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A case for resurrecting lost species. Review Essay of Beth Shapiro's, "How to Clone a Mammoth: The Science of De-extinction"

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The title of Beth Shapiro's 'How to Clone a Mammoth' contains an implicature: it suggests that it is indeed *possible* to clone a mammoth, to bring extinct species back from the dead. But in fact Shapiro both denies this is possible, and denies there would be good reason to do it even if it were possible. The de-extinct 'mammoths' she speaks of are merely ecological *proxies* for mammoths—elephants re-engineered for cold-tolerance by the addition to their genomes of a few mammoth genes. Shapiro's denial that genuine species de-extinction is possible is based on her assumption that the resurrected organisms would need to be *perfectly indistinguishable* from the creatures that died out. In this article I use the example of an extinct New Zealand wattlebird, the *huia*, to argue that there are compelling reasons to resurrect certain species if it can be done. I then argue that synthetically created organisms needn't be perfectly indistinguishable from their genetic forebears in order for species de-extinction to be successful.

Keywords
De-extinction; Species; Authenticity; Facilitated Adaptation; Huia

1. Introduction

The general idea behind de-extinction needs little introduction thanks to the *Jurassic Park* movies. Genes recovered from remnants of dead organisms are pasted into the genomes of living organisms. The aim is to resurrect extinct genes and traits, or—as in *Jurassic Park*—resurrect extinct species in their entirety.

De-extinction has arguably already passed from science fiction to science fact, with the first semi-successful (very brief) species de-extinction—involving the Pyrenean ibex—taking place in 2009. The paleogenticist, Beth Shapiro, describes the current technological state of play in her book, *How to Clone a Mammoth: The Science of De-extinction (Princeton University Press, 2015)*. The book outlines numerous issues to be addressed and impediments to be circumvented at each step of the de-extinction process.

From a philosophical perspective perhaps the book's most interesting element is Shapiro's stance regarding how de-extinction technology can and should be applied *for the purposes of wildlife conservation*. Shapiro mentions the following four potential applications (although without clearly distinguishing A1 and A2 from A3):

A1. Combatting inbreeding depression in a genetically depauperate species by inserting extinct genes from remnants of dead members of *the same* species.

A2. Genetically fortifying a species against some threat (e.g., disease, habitat loss, pollution, or climate change) by inserting genes from a *different* (potentially extinct) donor species. This is known as 'facilitated adaptation' (Thomas et al. 2013).

A3. Creating a proxy for an extinct keystone species by inserting some of its genes into a living relative of that species, with the aim of restoring or resurrecting *an entire ecosystem*.

A4. Resurrecting an extinct species.

A1—A4 are ordered in terms of how radical the proposed intervention is. A1 involves only the *intraspecies* gene-transfer. A2 instead involves the *interspecies* gene-transfer and the creation of a genetic hybrid, with the aim of protecting the recipient species from a threat. A3 is similar to A2 in involving interspecies gene-transfer, but its primary goal is the deliberate introduction of a genetically modified organism into an ecosystem in order to re-engineer the ecosystem itself. Whereas A1—A3 each involve only de-extinction of *genes*, A4 involves the wholesale de-extinction of *species*—i.e., of entire *genomes*. The following versions of A4 can be distinguished:

A4a: Resurrecting a species humans *didn't* drive to extinction.
A4b: Resurrecting a species humans *did* drive to extinction.

A4i: Resurrecting a species that underwent *unmanaged* extinction.
A4ii: Resurrecting a species that underwent *managed* extinction.

Here a 'managed extinction' is an extinction that takes place *after* deliberate preparatory groundwork has been laid for subsequent de-extinction (including, say, the cryopreservation of genetically diverse live tissue samples).

Because humans are implicated in virtually all extinctions recent enough for usable DNA to still exist, prospective species de-extinctions will, with rare exceptions, be of types A4bi or A4bii, not A4ai or A4aii.

The following desiderata would need to be satisfied by any successful de-extinction project:

1. At some time, t_1, there was an ancestral population of organisms, P_a.

2. At some later time, t_2, there was no population of organisms standing in the 'same species' relationship to P_a.
3. At a yet later time, t_3, a new population of organisms, P_b, is created synthetically, such that P_a and P_b stand in a 'same species' relation to each other.

What is the 'same species' relation? What conditions is it necessary and sufficient for P_a and P_b to satisfy in order for them to be two populations of one species? This is a vexed question because the term 'species' is notoriously ambiguous. It is used to express at least twenty six distinct concepts within sub-fields of biology (Wilkins 2009; Hausdorf 2011), and it is *prima facie* possible that it is being used to express yet another (twenty-seventh) concept in the context of species de-extinction. Hence we can't resolve what the 'same species' relation consists in by just consulting a dictionary. But *whatever* it might consist in, it is clear for *some* salient sense of the expression 'the same species', P_a and P_b must indeed be of *the same species* in order for a species de-extinction project to be successful. Otherwise we would not, in creating P_b, have *resurrected P_a's species*.

Shapiro says little about A1 and A2, but endorses them both (pp. 9 & 205-206). Her focus is A3. She holds A3 to be the most valuable potential conservation application of de-extinction technology. Her primary example is a plan, already underway, to paste a small number of mammoth genes into the genome of the Asian elephant, in order to create a cold-tolerant elephant (perhaps with a woolly coat and haemoglobin that conveys oxygen efficiently at low blood temperature) adapted for life in the mammoth's former stamping ground. This plan combines aspects of A2 and A3. Where A2 is concerned, one major beneficiary would be the elephant itself, since the re-engineered elephants would be able to range into regions sparsely inhabited by people. Where A3 is concerned, the re-engineered elephants could perform important ecological roles in the arctic tundra formerly performed by creatures like mammoths and woolly rhinoceroses. In Shapiro's words, elephants would 'no longer be isolated to declining habitat in the Old World. Instead, they would be free to wander in the open spaces of Siberia, Alaska, and Northern Europe, restoring to these places all of the benefits of a large dynamic herbivore that have been missing for eight thousand years' (p. 207).

Whereas Shapiro is supportive of A1 and A2 and an earnest advocate of A3, she strenuously opposes A4 (including, I take it, A4bii). She doesn't think de-extinction technology *can* or *should* be used to resurrect extinct species. Her opposition to A4 is based on the following rationales:

S1. P_a and P_b will not stand in this 'same-species' relation to each other unless the following condition is met:

> *100% condition:* The organisms in P_a and P_b are 100% genetically, physiologically and behaviorally indistinguishable from each other.

S2. It will almost certainly never be technically possible to satisfy the 100% condition.

S3. Even if it were technically possible to resurrect an extinct species, which it isn't because of S1 and S2, there would be no compelling conservation-based reason to do so.

S1—S3 are framed in my words, not Shapiro's, but I believe they accurately summarize sentiments Shapiro expresses in passages like these:

> Extinct species are gone forever. We will never bring something back that is 100 percent identical—physiologically, genetically, and behaviorally identical—to a species that is no longer alive. (p. 10)

> The product of de-extinction won't be the same thing as the original species... Crucially however, *I don't care* that it's not the same thing as the original... The task ahead is not to make perfect replicas of species that were once alive. First, it is technically not possible to do so and is unlikley ever to be technically possible to do so. Second, there is no compelling reason to make perfect replicas of extinct species. (p. 205, her italics)

> In my mind, it is ecological resurrection, and not species resurrection, that is the real value of de-extinction. We should think of de-extinction not in terms of *which life form* we will bring back, but *what ecological interactions* we would like to see restored. (p. 131, her italics)

I am sympathetic to Shapiro's claim that A3 is an especially valuable prospective application of de-extinction technology. A3 differs from A1, A2, and A4 by promising an especially big conservation 'bang' for each de-extinction buck. It potentially involves transferring only a few well-chosen genes, yet could help restore entire lost ecosystems, benefitting innumerable species. But, while I agree with Shapiro that A3 may be de-extinction's 'killer app' in the short to medium term, I think: (i) that she is wrong to dismiss A4 as lacking conservation value; and (ii) that S1—S3 provide a flawed rationale for dismissing it. My own view is that A4, and especially A4bii, is liable to be of immense conservation value in the long (and very long) term, by enabling the recovery of some small but precious fraction of the innumerable species that will

be lost to anthropogenic causes like climate change over coming decades and centuries.

The remainder of this paper is dedicated to critiquing Shapiro's position. Since Shapiro is the paleogeneticist while I am the philosopher, and since S2 is an empirical claim concerning limitations of de-extinction technology, I bow to her judgment where S2 is concerned. I focus instead on refuting S1 and S3. In doing this I use the prospective de-extinction of an extinct New Zealand wattlebird species, the huia (*Heteralocha acutirostris*), as an example. §2 describes why the huia is a good technical candidate for de-extinction, and why—contrary to S3—there are compelling conservation-based reasons to resurrect it. §3 argues—contrary to S1—that such a resurrection could count as being successful even if the 100% condition were not met. §4 briefly considers the nature of the 'same species' relation. §5 wraps things up.

Before I start, some caveats. In arguing for the conservation value of species de-extinction (i.e., A4) I am not suggesting that existing, inadequate conservation resources be diverted to species de-extinction. Where species de-extinction is concerned conservationists have a rare luxury—all the time in the world. The strategy, in almost all cases, should be to freeze sources of extinct genes to stop DNA degradation (which is inexorable at room temperature), and then revive the species only *if and when* de-extinction becomes sufficiently inexpensive or resources become available (Ryder et al. 2000; Crist 2008).

Nor am I suggesting that de-extinction offers a sensible alternative to preventing extinctions occurring in the first place, or a technological 'quick fix' to the looming Holocene mass-extinction event. Only species with unusual combinations of attributes are plausible candidates for de-extinction in the first place (Seddon, Moehrenschlager, and Ewen 2014), and in the rare cases when de-extinction is technically feasible 'starting from zero' will almost always be immensely more problematic and difficult than starting from an intact breeding population, however small it might be.

Finally, if I am right then—*contra* Shapiro—there are compelling reasons to make some species, like the huia, de-extinct, but it remains possible that these reasons, compelling though they are, are offset *by even more compelling reasons not to* (e.g., reasons involving moral hazard or unexpected environmental impacts). Any decision whether to resurrect species must be based on a thorough-going cost-benefit analysis far beyond the scope of this article.

2. The huia as a candidate for de-extinction

It is difficult to argue convincingly for species de-extinction in wholly abstract, hypothetical terms. The details matter, and details emerge only in the context of real-life examples. The example I will work with is that of the huia, a New Zealand bird driven to extinction about a hundred years ago (the date is uncertain) by Victorian and Edwardian collectors, habitat loss, and introduced mammalian predators. The huia appears a remarkably good candidate for de-extinction both because of its very great aesthetic and cultural value (of which more shortly) and for the following technical reasons:

1. *Genetic material.* Huia were shot in their thousands by collectors for their skins and feathers, which are now held in large numbers by museums around the world. For this reason the chances of the huia's genome and genetic diversity being recoverable appear relatively good.[1]
2. *Habitat.* New Zealand has numerous predator-free 'mainland islands' and offshore islands where de-extinct huia could be released and would likely flourish (as demonstrated by many successful translocations of endangered birds into the same places).
3. *Animal husbandry.* Huia were extremely confiding birds and easily kept in captivity, as would be necessary in the early stages of a de-extinction project (Buller 1888, 9–14). Moreover, conservationists have considerable experience in the captive rearing of closely related species (kokako, and saddleback).
4. *Ease of containment.* Huia were (like kokako) incapable of sustained flight. Hence populations of transgenic huia could easily be kept geographically contained as required.
5. *Founder group size.* Huia pair-bonded for life. This increases effective population size, reduces genetic drift and means only a relatively small founder group is required to create a genetically healthy population (Miller et al. 2009).
6. *Genome size.* Birds have significantly smaller genomes than mammals and reptiles, easing genome-reconstruction.
7. *Technique.* Birds are amenable to de-extinction via *primordial germ cell transplantation* (PGCT), a technique much more efficient than cloning (Shapiro 2015, 81 & 153–158). As applied to huia, it might proceed roughly as follows. Huia genes would be inserted in place of kokako genes in living kokako cells. These cells would be transformed into primordial germ cells, then injected into the bloodstreams of fetal chickens. The

[1] Unfortunately skins were usually preserved using formalin, which damages DNA and complicates the task of reconstructing the genome. But see (Lambert et al. 2009).

chimeric chickens thus produced would be allowed to mature and breed with other such chickens. 'Huia' would hatch from the resulting eggs.

Why resurrect huia? It might be suggested it should be done to salve our guilty consciences, or to pay a debt of restorative justice we owe the huia because we exterminated them (Crist 2008; Sherkow and Greely 2013; Cohen 2014). Arguably these are not good reasons. As noted by Sandler (2013), we can't owe a debt of restorative justice *to a species* since species are not intentional agents. Nor can we owe such a debt to individual huia, since presently none exist. Moreover, as many have pointed out, it is not obvious that there is generally anything morally wrong in one species causing the extinction of another (such extinctions being regular and inevitable events in natural history), or any reason why we should feel guilty for our ancestors' extirpation of other species (a child not being guilty of her parent's crimes). Nor, as Shapiro notes (2015, 26), is it obvious that our guilty feelings, if justified, would provide good reason to bring species back from the dead.

But if *some* reasons for resurrecting the huia are bad, it nowise follows that *all* are. An obvious reason to stop a species going extinct in the first place is *because we don't want to lose something that is valuable to us*. This suggests, by extension, that a reason to resurrect an extinct species might be *to recover something of value to us that has been lost already*. On this way of thinking about de-extinction, the aim is not so much to undo a crime *we* committed against *an extinct species*, as to undo a crime *previous generations of people* committed against *us and future generations* by exterminating a species we would greatly value if it still existed. This is, I think, a compelling reason to resurrect huia.

In what respects were huia of value? Huia were the most sexually dimorphic of any bird species on Earth, with males and females having beaks of radically different lengths and shapes specialized for different modes of feeding. On a plausible theory of how biodiversity is to be measured (Maclaurin and Sterelny 2008), huia made an outsized contribution to the Earth's biodiversity because of this phenotypic uniqueness.

Huia were also of enormous value as a *cultural treasure* to the Māori. The Māori considered them the most sacred (*tapu*) of all New Zealand's fauna, with, for example, the wearing of huia feathers and skins being reserved for chiefs of the highest status. (This played an unfortunate part in their demise. A European fashion for wearing huia feathers in hats began when, as a token of respect, a Māori guide placed a huia tail-feather in the hatband of the visiting Duke of York, soon to be King George V. The species was then quickly

decimated.) The huia were central to the identity of the Ngati huia, who were custodians of much of the forest to which huia were confined. The huia's extinction was a shocking cultural loss for the Ngati huia. When the huia's de-extinction was first mooted in the 1990's the plan gained the tribe's backing.

Yet another reason why huia were of value—and it is this reason I will focus on—is because of their capacity to help stimulate and foster human aesthetic enjoyment and appreciation of New Zealand's wilderness. Huia were, by all accounts, extraordinarily beautiful and charismatic creatures. The deep impression they made on early European settlers is apparent in the many roads, schools, and geographical features named after them, in the fervor with which collectors hunted them, and in passages like these from the writings of avid collector, Sir Walter Buller (a major historical source of information about huia):

> a pair of Huia, without uttering a sound, appeared in a tree overhead, and as they were caressing each other with their beautiful bills, a charge of No. 6 brought them both to the ground together. The incident was rather touching and I felt almost glad that the shot was not mine... (Buller 1888, 13)

> In a few seconds, without sound or warning of any kind, a Huia came bounding along, almost tumbling, through the close foliage of the pukapuka, and presented himself to view at such close range that it was impossible to fire. This gave me an opportunity of watching this beautiful bird and marking his noble bearing, if I may so express it, before I shot him. (ibid.)

Due in part to the absence of indigenous land mammals in New Zealand, native birds—and especially beautiful, charismatic and confiding birds—are the 'stars' of the New Zealand bush. Their existence is a great part of the reason why humans enjoy and appreciate the bush, and thus cherish and protect it. Were any of the most charismatic of the bird species—e.g., the fantail, tui, or kereru—to go extinct, it would be universally deemed a tragic loss, and not just for the species in question but also for present and future generations of New Zealanders. The loss of the huia was plausibly a tragedy of even greater magnitude, for huia were arguably the most beautiful and charismatic of all the New Zealand birds—the greatest of the 'stars'. Wonderful though it still is, the New Zealand bush is, thanks in part to the loss of the huia (along with many other remarkable species), very much less wonderful than it used to be. The extermination of the huia is in this respect comparable to the destruction of a beautiful natural or historical landmark or monument (Norton 1986, 108–109). It was (to modern eyes) an act of barbaric environmental vandalism that has

harmed us and future generations by 'detracting from the quality of human experience as a whole' (ibid., 109). In doing this it has also indirectly harmed other, less charismatic species by reducing our incentive to value and protect their habitat.

Imagine the following hypothetical scenario. Conservationists carefully survey a remote New Zealand valley and—miraculously!—discover a tiny, remnant population of huia still clinging to survival. An urgent and successful recovery program is launched, with the result that decades later huia are again widespread. People can once more know the delight of encountering these birds, providing a further, powerful reason to love, protect and regrow the bush. A major conservationist victory is thereby won.

Probably the victory cannot be won this way, it being most unlikely that any remnant population of huia still exists.[2] But—and this is the crucial point—*de-extinction promises an alternative way of securing the same, very valuable outcome*. This being so, and contrary to what Shapiro says, there is surely a compelling conservation-based reason to resurrect species like the huia *provided it can be done*.

3. Can huia be resurrected without satisfying the 100% condition?

In contending that species de-extinction is technically impossible, Shapiro assumes that a species can have been successfully resurrected only if the newly created organisms satisfy the 100% condition with respect to the ancestral population. Shapiro doesn't justify this assumption. It *might* be defended using the following argument (loosely suggested by some of her words – see p. 205):

> If the product of de-extinction isn't a population of organisms that satisfies the 100% condition with respect to the original species, then it is not *the same thing* as the original species, and if it is not *the same thing* as the original species, then the original species has not been successfully resurrected.

But this argument is obviously invalid. It confuses qualitative non-identity with numerical non-identity. It is true that if the newly created population, P_b, doesn't satisfy the 100% condition with respect to the ancestral population, P_a, then P_a and P_b are *qualitatively non-identical* populations (i.e., they have different properties). But it nowise follows that P_a and P_b are populations of

[2] In 2013 the official status of the South Island kokako, a very close relative of the huia, was changed from 'extinct' to 'data deficient' based on the first accepted sighting for forty years. It is very faintly possible that huia are likewise still hiding somewhere.

numerically distinct species. After all, adaptation and genetic drift constantly cause small changes in the physiology, behavior and genetics of species, and we don't declare one species to have passed away and a new species to have been created every time there is some such tiny change. Given that the 'same species' relation is in this way tolerant of minor changes through time in the properties of species, it is difficult to understand why a species de-extinction attempt must avoid introducing *any* such changes if it is to be successful.

Not only does Shapiro's 100% assumption seem implausible on its face, but her own book contains powerful reasons for thinking it false. Shapiro describes techniques that can be used to produce organisms belonging to one species, *A*, using living cells from species *A* and the surrogacy services of another (usually closely related) species, *B* (pp. 137-138 & 153-158). These techniques include interspecies *somatic cell nuclear transfer* (cloning) and interspecies PGCT (mentioned above). Shapiro explains how these techniques can be (and indeed, *already have been*) used to boost the populations of endangered breeds and species by using the surrogacy services of other breeds and species. For example, she explains how PGCT can be used to produce 'a pure-bred rare-breed chicken that hatches from the egg laid by a common chicken', so as to 'boost the population size of rare or endangered chicken breeds' (p. 156)

As explained in § 1, Shapiro also endorses A2—the idea that we can save endangered species from extinction by facilitated adaptation. In using this technique we would start with an initial population, P_a—say the current population of Asian elephants—which we would then transform into a new, genotypically and phenotypically different population, P_b—say, a population of cold-adapted 'woolly' Asian elephants. P_b would obviously *not* satisfy the 100% condition with respect to P_a, the whole point of facilitated adaptation being to increase the fitness of a species by *deliberately altering* aspects of its physiology and/or behavior. Thus by endorsing facilitated adaptation as a means of saving species from extinction Shapiro is tacitly committed to holding that the 100% condition *need not* be satisfied *at least in the context of facilitated adaptation*. Otherwise by reengineering Asian elephants for cold tolerance we would be *destroying the elephant species*, by turning elephants into non-elephants, not *saving* the elephant species (Siipi 2014, 85).

Now consider the following sequence of hypothetical scenarios:

Scenario 1 (population boosting, with intermixing)

i. A tiny remnant population of living huia, P_a, is found surviving in a remote valley. Their cells are sampled and cryogenically preserved.

ii. The cells sampled in step *i* are used to create a new population of 'huia', P_b, via interspecies PGCT and the surrogacy services of (say) chickens. P_b satisfies the 100% condition with respect to P_a.

iii. The two populations, P_a and P_b, are now allowed to mix and interbreed.

Scenario 2 (population boosting, without intermixing)
As for scenario 1, except that the original population, P_a, dies out *after* P_b has been created but *before* P_a and P_b have the opportunity to intermix and interbreed. (So the new 'huia' never get to meet their forebears.)

Scenario 3 (a de-extinction that satisfies the 100% condition)
As for Scenario 2, except that the original population, P_a, dies out *after* their cells have been sampled and preserved but *before* P_b has been created—meaning that there is a brief interlude when the huia population falls to *zero* (i.e., huia are briefly extinct).

Scenario 4 (a de-extinction that satisfies the 100% condition, followed by facilitated adaptation)
As for scenario 3, except that after P_b has been created it is subjected to facilitated adaptation, transforming it into a new population, P_c, that is genetically protected from some threat (say, a disease). P_c thus differs from P_b in that it no longer satisfies the 100% condition with respect to P_a.

Scenario 5 (a de-extinction that doesn't satisfy the 100% condition)
As for Scenario 4, except that the two steps, of creating P_b, and then modifying P_b to create P_c, are collapsed into a single step, in which P_c is created directly, without creating P_b first.

Scenario 1 is a straightforward case of PCGT being used to boost the numbers of a critically endangered species (albeit with the added feature that the synthetically created organisms are 100% indistinguishable from the original population). Since Shapiro endorses this method of boosting an endangered species' population as being a valuable technique in the conservationist's arsenal, she will, I take it, accept that the newly created P_b birds of scenario 1 *really are huia* (which can therefore interbreed with the original P_a birds without undermining or diluting the integrity of the species).

Scenarios 2 and 3 differ from scenario 1 only with respect to the fate of the original huia population, P_a. It is very difficult to understand why extrinsic

facts about the times of death of the P_a huia should make any difference to whether or not P_b 'huia' *are* huia. (Surely the facts about whether a P_b bird is an authentic huia won't depend on whether, at the time when this P_b bird was created, some P_a bird still happened to be alive somewhere in the bush.) For this reason it seems Shapiro must, having granted that the P_b birds of scenario 1 are authentic huia, make the same concession regarding the P_b birds of scenarios 2 and 3.

The P_c birds of scenario 4 are in effect obtained by subjecting the P_b birds of scenario 3 to facilitated adaptation. As explained above, Shapiro is tacitly committed to accepting that facilitated adaptation leaves the authenticity of a species intact (for otherwise it wouldn't offer a way of *saving* a species from a threat). Thus, having conceded that the P_b birds of scenario 3 are authentic huia, it appears Shapiro must say the same of the P_c birds of scenario 4.

Finally, the P_c birds of scenario 5 differ from those of scenario 4 only in having been produced by a more efficient, one-step process (wherein P_c birds are created *directly*, instead of by *first* creating P_b birds that are 100% the same as P_a birds and *then* modifying these P_b birds to create P_c birds). It is very difficult to understand why collapsing two steps into one would detract from the authenticity of the resulting organisms. Thus, having conceded that the P_c birds of scenario 4 are authentic huia, it seems Shapiro has no option but to grant that the P_c birds of scenario 5 are authentic too.

Now, to the point. The reasons just adduced for holding that the P_c birds of scenario 5 are authentic huia are, I believe, compelling. In so far as Shapiro is committed by what she says to granting the authenticity of these birds, there is, I think, nothing wrong with her position; she is on solid ground. But these reasons for accepting the authenticity of the birds created in scenario 5 *double as reasons for thinking Shapiro's 100% assumption is false*. Scenario 5 is, after all, a scenario in which we make huia de-extinct by creating a new population of birds *that do not satisfy the 100% condition with respect to the ancestral population*.

Shapiro can't have it both ways. Given she accepts (i) that interspecies PGCT (and/or cloning) can be used to boost populations of endangered species, and (ii) that facilitated adaptation can be used to protect species from a threat, then she can't also maintain (iii) that a species de-extinction project must satisfy the 100% condition in order to be successful. (i) and (ii) subtly contradict (iii).

4. What is the 'same species' relation?

How are we to judge whether a resurrected 'huia' is an authentic huia? The 100% condition is a purported answer to this question. There are strong reasons, just explained, to reject this answer as unsatisfactory. But our reasons for rejecting it would be much stronger still if we had a better answer to offer in its place. What might a better answer look like?

Consider the following hypotheses:

H1. At least for de-extinction purposes, P_b counts as being the same species as P_a iff the members of P_b and P_a are sufficiently similar in outward appearance and behavior.

H2. At least for de-extinction purposes, P_b counts as being the same species as P_a just to the degree that many of the evolutionarily adaptive traits possessed by the members of P_a have been genetically inherited by and are being phenotypically expressed by members of P_b.

H1 is implausible, but it will be illuminating to examine *why* it is implausible before we turn to H2. H1 implies that de-extinct 'huia' must merely outwardly resemble ancestral huia to be authentic. For example, imagine that the genome of a common raven (or another bird only distantly related to the huia) was modified to create birds with body-shape, plumage, diet, song, sexual-dimorphism and behavior approximating the huia's. Moreover, imagine this was done by brute-force genetic engineering, not by replacing raven genes with huia genes. Thus with regards their underlying genetics and physiology the new birds are—to the extent they resemble *any* naturally occurring species—raven-like, not huia-like. Provided these new 'huia lookalikes' are sufficiently outwardly similar to ancestral huia, H1 implies that we would, in creating them, have re-created authentic huia.

Intuitively this seems wrong, but why? Light is shed on the answer to this question by considering the *purpose* of species de-extinction. Let the *aesthetic quality* of a thing (e.g., of a species) be its capacity to evoke human feelings of wonder, awe, pleasure and appreciation. In §2 I argued, in effect, that one powerful reason to resurrect the huia is to recover the aesthetic quality lost when the huia went extinct. Now, would we successfully recover this lost aesthetic quality by creating modified ravens that outwardly resemble huia? I think it is clear we would not. It is surely the case that, at least for a well-informed person, a significant part of what would be so wonderful about seeing huia in the New Zealand bush again would be recognizing them to be the product of natural section operating on ancestral huia in the same bush over unfathomable eons of time. A bird that lacked this intimate historical connection

with ancestral huia and with primeval New Zealand would lack much of the aesthetic quality of ancestral huia, no matter how much it might look like a huia on the surface. Most of the details of the design of the modified ravens will have been settled by evolution operating, not on ancestral *huia* populations, but on ancestral *raven* populations. Although such birds should perhaps still stimulate our awe, it would be awe at the skill of the scientists who created them, not awe at seeing marvelous and beautiful biochemical machines whose innumerable working parts have been sculpted by millions of years of adaptation for survival in the New Zealand bush. Why then are the modified ravens *not* authentic huia? Because we would not, in creating them, have successfully attained a primary goal of a project to resurrect the huia—viz., to recover the aesthetic quality lost when huia went extinct.

H2 is much more promising. It improves on H1 by implying that a creature's authenticity depends on its inheritance of evolved traits from the ancestral population. It also makes authenticity *a matter of degree* and dependent on *how many* adaptively significant traits are copied from P_a to P_b. For example H2 implies that recreated 'huia' would be *mostly*, but not *fully*, authentic if the only genetic discrepancy between the recreated and ancestral birds was in a gene (say, a gene for eye color) that made little or no difference to the expression of the vast majority of adaptive traits. This is supported by the idea that we would judge the aesthetic quality of the huia to be *mostly*, but not *fully*, restored in such a case. H2 also implies that it is unnecessary to accurately copy *adaptively unimportant* DNA sequences from ancestral huia, that play no protein-coding or regulatory role (and that have therefore been shaped by random genetic drift rather than by natural selection). It implies that only genes, and aspects thereof, that have been shaped by natural selection matter. This is supported by the thought that it would be a pointless waste to devote resources to accurately copying parts of the ancestral huia genome that have no phenotypic effect.

Limitations of space mean I must refine and defend H2 elsewhere. My purpose in briefly outlining it here is only to show that the task of finding alternatives to the 100% condition is by no means hopeless or impossible.

5. Conclusion

In denying that resurrecting species would, even if practicable, be worthwhile, Shapiro fails to consider that its worth might lie in recovering things of value lost when species went extinct, like aesthetic quality, cultural importance, or biodiversity. In denying that species de-extinction is technically possible in the first place she assumes de-extinct organisms would need to

satisfy the 100% condition in order to be authentic. I hope to have persuaded the reader that this assumption is neither plausible, nor compatible with other views she expresses, nor forced on us by a dearth of alternative hypotheses.

Fortunately these weaknesses in Shapiro's philosophical position matter little where the main value of her book is concerned. It is a font of fascinating information about the current science and technology of de-extinction.

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