupt newfound ecological balance in the target area or have detrimental effects through the spread to non-target ecosystems. If the prey or plant matter a revived animal species consumed is no longer present, they will have to turn to other food sources. An adequate food source may not be available, dooming

the species to another extinction, or the re-created species could have a negative impact on ecosystems through predation, herbivory, or competition. The more time since extinction of the species and the greater the habitat changes in its indigenous range, the greater the uncertainty concerning possible ecological risks (Seddon et al. 2014). As stated by P.J. Seddon and colleagues, “spatial and temporal change means that former distribution does not imply current suitability, past absence does not imply current unsuitability, and current suitability does not imply future suitability.”

For example, the discovery of mammoth remains with intact DNA has science buzzing about the possibility of reviving this species, but there would be important ecological consequences of its re-introduction (Mueller 2009). These animals lived long ago, so their natural habitat no longer exists, and re-introduction will not reestablish their former ecosystem (Cottrell et al. 2013). Woolly mammoths ate about 181 kg of grass and sedge per day, so current ecosystems may not be able to support this and could be seriously harmed by this re-introduction (Lister and Bahn 2007). Mammoth introduction could change ecosystem dynamics causing extinction or threat of other species (Cottrell et al. 2013). One consolation to this grim scenario is that mammoths did not have a high reproduction rate, like many other mammalian de-extinction candidate species, and therefore would be unlikely to spread rapidly like an invasive species (Sandler 2013). Mammoths could have some positive ecological effects by providing lost services, but due to ecological changes and consequent uncertainty and risk associated with their re-introduction, they do not seem to be a suitable candidate for this.

In order to prevent extensive damage to ecosystems, some have suggested engineering revived extinct species so that they could be easily eradicated from natural habitats if necessary (Kumar 2012). However, this carries the danger that these species could interbreed with native species and cause them to be wiped out as well if the harbinger of eradication needs to be released. However it is done, a removal plan needs to be formulated in case of unexpected negative consequences of the re-introduction of re-created species (Seddon et al. 2014). This is essential, and if it would be too problematic to remove or destroy the free ranging organisms, then re-introduction of the revived species should not be pursued (Seddon et al. 2014). This removal plan becomes particularly important since the process of re-creation is likely to take place far from the re-introduction site of the species and there is

consequently a risk of parasite or pathogen introduction from this source (Seddon et al. 2014).

The considerations of reviving extinct species for the purpose of re-introduction are similar to the considerations underlying translocations of extant species to areas from which they were lost. Thus, the IUCN Guidelines on Reintroductions and Other Conservation Translocations used for extant species can be used to help determine which extinct species are the best candidates for revival (Seddon et al. 2014). Applying these guidelines would act as a “first-cut” exercise to eliminate unsuitable extinct species and would set up a more in-depth evaluation of likely candidate species for de-extinction and ecological restoration (Seddon et al. 2014). When reviving and re-introducing extinct species for the purpose of ecological restoration, the timeline must be considered. How long ago did the species exist? What time period are we trying to restore the ecosystem to?

Also for ecological restoration, exotic species introductions have sometimes been proposed so these species can provide essential ecosystem services or species interactions lost with extinctions. In an effort to restore ecosystem services lost with the extinction of North American megafauna 13,000 years ago, some have even suggested introducing large mammals from other continents as proxies (Donlan, 2005). However, this idea of introducing exotic species with the explicit purpose of providing lost ecosystem functions and the idea of reviving and re-introducing extinct species may often be at odds. Why bother re-creating an extinct species for re-introduction to natural habitats when a suitable extant proxy can be found? On the other hand, why try to find an inferior proxy for an extinct species when the actual extinct species can be re-created? Reviving an extinct species for re-introduction will likely be much more costly than introducing an exotic extant proxy, but re-introducing an extinct species may be less likely to have negative unintended consequences since that species used to be in the ecosystem. Some extinct species may not be able to be revived, so a functional proxy would be the only option for trying to restore ecosystem function, but for other extinct species a functional proxy may not exist, so revival would be the only option (Seddon et al. 2014). However, re-created species may not even be perfect replacements for themselves in the past.

#### DISSIMILARITY

Containing the same DNA does not mean the revived species will in actuality be the same and fill the

same ecological role as previously. The original context in which extinct species were found may be gone, depending in part on how long ago the species went extinct (Sandler 2013), so even if the species is genetically identical it will not fill the same role. Phenotypic plasticity could make re-introduced revived species different in their behaviors and ecological roles. Additionally, iSCNT means the re-created species would be transgenic with the cytoplasmic DNA of a different extant species, and these differences could also have ecological consequences (Sandler 2013). Since re-created species could be considered genetically modified organisms, they may be subject to more stringent regulations about transport, importation, and release (Seddon et al. 2014).

### CONSERVATION CONCERNS

Reviving extinct species could exist as a last resort conservation effort to prevent the permanent loss of biodiversity. However, it does not address the underlying problem of why species are going extinct and could even detract from this issue (Sandler 2013). If the problems causing extinctions are not resolved, a revived species re-introduced to natural habitats may be doomed to another extinction. In order for an extinct species to be a good candidate for re-introduction to natural habitats, the cause of its extinction must be known and have been mitigated (Seddon et al. 2014). Traditional conservation efforts and re-creating extinct species may not compete for the same funds, particularly if money comes from private citizens (Cottrell et al. 2013). But if they do, efforts to revive extinct species could have negative consequences for conservation efforts aimed at protecting extant species, and this would be unethical. However, re-introducing a revived species to an ecosystem could make that ecosystem more of a focal point for conservation, thereby aiding in conservation efforts. For some extinct species the closest extant relative that would need to be used in iSCNT may be endangered or threatened. For example, the Asian elephant is the closest living relative of the mammoth, so efforts to revive the mammoth would probably require oocyte removal from Asian elephants and using Asian elephants as surrogate mothers (Piña-Aguilar 2009). The Asian elephant is already endangered, so this would be unethical.

Additionally, reviving an extinct species would be creating an endangered species that does not currently exist (Cottrell et al. 2013). Legally, these species would require protection, and it would be morally unacceptable for resources dedicated to the protection and maintenance of a

species that does not currently exist to exceed those dedicated to extant species, especially if the revived species is not being introduced to natural habitats for the purpose of ecological enrichment (Cottrell et al. 2013). If we start re-creating extinct species, laws would need to be made to prevent resources for traditional conservation from being funneled excessively into the creation, maintenance, and protection of revived species (Cottrell et al. 2013).

Using de-extinction as a back-up plan may make us less willing to implement conservation efforts to save endangered species. The mindset that we can always go back and revive any species as long as we have a DNA sample may cause further deterioration of habitats, ecosystems, and biodiversity. Bottom-line, we cannot let the re-creation of extinct species detract from conservation of existing ones.

### FEASIBILITY

Currently, there has been very modest success in iSCNT, so it does not seem feasible to recreate whole populations of extinction species for re-introductions. The cost of cloning a dog or cat averages at \$50,000 USD, and cloned livestock can cost from \$4,000-\$15,000 (Flock 2012;Plume 2009). The cost of cloning a single individual from a tissue sample from an extinct species could conceivably be even higher, making re-creating entire populations incredibly expensive. Genetic diversity within recreated, introduced populations could also be a major problem. A population with very little genetic diversity will not be viable for a long period of time. There will have to either be a great number of tissue samples from an extinct species in order to be able to create a population with genetic diversity or a way to artificially create genetic diversity within populations for re-introductions of revived species to work. The most cloning success has been in mammals, so other taxa may have longer to wait (Cottrell et al. 2013).

### CONCLUSION

Ethical reasons against re-creating extinct species such as its unnaturalness or that it represents hubris of humans are not convincing enough to halt this line of research. Justice for extinct species is not an incredibly compelling reason to pursue de-extinction, but the possibilities of using re-created species in research or to provide important ecological functions are exciting. However, there are a couple problems with the idea of re-introducing revived species to natural habitats.

First, the idea that an ecosystem is incomplete or

doomed without a particular species can be fallacious. There are species that are important to ecosystem functioning and that when removed a net decline in biodiversity results, and in some cases re-introducing an extinct, or at least missing, species may be important to restoring ecosystem health. For example, when gray wolves, an extant species, were re-introduced to Yellowstone where they historically lived, ecosystems flourished (Chadwick 2010). However, ecosystems are not static. Ecosystems and the species within them adapt and change with changing conditions. It is too simplistic to think of an ecosystem as existing in one state and that if altered it enters a particular damaged state until the problem is fixed. The ecosystem could enter a dangerous cycle toward deterioration, but ecosystems respond to species extinctions and thus may not be doomed to deterioration and speciation could in time create more species. We should take care of ecosystems and minimize the damage done to them, but we can also embrace their dynamic nature. If introducing revived species to natural habitats becomes feasible we would need to take a species specific approach and not blindly endorse re-introduction of all extinct species, or even re-introduction of all species that went extinct due to anthropogenic causes. We need to consider the risks and uncertainties of re-introducing a revived species, but also the potential benefits to ecosystems and humans to identify the best candidate species for revival and re-introduction. Species that recently went extinct may generally be more justifiably re-created than those that went extinct long ago.

The second major problem with reviving extinct species is that it may cause us to pursue conservation of extant species with less rigor and attention. We need to make conserving extant species more of a priority than reviving and re-introducing extinct ones, and if reviving extinct species detracts from conserving extant ones that would be unethical.

Currently reviving extinct species is not feasible for purposes of species re-introductions, but it may be for creating a few individuals for scientific study. I think species re-creation is an avenue that should continue to be explored, mainly for the research value currently. Interspecies somatic cell nuclear transfer, along with use for de-extinction of species, has potential to be used in the conservation of endangered species, especially if other reproductive technologies are not useful to conserving a particular species because of its biological characteristics (Piña-Aguilar 2009). I do agree with Seddon and colleagues that technological improvement to allow the

resurrection of extinct species for re-introduction at some future point is probably inevitable. We need to make informed, reasonable, and cautious decisions about candidate species for de-extinction and consider their potential effects on ecosystems, human societies, and conservation efforts of extant species for when technology reaches this point.

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