# Toward a participatory and adaptive ecology of biodiversity conservation

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## Abstract

Conservation biology emphasizes, with good reason, the harmful impacts of human activity but often extends the same antagonism to novel, potentially beneficial biodiversity that also arises through human involvement. This asymmetry is rooted in a pervasive nature/culture dualism that affords ecological value primarily to processes considered "natural." Such a framing constrains conservation's ability to engage productively with adaptive cultural and societal processes that could support global efforts to prevent extinction under rapid environmental change. Using gardens as an example, we illustrate how cultural processes can accelerate opportunities for species persistence, facilitate assisted movement under climate change, and foster adaptive dynamics, whilst taking into account potential ecological risks. Integrating human-mediated and human-dependent processes expands conservation's opportunity space for buffering the many ecological uncertainties ahead and highlights how societal participation can help reduce net extinction rates.

## In a nutshell

- Although a bird and a human may both disperse a seed, current conservation paradigms value human processes very differently from "natural" ones. We illustrate how society and culture could support biodiversity if such dualistic thinking is overcome.
- This is highly contentious, as precautionary principles dominate conservation practice and broader societal participation is often seen as risky. Yet under rapid global change and ecological uncertainty, precaution that resists change may itself be risky.
- Wrestling with how to value culturally mediated (novel) biodiversity, both empirically and normatively, will be essential to prepare conservation for the challenges of a radically new future.

## Main text

### Diversifying conservation strategies in a changing world

Conservation biology, as a scientific discipline, developed in the late 20th century in response to accelerating losses of species and ecosystems (Soulé 1985). It was built on a "nature for itself" paradigm (Mace 2014), which held that nature should be protected from human influence, reflecting early conservation ideals that envisioned wilderness as landscapes "untrammeled by man" (Cronon 1996; Marris 2013). This idea rests on an ontological nature/human dualism that defines the natural in opposition to the cultural, thereby situating humans outside the natural realm, and is often coupled with the assumption that nature exists in an undisturbed state of equilibrium in the absence of human intervention (Dussault 2016). This dualism continues to shape ecological research and conservation's goal of protecting natural systems from humans, preserving historical baselines, and privileging biological nativism (Lundgren *et al.* 2026). While this mindset brought major successes (Langhammer *et al.* 2024), it also narrows how we imagine opportunities to support biodiversity in a world that has long been—and is increasingly—shaped and overlaid by human culture.

From Late Pleistocene extinctions (Svenning *et al.* 2024) to anthropogenic "gardens" in the Amazon (Rostain *et al.* 2024), the Agave gardens of the Hohokam in Arizona (Hodgson *et al.* 2023), and many forest and grassland types in Europe, humans have long co-created ecosystems now considered "natural". Recognizing that Holocene ("wild") baselines have long been shaped by people has opened new ways of thinking about conservation, producing several coexisting framings (Kareiva and Marvier 2012; Marris 2013; Mace 2014). "Nature despite people" acknowledges pervasive human impacts and aims to conserve in spite of them, "nature for people" foregrounds ecosystem services and human benefits, and more recent "people and nature" approaches emphasize sustainable, resilient interactions between human societies and the environment (Mace 2014). Despite broadened perspectives, much of conservation remains focused on preserving or reinstating (pre-)historic baselines, functionality and nativeness (even in dynamic approaches such as rewilding), and continues to value human processes differently than those considered "natural" (henceforth, referred to as mainstream conservation).

The implications of this prevailing paradigm are evident across many areas of conservation but are particularly visible in plant conservation, which provides a useful illustration. Human-mediated plant dispersal, for instance, is typically cast as an external interference that "disrupts" native floras or causes biological invasions (e.g., Cai *et al.* 2025), even though it can also be seen as an ecological process in its own right, one that acts in both directions and can equally facilitate species persistence (Segar *et al.* 2022; Staude *et al.* 2025; Lundgren *et al.* 2026). For example, the common snowdrop (*Galanthus nivalis*) is listed as Near Threatened in Germany even though it flowers in millions of gardens and parks each spring (Metzing *et al.* 2018). Such cases exemplify that mainstream conservation typically recognizes only "wild", populations as valid, while human-mediated dispersal and habitats, even when they support species, fall outside what conservation recognizes as legitimate nature. This framing limits how conservation biology can learn from and work with these human-established, human-dependent forms of supporting species and the novel biodiversity they produce.

A plethora of more holistic and dynamic views of nature exists today (Dussault 2016), but their origins in Western philosophy can already be found in Spinoza's 17th-century philosophy (Spinoza 2016; Notes S1). In modern ecological language (Stephano 2017; Notes S1), Spinoza can be understood as conceiving nature, including humans, as a single system in which each part strives to maintain and increase its ability to persist and adapt. Value does not derive from imposed ideals such as the preservation of historical baselines chosen by humans but arises internally through the effects that species have on one another's ability to persist (Stephano 2017; Notes S1). What is "good" is whatever enables adaptive dynamics that maintain or increase *average* fitness (*sensu* Carroll *et al.* 2023). Human activities are therefore not judged as artificial but simply as one of nature's many processes that can accelerate disruption yet also accelerate opportunities for species to persist or evolve. This reframes human-mediated and human-dependent biodiversity as legitimate expressions of nature and opens space for conservation to engage with cultural processes in ways that support biodiversity.

Here, we build on these Spinozist principles and turn to their practical application in conservation amid the dynamic and inevitable changes in biodiversity under rapid global change. These changes require a rethinking of conservation concepts grounded in historical baselines and equilibrium assumptions, as such concepts can no longer be expected to function invariably under the uncertainties of change (Holling and Meffe 1996; Grainger *et al.* 2025). This creates a need to spread the risk of failure in conservation by diversifying our strategies. We use gardens to illustrate how non-dualistic thinking allows cultural processes to contribute to conservation by supporting the persistence, movement, and adaptive potential of species that might otherwise decline. We also address the tensions this raises within mainstream conservation and show how an approach informed by Spinozist principles recognizes human-created ecological novelty as part of how diversity is expressed in nature, treating ecological risks arising from human participation not as reasons for exclusion but as information for understanding and guiding it.

## Climate change and human participation in species redistribution

Climate is shifting at rates of several kilometers per year in many regions (Kosanic *et al.* 2019), yet most plant species disperse only tens of meters per generation (Lososová *et al.* 2023). Animal dispersers which play key roles in long-distance seed movement, such as birds and mammals, are in decline, and this loss is estimated to have reduced plants' capacity to track climate change by up to 60 % (Fricke *et al.* 2022). Additional barriers, both human-made (e.g., fragmentation) and natural (e.g., mountains and water bodies) (Sanczuk *et al.* 2025), further constrain movement, and even when seeds reach new areas, unsuitable soils often prevent establishment (Ni and Vellend 2024). Together, this severely limits species' capacity to disperse and expand their ranges, with effects on ecosystem functioning and human well-being (Gardner and Bullock 2025). Restoring the conditions that enable dispersal and mitigating the human processes that disrupt them is important. Yet in doing so, we must not overlook the human processes that also move species and that could be adaptive.

Narratives of constrained "natural" dispersal and ongoing scientific debates over assisted colonization (Twardek *et al.* 2023) tend to bracket out the fact that humans move species all the time. The issue is not a lack of awareness of potential ecological harm, but a neglect of how this human process could be beneficial. In this context, gardens (and the many millions of people who garden) form an extensive yet underappreciated cultural infrastructure for species movement that could help prevent extinctions and foster adaptive dynamics. While invasion biology has long emphasized the potential negative ecological consequences of horticultural plant movements (Dehnen-Schmutz *et al.* 2007; Van Kleunen *et al.* 2018), recent work shows that gardens can also support the conservation of species (Segar *et al.* 2022; Staude 2024; Bucher *et al.* 2025). Given a world in which human activity has reshaped the very conditions under which species now persist, focusing only on "natural" processes and removing human processes from the equation becomes inconsistent. Gardens offer a tangible example and pathway for integrating cultural processes to support species.

## Gardens as distributed infrastructure for plant movement and persistence

First, gardens can act as refugia for native species declining in their native range, thereby expanding ex-situ conservation efforts (Ismail *et al.* 2021; Segar *et al.* 2022). A notable example is the Wollemi pine (*Wollemia nobilis*), endemic to Australia, which is expected to go extinct in the wild soon but persists in home gardens (Offord and Zimmer 2023). In Germany, the community-science project GartenDiv[1] has begun documenting garden plant diversity using the Flora Incognita plant identification app (Mäder *et al.* 2021). In its pilot phase, ~7% of 91,600 observations from 1,502 gardens were nationally red-listed species (Fig. 1). An extrapolation (ignoring, for now, the many biases of community-science data) to Germany's ~17 million gardens suggests millions of individuals across hundreds of declining native species may already occur in these gardens. Commercial availability of native plants is increasingly well developed in Central Europe (Munschek *et al.* 2023), Australia (Esperon-Rodriguez *et al.* 2025) and North America (Fertakos *et al.* 2026), and is beginning to emerge in megadiverse countries such as Brazil (Flavia *et al.* under review).

[1] https://floraincognita.de/gartendiv/

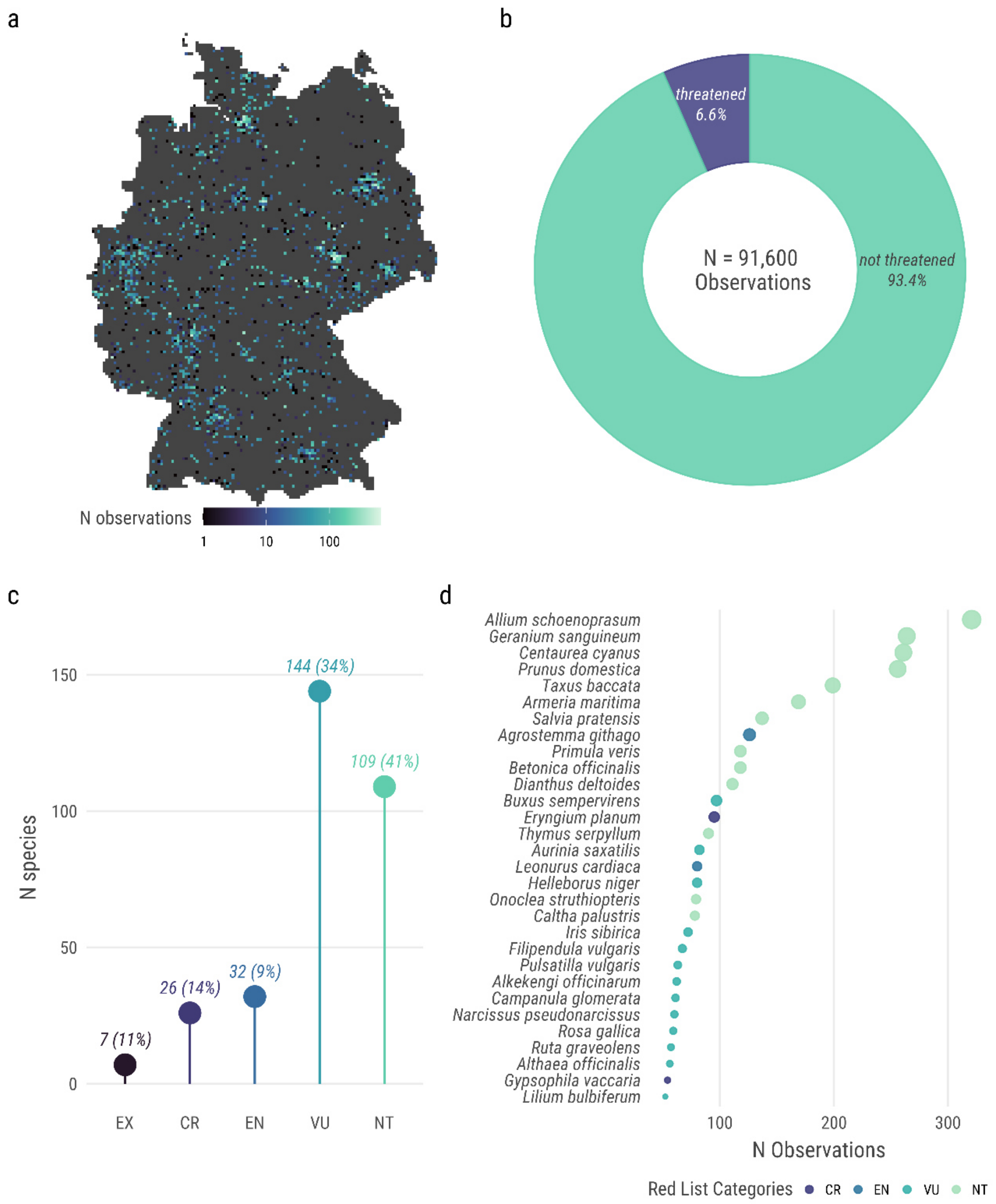



Fig. 1: **Data from a Germany-wide community science project monitoring plant diversity in gardens**. a) Spatial distribution of observations recorded during the pilot phase of GartenDiv (May–October 2025). b) Of the 91,600 garden observations, approximately 7% belong to threatened or declining plant species. c) Number and proportion of species across red list categories. d) Number of observations of the 30 most frequently observed declining native plant species in German gardens. Red list categories refer to the German national assessment: EX = Extinct or lost, CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened.

Second, gardens (and nurseries; Veken *et al.* 2008) can give species that cannot move northward fast enough a head start in their range shifts. A key contentious issue here, however, is who has the power to decide what counts as assisted migration (Lundgren *et al.* 2025). There is a tendency for conservationists in positions of authority to control the narrative, whereas democratic dispersion of assisted migration is often considered rash. A productive example illustrating this tension is the threatened Florida Torreya (*Torreya taxifolia*), an endemic conifer moved northward by citizen volunteers (Barlow and Martin 2004). Species most likely to benefit from assisted migration through gardens are those with contracting or very narrow ranges that have difficulty shifting their ranges, e.g., due to dispersal barriers or slow growth (*T. taxifolia* is a case in point; Thomas 2011), as well as near-native species with low risks of unintended ecological consequences that help maintain ecosystem functioning, especially in regions where barriers limit species range expansions from further south (e.g., surrounding seas in the case of Great Britain; Gardner and Bullock 2025).

Third, gardens, unlike wild areas, provide largely controlled environments where potential risks of assisted migration (e.g., rapid spread) can be quickly detected and addressed. GartenDiv already shows that gardens extend the northward distributions of several native plant species with contracting ranges (Fig. 2). If the right digital platforms exist, contracting and/or climate-threatened native and non-native species could be monitored through community science (enabled by species identification apps) to assess their persistence and performance under new conditions, detect early signs of invasiveness, track ecological interactivity, and identify species that could provide functional insurance when climate-sensitive native species decline. Such platforms and emerging social media networks for gardeners, could further support the creation of participatory digital ex-situ collection databases and mobilize hands-on cultivation knowledge for many species. Creating digital feedback loops, e.g., alerts when a planted species is invasive elsewhere, could connect gardeners' decisions with scientific inputs to assist in conservation efforts.

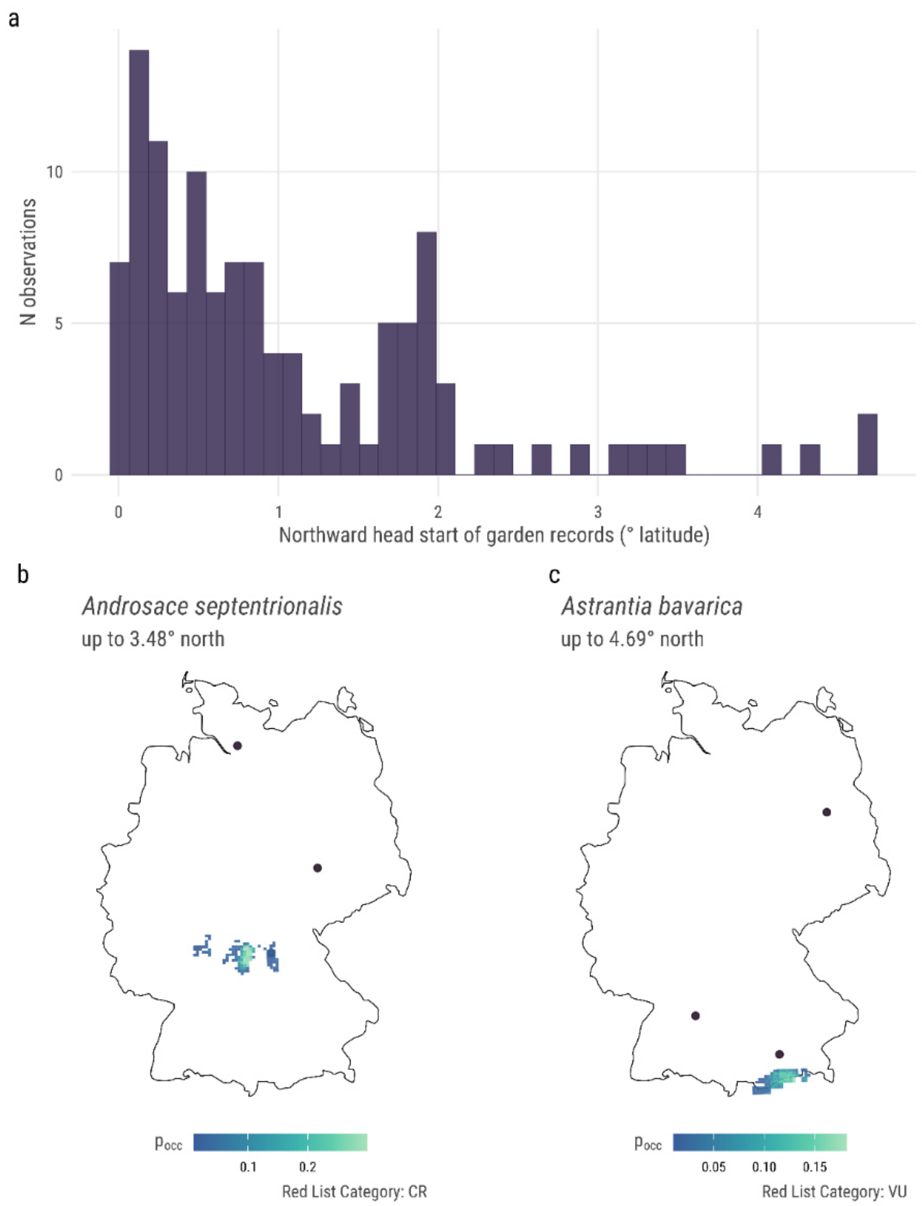



Fig. 2: **Gardens as sites for participatory assisted migration.** a) Histogram showing the number of observations of 39 threatened native plant species recorded in the pilot phase of GartenDiv that occurred north of their native range limits in Germany (x-axis shows the latitudinal difference (°) between each garden record north of the limit and the species' northern native range boundary). As an example, (b) *Androsace septentrionalis* (CR) was recorded in gardens up to 3.5° north of its range limit, and (c) *Astrantia bavarica* (VU), was recorded up to 4.7° north. Native range in A–C is based on Eichenberg (2022) data for the period 1997–2017, which provide distribution estimates for >2000 species on a 5×5 km grid across Germany with an occurrence probability ($P_{occ}$) for each grid cell. For all calculations, cells with $P_{occ}<0.01$ were removed. Purple dots represent northern GartenDiv occurrences.

Together, these functions show how millions of gardens could embed adaptive cultural and societal processes within conservation under a Spinozist framework, once we stop seeing these processes as hopelessly alien to nature. A good example that elements of such cultural conservation infrastructures already exist is provided by the National Plant Collections[2] in

[2] https://www.plantheritage.org.uk/

Britain. This network currently holds c. 730 collections that together safeguard c. 100,000 taxa, ranging from cultivars of garden ornamentals to rare wild species. Some are maintained by botanic gardens or commercial nurseries, but large numbers are maintained by enthusiastic amateurs. Although these collections are organized mainly by plant group and horticultural interest[3] rather than by conservation status, they provide a useful foundation and model that could be leveraged for conservation purposes. For example, with scientific input on which species are climate-threatened and with low invasion risk (Dehnen-Schmutz 2011), such collections could serve as valuable sources for assisted migration. Yet despite this potential, gardens are largely overlooked in mainstream conservation strategies.

**Tensions with mainstream conservation**

Plant conservation has long viewed gardens as artificial environments and "biological deserts" (Elton 1966), as sources of problematic non-native species, and, even when native species are planted, as sites where the use of non-local provenance and hybridization between cultivated and wild taxa may erode the genetic integrity of native populations (cf. Skowronek *et al.* 2023). Maintaining historical community composition and local adaptation is important for conserving (genetic) diversity. Yet what may hold under equilibrium assumptions becomes increasingly uncertain under conditions of rapid change (Grainger *et al.* 2025). These concerns also rest, at least in part, on normative ideas about authenticity in nature, i.e., that "unchanged" populations better conserve (genetic) diversity. A Spinozist view would not categorically exclude these processes because of their risks but would recognize them as processes that may contribute to the ongoing expression of natural diversity (Fig. 3). Importantly, acknowledging that such processes can generate adaptive novelty does not mean dismissing their risks but rather using them as information to refine human participation.

A first implication of this view concerns non-native populations. Roughly a quarter of all plant species established outside their native range are endangered in parts of their native range (Staude *et al.* 2025; Lundgren *et al.* 2026). For example, Moon's agave (*Agave vera-cruz*, Mexico), and Angel's trumpet (*Brugmansia suaveolens*, Brazil), are both considered globally extinct in the wild yet have established wild introduced populations in several countries via gardening. The possibility that such introduced organisms may have conservation value is highly contentious under current conservation paradigms. Non-dualist thinking opens space to engage with these cases as part of global efforts to prevent extinction. Endangered, non-native plants (e.g., climate-threatened endemics facing dispersal barriers) could increasingly be part of nursery offerings in biogeographically near-native regions, while measures are taken to limit risks (e.g., avoiding garden plantings in regions rich in native endemics). In this way, conservation-minded gardeners could, whilst still prioritizing native species, plant non-native species, taking into account both risks and benefits, and help reduce their risk of extinction.

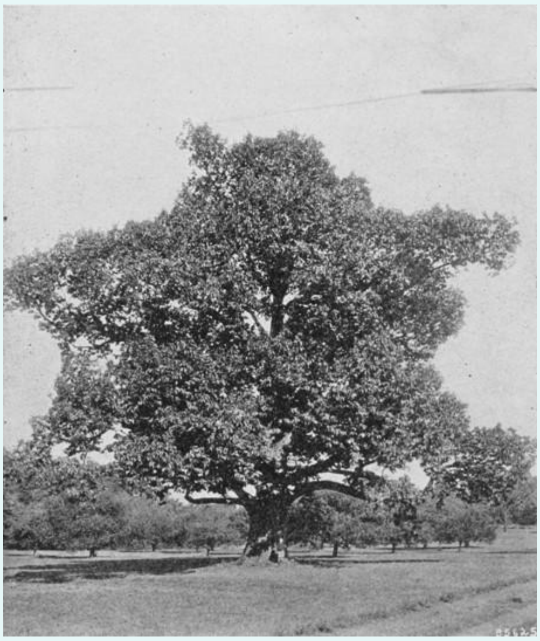
The same reasoning extends to provenance and genetic mixing. Although conservation prioritizes local provenance to preserve genetic integrity (Skowronek *et al.* 2023), evidence shows that mixing with non-local provenances enhances fitness in changing environments

[3] https://www.plantheritage.org.uk/national-plant-collections/search-the-national-plant-collections/

(Kottler *et al.* 2021). Similarly, gardens with their mixed and uncertain provenance plant material are seen as having no conservation value and as posing risks of introgression into wild populations. Yet the genetic diversity arising from countless individual choices and multiple sources of plant material (e.g., seed exchanges) can also provide non-trivial amounts of potentially adaptive genetic variation that remains largely unstudied. Rather than excluding gardens on the premise of purity and risk, a Spinozist conservation refines participation. This could mean enabling nurseries (so far sidelined from conservation) to produce local-provenance seeds at scale (so that these are widely available to gardeners), without rigidly restricting genetic mixing. This would increase genetic diversity via widespread production of local-provenance seeds while allowing the gene flow needed for adaptation under change.

Horticultural practices, including intentional hybridization, offer similar ambiguities. While mainstream conservation treats hybridization as a threat to species identity, evolutionary ecology recognizes it as a driver of adaptation (Zhang *et al.* 2025) and diversification (Thomas 2015; Marques *et al.* 2019). Introductions of non-native plants are known to produce new taxa via hybridization with native congeners (Vallejo-Marín and Hiscock 2016; Faurby *et al.* 2022; Staude and Ebersbach 2023), and the number of garden hybrid varieties that represent new human associated/dependent species is unknown. Such processes are usually dismissed as artificial, yet they expand genetic and phenotypic diversity within species. Some hybrid varieties and cultivars reduce ecological value, while others add value, e.g., by supporting more pollinators than their wild relatives (Ricker *et al.* 2019). While much of this still needs to be better understood, the point here is to highlight that a Spinozist view would not dismiss such processes based on being artificial. Instead, it would recognize them as part of how diversity is generated in a world where human and non-human processes are intertwined.

The **wild apple** (*Malus sylvestris*) is a valuable component of cultural landscapes, yet its existence as a distinct species has become uncertain. Numerous cultivated apple forms, as well as wild relatives from Asia, are closely related to *M. sylvestris* and frequently hybridize with it, producing individuals with traits intermediate between wild and cultivated forms. We are thus losing the wild apple through hybridization with its domesticated relatives, while also gaining many new genotypes that may be better adapted to human-shaped landscapes than the original *M. sylvestris*, which relied on seed dispersal via the digestive tracts of large herbivores, now largely absent. From a mainstream conservation viewpoint, the erosion of the species' genetic integrity is concerning; from a Spinozist viewpoint, it presents diversification and adaptation due to human processes.



The **American chestnut** (*Castanea dentata*) was once a cornerstone of eastern North American forests but was driven to near extinction in the wild by chestnut blight (*Cryphonectria parasitica*), a fungal pathogen introduced from Asia. Breeding programs have sought to restore the species by crossing surviving American individuals with Asian relatives (*C. mollissima* and *C. crenata*), which carry natural resistance to the blight. Successive backcrosses aim to retain the American chestnut's characteristics while incorporating disease resistance. Today, many of these hybrids have been planted in forests, restoration sites, and gardens, where they serve as both experimental populations for evaluating blight resistance and as reservoirs of genetic diversity. These efforts illustrate how horticultural processes, such as intentional hybridization, can be part of conservation.

Fig.3: **Human participation and adaptive processes.** A Spinozist perspective shifts the focus from judging human-mediated ecological novelty as artificial, to recognizing it as part of how diversity is formed and re-formed in a world where human and non-human processes are inseparable. In the two examples, it is not about uncritical acceptance of processes such as hybridization, but to consider in what way human participation can, and at times already does, support adaptive processes. This could include, for instance, broader collaboration between conservation and horticulture to support endangered species of both ecological and cultural importance. Photo credits: *Malus sylvestris* and *Castanea dentata*, CC0/Public Domain.

## Toward a participatory and adaptive ecology of conservation

A participatory and adaptive ecology of conservation is not without risks: ill-considered species choices, inadvertent spread or mixing with harmful ecological consequences, ethical complacency, or economic participation that is performative rather than ecologically meaningful. Yet these risks do not stand in opposition to the potential benefits of involving cultural processes. Instead, they form part of the same ecological process and provide feedback through which participation can be guided and improved. From this perspective, risks are neither ignored nor grounds for excluding participation but are incorporated into an adaptive approach that refines how participation unfolds. Moreover, traditional strategies that are biased toward resisting change also carry risks under rapid changes in global climate (e.g., losing populations altogether, risking loss of ecosystem function). These risks can be mitigated by relying on a diversity of approaches. It is clear that gardens, as an example of a participatory approach, are not a panacea for biodiversity conservation. But this is not an "either–or" choice but a "both/and," a synergy of approaches that buffer uncertainties under change.

Many human activities undeniably drive the biodiversity crisis. We argue, however, that this crisis narrative is also shaped by an asymmetry in attention. That is, conservation frameworks readily recognize the harmful ecological outcomes of human activity while treating novel, potentially beneficial ones with antagonism or ambivalence (Thomas 2017). Such frameworks can restrict our ability to develop creative and productive directions of thinking. Embracing ecological novelty that is mediated or dependent on humans in conservation challenges us to examine how assumptions and advocacy shape scientific interpretation (Cardou and Vellend 2023), encouraging a shift from judging processes as "natural" or "artificial" to assessing their actual, empirical contributions to species persistence. Here, we have outlined how humans, while often accelerating disruption beyond many species' limits, can also participate in accelerating opportunities that help prevent species extinctions. Creating an atmosphere that enables societal participation in a societal problem, i.e., the biodiversity crisis, will be key to broader transformative change.

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Supplementary Material

For

# Toward a participatory and adaptive ecology of biodiversity conservation

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**Content:**

## Notes S1: Conceptual Background

Although several Indigenous communities, notably the Indigenous North American creation stories of Sky Woman and Turtle Island (Kimmerer 2013), have long lived by an ethos of co-creation, this perspective was rather revolutionary for Western thought. About two centuries before Darwin's Origin of Species established humans as part of evolutionary processes, Baruch Spinoza (1632–1677) articulated a monist vision of nature in his Ethics (1677). In his philosophy, which was radical at the time, everything that exists is a modification of a single reality. Spinoza argued that this reality consists of a single substance, which he called *Deus sive Natura* (God or Nature). In Ethics, he describes it as "a substance consisting of infinite attributes, each expressing eternal and infinite essence" (Ethics I p11). Everything we encounter in the world is a *mode* of this substance, i.e., a finite expression of Nature that exists only through its relations with other modes (Ethics I d5). These relations unfold through *affects*, understood as the capacities of modes to affect and be affected. Through these affects, modes persist, change, and interact. Every mode strives "as far as it can by its own power, to persevere in its being" (*conatus*; Ethics III, p6). Yet its actual power (*potentia*) always depends on the situation and the relations it enters into. Relations that enhance a mode's ability to persist and act increase potentia; relations that constrain this ability diminish it. Spinoza rejects the idea that humans stand outside nature. As he writes in the Preface to Part III, many authors "seem to conceive man in nature as a dominion within a dominion," as if human actions were external to nature.

Spinoza therefore provides an ontology in which humans are internal participants in nature rather than external agents acting upon it. His concepts of conatus and potentia offer a dynamic account of persistence. Beings strive to continue in existence, and their success depends on the relations that expand or diminish their power to act. Stephano (2017) builds on this ontology to formulate an immanent ecological ethic that evaluates relations not by externally imposed standards (for example, historical baselines or ideals of "pristine" nature) but by how they modulate the capacities of beings to persist, adapt, and thrive. As Stephano puts it, "what is *good* is whatever increases a body's capacity to act, and what is *bad* is whatever diminishes this capacity" (2017, p. 157). This shifts ethical attention from protecting nature from humans, preserving historical baselines and privileging biological nativism to fostering relations that enhance collective capacities to persist and evolve. Carroll *et al.* (2023) complement these insights with an ecological framework (adaptive community dynamics) that describes how changes in community composition can increase the match between species' traits and shifting environments and thereby maintain or increase community-level fitness. In that vein, we propose that conservation should not default to treating human-mediated novelty with default antagonism or ambivalence. Instead, conservation can evaluate human-mediated and human-dependent forms of biodiversity (gardening, plant propagation, assisted movement, hybridization) through their effects on the capacities of species and communities to persist and adapt. Such an approach would situate humans and the novel biodiversity they create within the same adaptive dynamics through which ecosystems respond to change.

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