



Anabiosis and the Liminal Geographies of De/extinction

ADAM SEARLE

Department of Geography, University of Cambridge, UK

Abstract The spectacle of de-extinction is often forward facing at the interface of science fiction and speculative fact, haunted by extinction's pasts. Missing from this discourse, however, is a robust theorization of de-extinction in the present. This article presents recent developments in the emergent fields of resurrection biology and liminality to conceptualize the anabiotic (not living nor dead) state of de/extinction. Through two stories, this article explores the epistemological perturbation caused by the suspended animation of genetic material. Contrasting the genomic stories of the bucardo, a now extinct subspecies of Iberian ibex whose genome was preserved before the turn of the millennium, and the woolly mammoth, whose genome is still a work in progress, the author poses questions concerning the existential authenticity of this genomic anabiosis. They serve as archetypal illustrations of salvaged and synthesized anabiotic creatures. De/extinction is presented as a liminal state of being, both living and dead, both fact and fiction, a realm that we have growing access to through the proliferation of synthetic biology and cryopreservation. The article concludes through a presentation of anabiotic geographies, postulating on the changing biocultural significances we attach to organisms both extinct and extant, and considering their implications for the contemporary extinction crisis.

Keywords de-extinction, liminality, spectral geographies, anabiosis, cloning

It Begins by Coming Back: The Emergence of De/extinction

Extinction is not a moment or singular event. Extinctions, as ecologically and culturally significant as they may be, are difficult to locate, define, understand, or even imagine.¹ Often the term itself assumes some pre-given contextual meaning that masks its polymorphous ambiguity. Amidst narratives of Anthropocenes,² the sixth mass extinction,³ and the emergence of novel technologies in synthetic biology,⁴ both

1. van Dooren, *Flight Ways*; Heise, *Imagining Extinction*.
2. Lorimer, "The Anthro-Scene."
3. Barnosky et al., "Has the Earth's Sixth Mass Extinction Already Arrived?"
4. Adams, "Geographies of Conservation I."

conservation and geographical research face a series of epistemic and ontological questions. The multifaceted nature of extinction invites us to make sense of it empirically, in grounded and relatable “stories,”⁵ facilitating and affording the affective reimagining of alternatives and capacities for responses.⁶ Amidst an emergent ontology between existential extremes of extinct and extant, scientific speculation and practice are reworking the significances of extinction. This article aims to de-speculate biotechnical assemblages unsettling preceding epistemologies of extinction: contingent on the extinct as permanent and non-negotiable within evolutionary time. This article discusses two nonhuman protagonists at the heart of this emergent ontology: the bucardo, the only extinct animal to have ever been cloned;⁷ and the woolly mammoth, perhaps the most charismatic de-extinction candidate.⁸

The promise of de-extinction radically alters the way we perceive the event of extinction, through an introduced potential for the resurrection of extinct species. Some commentators note that it may inspire agnosticism toward extant animals,⁹ whereas others openly celebrate the prospect of optimism in public perceptions of conservation.¹⁰ De-extinction has been perceived by some as active engagement with the Anthropocene,¹¹ symptomatic of the emergent role of technoscience in more-than-human relations,¹² or as an extreme on the spectrum of introductory techniques in the conservationist’s toolbox.¹³ Many scholars in the environmental humanities have demonstrated the multiplicities of extinction.¹⁴ Through an approach inspired by this literature, this article explores the various practices and performances at the interface of biology, technology, and culture in grounding the multiplicities of de-extinction, outlining differences between the bucardo and mammoth de-extinction stories. Taking into account these multiplicities of meaning, defining de-extinction becomes increasingly difficult, especially as one comes up against questions such as: are reintroductions (say, for example, of beavers in Scotland) de-extinctions? However, for ease of argument I follow the typology of Sherkow and Greely in their 2013 *Science* article,¹⁵ which maintains that de-extinction comes in three forms: back-breeding, cloning, and genetic engineering.

5. Rose, van Dooren and Chrulew, *Extinction Studies*.

6. Despret, *What Would Animals Say*; Chrulew, “Freezing the Ark.”

7. Folch et al., “First Birth of an Animal from an Extinct Subspecies.”

8. Lorimer, “Nonhuman Charisma”; Seddon, Moehrensclager, and Ewen, “Reintroducing Resurrected Species”; Lalueza-Fox, *Des-extinciones*.

9. Campagna, Guevara, and Le Boeuf, “De-scenting Extinction.”

10. Preston, “De-extinction and Taking Control.”

11. Sandler, “De-extinction and Conservation Genetics.”

12. Haraway, “Cyborgs to Companion Species.”

13. Jørgensen, “Reintroduction and De-Extinction”; Seddon et al., “Reversing Defaunation”; Corlett, “A Bigger Toolbox”; Shapiro, “Pathways to De-Extinction.”

14. de Vos, “Extinction Stories”; Rose, van Dooren and Chrulew, *Extinction Studies*.

15. Sherkow and Greely, “What If Extinction Is Not Forever?”

Back-breeding, the practice of selective breeding in an attempt to reverse domestication, is an interesting approach to ecological restoration for extinct biota currently utilized by some practitioners in the rewilding movement.¹⁶ This article focuses on the cloning and genetic engineering approaches to de-extinction, due to the use of novel technologies in the genetic governance of life, and their active interactions with the genome. The bucardo and the mammoth are perhaps the classic examples for exploring the practices of speculative science in the global de-extinction discourse. Cloning as a de-extinction tool is contingent on the availability of intact genetic material.¹⁷ The bucardo is the only extinct mammal to be outlived by their cryopreserved material,¹⁸ and therefore unique in its resurrection subjection to cloning, yet in an age of salvage cryogenics it is likely the first of many. The mammoth, conversely, is de-extinction's celebrity candidate. As elaborated by Stephanie Turner, "for extinction narratives, the development of molecular biology means that species such as woolly mammoths and Neanderthals are not lost after all, but continue to exist as genetic codes residing in their remains, codes we are getting better and better at reading and interpreting."¹⁹ It is speculatively engaged by synthetic biologists owing to the relative abundance of its genomic material; the rate of biological deterioration diminished through the aid of permafrost. Yet intact cells remain fantastical, and as such a mammoth de-extinction would rely on a process of hybridization with the embryonic material of elephants.²⁰

Entanglements with extinction in both of these cases are archetypal and the most developed, both theoretically and empirically, the justification for their inclusion in this essay. Beyond contrasting techniques, their juxtaposition invites reflection on the changing temporalities and materialities of extinction. Charismatic vertebrates have dominated the global de-extinction discourse, with birds and mammals populating candidate lists disproportionately.²¹ Invertebrates and plants are rarely featured, reflecting the broader allocation of attention in wildlife conservation. Acknowledging that drawing upon these examples may further propagate this oversight, I would emphasize that these two de-extinction stories have been selected for their technoscientific peculiarities rather than the spectacle of the animals themselves.

This article is not an argument for or against de-extinction, which is a blossoming and encapsulating debate in the ecological and environmental sciences,²² bioethics,²³

16. Lorimer and Driessen, "From 'Nazi Cows' to Cosmopolitan 'Ecological Engineers'"; Jepson, Schepers, and Helmer, "Governing with Nature."

17. Richmond, Sinding, Gilbert, "The Potential and Pitfalls of De-extinction"; Shapiro, "Pathways to De-extinction."

18. Lalueza-Fox, *Des-extinciones*.

19. Turner, "Open-Ended Stories."

20. Shapiro, *How to Clone a Mammoth*.

21. Seddon, Moehrensclager, and Ewen, "Reintroducing Resurrected Species."

22. Donlan, "De-extinction in a Crisis Discipline"; Seddon et al., "Reversing Defaunation"; Iacona et al., "Prioritizing Revived Species."

23. Cohen, "The Ethics of De-extinction"; Sandler, "The Ethics of Reviving Long Extinct Species"; Rohwer and Marris, "Mammoth De-extinction"; Sandler, "De-Extinction."

law,²⁴ genetics,²⁵ and even tourism studies.²⁶ The list goes on in countless other disciplines, the media, and public imaginations. Phillip Seddon speaks for a significant number of people when he affirms that “de-extinction will be pursued—the reality of the idea is too sexy to ignore, and it could be driven by aesthetic, commercial, scientific, or some other hitherto unanticipated imperatives and motivations.”²⁷ As noted by Bill Adams, the prospect of de-extinction has the ability to grab headlines, to circulate and multiply to the extent that it has fallen out of contact with the scientific community.²⁸ Consequentially, de-extinction has been subject to intense speculation, and the means in which many come to engage it is at the interface of science fiction and speculative fact.²⁹ After calls for a social scientific narrative to de-speculate de-extinction,³⁰ this article works toward a theorization of de-extinction’s geographies in the present. I begin by introducing key theoretical aspects of this changing landscape, through which to interrogate the empirical stories of the mammoth and bucardo. These changing epistemologies implicate the geographies and ontologies of extinction.

De-extinction is a speculative practice engaging the anabiotic: the liminal materiality between living and dead. Liminality is an established tradition in geography, initially conceptualized within the anthropology of ritual,³¹ and is commonly understood as a transitional process between and on both sides of a boundary or threshold. Examples of geographical applications have included identities in cyberspace,³² theoretical examinations of borders and diplomatic arenas,³³ international relations,³⁴ and diaspora;³⁵ the diversity of its conceptual malleability illustrated in a recent edited book called *Breaking the Boundaries: Varieties of Liminality*.³⁶ “Liminality is also a provocation to take process, creativity, and aspiration seriously.”³⁷ Liminality is, itself, a conceptual frame that works through “shaking up epistemological assumptions”³⁸ by collapsing binaries around constructed ontological borders, such as extinct/extant, dead/alive, immaterial/material, nonlife/life, and technological/vital. Recent scholarship has applied the concept to animals,³⁹ or liminanimals, as Clemens Wischermann and Phillip Howell

24. Alta Charo and Greely, “Crispr Critters”; Wagner et al., “De-extinction, Nomenclature, and the Law”; Carlin, Wurman, and Zakim, “How to Permit Your Mammoth.”

25. Shapiro, “Mammoth 2.0”; Steeves et al., “Maximizing Evolutionary Potential.”

26. Whittle, Stewart, and Fisher, “Re-creation Tourism.”

27. Seddon, “The Ecology of De-extinction,” 994.

28. Adams, “Geographies of Conservation I.”

29. Haraway, *Staying with the Trouble*.

30. Frieese and Marris, “Making De-extinction Mundane?”

31. van Gennep, *Rites of Passage*; Turner, *Forest of Symbols*.

32. Madge and O’Connor, “Mothers in the Making?”

33. McConnell, “Liminal Geopolitics.”

34. Mälksoo, “The Challenge of Liminality.”

35. Mitchell, “Different Diasporas.”

36. Horváth, Thomassen, and Wydra, *Breaking Boundaries*.

37. McConnell, “Liminal Geopolitics,” 150.

38. McConnell, “Liminal Geopolitics,” 142.

39. Wischermann, Steinbrecher and Howell, *Animal History in the Modern City*.

celebrate the creativity of the hybrid encounter.⁴⁰ Through the stories presented later, I will explore the liminal geographies emerging at the heart of narratives encompassing taxa resurrection, those salvaged and the synthesized genomes in the geographies of de-extinction.

De-extinction technologies and ideas unsettle, distort, and disfigure the spaces and temporalities of extinction. This liminal state of de/extinction recalibrates genetics and the genome into a multifaceted existence, being both in potentiality as information and in actuality as deoxyribonucleic acids, exceeding and encompassing the aforementioned dualisms. I use a slash (/) to differentiate this existential liminality from the concept or process of resurrecting extinct taxa that is denoted by hyphenation (-). This discursive function of the slash indicates “an active and reiterative (intra-active) rethinking of the binary,”⁴¹ allowing the conceptualization of binaries as dynamic and enmeshed rather than strictly oppositional,⁴² as liminal and uncanny. Depending on context, a slash can be used in three ways: to denote “and,” “or,” or the spanning of two discrete categories (e.g. 2011/12). De/extinction should be thought of as a proactive and interactive questioning of the extinction concept, one accounting for both extinction and de-extinction as coexisting actions perpetually rethinking one another, forceful and metamorphic. De/extinction is relative and only makes sense with a contemplation of trace; that is, to consider de-extinction is to consider what extinction is *not*, and vice-versa.⁴³ This ontology exists in a plane of potentiality with agency to shape the ways we engage with and perceive the worlds we inhabit, certainly questioning the notion of extinctions as irreversible and indefinite.

In what follows this article will explore liminal materialities, two anabiotic existences that unsettle the previously held epistemologies of extinct and extant: the bucardo and the mammoth. Through exploring the materialities and agencies of DNA itself, these genomes distort the discreteness of life and death. Biologists engaging de/extinction optimistically make sense of candidate genomes dissimilarly: they are the salvaged ghosts of extinction’s lost pasts, the synthesized ghosts of extinction’s lost futures. The bucardo and the mammoth provide archetypal illustrations of salvaged and synthesized anabiosis, the “not anymore” and “not there yet.” Genomes are simultaneously material amino acids and immaterial codes of semiotic programming, the program of which is referred to as a text by the molecular biologist, the scriptural model of which Derrida contends is central to advances in postwar science.⁴⁴ “Literary metaphors have been woven into the fabric of molecular biology since its inception. The determination of the human genome sequence has brought these metaphors to the forefront

40. Wischermann and Howell, “Liminality.”

41. Juelskjær, Schwennesen, and Barad, “Intra-active Entanglements,” 19.

42. Radomska, “Non/Living Matter.”

43. Derrida, *Of Grammatology*.

44. Derrida, *Of Grammatology*.

of the popular imagination, with the natural extension of the notion of DNA as language to that of the genome as the ‘book of life.’⁴⁵ These systems of meaning are appropriately engaged through a posthumanist lens, which “expresses multiple ecologies of belonging,”⁴⁶ encompassing the matters of language, discourse, culture; but, most notably, matter itself. Posthumanist thought has been influenced through Derrida’s writings on biology, founded through his conceptualization of trace [trace],⁴⁷ referring to that which formulates difference and its deferral of meaning [différance].⁴⁸ This postponement of action or event creates meaning and presence through absence, and is the opening in which binary oppositions can operate: those aforementioned concepts of life/death, extant/extinct, and nature/culture. Exploring the trace of bucardo and mammoth’s genomes poses to offer insights into what anabiosis ontologically and existentially is at present.

Salvaged Anabiosis: Bucardo

For the first and only time in history a mammal has been outlasted by its own living cells . . . welcome to anabiosis. The bucardo (*Capra pyrenaica pyrenaica*) has always been a spectral animal, owing its fame to a liminal presence/absence, desired—but rarely encountered—by the bourgeois hunters whom it would attract to the Pyrenees from Victorian England.⁴⁹ As a magnificent and impressionable animal, the bucardo became renowned as the most sought-after trophy among the European upper classes, as its image and legend circulated throughout Europe in the late-nineteenth century (fig. 1). Officially, the bucardo has been recognized as a subspecies of Iberian ibex (or wild goat), a status unchanged since the influential publications of Ángel Cabrera in 1911.⁵⁰ To avoid opening a Pandora’s box of taxonomic debate, it is crucial to note that these classifications have been greatly contested since the emergence of genetic knowledges,⁵¹ and that there exists varied schools of thought regarding the bucardo’s status as a species, subspecies, or race of ibex.⁵² Subject to numerous cave-art depictions in both Marsoulas and Lascaux, the bucardo arrived in the Pyrenees circa 90,000 years ago during the Palaeolithic period and thrived.⁵³

Their habitat had spanned from the Atlantic to the Mediterranean, however by 1907 the bucardo population had been reduced to a small nucleus of eight or nine individuals, described by Cabrera as refugees (*refugiados*) scattered throughout the secluded

45. Searls, “The Language of Genes,” 211.

46. Braidotti, “Posthuman Critical Theory,” 25.

47. Derrida, *Of Grammatology*, 9.

48. Derrida, *Writing and Difference*.

49. Buxton, *Short Stalks*; Brooke, *Sir Victor Brooke*.

50. Cabrera, “The Subspecies of the Spanish Ibex” and *Fauna Iberica*.

51. Acevedo and Cassinello, “Biology, Ecology and Status of Iberian Ibex.”

52. Manceau et al., “Identification of Evolutionary Significant Units”; Ureña et al. “Unraveling the Genetic History.”

53. Ureña et al., “Filogenia y Evolución.”



Figure 1. Joseph Wolf, *The Bucardo*, 1898.

valleys of Mount Perdido, in the high altitudes of Aragón, Spain.⁵⁴ The lack of ecological concern regarding the diminution of the bucardo population was largely due to its almost less entitled status as a subspecies,⁵⁵ which even today in the eyes of many conservation organizations equates to less importance in terms of biodiversity conservation. Together with a lack of habitat protection and increased human presence in the Pyrenees, centuries of overhunting had reduced the bucardo to an existence on the edge of extinction. However, the cultural status of the elusive animal played a significant role in the formation of one of Spain's oldest national parks in 1918, *Ordesa y Monte Perdido*.⁵⁶ Due to both the sheer infrequency of bucardo sightings and the dooming

54. Cabrera, *Fauna Ibérica*, 316.

55. Gippoliti et al., "Poor Taxonomy and Genetic Rescue."

56. de las Cuevas, "Los Parques Nacionales."

legacy of war, population estimates were uncommon and always highly uncertain.⁵⁷ By the 1990s there were between six and fourteen individuals,⁵⁸ and in 1997 there remained just one female left, known to many internationally as Celia.⁵⁹

Anabiotic Imaginaries

De/extinction is an ontological category that speaks to the anabiotic. Anabiosis, coming from the Greek *ana-* (*ἀνά*: again, anew) and *-biosis* (*βίωσις*: a specified mode of vital existence), is an out-of-fashion term in biology and medicine that signifies a return to life from a seemingly dead organism.⁶⁰ The introduction of anabiosis was firmly rooted in Enlightenment thought, inspired by the eighteenth-century experiments and philosophies of John Hunter and Benjamin Franklin, who sought to prolong life through a primitive form of cryogenics.⁶¹ The concept was of biological intrigue for some time, including an 1860 commission by the Société de Biologie in Paris⁶² and revisited by Russian and Soviet scientists in the early twentieth century.⁶³ In the context of this article, anabiosis can be thought of as the liminal realm between life and nonlife, a spatiotemporal interruption of extinction or death mediated through emergent technoscientific assemblages. Under present scientific capabilities, anabiosis is found through two scientific approaches: cloning from cryogenics and genetic engineering. Both of these approaches pose questions concerning the authenticity of de-extinction due to a range of ecological and genetic issues;⁶⁴ for instance, “Is a bucardo clone born in a laboratory a genuine de-extinction?” “Is a genetically engineered elephant that genetically and morphologically resembles a mammoth *really* a mammoth?” The significance and exceptionality of de-extinction as a practice is its entanglement and interactivity with “the discontinuity or breakdown of some molecular, cellular, behavioural, and ecological processes,”⁶⁵ a radical rethinking of this discontinuity, or an experiment with the anabiotic.

The last bucardo died as she was crushed under a falling fir tree on the sixth of January 2000. But this was no ordinary death. It was the genesis of new meanings within the technoscientific assemblages mediating, engaging, and understanding what death is. This was an extinction preceded by salvage genomics. Less than a year before

57. García-González and Herrero, “El Bucardo.”

58. García-González, “Inventario de la Población”

59. The name Celia was popularized within the Anglophone press and is how the last bucardo became known internationally; however, it is important to note that those from the settlement of Torla-Ordessa (which has an incredibly rich history of human-bucardo interactions) know her as Laña. For purpose of narrative, I refer to her as Celia, as this is how she was named and perceived by the geneticists whose thought and worldviews made the bucardo’s de/extinction spectacular.

60. “Anabiosis,” *Oxford English Dictionary*.

61. Gruman, “Prolongation of Life.”

62. Broca, “De la Reviviscence des Animaux.”

63. Schmidt, “Anabiosis of the Earthworm”; Krementsov, *Revolutionary Experiments*.

64. For a discussion of de-extinction’s authenticity, see Siipi, “The Authenticity of Animals.”

65. Robert et al., “De-extinction and Evolution.”

her death, in a final attempt to preserve the bucardo's genetic resources, Celia was captured, and cells from a skin biopsy were obtained, multiplied, and kept frozen in liquid nitrogen.⁶⁶ Such practice would never have materialized without the imaginings facilitated by the fascinations of both science and the media with the world's most famous lamb, Dolly, born only a few years earlier. Comparable and not disassociated with the contemporary epistemological tremors radiating from de/extinction, Dolly's birth in 1996 changed reproductive biology forever through a biocultural reframing of the possible, as an assemblage choreographed through reproductive technologies facilitated the *coming together* of divergent ontologies.⁶⁷ As sociologist Sarah Franklin elaborates, it is unviable to separate Dolly's creation from the hype that surrounds it, "insofar as *hype* refers to imagined sets of connections and exaggerated implications, it signifies a reaching beyond, or an expansion of range. Dolly is in this sense both a frontier and a horizon—a relational someplace and no place signalling future possibility and direction."⁶⁸ Dolly's *hype* is therefore her unique concurrent platforming as a figurative technological frontier and the literal embodiment of nuclear transfer. As Franklin argues, the resultant phenomenon of Dollymania cannot be reduced to fallaciousness; it is this very hype which makes her charisma as an iconic and symbolic animal of great socio-cultural significance. A technoscientific floodgate had been opened, and cloning techniques were all at once reframed within our conceptualizations of what is possible.

Dollymania had merged science fiction with speculative fact, and a team from the animal reproduction laboratory at the *Centro de Investigación Tecnología y Agroalimentaria* of Aragón were seeing the diminution of the bucardo population to just one female under a new lens of opportunity, outside scientific normativity. Even before the successful skin biopsy on Celia, a 1998 piece in *La Vanguardia* discussed the possibility of her cloning,⁶⁹ as most media and popular science discourses following the 1999 capture-release drew technical parallels between Celia and Dolly as stories of genetic research and technological advancement.⁷⁰ This is what contextualizes Celia's story and makes apparent the sheer partialities of de/extinction; the genealogy which transformed her genes from that of a wild thing into a space of experimentation as an animal of potentiality understood in terms of an orientation toward the future.⁷¹ The bucardo had to be imagined as anabiotic, its materiality becoming one with an entirely altered and radically different biocultural coding.

Once the skin biopsy had been performed, Celia's cells were transported to a laboratory in the outskirts of Zaragoza, where they began to take on new meanings; her genes themselves entangled in a meshwork of contrasting ontologies facilitated by

66. Folch et al., "First Birth of an Animal from an Extinct Subspecies," 1021.

67. For a thorough and stimulating discussion, see Thompson, *Making Parents*.

68. Franklin, *Dolly Mixtures*, 5.

69. Ortega, "Clonación Para el Bucardo."

70. For example, Diario del Alto Aragón, "Clonar ya al Bucardo"; *La Vanguardia*, "Todo Listo Para Clonar."

71. Friese, *Cloning Wild Life*.

genetic and cryogenic technologies. In fact, this material and geographical disjunction (of living cells and living animal) facilitated an unprecedented response to the death of the last bucardo, who died just a few months later having been re-released to her habitat in Ordesa. Of course, many grieved and mourned the loss of an iconic animal who had become profoundly interwoven into the cultural landscape of the Pyrenees, yet like extinctions of most charismatic fauna the absence of hope was by now deeply entrenched. The bucardo had been considered essentially extinct long before Celia's death, and for over a century it had simply been as if the inevitable were being delayed. Somatic cell nuclear transfer and the emergence of reproductive cloning had given new life to the bucardo, albeit solely through potentiality, because there existed some fleeting idea that the process might one day repopulate the Pyrenees.⁷² Laboratories are peculiar sites of knowledge production, where the coming together of experiences and expertise takes place on interpersonal levels, and the scientists in Zaragoza collaborated with a group of French cell biologists who had in 1998 successfully completed nuclear transfer from skin biopsies.⁷³ Bucardo nuclei were transferred into denucleated oocytes collected from various goat and ibex females, a method which had been practiced by the Aragonese team some years before,⁷⁴ all the time working with the intention of constructing a strategy of bucardo cloning.⁷⁵

The donors of these oocytes—immature egg cells produced by female mammals through the process of oogenesis—were curious mixtures of *Capra* hybrids who lived and grazed in the fields outside the laboratory where Celia's cells were enmeshed in a multiplicity of epistemological processes.⁷⁶ These hybrids of Spanish ibex (*C. pyrenaica hispanica*) and domestic goats (*C. hircus*) were interspecies liminimals, themselves created for the purposes of surrogacy, animals with the conceivability of carrying a bucardo clone at the interface of feral/cultivated/wild.⁷⁷ The gestation period of the Spanish ibex is closer to that of the bucardo, meaning a fetus would have sufficient time for development. Despite this, they are unable to maintain prenatal health in captivity; domestic goats, on the other hand, are able to bear kids in captivity, however their shorter gestation period would likely result in the underdevelopment of a bucardo clone.

In her book *Transpositions*, posthumanist philosopher Rosi Braidotti defines the genetic social imaginary,⁷⁸ whereby a perception of the genome as a data bank of potentiality has constructed certain cultural ideas about bodies and their function. Similarly,

72. Lee, "Can Cloning Save Endangered Species?"

73. Vignon et al., "Developmental Potential of Bovine Embryos."

74. Fernández-Arias et al., "Successful Interspecific Embryo Transfer."

75. Fernández-Arias et al., "Interspecies Pregnancy of Spanish Ibex."

76. Fernández-Arias et al., "Use of Hybrids as Recipients."

77. This threefold classification is a key theme of Maan Barua's *Urban Ecologies* research Project (<http://urbanecologies.org/>).

78. Braidotti, *Transpositions*.

the emergence of anabiotic imaginaries through the development of both ideas and technologies within the bioscientific remits of de/extinction have engendered new societal approaches to agencies of the genetic in more-than-human worlds. A medley of hybridities—surrogate *Capras*, bucardo nuclei, and denucleated oocytes—all facilitated by a technoscientific assemblage of practical apparatus and knowledges resulted in the production of fifty-seven bucardo embryos.⁷⁹ Following embryonic transfer, an animal had been impregnated by a ghost for the only occasion in history, and the time was well and truly out of joint.

The Revenant

“It was Wednesday, July 30, 2003, a turning point in the history of biology. For on that date, all at once, extinction was no longer forever,” proclaimed the synthetic biologist George Church in his coauthored book *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*.⁸⁰ Seven years after the first mammal birth following somatic cell nuclear transfer, geneticists had, even for seven minutes alone, defied biology’s most inevitable certainty. As discussed in the article detailing the practice of the bucardo clone:

The delivered kid was genetically identical to the bucardo, disregarding the influences of mitochondrial DNA from the oocyte of the domestic donor and of the uterine environment of the hybrid recipient. The newborn displayed serious respiratory distress and died [a] few minutes after the caesarean section. . . . At present it can be assumed that cloning is a not very effective way to preserve endangered species, because the complexity to handling the experimental wild animal and the insufficient knowledge on both, the cellular mechanisms involved in the technique and on the reproductive characteristics of the animals. . . . However, in species as bucardo, cloning is the only possibility to avoid its complete disappearance. The present work encourages [conservationists] to appropriately store somatic tissues and cells of all endangered species or suitable animals, as they may be useful for future cloning-based conservation programs.⁸¹

Whether this was a genuine de-extinction or not depends on who you ask: for the likes of George Church and other high-profile supporters of de-extinction, this was a greatly significant event that signaled the end of extinction as we knew it. For critics of the global de-extinction movement this was a failed cloning attempt that, even had the clone lived and experienced life beyond the walls of a laboratory, would have amounted to nothing more than the clone of an “old, infertile, highly heterozygous female”—a singular specimen further prolonging the inevitability of bucardo extinction.⁸² Regardless of opinion, this exemplifies the liminal ambiguity of de/extinction, at once

79. Folch et al., “First Birth of an Animal from an Extinct Subspecies.”

80. Church and Regis, *Regenesis*, 136.

81. Folch et al., “First Birth of an Animal from an Extinct Subspecies,” 1032–33.

82. García-González and Maragallida, “Against Cloning.”

the archetypal case of reversing extinction, while at the same time the clone of an animal from anabiotic cells that had never been extinct; after all, “it made no difference to the frozen cells that they happened to be last of the line: cells were cells.”⁸³ Engaging the geography and political ecology of these cells, too, would maintain that they are materially inseparable from their entanglement in processes of ongoing habitat degradation and commodification. The mere eventuality in which a species is outlived by its genomic materiality is one that is open to a plethora of critical scholarship.⁸⁴

De/extinction is a haunting, or in Jacques Derrida’s terms,⁸⁵ a *hauntology* (*hantologie*): it simultaneously speaks to and from both absence and presence. This hauntology is a geographical rupture through the figure of the *ghost*, itself neither living or dead, neither absent nor present. Derrida writes

Repetition *and* first time: this is perhaps the question of the event of the ghost. What is a ghost? What is the *effectivity* or the *presence* of a specter, that is, of what seems to remain as ineffective, virtual, insubstantial as a simulacrum? Is there *there*, between the thing itself and its simulacrum, an opposition that holds up? Repetition *and* first time, but also repetitions *and* last time, since the singularity of any *first time*, makes it also a *last time*. Altogether other. Staging for the end of history. Let us call it a *hauntology* . . . a question of repetition: a specter is always a revenant. One cannot control its comings and goings because it begins by coming back. . . . What seems almost impossible is to speak always *of the specter*, to speak *to the specter*, to speak with it, therefore especially *to make or to let a spirit speak*.⁸⁶

Ghosts have become of interest recently within the humanities of wildlife and conservation,⁸⁷ particularly as the forceful and affective capacities of hauntings are understood in terms of their potential to inspire novel modes of environmentalism, as these “ghosts remind us that we live in an impossible present—a time of rupture, a world haunted by the threat of extinction.”⁸⁸ This hauntology of de/extinction is never present or absent, it is always both, speaking to, with, and of the living and the dead; or rather, actively challenging and passing between the boundaries that make these categories distinct, *beginning by coming back*.

The event of the bucardo’s cloning shook the authority of extinction. But it also brought into question the authority of de-extinction as an anabiotic imaginary: how would other animals, such as the thylacine or passenger pigeon, ever become revenants if we were unable to reverse extinction with *living* cells? To this day, it highlights the

83. Church and Regis, *Regenesis*, 134.

84. For a comprehensive and radical take on extinction, see Moore, *Capitalism in the Web of Life*.

85. Derrida, *Specters of Marx*.

86. Derrida, *Specters of Marx*, 10–11.

87. van Dooren, “Life at the Edge of Extinction”; Garlick, “Cultural Geographies of Extinction”; McCorristine and Adams, “Ghost Species.”

88. Gan et al., “Haunted Landscapes,” G6.

subjective and multiple meanings of de/extinction and the spectrality of nonhuman existence in the post-genomic age, speaking to a conjuring, a revenant, in which “the living maintain the dead, play dead, let themselves be entertained and occupied and played or tricked [*jouer*] by the dead, speak them and speak to them.”⁸⁹ It signaled a possibility, further plunging into the metaphysical arena of haunting: both present and absent, living and dead, fact and fiction.

Playing himself in Ken McMullen’s experimental film *Ghost Dance*,⁹⁰ Derrida argues that rather than distancing us from the realm of ghosts, modern technologies enhance the power of ghosts to haunt us. The bucardo’s cells are still kept in two locations, living, but also dead. It was not only the first de-extinct animal but also the first to go extinct twice, subject to what we could call a *re-extinction*. It is the only example of a mammal whose cells have outlived its population, who is anabiotically entangled in the liminal geographies of de/extinction, distorted between the spaces of science and evolution. Synthetic biologists look to the story of the bucardo as one of inspiration, as the dawn of the de-extinction age, and these events are revisited every day in laboratories around the world through the anabiotic imaginaries of other charismatic fauna defying our previously held ontologies of extinction.

Synthesized Anabiosis: Mammoth

Technically and methodologically, the events punctuating the cloning of the bucardo were almost identical to that of Dolly, albeit this time mediated through *interspecific* somatic cell transfer as opposed to within the same species (a feat achieved just once before with the cloning of the *gaur*—the Indian bison—whose clone had also died shortly after birth, further highlighting the technological difficulties of this process).⁹¹ For animals such as the bucardo, their anabiosis is imagined and engaged as an idea, while there are still populations living. This is evident through the precautionary cryogenic measures gaining popularity among many conservationists, those intent on “freezing the ark,”⁹² an act which itself defies the distinctions of life/nonlife and living/nonliving.⁹³ Yet just as “Dollymania” profoundly affected the significance of the bucardo’s de/extinction, anabiotic imaginaries of species lost far before living memory are emerging in laboratories all over the world due to advances in DNA sequencing and synthesis. How may we begin to engage with the idea of animals long-gone being-here?

The woolly mammoth (*Mammuthus primigenius*) was depicted alongside ibex some 15,000 years ago in the caves of the Pyrenees (fig. 2).⁹⁴ It is the most famous extinct mammal and had suffered extinction long before humans learned to inscribe language.

89. Derrida, *Specters of Marx*, 142.

90. McMullen, “Ghost Dance.”

91. Lanza et al., “Cloning of an Endangered Species.”

92. Chrulew, “Freezing the Ark.”

93. TallBear, “Beyond the Life/Non-life Boundary.”

94. Lahlil et al., “Spectroscopic Analysis.”



Figure 2. Woolly mammoth and ibex depicted together in the Grotte de Rouffignac.

Contemporary imaginaries of mammoths are the product of strange biocultural assemblages. At the interface of cave art we are encouraged to experience the elemental differences of non/inhuman forces, suggesting “an ontological intimacy with other entities and the dismantling of the boundaries between life and environment.”⁹⁵ Cave art is inseparable from engagements with deep time: the geologic and the genetic. The traces of biological remains left by the mammoth, scattered through the Siberian tundra, offer these potentials of multitemporal affective encounters. If we understand these genomic traces in the Derridean sense, then they function as ontological and epistemological opportunities for the questioning of boundaries, like those of extinct and extant. To engage and perform the revenants of deep time, speculative experimentation is utilized using a range of rapidly developing technologies. *Living* cells are required to perform somatic cell transfer, and therefore the anabiosis of animals long-gone must materialize in another manner, through *anabiotic synthesis*.

Synthesizing the Anabiotic

The mammoth is engaged through another anabiotic approach, one further virtualized from the material world but just as real. Information is the lowest common denominator of all genetics, and since the sequencing of the human genome in 2003 a plethora of

95. Yusoff, “Geologic Subjects.”

opportunities have emerged facilitating a greater understanding of ancient DNA and a technological capacity to assemble the genomes of extinct taxa.⁹⁶ Beth Shapiro, evolutionary molecular biologist, and the author of *How to Clone a Mammoth*,⁹⁷ has routinely maintained that the coinciding of these techno-epistemological developments pave “the most likely route to de-extinction . . . advances in ancient DNA (aDNA) extraction and DNA sequencing technologies are making it increasingly feasible to reconstruct full genome sequences from extinct species.”⁹⁸ In conjunction with long cultural fascinations surrounding the charismatic megafauna, often spurred by the excitement surrounding the *discovery* of remains (of either bodies or ancient depictions), genome sequencing has afforded novel systems of allowing the mammoth specters to speak and affect us. aDNA understandings and practices have developed at a staggering rate over the past decades; the materiality of mammoth genome being translated into coded information through quantitative polymerase chain reaction sequencing comparatively using both Asian and African elephant genomes.⁹⁹ Sequence identity between mammoth aDNA and African elephant DNA has been found to be greater than 98.5 percent,¹⁰⁰ meaning that most mammoth DNA is among living animals today.

All biological life is a living library of aDNA enmeshed deeply within evolutionary time. For the synthetic biologist, amidst the technoscientific possibilities of cutting and pasting genomes as if assembled on a Microsoft Word document, these hybridities-to-come will depend on the “genomes of living species [that] must be used as scaffolds to align ancient DNA fragments.”¹⁰¹ This synthesis of life is not devoid of human intervention, as is endemic in questions of liminality between humans and other animals.¹⁰² These uncanny beings would have a unprecedented genetic makeup: *the evolutionary time would be out of joint*. As described by Beth Shapiro,

Coincident with the release of the latest in the *Jurassic Park* series of movies, George Church’s lab at Harvard University’s Wyss Institute reported their first successes in editing living elephant cells so that they contain gene sequences from the elephant’s recently extinct relative, the woolly mammoth. Using a CRISPR (clustered regularly interspaced short palindromic repeats)-Cas9 approach, Church’s team replaced 14 loci in the elephant genome with the mammoth version of those sequences. Although they have not yet created a mammoth, their success blurred the already fuzzy line that separates science from science fiction, bolstering hopes (and fears) that de-extinction, the resurrection of extinct species, may soon be reality.¹⁰³

96. Shapiro and Hofreiter, “A Paleogenomic Perspective.”

97. Shapiro, *How to Clone a Mammoth*.

98. Shapiro, “Pathways to De-extinction.”

99. Debryne, Barriel, and Tassy, “Lyakhov Mammoth.”

100. Poinar et al., “Metagenomics to Paleogenomics.”

101. Novak, “De-extinction.”

102. Wischermann and Howell, “Liminality.”

103. Shapiro, “Mammoth 2.0.”

Bill Adams has noted that synthetic biology is just seen by many conservationists as one extreme of new methodologies and epistemologies centered on tweaking genomes in wildlife conservation.¹⁰⁴ Others have considered the potential for functional de-extinction within biological epistemological frameworks founded on the *ecological species concept*, whereby the niche receives definitional priority over the genetic code, affording the ability of nonhuman self-definition through action and interaction.¹⁰⁵ This identification is therefore one guided by animals' geographies,¹⁰⁶ whereby the lived ecologies, habitats, and trophic function are understood as the *raison d'être*, not only evolutionary histories.

Anabiotic synthesis is an engagement with biological time machines,¹⁰⁷ where “at a minimum, the choice of a species concept is ambiguous with respect to the definition of ‘extinction.’”¹⁰⁸ The perception of taxa as self-defined through their own agencies and ecological exchanges expresses an affinity for hauntology and de/extinction, as made apparent by many ideas among rewilding practitioners working with the *proxies* of animals long gone such as the auroch¹⁰⁹—the ancestor of domestic cattle—the idea of which has been spectacularized by molecular biologists and the development of synthetic biology. Genetically, these anabiotic syntheses are challenging previously held categorizations at the species-level; the chimera that could be born as a result of this genomic engineering would be a mammoth based on *function* rather than (genetic) form, realized through hybridization.

George Church discusses potential hybridizations with extinct species as exciting new dawns for life on Earth, as he outlines to a crowded room at the internationally renowned TEDx DeExtinction event: “We’re trying to make species from information alone.”¹¹⁰ Interestingly, this event projects de/extinction as ageographical in the scientific sense, whereby the methods, theories, and practices of de-extinction are bestowed as universal. However, exploring the empirical diversity of the event itself, which utilizes a range of nonhuman protagonists, technological practices, and imaginaries of future environmentalism, illustrates rather explicitly the importance of geographies in de/extinction (for example those considerations of habitat, history, cultural and ecological significance). A synthesis of the anabiotic, founded through the engagement of genetics as information and code, has given new life to the mammoth through potentiality and speculation. The permanence of extinction is called into question through genomic hybridization and the emergence of genetic liminalities. Just as endangered taxa are seen through a different lens in an era of cryogenic conservation and the

104. Adams, “Geographies of Conservation I.”

105. Slater and Clatterbuck, “A Pragmatic Approach.”

106. Hodgetts and Lorimer, “Methodologies for Animals’ Geographies.”

107. I borrow this term from Loi et al., “Biological Time Machines.”

108. Siipi and Finkelman, “The Extinction and De-extinction of Species.”

109. Lorimer and Driessen, “Bovine Biopolitics” and “Wild Experiments.”

110. Church, “Hybridizing with Extinct Species.”

development of interspecific cell transfer technologies, animals (and plants) that have been absent from Earth for a considerable time are given new presence through the concept of anabiotic synthesis.

De/extinction and Potentiality

If we revisit anthropological ideas of potentiality, one could make a case that the mammoth could already be classed as de/extinct, as are many taxa disturbing the finality of extinction. The post-genomic era is one that has been marked by the discourses of potentiality, often articulated as a “hopeful idiom through which to imagine,”¹¹¹ a virtuality with its own reality and cultural agency. *Revive and Restore*, a foundation and advocacy organization that has secured considerable funding for de-extinction projects in the United States, portrays its mammoth project in a comparable vein of potentiality:

As the possibilities of biotechnology innovations were revealed, the idea of resurrecting the woolly mammoth quickly captured the imagination. . . . Breakthrough advances in genomic biotechnology are presenting the possibility of bringing back long-extinct species—or at least proxy species with traits and ecological functions similar to the extinct originals. . . . Not only does this research build the foundations of mammoth de-extinction, it provides potentially valuable insight to evolution for different climate conditions. . . . Dr. Zimov’s perspective illuminates an additional function that must be considered: the mammoth’s potential role in providing resilience in the face of climate change. . . . Mammoth haemoglobin, for example, may reveal information about mammalian blood useful to treating human diseases, and potentially the future of human space exploration.¹¹²

The mammoth is already engaged in multiple meanings, subject to potentialization as a symbolic project, already guiding scientific and technological innovations of the future. Its resurrection is discussed by de/extinction practitioners with an air of certainty and inevitability, allowing cultural imaginaries to develop as the virtual is interwoven into ideas of wildlife and extinction. The mammoth is currently actualized in narratives of research and epistemological function; as a means of developing scientific understandings of ecological niches, (paleo)climatology, climate change resilience, human health and epidemiology, and even the prospects of space exploration and terraforming. Such becomings profoundly question the idea of the mammoth as an extinct animal. These anabiotic imaginaries are very much real, and cultural responses from both inside and outside the scientific community animate the mammoth as an animal of the future, while simultaneously an animal of the past.

It is a haunting, a question of repetition and first time, a return to as a departure from. It is already present in its absence, and absent in its presence. Consider the well-

111. Tassig, Hoeyer, and Helmreich, “The Anthropology of Potentiality.”

112. “Woolly Mammoth Revival.”

known case of Sergey Zimov's Pleistocene Park in Siberia,¹¹³ "the future of the past," where the mammoth is the affective and charismatic driving force for the (re)establishment of an ecosystem that resembles the most recent glacial maximum. This radical attempt to engage wildlife is inseparable from the ghosts of mammoths and is just one example of how the fauna is defying the idea of a simple categorization between extinct and extant: the mammoth is *already* the pioneer of conservation projects and a contributor to knowledge production in conservation biology. It is de/extinct through its potentiality, its genomic liminality enacting material changes all over the world, a life of virtual reality.

Anabiotic Geographies

These two very different de/extinction accounts have illustrated the changing natures of extinction in the post-genomic age. According to McCauley et al., "Historically, extinction was permanent in a way that few biological processes are. The binary finality of extinction, however, is being challenged by fast-moving progress in de-extinction science."¹¹⁴ Genomes themselves have emerged as the material and immaterial subjects of novel ideas about how humans and nonhumans engage and affect one another. They are subjugated and made sense of through human and technological modes of signification yet oblivious to these meanings;¹¹⁵ simultaneously as the actual *living thing* in the test tube, and/or as the virtual *nonliving thing* signified as a potentiality through genetic code, acting in between. I agree with de/extinction scientist Ben Novak when he states that "biotechnology changes the concept of extinction,"¹¹⁶ yet I would contend that these biotechnologies are produced at the interface of wildlife, endangerment, and extinction being subjected to the future imaginaries of resurrection. In an era of hauntings.

Of first times and repetitions. Cells extracted from bucardo skin in the last millennium continue existing in their anabiotic state *in vitro*, their cloning viability unaltered, as recently confirmed by a scoping study in 2013.¹¹⁷ "The bucardo population consists of zero multi-celled individuals and several million single-celled clonal individuals currently cryopreserved."¹¹⁸ And the mammoth genome exists as information and through the labor of synthetic biology, the result of countless genetic studies and experiments, as signifier of potentiality. But their effects are felt by living things making sense of the world, with real politics and real geographies. From the perspective of scientific practice, there is some concern that this is a somewhat tunnel-vision approach that aims to "mimic the biology of extinct species, but fails to resurrect their ecology."¹¹⁹ It is

113. Zimov, "Pleistocene Park."

114. McCauley et al., "A Mammoth Undertaking."

115. A theme explored in the context of microbial life by Paxson and Helmreich, "Microbial Abundance."

116. Novak, "De-extinction."

117. Rincon, "Fresh Effort to Clone."

118. Novak, "De-extinction," 8.

119. McCauley et al., "A Mammoth Undertaking," 1003.

essential that the de/extinction is contextualized and ecologized, within trophic entanglements as well as cultural landscapes.

The liminality of de/extinction *in the present* is taking-place and taking-shape in numerous contexts as a genomic library of nonhuman life; while technologies and imaginaries emerge so too are conceptualizations of immortality at the population level. The epistemological conventions of extinction are just as relevant, albeit with changed significances, and conservation will need to grapple with the possibility of a conservation without extinction in response. What might that mean, and how might that materialize? Perhaps living within anabiotic worlds may inspire apathy toward the diversity of wildlife on Earth. If extinction isn't a permanent deal, why devote our attention and resources to the protection of nonhuman life when it could go elsewhere? It even may engender hyper-conservative and promethean narratives akin to that of eco-modernism, whereby global ecocide may be tolerated in the present due to a conviction that there will be a technological fix somewhere in the future. Such horizons are disquieting but may be mitigated or evaded through robust narratives from the social sciences and humanities of wildlife conservation, where de/extinction should be an invitation to consider wildlife beyond the simple binary quantification of dead or alive, extinct or extant. Whether opposed to or in favor of the concept of technologically (re?)introducing ghosts into ecosystems, this liminal category may feasibly serve as a stimulus to uncover new affective connections with living things, attending to recombinant and subjective ecologies.

The liminal geographies of de/extinction are intriguing and complex. They are opportunities for creativity and new epistemologies. This betwixt and between area, between being extinct and being extant, is profoundly geographical and multiple, deeply entangled within the politics and histories of relationships between living organisms, their environments, and their ecologies. Extinctions and de-extinctions take place and are materialized through some application of cultural and ecological significance, which tends to favor charismatic and spectacular nonhumans. In these emerging geographies encompassing the anabiotic, we find novel circumstances and chances for a rethinking of the role of humans and technologies in the diversity of worldly life. The salvaged and the synthesized creatures of scientific work emerge as compelling and uncanny mediators.

Earth is home to an innumerable magnitude of virtually extinct taxa, examples where it is merely a matter of time before the last individual passes away. And as anabiotic geographies emerge in many of these contexts, the lives and actions of those who remain are enmeshed within imaginaries regarding their resurrection, as recently exemplified by the discourses surrounding the northern white rhino. Extinction is an incredibly useful concept that makes conservation decision-making significantly easier. However perhaps it is time to embrace radically different objectives in the ways we relate with and to wildlife, such as those prioritizing the agencies and geographies of nonhumans, as the ontological foundations for the global rewilding movement have

sought to engage. Many new modes of understanding have explored these cosmopolitics for wildlife, which are “not neatly aligned, linear, or concordant.”¹²⁰ And in many cases, as illustrated through countless accounts of science fiction (think the *Jurassic Park* enterprise), the futures of de/extinction may seem like a disaster. But similar to Jamie Lorimer’s take on the Anthropocene, with this comes the presentation of novel opportunities for understanding existence on Earth.

These anabiotic geographies are very much real and a key element of our relationship with nonhuman life, and as technological and cultural capacities for engaging these worlds develop, agencies of the anabiotic will become an even greater aspect of these encounters. But, as I hope these de/extinction stories have illustrated, de/extinction is not just an inevitability of the future. It is active and forceful in the present, entangled in geographies and histories of extinctions and endangerments worldwide, speaking to specters and allowing them to speak to us.

ADAM SEARLE is a cultural and environmental geographer at the University of Cambridge, where he is researching the extinction and de-extinction of the bucardo and, more broadly, exploring themes related to the roles and significances of genetic technologies in human-nonhuman relations. This article was written while he was a visiting researcher at the Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona (ICTA-UAB).

Acknowledgments

I would like to thank Bill Adams and Jonny Turnbull for countless hours of conversation that have undoubtedly found their way into this article and for comments on earlier versions of this article that were presented at the Unversidade de Santiago de Compostela in September 2018 during the inaugural “Rethinking Animality” conference and at the conference “Animal Remains,” which was held at the University of Sheffield in April 2019. Many thanks to Ben Garlick and Kate Symons for their work on this exciting special issue and to Thom van Dooren for assistance in the editorial process.

References

- Acevedo, Pelayo, and Jorge Cassinello. “Biology, Ecology, and Status of Iberian Ibex *Capra Pyrenaica*: A Critical Review and Research Prospectus.” *Mammal Review* 39, no. 1 (2009): 17–32.
- Adams, William M. “Geographies of Conservation I: De-Extinction and Precision Conservation.” *Progress in Human Geography* 41, no. 4 (2017): 534–45.
- Barnosky, Anthony D., Nicholas Matzke, Susumu Tomiya, Guinevere O. U. Wogan, Brian Swartz, Tiago B. Quental, Charles Marshall, et al. “Has the Earth’s Sixth Mass Extinction Already Arrived?” *Nature* 471, no. 7336 (2011): 51–57.
- Braidotti, Rosi. “Posthuman Critical Theory.” In *Critical Posthumanism and Planetary Futures*, edited by Debashish Banerji and Makarand R. Paranjape, 13–32. New Dehli: Springer India, 2016.
- Braidotti, Rosi. *Transpositions: On Nomadic Ethics*. Cambridge: Polity Press, 2006.
- Broca, Paul. “Rapport sur la question soumise à la Société de Biologie au sujet de la reviviscence des animaux desséchés.” *Mémoires de la Société de Biologie, Paris 2* (1860): 1–140.
- Brooke, Victor. *Sir Victor Brooke: Sportsman and Naturalist*. London: John Murray, 1894.

120. Lorimer, *Wildlife in the Anthropocene*, 180.

- Buxton, Edward North. *Short Stalks: Or, Hunting Camps, North, South, East, and West*. London: Edward Stanford, 1892.
- Cabrera, Ángel. *Fauna Ibérica: Mamíferos*. Madrid: Museo Nacional de Ciencias Naturales, 1914.
- Cabrera, Ángel. "The Subspecies of the Spanish Ibex." *Proceedings of the Zoological Society of London* 81, no. 4 (1911): 963–77.
- Campagna, Claudio, Daniel Guevara, and Bernard Le Boeuf. "De-Scenting Extinction: The Promise of De-Extinction May Hasten Continuing Extinctions." *Hastings Center Report* 47, no. 4 (2017): S48–52.
- Carlin, Norman F., Ilan Wurman, and Tamara Zakim. "How to Permit Your Mammoth: Some Legal Implications of 'De-Extinction.'" *Stanford Environmental Law Journal* 33, no. 1 (2014): 3–47.
- Charo, R. Alta, and Henry T. Greely. "Crispr Critters and Crispr Cracks." *American Journal of Bioethics* 15, no. 12 (2015): 11–17.
- Chrulew, Matthew. "Freezing the Ark: The Cryopolitics of Endangered Species Preservation." In *Cryopolitics: Frozen Life in a Melting World*, edited by Joanna Radin and Emma Kowal, 283–305. Cambridge, MA: MIT Press, 2017.
- Church, George. "Hybrizing with Extinct Species: George Church at TEDxDeExtinction." www.youtube.com/watch?v=oTH_fmQo3Ok (accessed February 20, 2020).
- Church, George, and Ed Regis. *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*. New York: Basic Books, 2012.
- Cohen, Shlomo. "The Ethics of De-extinction." *NanoEthics* 8, no. 2 (2014): 165–78.
- Corlett, Richard T. "A Bigger Toolbox: Biotechnology in Biodiversity Conservation." *Trends in Biotechnology* 35, no. 1 (2017): 55–65.
- de las Cuevas, Enrique. "Los Parques Nacionales." *España Forestal* 65 (1920): 128–39.
- de Vos, Rick. "Extinction Stories: Performing Absence(s)." In *Knowing Animals*, edited by Laurence Simmons and Philip Armstrong, 183–95. Leiden, the Netherlands: Brill, 2007.
- Debruyne, Régis, Véronique Barriél, and Pascal Tassy. "Mitochondrial Cytochrome *b* of the Lyakhov Mammoth (Proboscidea, Mammalia): New Data and Phylogenetic Analyses of Elephantidae." *Molecular Phylogenetics and Evolution* 26, no. 3 (2003): 421–34.
- Derrida, Jacques. *Of Grammatology (De la Grammatologie)*, translated by Gayatri Chakravorty Spivak. Fortieth anniversary ed. Baltimore: Johns Hopkins University Press, 2016.
- Derrida, Jacques. *Specters of Marx (Spectres de Marx)*, translated by Peggy Kamuf. London: Routledge, 2006.
- Derrida, Jacques. *Writing and Difference (L'Écriture et la Différence)*, translated by Alan Bass. London: Routledge, 1978.
- Despret, Vinciane. *What Would Animals Say If We Asked the Right Questions?*, translated by Brett Buchanan and edited by Cary Wolfe. Minneapolis: University of Minnesota Press, 2016.
- Diario del AltoAragón. "Los cieíficos extraen el material suficiente para poder clonar ya al bucardo." *Diario del AltoAragón*, May 6, 1999.
- Donlan, Josh. "De-extinction in a Crisis Discipline." *Frontiers of Biogeography* 6, no. 1 (2014): 25–28.
- Fernández-Arias, Alberto, José Luis Alabart, José Folch, and Jean-François Beckers. "Interspecies Pregnancy of Spanish Ibex (*Capra Pyrenaica*) Fetus in Domestic Goat (*Capra Hircus*) Recipients Induces Abnormally High Plasmatic Levels of Pregnancy-Associated Glycoprotein." *Theriogenology* 51, no. 8 (1999): 1419–30.
- Fernández-Arias, Alberto, Jose Folch, José Luis Alabart, and Julio P. Ramón. "Successful Interspecific Embryo Transfer between Spanish Ibex (*Capra Pyrenaica*) and Domestic Goat (*Capra Hircus*) Using Micro-Osmotic Pumps for FSH Administration." *Theriogenology* 45, no. 1 (1996): 247.
- Fernández Arias, Alberto, Alberto Roche, Ramiro Alberio, José Luis Alabart, and José Folch. "Use of Hybrids as Recipients in Interspecies Embryo Transfer in the *Capra* Genus." *Theriogenology* 55, no. 1 (2001): 383.

- Folch, José, María Jesús Cocero, Patrick Chesné, José Luis Alabart, Verónica Domínguez, Yves Cognié, Alberto Roche, et al. "First Birth of an Animal from an Extinct Subspecies (*Capra Pyrenaica Pyrenaica*) by Cloning." *Theriogenology* 71, no. 6 (2009): 1026–34.
- Franklin, Sarah. *Dolly Mixtures: The Remaking of Genealogy*. Durham, NC: Duke University Press, 2007.
- Friese, Carrie. *Cloning Wild Life: Zoos, Captivity, and the Future of Endangered Animals*. New York: NYU Press, 2013.
- Friese, Carrie, and Claire Marris. "Making De-extinction Mundane?" *PLOS Biology* 12, no. 3 (2014): e1001825.
- Gan, Elaine, Anna Tsing, Heather Swanson, and Nils Bubandt. "Haunted Landscapes of the Anthropocene." In *Arts of Living on a Damaged Planet: Ghosts and Monsters of the Anthropocene*, edited by Anna Tsing, Heather Swanson, Elaine Gan, and Nils Bubandt, 61–15. Minneapolis: University of Minnesota Press, 2017.
- García-González, Ricardo. "Elementos para una filogeografía de la cabra montés ibérica (*capra pyrenaica schinz*, 1838)." *Pirineos* 166 (2011): 87–122.
- García-González, Ricardo. *Inventario de la población Española de bucardo*. Huesca: Instituto Pirenaico de Ecología, 1991.
- García-González, Ricardo, and Juan Herrero. "El bucardo de los pirineos: Historia de una extinción." *Galemys* 11, no. 1 (1999): 17–26.
- García-González, Ricardo, and Antoni Margalida. "The Arguments against Cloning the Pyrenean Wild Goat." *Conservation Biology* 28, no. 6 (2014): 1445–46.
- Garlick, Ben. "Cultural Geographies of Extinction: Animal Culture among Scottish Ospreys." *Transactions of the Institute of British Geographers* 44, no. 2 (2019): 226–41.
- Gippoliti, Spartaco, Fenton P. D. Cotterill, Colin P. Groves, and Dietmar Zinner. "Poor Taxonomy and Genetic Rescue Are Possible Co-Agents of Silent Extinction and Biogeographic Homogenization among Ungulate Mammals." *Biogeographia—The Journal of Integrative Biogeography* 33 (2018): 41–54.
- Gruman, Gerald J. "A History of Ideas about the Prolongation of Life: The Evolution of Prolongevity Hypotheses to 1800." *Transactions of the American Philosophical Society* 56, no. 9 (1966): 1–102.
- Haraway, Donna J. "Cyborgs to Companion Species: Reconfiguring Kinship in Technoscience." In *Chasing Technoscience: Matrix for Materiality*, edited by Don Ihde and Evan Selinger, 58–82. Bloomington: Indiana University Press, 2003.
- Haraway, Donna J. *Staying with the Trouble: Making Kin in the Chthulucene*. Durham, NC: Duke University Press, 2016.
- Heise, Ursula K. *Imagining Extinction: The Cultural Meanings of Endangered Species*. Chicago: University of Chicago Press, 2016.
- Hodgetts, Timothy, and Jamie Lorimer. "Methodologies for Animals' Geographies: Cultures, Communication and Genomics." *Cultural Geographies* 22, no. 2 (2015): 285–95.
- Horváth, Ágnes, Bjørn Thomassen, and Harald Wydra, eds. *Breaking Boundaries: Varieties of Liminality*. New York: Berghahn Books, 2015.
- Iacona, Gwennlian, Richard F. Maloney, Iadine Chadès, Joseph R. Bennett, Philip J. Seddon, Hugh P. Possingham, and Ken Thompson. "Prioritizing Revived Species: What Are the Conservation Management Implications of De-Extinction?" *Functional Ecology* 31, no. 5 (2017): 1041–48.
- Jepson, Paul, Frans Schepers, and Wouter Helmer. "Governing with Nature: A European Perspective on Putting Rewilding Principles into Practice." *Philosophical Transactions of the Royal Society B: Biological Sciences* 373, no. 1761 (2018): 1–12.
- Jørgensen, Dolly. "Reintroduction and De-Extinction." *BioScience* 63, no. 9 (2013): 719–20.
- Juulskjær, Malou, Nete Schwennesen, and Karen Barad. "Intra-active Entanglements: An Interview with Karen Barad." *Kvinder, Køn, and Forskning* 12, no. 1–2 (2012): 10–23.
- Krementsov, Nikolai. *Revolutionary Experiments: The Quest for Immortality in Bolshevik Science and Fiction*. Oxford: Oxford University Press, 2014.
- Lahlil, Sophia, Matthieu Lebon, Lucile Beck, Hélène Rousselière, Colette Vignaud, Ina Reiche, Michel Menu, Patrick Paillet, and Frédéric Plassard. "The First in Situ Micro-Raman Spectroscopic

- Analysis of Prehistoric Cave Art of Rouffignac St-Cernin, France." *Journal of Raman Spectroscopy* 43, no. 11 (2012): 1637-43.
- Lalueza-Fox, Carles. *Des-extinciones: Una inmersión rápida*. Barcelona: Tibidabo Ediciones, 2017.
- Lanza, Robert P., Jose B. Cibelli, Francisca Diaz, Carlos T. Moraes, Peter W. Farin, Charlotte E. Farin, Carolyn J. Hammer, Michael D. West, and Philip Damiani. "Cloning of an Endangered Species (Bos Gaurus) Using Interspecies Nuclear Transfer." *Cloning* 2, no. 2 (2000): 79-90.
- Lee, Kenneth. "Can Cloning Save Endangered Species?" *Current Biology* 11, no. 7 (2001): R245-46.
- Loi, Pasqualino, Teruhiko Wakayama, Joseph Saragustry, Josef Fulka Jr., and Grazyna Ptak. "Biological Time Machines: A Realistic Approach for Cloning an Extinct Mammal." *Endangered Species Research* 14, no. 3 (2011): 227-33.
- Lorimer, Jamie. "Nonhuman Charisma." *Environment and Planning D: Society and Space* 25, no. 5 (2007): 911-32.
- Lorimer, Jamie. "The Anthropo-Scene: A Guide for the Perplexed." *Social Studies of Science* 47, no. 1 (2017): 117-42.
- Lorimer, Jamie. *Wildlife in the Anthropocene: Conservation after Nature*. Minneapolis: University of Minnesota Press, 2015.
- Lorimer, Jamie, and Clemens Driessen. "Bovine Biopolitics and the Promise of Monsters in the Rewilding of Heck Cattle." *Geoforum* 48 (2013): 249-59.
- Lorimer, Jamie, and Clemens Driessen. "From 'Nazi Cows' to Cosmopolitan 'Ecological Engineers': Specifying Rewilding through a History of Heck Cattle." *Annals of the American Association of Geographers* 106, no. 3 (2016): 631-52.
- Lorimer, Jamie, and Clemens Driessen. "Wild Experiments at the Oostvaardersplassen: Rethinking Environmentalism in the Anthropocene." *Transactions of the Institute of British Geographers* 39, no. 2 (2014): 169-81.
- Madge, Clare, and Henrietta O'Connor. "Mothers in the Making? Exploring Liminality in Cyber/Space." *Transactions of the Institute of British Geographers* 30, no. 1 (2005): 83-97.
- Mälksoo, Maria. "The Challenge of Liminality for International Relations Theory." *Review of International Studies* 38, no. 2 (2012): 481-94.
- Manceau, Valérie, JeanPaul Crampe, Pierre Boursot, and Pierre Taberlet. "Identification of Evolutionary Significant Units in the Spanish Wild Goat, *Capra Pyrenaica* (Mammalia, Artiodactyla)." *Animal Conservation* 2, no. 1 (1999): 33-39.
- McCauley, Douglas J., Molly Hardesty-Moore, Benjamin S. Halpern, Hillary S. Young, and Philip J. Seddon. "A Mammoth Undertaking: Harnessing Insight from Functional Ecology to Shape De-Extinction Priority Setting." *Functional Ecology* 31, no. 5 (2017): 1003-11.
- McConnell, Fiona. "Liminal Geopolitics: The Subjectivity and Spatiality of Diplomacy at the Margins." *Transactions of the Institute of British Geographers* 42, no. 1 (2017): 139-52.
- McCorristine, Shane, and William M. Adams. "Ghost Species: Spectral Geographies of Biodiversity." *Cultural Geographies* 27, no. 1 (2020): 101-15.
- McMullen, Ken. *Ghost Dance*. United Kingdom: Channel Four Films, 1983.
- Mitchell, Katharyne. "Different Diasporas and the Hype of Hybridity." *Environment and Planning D: Society and Space* 15, no. 5 (1997): 533-53.
- Moore, Jason W. *Capitalism in the Web of Life: Ecology and the Accumulation of Capital*. London: Verso, 2015.
- Novak, Ben Jacob. "De-extinction." *Genes* 9, no. 11 (2018): 548.
- Ortega, Jordi. "Clonación para el bucardo." *La Vanguardia*, June 19, 1998.
- Paxson, Heather, and Stefan Helmreich. "The Perils and Promises of Microbial Abundance: Novel Natures and Model Ecosystems, from Artisanal Cheese to Alien Seas." *Social Studies of Science* 44, no. 2 (2014): 165-93.
- Poinar, Hendrik N., Carsten Schwartz, Ji Qi, Beth Shapiro, Ross D. E. Macphee, Bernard Buigues, et al. "Metagenomics to Paleogenomics: Large-Scale Sequencing of Mammoth DNA." *Science* 311, no. 5759 (2006): 392-94.

- Preston, Christopher J. "De-extinction and Taking Control of Earth's 'Metabolism.'" *Hastings Center Report* 47, no. 4 (Jul 2017): S37–42.
- Radomska, Marietta. "Non/Living Matter, Bioscientific Imaginaries, and Feminist Technoecologies of Bioart." *Australian Feminist Studies* 32, no. 94 (2017): 377–94.
- Richmond, Douglas J., Mikkel-Holger S. Sinding, and M. Thomas P. Gilbert. "The Potential and Pitfalls of De-Extinction." *Zoologica Scripta* 45, no. S1 (2016): 22–36.
- Rincon, Paul. "Fresh Effort to Clone Extinct Animal." BBC News, November 22, 2013. www.bbc.co.uk/news/science-environment-25052233.
- Robert, Alexandre, Charles Thévenin, Karine Princé, François Sarrazin, Joanne Clavel, and Philip Seddon. "De-extinction and Evolution." *Functional Ecology* 31, no. 5 (2017): 1021–31.
- Rohwer, Yasha, and Emma Marris. "An Analysis of Potential Ethical Justifications for Mammoth De-extinction and a Call for Empirical Research." *Ethics, Policy, and Environment* 21, no. 1 (2018): 1–16.
- Rose, Deborah Bird, Thom van Dooren, and Matthew Chrulew, eds. *Extinction Studies: Stories of Time, Death, and Generations*. New York: Columbia University Press, 2017.
- Sandler, Ronald. "De-extinction and Conservation Genetics in the Anthropocene." *Hastings Center Report* 47, no. 4 (2017): S43–47.
- Sandler, Ronald. "De-extinction: Costs, Benefits and Ethics." *Nature Ecology and Evolution* 1, no. 4 (2017): 105.
- Sandler, Ronald. "The Ethics of Reviving Long Extinct Species." *Conservation Biology* 28, no. 2 (2014): 354–60.
- Schmidt, Peter. "Anabiosis of the Earthworm." *Journal of Experimental Zoology* 27, no. 1 (1918): 57–72.
- Searls, David B. "The Language of Genes." *Nature* 420, no. 6912 (2002): 211–17.
- Seddon, Philip J. "The Ecology of De-extinction." *Functional Ecology* 31, no. 5 (2017): 992–95.
- Seddon, Philip J., Christine J. Griffiths, Pritpal S. Soorae, and Doug P. Armstrong. "Reversing Defaunation: Restoring Species in a Changing World." *Science* 345, no. 6195 (2014): 406–12.
- Seddon, Philip J., Axel Moehrensclager, and John Ewen. "Reintroducing Resurrected Species: Selecting De-extinction Candidates." *Trends in Ecology and Evolution* 29, no. 3 (2014): 140–47.
- Shapiro, Beth. *How to Clone a Mammoth: The Science of De-extinction*. Princeton, NJ: Princeton University Press, 2015.
- Shapiro, Beth. "Mammoth 2.0: Will Genome Engineering Resurrect Extinct Species?" *Genome Biology* 16, no. 1 (2015): 228.
- Shapiro, Beth. "Pathways to De-Extinction: How Close Can We Get to Resurrection of an Extinct Species?" *Functional Ecology* 31, no. 5 (2017): 996–1002.
- Shapiro, Beth, and Michael Hofreiter. "A Paleogenomic Perspective on Evolution and Gene Function: New Insights from Ancient DNA." *Science* 343, no. 6169 (2014): n. pag.
- Sherkow, Jacob S., and Henry T. Greely. "What if Extinction Is Not Forever?" *Science* 340, no. 6128 (2013): 32–33.
- Siipi, Helena. "The Authenticity of Animals." In *The Ethics of Animal Re-Creation and Modification: Reviving, Rewilding, Restoring*, edited by Markku Oksanen and Helena Siipi, 77–96. London: Palgrave Macmillan, 2014.
- Siipi, Helena, and Leonard Finkelman. "The Extinction and De-extinction of Species." *Philosophy and Technology* 30, no. 4 (2017): 427–41.
- Slater, Matthew H., and Hayley Clatterbuck. "A Pragmatic Approach to the Possibility of De-extinction." *Biology and Philosophy* 33, no. 4 (2018): 1–21.
- Steeves, Tammy E., Jeff A. Johnson, Marie L. Hale, and Philip Seddon. "Maximising Evolutionary Potential in Functional Proxies for Extinct Species: A Conservation Genetic Perspective on De-Extinction." *Functional Ecology* 31, no. 5 (2017): 1032–40.
- TallBear, Kim. "Beyond the Life/Non-Life Boundary: A Feminist-Indigenous Reading of Cryopreservation, Interspecies Thinking, and the New Materialisms." In *Cryopolitics: Frozen Life in a Melting World*, edited by Joanna Radin and Emma Kowal, 179–202. Cambridge, MA: MIT Press, 2017.
- Taussig, Karen-Sue, Klaus Hoeyer, and Stefan Helmreich. "The Anthropology of Potentiality in Biomedicine." *Current Anthropology* 54, no. S7 (2013): S3–14.

- Thompson, Charis. *Making Parents: The Ontological Choreography of Reproductive Technologies*. Cambridge, MA: MIT Press, 2005.
- "Todo listo para clonar al último bucardo con células de su piel." *La Vanguardia*, May 6 1999.
- Turner, Stephanie S. "Open-Ended Stories: Extinction Narratives in Genome Time." *Literature and Medicine* 26, no. 1 (2007): 55–82.
- Turner, Victor W. *The Forest of Symbols: Aspects of Ndembu Ritual*. Ithaca, NY: Cornell University Press, 1967.
- Ureña, Irene, Juan Luis Arsuaga, María Ángeles Galindo-Pellicena, Anders Götherström, and Cristina Valdiosera. "Filogenia y evolución local de cabra montés (*capra pyrenaica*) en el yacimiento cuaternario de chaves (Huesca, España)." *Boletín de la Real Sociedad Española de Historia Natural* 105 (2011): 5–14.
- Ureña, Irene, Erik Ersmark, José Alfredo Samaniego, María Ángeles Galindo-Pellicena, Evelyne Crégut-Bonnoure, Héctor Grau Bolívar, Asier Gómez-Olivencia, et al. "Unraveling the Genetic History of the European Wild Goats." *Quaternary Science Reviews* 185 (2018): 189–98.
- van Dooren, Thom. *Flight Ways: Life and Loss at the Edge of Extinction*. New York: Columbia University Press, 2014.
- van Dooren, Thom. "Life at the Edge of Extinction: Spectral Crows, Haunted Landscapes, and the Environmental Humanities." *Humanities Australia* 5 (2014): 8–22.
- van Gennep, Arnold. *The Rites of Passage*. London: Routledge, 1960.
- Vignon, Xavier, Patrick Chesné, Daniel Le Bourhis, Jacques Edmond Fléchon, Yvan Heyman, and Jean-Paul Renard. "Developmental Potential of Bovine Embryos Reconstructed from Enucleated Matured Oocytes Fused with Cultured Somatic Cells." *Comptes Rendus de l'Académie des Sciences—Series III—Sciences de la Vie* 321, no. 9 (1998): 735–45.
- Wagner, Norman, Axel Hochkirch, Henrike Martin, Daniela Matenaar, Katja Rohde, Frank Wacht, Charlotte Wesch, et al. "De-extinction, Nomenclature, and the Law." *Science* 356, no. 6342 (2017): 1016–17.
- Whittle, Patrick M., Emma J. Stewart, and David Fisher. "Re-creation Tourism: De-extinction and Its Implications for Nature-Based Recreation." *Current Issues in Tourism* 18, no. 10 (2015): 908–12.
- Wischermann, Clemens, and Philip Howell. "Liminality: A Governing Category in Animate History." In *Animal History in the Modern City: Exploring Liminality*, edited by Clemens Wischermann, Aline Steinbrecher, and Philip Howell, 1–24. London: Bloomsbury, 2019.
- Wischermann, Clemens, Aline Steinbrecher, and Philip Howell, eds. *Animal History in the Modern City: Exploring Liminality*. London: Bloomsbury, 2019.
- "Woolly Mammoth Revival." Revive and Restore. reviverestore.org/projects/woolly-mammoth/ (accessed January 25, 2020).
- Yusoff, Kathryn. "Geologic Subjects: Nonhuman Origins, Geomorphic Aesthetics, and the Art of Becoming Inhuman." *Cultural Geographies* 22, no. 3 (2015): 383–407.
- Zimov, Sergey A. "Pleistocene Park: Return of the Mammoth's Ecosystem." *Science* 308, no. 5723 (2005): 796–98.