

ARTICLE

Worlding and weirding with beaver: A more-than-human political ecology of ecosystem engineering

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Abstract

Scientists and policy-makers promote 'Nature-based Solutions' to the interconnected challenges associated with the Anthropocene. Often these involve the strategic use of ecosystem engineers: animals, plants, and microbes with disproportionate ecological agency capable of regional or even planetary-scale niche construction. This environmental mode of biopolitics is promoted as biomimicry: restoring, rewilding, or rewetting diverse ecological systems. This paper critically examines the multispecies relations promised by this model through a focus on beaver in Britain over the last 12,000 years. It begins with beaver making Britain hospitable for early settlers and agriculturalists as they returned after the last ice age. It traces the subsequent demise of beaver due to hunting and land use change, and then follows the recent return of beaver as tools for natural flood management and nature recovery. It attends to situations in which these multispecies world-making projects go awry in the weird ecologies of the Anthropocene. This story of beaver helps situate enthusiasms for proactive ecosystem engineering in deeper time. It highlights the beguiling potential of Nature-based Solutions while cautioning against tendencies towards anthropocentrism, an apolitical mononaturalism, and an ecomodernist hubris. The paper combines concepts from archaeology, ecology, anthropology, and geography into a new framework for theorising multispecies acts of worlding and weirding.

KEYWORDS

beaver, biopolitics, Britain, Nature-based Solutions, niche construction, weird

1 | ECOSYSTEM ENGINEERING

The rise of Earth System Science and the diagnosis of the Anthropocene are reconfiguring the geographies of wildlife conservation. A prevalent (though contested) metanarrative presents the planetary (Chakrabarty, 2021): an ontology of a dynamic Earth divided into interacting spheres marked by thresholds or tipping points. Humans (essentialised as a

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species) are identified as an earth-shaping force (Steffen et al., 2011a; Steffen et al., 2011b) capable of long-term niche construction on a 'used planet' (Ellis et al., 2013). Wilderness is debunked as an ecological fallacy and alarm is raised that the twentieth-century 'Great Acceleration' (Steffen et al., 2015) in resource extraction has so radically reconfigured planetary metabolic cycles that it risks pushing the Earth up to and over 'planetary boundaries' (Richardson et al., 2023), threatening a rupture in the transition out of the Holocene so profound it will endanger human civilisation and precipitate a sixth mass extinction.

In response, prominent scientists appeal for new models of 'planetary stewardship' (Steffen et al., 2011a; Steffen et al., 2011b), enlightened models of earth system governance to keep within planetary boundaries. These range from 'hard', 'grey' plans for geo-engineering to 'soft', 'green' frameworks for 'Nature-based Solutions' (NbS) (Seddon et al., 2020), in which an underspecified Nature grounds an ecological model of biopolitics. This paper focuses on a subset of NbS which deploys ecologically powerful organisms as 'ecosystem engineers' to modulate biogeophysical processes to help maintain and repair Earth systems. High-profile examples include fast-growing plants that sequester carbon dioxide, legumes that fix nitrogen, bacteria that eat plastic, and – the focus of this paper – beaver that modulate water and deliver biodiversity in river catchments. Guided by ecological science, these organisms are put to work as living tools for securing Holocene-proximate futures, as agents for biomimicry often unravelling and reworking the modes of environmental management that were central to the discourses and practices of modern development and improvement that drove the Great Acceleration.

These appeals to Nature are beguiling, but they confound geographers' efforts over past decades to reveal the slipperiness of this term and the political work it can do (Castree, 2012). In so doing, NbS risk perpetuating the problems geographers (and others) have diagnosed with (eco)modernist approaches to environmental governance that use science to short-cut politics (Latour, 2004), by assuming a singular view of the nonhuman world, that is reduced to the provider of a set of functions and services. There is a risk that Nature-based approaches to ecosystem engineering become founded on what John Law (2015) terms a 'one-world' worldview, effacing epistemic and ontological difference (Osaka et al., 2021). Critics suggest that this 'mononaturalism' perpetuates the epistemic violence and colonialism of forms of environmental governance premised on the primacy of universal objective science (de la Cadena & Blaser, 2018). In response, they encourage critical analysis of the multiple worlds of salient human and nonhuman actors, sensitive to the emergent, non-analogue, and often weird ecologies that characterise the Anthropocene.

This paper takes up this challenge to deliver three main aims. It first situates this emerging model of proactive ecosystem engineering in a Holocene environmental history, drawing on revisionist work in multispecies archaeology that flags the role of plants and animals in making worlds hospitable for people. It flags the significance for the geographies of conservation of thinking with deep time to understand nonmodern human–environment interactions. Second, it critically examines the multispecies political ecology enacted by this model of NbS, focusing on both the political status afforded nonhuman ecosystem engineers and how it deals with the violence and iniquities of past colonial and capitalist environmental transformation. Finally, the paper builds from the challenges posed by this analysis to offer suggestions as to how emerging frameworks for NbS might best enable a just transition within the weird ecologies of the Anthropocene.

2 | BEAVER

It delivers these aims by telling an environmental history of beaver (*Castor fibre* and *Castor canadensis*), primarily focused on Great Britain. Scientists, philosophers, and other enthusiasts have long celebrated beaver as the 'quintessential ecological engineer' (Brazier et al., 2021). Beaver seek landscapes with stable water levels to construct lodges with submarine access points protected from predation (Figure 1). They build dams to control fluctuating water levels. Dams store water, trap sediment, and profoundly affect river dynamics, so that beaver have been described as 'zoogeomorphic agents' (Gurnell, 1998) capable of landscape-scale transformation (Figure 2). Beaver fell trees to build dams and to access bark and leaves, which are their primary food. They therefore act as 'keystone species' (Rosell & Campbell-Palmer, 2022) whose trophic relations shape riparian vegetation structure, and by creating ponds and meadows full of alluvial soil and deadwood they generate habitats that are rich in biodiversity (Figure 3). As engineers and keystones, beaver figure as the paradigmatic nonhuman 'niche constructor' (Odling-Smee et al., 2003). Like humans, their engineering leaves an ecological legacy in the landscape that shapes the evolutionary conditions of those around them and those that come after them.

In the last 30 years, beaver have been deployed in regimes for natural flood management (Dadson et al., 2017). They are used to reverse long histories of modern drainage and flood prevention that separated water and land and accelerated the flow of water through a catchment. They are enrolled for rewetting artificially drained floodplains and for rewiggling straightened river channels (Brazier et al., 2021) to 'slow the flow' of water. They are also employed as ecological tools



FIGURE 1 Beaver den construction.

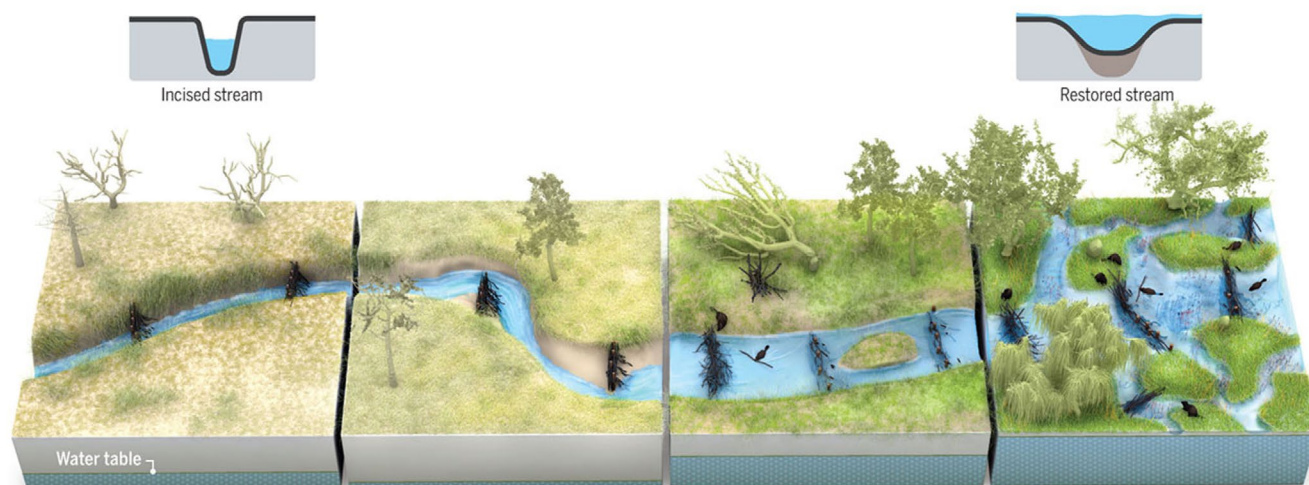


FIGURE 2 Beaver as zoogeomorphic agents (image produced by the United States Fish and Wildlife Service).

for rewilding, managing vegetation and hydrology to create biodiversity and to improve water quality. At this stage it is important to note that ‘beaver’ is a genera-level aggregation that masks significant variation among individual organisms. In this paper, I am most interested in the consistent hydrological and ecological functions that beaver perform across diverse contexts.

The paper tells a chronological story of beaver in four parts. It begins with the return of beaver to (what became known as) Great Britain at the start of the Holocene after the retreat of the glaciers. It traces how beaver helped create hospitable landscapes for early hunter-gatherers and then farmers. It then follows the demise of beaver and their eventual extinction in the sixteenth century through land use change and hunting pressure. A third section explores the return of Britain to beaver after their reintroduction in the late-twentieth century, initially through illegal release by restoration enthusiasts and then through state-sanctioned programmes for natural flood management. Finally, it examines how some beaver make novel political ecologies in the scrambled biogeography of the Anthropocene.

Methodologically, the paper draws selectively from the extensive literatures on beaver that are found across numerous disciplines and historical periods. It combines work in archaeology, ecology, geography, history, and anthropology about beaver in both Europe and North America. It interrogates historical sources coupled with some modest primary data collection comprised of field visits to reintroduction sites and interviews with scientists, policy-makers, and practitioners involved in beaver restoration and management in Great Britain and elsewhere in Europe. As occasional islands, the land



FIGURE 3 Beaver as keystone species (image produced by Jeroen Helmer).

mass of Britain makes a compelling case study for the deep time analysis offered here. Species come and go depending on the vicissitudes of biological, geomorphic, and hydrological mobilities. But once locally extinct, terrestrial animals like the beaver can only return with human assistance, raising legal and political questions less prominent on the continent. This is not a comprehensive account of beaver worldings. It selects stories that are indicative of the types of locations, periods, and interactions identified for thematic analysis. Many other beaver worlds exist.

3 | WORLDING AND WEIRDING

Niche construction theory (Odling-Smee et al., 2003) has risen to prominence in the natural sciences as a means of conceiving the disproportionate ecological and geomorphic influences of ecosystem engineers like beaver (and humans). The theory departs from orthodox accounts of evolution, which emphasise adaptation by natural selection to an external environment over which organisms have no influence. Instead, it focuses on how organisms shape their environment, establishing feedback relationships that configure future ecologies, behaviours, and selection pressures.

Niche construction theory and the idea of ecosystem engineering inform the discussions of conservation in the Anthropocene that I introduced above. Key figures like Erle Ellis (2015) present humans as planetary-scale niche constructors and trace the long-term anthropogenic impacts on biodiversity of hunting, resource extraction, and agriculture. They map environmental histories characterised by the loss of biological diversity and abundance, the profound scrambling of biogeographical patterns by globalisation, widespread 'trophic downgrading' (Estes et al., 2011) due to megafauna extinction, and the domestication of total plant and animal biomass into populations of cereal crops and livestock (Smil, 2013). This ecological research is high profile and has clear political aims. It flags biodiversity loss, while noting a history of human niche construction that is far longer than that centred by both mainstream environmentalism

and the late twentieth-century start dates for the Anthropocene. At its most hyperbolic, it normalises humans as a quasi 'God species' (Lynas, 2011) capable of both planetary-scale destruction and acting as an enlightened 'hyper-keystone species' (Worm & Paine, 2016) devising and delivering Nature-based programmes for planetary stewardship (e.g., Schmitz et al., 2023; Svenning et al., 2016).

Niche construction theory has had a more ambivalent reception in the social sciences. It is both popular and contested in archaeology and anthropology (Schultz, 2021; Spengler, 2021), but has had limited traction in geography (though see Royle, 2018). Authors coming to the concept from the 'cultural' and/or 'critical' conceptual persuasion favoured in this paper seem wary of deploying the scientific terminology of the niche (e.g., Scott, 2017; Tsing, 2015). Despite its 'progressive' (Fuentes, 2016) associations, they are perhaps cognisant of how neo-Darwinian sociobiology was (ab)used to naturalise selfish, violent, and patriarchal social formations (Castree, 2005; Sahlins, 1976). They tend to use the alternative lexicon of worlding.

Worlding is a popular and promiscuous concept in geography and anthropology (McCormack, 2017). Here I draw on a conceptualisation grounded in process philosophy in which worlding is 'multinatural' (Lorimer, 2012) or 'pluriversal' (Escobar, 2020). It describes coupled material and semiotic processes and seeks to capture both the ontological entanglement of people with technologies, organisms, and the elements, as well as the practices through which such worlds are known, controlled, and contested. Worlding is an ongoing process and worlds are always becoming. A world is more-than-human in as much as it is comprised of myriad agents, and worlds are multiple as they are inhabited, sensed, and enacted by a range of actors, including beaver. In the words of Marisol de la Cadena and Mario Blaser, we live in a 'world of many worlds' (de la Cadena & Blaser, 2018).

For Anna Tsing (2015), such worlds are 'polyphonic', comprised of diverse and sometimes discordant temporalities. They are haunted by absences and past events and are non-equilibrium with the potential to tip and change state. Worlds are not flat, as agency within them is unevenly distributed, with some actors having disproportionate ability to shape the worlds of others. Various terms have been offered to capture the relational material constitution of these worlds, including assemblages (Latour, 2005), entanglements (Haraway, 2008), knots (Haraway, 2016), and a meshwork (Ingold, 2011). As I explain below, strands of this work on worlding connect with – and make weird – the type of 'Gaian' systems theory that underpins the ecological theory of niche construction (Clarke, 2020).

Geographers, archaeologists, and anthropologists have long been concerned with the worlding practices of people and their consequences for plants, other animals, and the ecologies they comprise. Archaeologists and anthropologists have also traced environmental histories of hunting, domestication, and agriculture, as well as of disease. Historical accounts tended to be both anthropocentric and colonial, frequently celebrating Western modernity, settler colonialism, and the agricultural mastery over nature (Anderson, 2006a, 2006b; Scott, 2017). More recent accounts, associated with the multi-species and more-than-human turns that cut across these disciplines (Birch, 2018; Kirksey & Helmreich, 2010; Lorimer & Hodgetts, 2024), have drawn attention to nonhuman worlding practices and experiences, as well as to the agency of useful, tasty, narcotic, and charismatic nonhumans in shaping human worlding (Mintz, 1986; Pollan, 2006; Swanson et al., 2018). Meanwhile revisionist work critiques linear accounts of agricultural development (Graeber & Wengrow, 2021) and draws attention to the violence done to indigenous worlds by agricultural transitions and resource extraction, casting doubt on the purported benefits of modern agriculture and the forms of civilisation it enables (Scott, 2017). In the context of the Anthropocene, attention has firmly shifted to the anthropogenic unworlding (Chao, 2022) of Holocene ecologies, especially by plantation agriculture (Barua, 2022).

This work on unworlding encourages a scepticism about bright green ecomodernist plans for planetary ecosystem engineering, on both political and ecological grounds (Clark & Szerszynski, 2020). Instead, it suggests we figure the novel worlds of the Anthropocene as 'weird' and offers 'global weirding' as a term to describe both anthropogenically changed worlds and the dark, uncanny, disorientating affective experience of living in them (for a review see Turnbull et al., 2022). Here, the weird describes a more-than-human world in which time is out of joint, spatial patterns and connections are scrambled, and the metabolic pathways of the earth system are radically reconfigured. Once aligned worlds jar and glitch. For Haraway (2016) this is the Chthulucene, a non-analogue world of surprises, in which monsters emerge from within, as thresholds are crossed, systems tip, and phases change (see also Tsing & Bubandt, 2017). These are ruined worlds haunted by absences in at least two registers. First, by the ecological legacies of missing ecosystems engineers that give rise to contemporary dysbiosis. Second, in affective conditions like 'ecological grief', confusion, and 'solastalgia' (Albrecht et al., 2007) that are engendered by the experience of rapid environmental change and the knowledge of what has been lost. As the final section of the analysis illustrates, this reading of Gaian science (Clarke, 2020) describes worlds inhabited by strange, dislocated subjects caught in discordant ecologies, animated by earth system processes far beyond the prediction and control of ecosystem engineers – human or otherwise.

What counts as worlding and what counts as weirding is clearly a matter of scale, degree, and positionality. Well-worlded worlds for some will be weird worlds for others. And worlds have been weird at past moments of local and planetary change. But it is fair to anticipate that the passage of the Earth further into the Anthropocene will be accompanied by an aggregate increase in weirding for more organisms.

4 | BEAVER WORLDING

Beaver originated in North America in the late Eocene (c. 33 million years BP) well before *Homo sapiens*. They colonised Eurasia via the Bering land bridge, giving rise to the two surviving beaver species. *Castor fibre* is the European variant. The organisms gathered under this category have a long history on the land that is now known as Great Britain, arriving and retreating in the ebb and flow of the glacial cycles that successively scoured the earth. I start this story as the glaciers were retreating at the end of the last ice age some 13,000 years ago. Britain was still connected to the continental land mass and beaver began moving north and west from their glacial refugia in Spain and South East France. Beaver are mobile animals and followed river valleys to colonise the new riparian habitats emerging in a warming climate. Here, they occupied an ecological niche already engineered by past waves of colonising species like the bacteria, lichen, and earthworms that built British soils. They flourished, so that when Britain became an island c. 6000–4000 BC there were estimated to be over 100,000 beaver living in rivers and lakes all over the country (Crane, 2016).

Work by multispecies archaeologists like Bryony Coles (Coles, 2006; see also Hussain & Brusgaard, 2023; Liarsou, 2013) traces how beaver transformed the British landscape, making a world that was especially hospitable for the people who travelled and settled alongside them. This research documents the key material and semiotic dimensions to this premodern multispecies worlding, first noting how beaver had profound effects on the hydrology and the ecology of Britain. Beaver created ponds that retained water to provide a dependable water supply and offered watering spots for favoured terrestrial prey like elk, aurochs, wild horses, and deer. These animals came to drink and graze, concentrating in densities that helped hunting. Beaver produced wetlands rich in fish and wildfowl, including tasty and nutritious species like duck, salmon, and European eels.

Meanwhile, beaver dams trapped alluvial sediment, and when beaver moved on and their dams decayed, they left behind beaver meadows. These are highly fertile patches of unforested land, often drained by the relict canals that beaver dug to stay submerged within their ponds and to transport timber. These beaver meadows served as ideal locations for grazing domesticated herbivores and then for early experiments in arable agriculture. They also created habitat for bees, opening early opportunities for the gathering of nutritious honey. As Coles and Orme put it: ‘we think that some of the land-take of the first farming communities may have been influenced by and in some cases a stealing from the beaver’ (Coles & Orme, 1983, p. 99).

Settlers also made ample use of resources harvested from beaver bodies and materials gleaned from beaver landscapes. They trapped, hunted, and killed beaver for food and used other body parts for clothing (fur), medicine (the castoreum gland that is rich in painkilling salicin derived from eating willow), and tools (teeth worked into tools for cutting and carving wood). From her extensive excavations in Somerset, Bryony Coles (2006) suggests that early settlers used uninhabited beaver lodges for shelter and were drawn to the ready availability of felled and dry wood provided by beaver, using wood chips and dead logs to kindle and sustain fires, thus overcoming the relative fire-resistance of the wet green British forest. She proposes that settlers repurposed convenient length branches to build fishing platforms and walkways over marshy ground. Mobile people made use of walking sticks and poles first cut and shaped by beaver. Meanwhile the fast-growing shoots of trees like hazel and willow that had coevolved with regular beaver browsing provided ideal materials for baskets, traps, and fencing.

These archaeologists speculate on how beaver shaped human mobilities. Coles suggests that beaver dams provided navigable causeways across wet ground and when abandoned left linear stepping-stones once the wood cleared. These solid features in the terraqueous landscape configured early routes shaping subsequent geographies of British communication, territory, and trade. Contemporary Brits still walk in the footsteps of beaver and live in places named after them. She suggests that close observation of beaver worlding inspired early evidence of biomimicry. She speculates that early farmers learnt from their aquatic engineering to develop the technologies for irrigation and drainage that became so central for subsequent agricultural development, while forestry practices like coppicing replicate the browsing of beaver to produce firewood and construction materials.

The material culture and grave goods from this period are rich in beaver remains (like teeth worked into tools and jewellery) and early written materials and illustrations are full of beaver symbolism. While the meaning of these artefacts

is often unclear, Hussain and Brusgaard (2023) highlight how many people would have been familiar with handling beaver bones, creating a haptic familiarity and sympathy for the animal. This beaver symbolism serves as an early chapter in the varied cultural veneration of that animal that I trace in following sections. It is suggestive of multispecies kinship relations akin to the perspectives of some lay and indigenous people living with beaver today, who think of the beaver outside of the instrumental logics central to NbS.

In summary, archaeologists highlight the substantial world-making activities of beaver in Neolithic Britain. They trace how beaver developed the ecological engineering of early pioneer species to construct an ecological niche conducive to the flourishing of myriad biodiversity. In this period, people largely encountered beaver in commensal, but sometimes parasitic, relationships. They lived alongside them, benefited from their work, ate them, but also venerated them and were inspired by their craft. People lived closely with beaver, but they did not domesticate them, as they did other animals at this time. Instead, both species were highly adaptable and became entangled in landscape-scale projects of ecological engineering, building a multispecies ecological and hydrological niche whose original architects and principal labourers were as beaver as they were human. Their activities were so aligned and their legacies so similar that archaeologists have found it difficult to disentangle which species was responsible. In Haraway's (2016) terms, people and beaver were entangled in world-making relations of sympoiesis, of 'making-with'.

5 | UNWORLDDING

From a likely high point around 4000 BC, beaver populations experienced a first gradual and then accelerating decline through the first and second millennia AD, so that the beaver were largely absent from Britain by the seventeenth century (Coles, 2006). This decline was mirrored across the rest of the species' Eurasian range, so that by the end of the 19th century the European beaver population was reduced to just eight isolated populations, amounting to a mere 1,200 animals (Rosell & Campbell-Palmer, 2022). The decline of the beaver and the unworlding of beaver-made landscapes was driven by two key sets of geographical processes: the trade in beaver body parts (fur and castoreum) and agricultural improvement. I focus on the latter, as it is most relevant for the story of more-than-human niche construction that I develop in this paper, and would direct readers to excellent critical histories that trace the transfiguration of the beaver into a fashionable commodity (Ogden, 2018; Poliquin, 2015; White, 1994). The demand for beaver fur and scent fuelled the violent social and ecological relations of North American settler colonialism. It made multimillionaires out of those who controlled the trade and caused the seventeenth-century 'beaver wars' between English and French colonialists and their rival indigenous allies vying to secure access to the most lucrative trapping grounds and trade routes.

Back in Britain, those beaver that survived the ravages of the European fur trade, which began in the Roman era and continued through the first millennium AD, were subject to the accelerating violent social and ecological transformations taking place in rural Britain from the fourteenth century onwards and that led to a profusion of agricultural revolutions (Rackham, 2000). British agricultural enlightenment (Jones, 2016) involved the large-scale enclosure of wet and marshy 'wasteland' and its improvement into fertile, well-drained farmland. This required the systematic control of river hydrology and was delivered through the digging of drains, the building of dams and levees, and the deployment of windmills and steam pumps. It involved the construction of the canal network and the rationalisation and canalisation of rivers to facilitate marine transportation of agricultural and industrial goods. Urban and industrial development expanded on the floodplain, requiring the strict separation of land and water to prevent flooding. And rivers were tamed as a source of hydraulic power to fuel the early (pre-fossil fuel) phases of the industrial revolution and then as a source of hydroelectricity (Raven & Holmes, 2019). Meanwhile, the development of commercial forestry led to a comparable rationalisation of tree planting and harvesting through the rise of plantation forestry (Watkins, 2014).

Fuelled by increasingly powerful earth-moving machinery, and armed with masonry and then concrete, human river managers no longer required beaver labour to shape rivers or to store soils. Woelfle-Erskine and Cole (2015) explain how the unpredictable or 'stochastic' world-making practices of beaver jeopardised these developments. By the sixteenth century, the status of beaver had shifted from food, furbearer, or hydrological guide to vermin that disrupted human property. Beaver became subject to bounty payments in programmes geared towards their total eradication. Beaver are one of myriad species whose worlds were unravelled by these accelerating practices of improvement. Biodiverse wild and agroecological landscapes were simplified, rationalised, and optimised for resource extraction and plantation agriculture. And favoured species like sheep, cattle, deer, wheat, and barley proliferated in the new ecologies they created.

From the perspective of the beaver, we can understand this decline as an unworlding in at least three registers: (i) the loss of individual beaver and the discrete animal worlds they embody. In aggregation, this loss culminates eventually in

(ii) the 'double death' (Rose, 2012) of a species-level extinction and (iii) the profound ecological dysfunctionality that the absence of the beaver has for those organisms (including some humans) whose worlds depend on the ecological niche they create. In this last case, unworlding describes the unravelling of sympoietic ecological relationships indexed to the beaver niche, often developed over long periods of time and degrading at different rates.

This unworlding leaves a legacy in the lifeworlds of other organisms. Beaver absence increases the risk of drought, fire, and flash flooding, and accelerates the loss of soil and wetland habitats. For ecologists, it is symptomatic of the ecological collapse caused by the extinctions of engineer species, manifest in a host of dysfunctional biochemical cycles, hydrological flows, and ecological relationships (Galetti et al., 2018). For anthropologists and geographers, this collapse generates 'blasted' (Tsing, 2014) landscapes that are 'haunted' by the ghosts of their absent formative engineers (McCorristine & Adams, 2019).

However, in many ways the haunting impact of beaver absence was deferred in Britain by a set of elaborate practices of beaver biomimicry. Coles (2006) suggests that British farmers, foresters, and water managers continued to practice beaver-like management long after beaver were gone, often unaware that they were doing so. One example is the development of water meadows in the sixteenth century. Here farmers used dams and irrigation channels to modulate river flow and to divert water to retain it on the land for controlled periods of time. A second example is the development of coppice woodland management involving the selective harvesting of timber from those riparian trees primed to regrow due to their co-evolutionary history with beaver. In these cases, human land managers replicate the beneficial niche construction activities of beaver on anthropocentric terms in ways that anticipate contemporary reworlding.

Beaver also exerted an influence from beyond the grave through their promiscuous literary circulation in metaphor and allegory. As Poliquin (2015) documents, influential figures across different historical periods have celebrated the reproductive, labouring, and ecological virtues of beaver (as well as finding a source of bawdy metonym). Beaver have been cast as paragons of family values (Owl, 1935/2020), as exemplary Protestant workers (Morgan, 1868), as evidence of the natural character of solidarity (Kropotkin, 1902/2006), alongside the enlightened ecosystem engineers in which guise they feature in this paper. Beaver are an anthropomorphic charismatic species with affective power, capable – even in absentia – of what Maan Barua describes as 'niche construction through affect' (2023, p. 181). This affection for beaver has been amplified in the media ecologies that drive contemporary projects of reworlding.

6 | REWORLDDING

Although beaver were kept in captivity throughout the nineteenth and early-twentieth centuries (Crumley, 2015), it is only in the last few decades that an international movement has emerged dedicated to their reintroduction into the British landscape. As I explained in the introduction, this was largely premised on a growing awareness of the consequences of beaver absence and a desire to restore the hydrological and ecological functions they provide. Though beaver are also charismatic animals, which species conservationists consider important in their own right, beyond their functional utility. 'Beaver believers' (Goldfarb, 2018) have been extremely successful. Beaver have returned from their 'fur trade refugia' (Rosell & Campbell-Palmer, 2022) to a substantial proportion of their original range, becoming the fastest growing wild animal population in Europe (Ledger et al., 2022). This has involved anthropogenic translocations and reintroductions, as well as beaver escaping from captivity and initiating their own recolonisation. The character, speed, and consequences of this return have proved controversial, pitting enthusiasts against some farmers, fishers, foresters, and traditional conservationists. It is early days and there is a live debate about the social, ecological, and economic impacts of their return.

The return of the beaver to Britain (and elsewhere) is well recorded in recent geographical scholarship (e.g., Crowley et al., 2017; Ward & Prior, 2020; Welden, 2023) and popular natural history (Gow, 2020). Beaver reworlding has been propelled by a small number of enthusiasts: 'guerrilla rewilders' (Thomas, 2022a) (including a mythical 'beaver bomber') willing to operate on the margins of the law to bring animals into the country and to secure their release into the wider countryside. These enthusiasts were frustrated by official inertia, despite the legal obligation for beaver introduction created by their listing in the 1992 EU Habitats Directive. In a novel form of prefigurative ecological politics, they successfully wagered that it would prove politically unpalatable for government officials and landowners to kill charismatic (though illegal) beaver (Crowley et al., 2017). They correctly anticipated that once present these animals would create ecological legitimacy for official trials, and political pressure for conservation funding and protective legislation.

At time of writing, beaver reworlding is characterised by two broad approaches (Ward & Prior, 2020). In the first official model, breeding pairs of beaver are sourced from free-ranging populations – initially in Germany or Norway and now from Scotland. They are trapped, transported, quarantined, and then translocated into fenced enclosures. These are

generally in areas with suitable habitat in the upper reaches of river catchments prone to flash flooding. Flash flooding is a significant environmental hazard in areas where deforestation and moor burning, alongside the improvement through drainage of upland areas accelerates the passage of water down a valley. Flooding became a hot political issue in the early 2000s, promoting research and policy enthusiasm for modes of natural flood management. This approach was developed in the absence of living beaver and sought to artificially mimic beaver engineering by constructing leaky dams, rewiggling rivers with heavy machinery, and rewetting flood plains through the mechanical removal of artificial field drains. The efficacy of these interventions helped legitimate the reintroduction of living organisms. This model of beaver in enclosures is popular among landowning conservation organisations as well as sympathetic private landlords. There is a vibrant market for live beaver, which trade for more than £1,000 per animal, and business is flourishing for those involved in their capture and relocation.

A second model of reworlding is illustrated by the growing number of free-ranging beaver in river catchments across Britain after either escaping from (sometimes deliberately porous) enclosures, or through planned unlicensed releases. The most established and high-profile population lives in the catchment that feeds the River Tay in Scotland, having been released or permitted to escape in the early 2000s from local private collections (Crumley, 2015). Beaver build dams in the tributaries and the lochs that feed the river, but also – and more controversially – have moved onto the floodplain and dug lodges in the embankments that protect some of Scotland's most fertile agricultural land from flooding. They have disturbed the manicured banks and channels of one of the country's premium salmon fishing rivers. Beaver created problems for farmers and land managers, who pressured the regulator (Scottish Natural Heritage, now Nature Scot) to intervene. When the authorities dallied, and in the absence of regulation (cf. Thomas, 2022c), they took matters into their own hands and started shooting beaver. Thus ensued a heated debate between beaver enthusiasts and those whose economic interests they threatened, creating a political and regulatory headache for the Scottish government.

An uneasy compromise has been reached (IUCN/CPSG, 2022), in which the self-willed recolonisation of the Tay is still permitted and conservation organisations and private individuals are even allowed to move beaver into Scottish lochs and rivers that they would have been unlikely to reach on their own. At the same time, problem beaver can be trapped with a licence, generating the supply required for the burgeoning beaver export market, or shot if no suitable alternative habitat is available. Meanwhile, an emerging collective of beaver wildlife managers have developed practical advice for co-existence, detailing how to secure the ecological, hydrological, and ecotourism benefits of beaver while minimising the harm they cause (Campbell-Palmer, 2016). For example, beaver experts advise on how to protect favoured trees with wire and/or sandy paint. They help build artificial flow modulation devices (or 'beaver deceivers'), which silently lower water levels in a dam to avoid attracting beaver repair work. They are learned to be affected by beaver, tuning into their lifeworlds and becoming sensitive to beaver sociology and welfare. Some report beaver personalities, describing a profound respect for the animal indicative of a non-instrumental ethics of multispecies kinship.

A comparison of these two examples helps briefly specify the more-than-human political ecology of different modes of reworlding. On the one hand, enthusiasts suggest that reworlding with beaver as 'self-determining agents' (Thomas, 2022a, 2022b, 2022c) can deliver social and ecological change akin to what Anna Tsing describes as resurgence: 'the work of many organisms, negotiating across differences to forge assemblages of multispecies liveability in the midst of disturbance' (Tsing, 2017, p. 52). In their work on beaver reintroduction in the Pacific North-West, Cleo Wölfe-Hazard (2022) suggests that free-ranging beaver undermine the ecological degradation and proprietorial logics associated with settler colonialism, arguing that beaver can be vital agents in the multispecies 'commoning' of land and for releasing the 'stochastic' potential of ecosystems to adapt and transform, becoming otherwise to craft landscapes of multispecies justice.

In contrast, others have noted how the transformative potential of beaver is often tightly constrained. A great deal of work goes into anticipating, taming, and disciplining the stochastic potential of beaver. Those returned to enclosures are often fenced in upland areas they would normally avoid, have their dams remoulded or removed, and face lethal consequences if they transgress. Annie Welden (2023) has traced how the allegory of beaver as workers naturalises their enclosure in labour camps, and facilitates the commodification and financialisation of their ecological labour through the powerful metrics and logics of ecosystem services. She draws on Maan Barua to suggest that beaver are becoming green infrastructure – 'enmeshed' in sophisticated technological apparatus for hydrological control and 'enfleshed' as a metabolic tool for modulating ecological dynamics to secure the future of fundamentally anthropocentric modes of environmental management.

Finally, the transgressive autonomy of beaver worries some established agricultural, forestry, and sporting interests (big and small), who see a threat to histories of landscape improvement and the politics of land management in Scotland (Lorimer, 2000). They argue that beaver undermine the infrastructure required for intensive agriculture and forestry,

flood roads, and create mess and disorder. They fear that accepting the illegality of their introduction will set a precedent for the return of other keystone species (like the lynx). More broadly, the return of the beaver is symptomatic of wider shifts in the politics of who speaks for nature in Scotland, characterised by both the rise of the 'Green lairds' (Davidson, 2022) – new landowners buying large estates for rewilding and carbon sequestration – and by an invigorated social movement calling for a just transition and nature recovery involving greater communal models of land ownership (MacDonald, 2018). Beaver enable a pincer movement from both the political left and the political right that challenges the status quo logics of improvement and recreation.

7 | WEIRDING

Earlier I explained how the concept of weirding helps capture both the ecological and the affective character of the novel ecosystems emerging in the Anthropocene. It names worlds whose ecologies have been scrambled, accelerated, and degraded by anthropogenic activity, causing a sense of loss, disconcertion, and sometimes wonder among human and nonhuman inhabitants. In this final section, I reflect on three situations in which the return of the beaver is seen by ecologists to go awry, in which unleashing the engineering potential of beaver and their wider stochastic autonomy leads to a discordance between the niches they shape and those desired by their local and sometimes global kin.

We start in Britain and other parts of Europe, where the returning beaver are descended from the survivors of the fur trade. They inherit the legacies of past persecution and ecological change, returning to agricultural, industrial, and urban ecologies that are marked by monoculture production and habitat fragmentation and are crosscut with transport and communications infrastructure. These are enclosed and privatised landscapes with a high density of fencing designed to restrict animal movement. Beaver move into tightly managed rivers, bisected by dams and weirs and sometimes heavily polluted by industrial waste, agricultural runoff, and sewage. They are exposed to unfamiliar diseases emanating from livestock and must learn to contend with domestic dogs.

For some farmers and land managers, beaver create 'mess', challenging the powerful orderly pastoral aesthetic that governs imaginaries of lowland Britain.¹ They flood land, fell trees, and are unpredictable. Rural beaver create weird unfamiliar landscapes for those whose ecological baseline is set well after their departure. In urban areas, beaver repurpose modern drainage infrastructure, favouring culverts that facilitate ease of dam building and water control. In cities in Germany, they build their dams from abandoned construction materials (Campbell-Palmer, 2016). Like other mobile rodents, they use anthropogenic routes like canals, sewers, and drainage channels to ease their foraging and dispersal (Howe, 2020). They continue to browse on native vegetation familiar to their predecessors, but have expanded their diets to include plants new to Europe since the Columbian exchange (like maize, potatoes, sugar beet, and oilseed rape) (Campbell-Palmer, 2016). Urban and agricultural beaver make recombinant ecologies (Barua, 2023), becoming synanthropic now they are no longer seen as furbearing quarry or a pest. Some artists and writers celebrate urban beaver as iconic of the weird multispecies ecologies and survival strategies of the modern city (Goldfarb, 2018). For London mayor Sadiq Khan and other urban environmentalists, urban beaver are tools for social justice, helping to weird the traditional British environmentalist preoccupation with rural pastoral natures and social groups.

In a second example from Arctic regions across Europe and North America, beaver are adapting to the weird ecologies associated with rapid global warming, which has extended the growing season leading to the greening of tundra habitats. In Canada and Alaska, beaver have been moving north, sustained by the newly available vegetation. On the one hand, scientists are hopeful that the arrival of beaver will 'enhance ecosystem responses to warming in the Arctic' (Tape et al., 2018, p. 4478), helping initiate the beaver worlding practices traced in the earlier section. But they are also concerned that the surface water ponds made by beaver dams radically accelerate permafrost thaw, leading to increases in methane emissions (Tape et al., 2022). Methane is a powerful greenhouse gas and the total quantity stored in the permafrost (approximately twice that stored in the atmosphere) could tip the Earth System over the greenhouse gas planetary boundary into a hothouse future Anthropocene. Scientists are unsure how beaver colonisation will affect the global climate, but they fear that pioneer beaver risk become unwitting protagonists in global weirding, helping to build a planetary niche far outside Holocene norms.

While the new ecologies emerging in the Arctic may not be weird for beaver, they are certainly strange for some indigenous societies whose worlds are strongly affected by the changing presence, abundance, and movements of its nonhuman inhabitants. Geographers have documented the profound loss and disconcertion that accompanies climate breakdown and this Arctic greening, as well as the economic harm it is causing (Sakakibara, 2020). Some Inuit psychologists write of solastalgia – the fear and grief caused by encounters with a rapidly changing environment (Middleton

et al., 2020). Though others caution that such apocalyptic narratives risk ignoring much longer histories of catastrophe associated with the violence of settler colonialism, noting that indigenous Arctic worlds have been weirded for much longer than is commonly understood. Kyle Whyte (2018) highlights the potential of indigenous science fiction for understanding the weird affective experiences of climate-accelerated unworlding and the alternatives offered by indigenous world-making practices. He echoes the hopes placed in this genre by those mapping new weird geographies (Turnbull et al., 2022).²

In the final, and possibly weirdest example, we encounter a population of North American beaver in Tierra del Fuego, at the tip of South America. In her book *Loss and Wonder at the World's End*, Laura Ogden (2021) traces how the ancestors of these animals were offered to the Argentinian government in 1946 by their Canadian counterparts as part of an economic development strategy aiming to kick start the fur trade. Twenty pairs of beaver were caught and flown south, becoming the first of their genus to enter the Southern Hemisphere. They were released and quickly bred and spread through the forests and the steppe grasslands that characterise the archipelago. A recent survey identified more than 200,000 beaver dams, suggesting a population of more than 100,000 beaver (Huertas Herrera et al., 2020). In making their new worlds, beaver encountered a host of tree and plant species unaccustomed to their presence, that are unable to regrow when browsed, or to regenerate in newly wetted ground. Instead, they create space for other introduced species, like the brown trout (Arismendi et al., 2020). For most ecologists, these beaver have caused ecological devastation, enacting the largest landscape-scale change in the region since the end of the last ice age. The beaver, whose economic value was never realised, have been cast as an invasive species and made subject to various (so far ineffectual) eradication programmes.

Beaver niche construction in Tierra del Fuego has created a dysfunctional ecology, whose parts do not gel, and whose rhythms will not sync. Thinking with Anna Tsing, these weird beaver worlds are exemplary of the 'blasted' landscapes of the Anthropocene, whose biogeography has been scrambled by the colonial movement of crops and livestock, and by the global swarms that 'proliferate' (Tsing, 2017) so effectively along the vectors of globalisation and amid the ruins of intensive agriculture. But in her collaborations with local researchers, community members, and artists, Ogden (2021) offers a more ambivalent reading of this beaver weirding. While they do not dispute the harm that beaver have caused to the forest and the desirability of their control, they document the gratitude and respect of local trappers, and seek to cultivate a sense of wonder at the animals' ability to flourish in this alien environment. Ogden (2018) figures beaver as a displaced 'diaspora' and in her collaborations with artists experiments with performance-based strategies – including wearing beaver costume – to document the 'dreamworlds' of the beaver and of the local trappers and pastoralists who benefit from this weird niche. They encourage us to recognise the forms of animal and multispecies difference that can be too easily subsumed by the category (invasive) species, and the responsibilities they engender for compassionate conservation.

These three examples illustrate the challenges posed by modern infrastructure, climate change, and biotic exchange for those planning projects for multispecies niche construction. They flag the weird conditions of the Anthropocene and caution that beaver can become otherwise as they make new worlds in non-analogue ecologies. They also hint at the pluriversal worlds of those who encounter beaver now and the animals' alluring potential to raise wider awareness of weird ecologies in cosmopolitan environments. Here the beaver figures less as a hard-working engineer and more as a fellow survivor involved in multispecies bricolage amid the ruins of past projects for anthropocentric control.

8 | TOWARDS A MULTISPECIES POLITICAL ECOLOGY OF ECOSYSTEM ENGINEERING

This paper provides an environmental history of beaver, primarily focused on Great Britain. It traced their arrival after the retreat of the ice sheets and followed how they helped construct a world hospitable for human settlement. It explored millennia of multispecies world-making, in which beaver guided land management. These practices declined with the rise of modern projects for environmental improvement. It mapped the still nascent reworlding of Britain by beaver, identifying different models under which beaver have made their return. A final section explored situations in which multispecies world-making goes awry in the weird ecologies of the Anthropocene.

In the introduction, I proposed that we take beaver reintroduction as exemplary of the wider enthusiasm for deploying ecological engineers to provide NbS to environmental problems. The analysis presented in this paper suggests that this Nature-based Solutions framework has great potential, but it also helps identify significant challenges that it will need to address. These relate to the tendency, anticipated in the introduction, towards a 'one world' worldview: a singular understanding of nature – or mode of 'mononaturalism' – that effaces the ontological multiplicity of

worlds enacted by a range of non-scientific and non-Western groups, as well as the lifeworlds of the animals enrolled in these projects. This version of Nature was central to the Enlightenment projects of improvement that led to the unworlding of beaver in Britain and it remains prominent in biodiversity conservation (Pascual et al., 2021), including in the discourse that shapes popular accounts of NbS (Welden et al., 2021). The analysis offered in this paper reveals that there are many different worlds shaped by beaver, not all of which are captured by the mononaturalism of natural science. Nature does not provide the single stable foundation for political solutions. Instead, ecosystem engineering is profoundly political. There is a growing awareness among prominent advocates of NbS of the need to engage lay and indigenous worldviews (Seddon, 2022). In Britain, such endeavours would be enhanced by lessons from the past worlds recreated by archaeologists, as well as by learning from the different perspectives on and of beaver that are mapped in the analysis above.

Beyond pluriversal ontological politics, the story of the demise of the beaver is also indexed to long and violent social histories. I have only scratched the surface of these here. Other geographers have explored in detail how species extinctions and reintroductions interface with the histories and legacies of capitalism, colonialism, and privileging of a Western, scientific account of the natural world (Adams & Mulligan, 2003). Yet we have seen enough in the story of the beaver to be concerned about the power and the prevalence of the one-world model. Beaver declined due to the rise of capitalist trade and agriculture and the systematic dispossession, denigration, and sometimes genocide of indigenous and other marginal peoples. As Wölfe-Hazard (2022) notes in their highly original work on river restoration and beaver reintroduction, beaver reworlding inherits these histories and cannot appeal to a pristine nature to ignore or short-cut the politics of land ownership and environmental decision-making. Any future programme for proactive multispecies niche construction must be firmly grounded in a political ecology for social justice and historic reparation.

A further challenge is the strong tendency towards anthropocentrism in the discourse and the practice of reworlding through NbS (Maller, 2021). The story of beaver documented here remains one of loss and ruination. The long environmental history of improvement drove a dramatic reduction in the abundance and diversity of British biodiversity. Beaver are only one of a range of species driven to extinction during this period. While we might herald their return as evidence of a green transition in modes of land management, we should remain firmly aware that beaver are largely back in Britain because they perform acts of ecological and hydrological repair. They are frequently put to work as ecological labourers and their future is conditional on their utility and productivity. In some cases, they become what Virginia Thomas (2022b) describes as 'animal machines' and 'expendable objects', in her analysis of the biopolitics of English rewilding. The scope for beaver to live lives not related to people is curtailed and the prevalent economic approach to NbS risks naturalising nonhuman work (Besky & Blanchette, 2019) while effacing the rights of nonhumans to the worlds they make. It may compromise their welfare, while enacting a biopolitics in which useless or functionally redundant lifeforms are let die.

Finally, the paper cautions that ecomodernist visions of planetary-scale management risk hubris. Tempering bright green optimism, it suggests we attend to the disconcerting affective experiences associated with weird ecologies. It hints at the risk of species reintroductions into non-analogue ecologies, flagging how the chequered history of animal introductions for biocontrol shows it is not always possible to model how any organism will behave or how a complex ecology will respond. Beaver have the ecological power to make new worlds that threaten human infrastructure, and they risk accelerating climate change. In their metabolic entanglement with the carbon cycle, beaver remind us of the 'radical asymmetry' (Clark, 2011) of agency in a warming world. Gaia has no fidelity to Holocene ecologies or to projects of human survival.

9 | CONCLUSIONS

Beaver illustrate how the recent enthusiasm for NbS and biomimicry has a long intellectual history, even in a country like Britain that helped inspire and accelerate the modern agricultural and industrial revolutions. Archaeologists document how hunter-gatherers and early farmers learnt from the world-making practices of beaver, copying strategies for managing water and for harvesting timber. They describe how people 'stole' beaver-made materials and how their patterns of movement, hunting, and farming were profoundly configured by beaver dams, ponds, and meadows. They note how 'sympathy' for beaver-inspired cultural practices of biomimicry were so powerful that they attenuated the impacts of beaver absence for many centuries. This cultural persistence has only recently become clear as shifts in the sciences of ecology, archaeology, and hydrology help realise the ghosts of beaver in the British landscape, revealing their haunting legacies in manifold environmental dysfunctionality and legitimating projects for their reintroduction. Current advocates for NbS in Europe can inherit this rich intellectual history, drawing on deep time archaeological research to explore

how premodern relationships of multispecies niche construction might inform the practices and the ethics of future interventions.

But contemporary reworlding with beaver differs from the past. It is proactive and largely science led and illustrates a 'probiotic' (Lorimer, 2020) model of environmentalism in which ecologically informed land managers use life to modulate the dynamics of natural systems and restore absent or degraded ecological functions. It evidences a novel mode of environmental biopower (Lemke, 2021) that leverages an ecological ontology of ecosystem engineers to justify deliberate interventions with the ultimate aim of governing catchment-, regional-, and even planetary-scale metabolic processes. Beaver can be set alongside fast-growing trees, nitrogen-fixing plants, and other ecosystem engineers as tools for manipulating nutrient cycling for the purpose of planetary stewardship.

These interventions happen in weird ecologies scrambled and haunted by histories of modern development and colonialism. Living well with beaver requires us to give up on many of the forms, logics, and affects that have framed the modern geographies of conservation. The scrambled and accelerated ecologies of the Anthropocene do not conform with any orderly, stable, and binary logics of Nature. The belated recognition of ancestral, lay, and indigenous perspectives requires a continued commitment to plural and participatory environmental knowledge-making. And disturbed, fast-changing, and ecosystem-engineered worlds generate new affective responses, ethical sensibilities, and aesthetic registers. Grief and fear are powerful drivers of concern, but so are wonder and curiosity premised on an openness to surprises. Granting autonomy to beaver and other ecosystem engineers may challenge the pastoral aesthetic that has been central to the culture and politics of much European conservation. These organisms create mess. Their repair makes landscapes weird. Following beaver enthusiasts, we might learn to find wonder in this weirdness, holding open its remedial potential when it aligns with transformative projects for a just transition.

Reading for difference across the versions of beaver worlding and weirding mapped here, we can begin to advocate a multinatural model for NbS. Only we might not call it such. There is a need to pluralise the *Natures* that are revealed by natural science, to recognise and reconcile the different epistemic foundations on which to *base* interventions, and to drop the language of *Solutions*, cognisant that thinking in solutions lends itself to techno-fixes abstracted from the historical and geographical processes that drive environmental change.

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DATA AVAILABILITY STATEMENT

The majority of the data that informs this article is in the public domain in the cited articles. A small amount may be available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

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ENDNOTES

¹ For example, the backlash to the decision by the judges at the 2022 Chelsea Flower Show to give top prize to a beaver-themed rewilding garden.

² For a compelling example relating to beaver, see this research creation that develops a queer counter-mythology to North American settler colonialism through a speculative song about giant beaver (Truman et al., 2023).

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