Participatory Design for Multispecies Cohabitation

By Trees, *for* Birds, *with* Humans

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Introduction: Towards More-than-Human Communities

How can we improve the lives of trees, birds, humans, and other beings in increasingly degrading environments? Might direct participation of non-human beings in design be an answer? We believe that such participation is not only possible, but crucial. The idea of trees as designers and birds as assessors might seem jarring, if not preposterous. We hope our readers might suspend their disbelief until the latter stages of the narrative. To tell our story, we refresh several common terms, including community, imagination, innovation, and participation. We derive these updates from scientific evidence, even where the consequences seem counterintuitive. Why do we need these novel understandings? After all, our case study could stand as a technical contribution to restoration ecology without an appeal for more-than-human participation. We shall be pleased to contribute in this way. However, we have another—strategic—ambition. Our overarching motivation is an expansion of moral consideration in human societies. We observe that more and more humans agree to protect the rights of human minorities, future human generations, and even whole systems such as rivers. An aspect of this ethical concern is the idea of helping all beings speak for themselves. 'Nothing about us without us' is a slogan that captures it well. This slogan motivates the disability movement and others struggling against injustice. Can it apply to non-human beings, too? Political empowerment of non-humans clashes with preconceptions about communities. However, ingrained habits are not a good reason to reject change, not amid the sixth mass extinction and widespread harms to numerous beings. With this in mind, we strive to give serious consideration to inclusive design that can use non-human knowledge to look into the future. In this chapter, we use data analysis and simulation to make one step forward in this long-term project.

Our strategic focus is on communal imagination. Informed by scientific advances in extended synthesis, niche construction, sensory ecology, cognitive ethology, and biosemiotics, we reframe imagination as a collective, communicative, and situated process that pertains to all forms of life. We do so by emphasising design roles that cast trees as designers, birds as discerning clients, and humans as facilitating apprentices.

To explore the notion of inclusive, or more-than-human design (Roudavski 2018, 2020), we consider interactions in a degraded ecosystem that is losing its trees. When

Figure 5.1 A large old tree near Canberra, Australia. Red: an artificial agent extracts 4,122 individual branches from this tree and classifies their type. Red boxes: branches preferred by birds.
Image by the authors.

large old trees (Figure 5.1) disappear, insects, birds, and bats have no homes. Humans attempt to help by providing artificial replacement structures. The use of such structures is of growing interest in ecological research (Watchorn et al. 2022) and is necessary to support organisms in many ecosystems, including wetlands (Mitsch 2014) and coral reefs (Baine 2001). When humans design such structures, they cannot know all needs of non-human inhabitants. In our case, although some artificial trees are successful (Hannan et al. 2019), their habitability and practicality remain in question. We suggest that human designers can find answers to these questions through an approach that invites contributions from birds and trees.

More-than-human concepts and practices can be useful in many fields. Reviewing the situation in environmental planning, Metzger (2020) insists that more-than-human framing holds promise but remains underdeveloped. Pollastri et al. (2021) argue that this framing would benefit from better data representation. Loh et al. (2020) apply more-than-human perspectives to critique tools used to measure performance of the built environment. Westerlaken et al. (2022) call for a greater focus on more-than-human relations in smart forests. Our chapter is a response to these gaps.

Recent research has investigated more-than-human, multispecies, and interspecies approaches in a variety of fields, including environmental humanities, animal studies, and non-human participation in political decisions (Gray & Curry 2016). Working within design, including architecture and urban planning, our research group extends this work to support practical action. Our projects investigate prosthetic structures for owls (Parker, Roudavski, et al. 2022), heritage of plants (Roudavski & Rutten 2020), and applications of artificial intelligence (AI) to habitat replication (Mirra et al. 2022). This chapter presents one of such projects to demonstrate the potential of more-than-human collaboration.

We align with work that already seeks to empower multiple voices (such as Morris & Spivak 2010). For instance, a growing body of work on decolonialised, queer, and feminist design, in combination with advancements in disability studies, already supports non-standard voices. Such voices may not be able to participate in design without support that Björgvinsson et al. (2012) and others have conceptualised as infrastructuring. This term refers to the effort of providing information infrastructure that often uses metaphors such as pipes, wires, or buckets. Established techniques of infrastructuring include the use of boundary objects (Star & Griesemer 1989), long-term participation (Saad-Sulonen et al. 2018), and prototypes of spaces, tools, and services (Sanders & Stappers 2014; Tironi 2018). Infrastructuring is particularly important in human communities, where decisions require negotiation and imagination becomes political (McBride 2005). There, conflicting participants' perspectives can be detrimental or beneficial, as discussed in adversarial design (Di Salvo 2012; Wienhues 2018).

To date, such work rarely considers non-human participants. We rethink these approaches in the context of diverse non-human bodies, senses, and behaviours. Discussions of such participations do exist (Jönsson & Lenskjold 2014; Clarke et al. 2019; Gatto & McCardle 2019) but tend to be speculative, with their authors calling for further research. Research into animal behaviour (Bekoff & Pierce 2017; Safina 2020) or plant capabilities (Karban 2015; Baluška & Mancuso 2021; Segundo-Ortin & Calvo 2022) in combination with ecocentric analyses of justice (Donaldson & Kymlicka 2011; Schlosberg 2013) highlight an opportunity to contribute.

After this Introduction, the Approach section introduces the case-study project, its stakeholders, and their contributions to communal imagination. The Findings section describes four data-driven operations: capture, predict, reconfigure, and return. The Analysis section follows by discussing participation-related outcomes produced by these operations. We show that they can capture ways in which habitats are meaningful to non-human dwellers, predict performance of habitat structures, assess possible artificial replacements, and prepare for their testing in the field. This section concludes by discussing how these operations can support more equitable communities and better lives.

Approach: Workflow Framing

Our case study is a project that we conduct in partnership with the Australian Capital Territory Parks and Conservation Service and the Fenner School of Ecology of the Australian National University. The project aims to improve on current practices by creating artificial structures that better match preferences of arboreal wildlife. This case study produces useful objects but also serves as a design experiment (Collins et al. 2004) that informs our theoretical work on more-than-human participation. To date, practical outcomes include new information about tree structures, novel algorithms for analysis, and prototypes of possible artificial replacements. Further physical prototypes and field-testing are in preparation. We now discuss the study methods, from the general to the specific.

More-than-human community

Let us begin by defining the notion of 'community' in more-than-human terms. Community is a highly contested concept. Our understanding combines evidence from multiple disciplines, including political studies and community ecology. Community ecology understands community as 'a group of species that occur together in space and time' (Mittelbach & McGill 2019, p.1). This definition does not exclude humans, but the discipline's practices tend to consider them as an external force. In humanities, a community is a group whose members share location (Rabinowitz 2015). In a mirror image of the views in community ecology, this interpretation presumes that communities consist only of humans.

Human communities increasingly recognise the importance of ecosystems. Responding to such recognition, cities engage in the practical work of restoration. However, attitudes that presume human superiority stifle further progress. The spread of human domination curtails the options for other lifeforms. Recent theory recognises the importance of 'communing' that seeks to enfranchise disempowered participants. It aims to include young children, elderly, and disabled into decision making. Similarly, research seeking to support wildlife finds that restoring autonomy in ecological systems is an effective measure of resilience and restoration (Strassburg et al. 2020). However, the work on enfranchisement also tends to focus on humans (Studdert & Walkerdine 2016) or presumes that non-human communities are incompetent and unimaginative.

Responding to this context, environmental humanities propose to abandon habitual binaries between human and non-human worlds (Plumwood 2002). Such work calls for multispecies approaches (Bresnihan 2016; Bastian et al. 2017) that recognise the shared fate of all life on earth. For example, emerging research on more-than-human interactions in urban communities emphasise relationships of care (Wiesel et al. 2020; Prebble et al. 2021). We support such ecocentric approaches (Eckersley 1992; Washington et al. 2017) when they aim to be more just or fair than alternative environmentalisms, such as resource conservation, human welfare ecology, or animal liberation.

In this chapter, we define 'community' as practised relationships, which create fuzzy, emergent groups consisting of humans as well as non-humans. Observable states of communities are traces of historically formed capabilities, interactions, and imaginations. Recent work calls for better interspecies relationships within such communities and emphasised the need for practical approaches such as those discussed later in this chapter (Houston et al. 2018). The next section describes one such community and the need for new techniques of future cohabitation.

Community members

To explore the notion of more-than-human community, we focus on the Molonglo region of Canberra, Australia. This area includes endemic grassy woodlands, a once widespread but now highly fragmented ecological community (Flapper et al. 2018). European settlers converted most of this land to pasture and undermined faunal habitats. Despite this degradation, birds, mammals, reptiles, amphibians, and invertebrates use the remnant grasses, herbs, shrubs, and trees for foraging, roosting, nesting, raising the young, and migration. Human-induced pressures continue to increase as the government works to develop this area into a new community of some 70,000 human residents (Treasury and Economic Development Directorate 2019) (Figure 5.2, solid orange).

To emphasise interspecies interactions, we focus on three groups:

1. ***Remnant large old eucalypts ('trees')***. Isolated old trees persist in Molonglo's paddocks, roadsides, and parks (Figure 5.2, green dots). They are crucial for many ecosystem interactions. We select this group because it includes the oldest living community members. These trees form part of the remaining 3% of pre-European yellow box (*Eucalyptus melliodora)* grassy woodland (Figure 5.2, solid purple), which once covered millions of kilometres in south-eastern Australia (Figure 5.2, purple outline) (Threatened Species Scientific Committee (TSSC) 2006) (Figure 5.2, solid orange). The main challenge for the large old trees is to survive as a type. Although young individuals are common, the older trees are rare (Figure 5.2, green dots). Without these elders, tree taxa struggle to make the beneficial contributions on which many lifeforms depend for survival.
2. ***Arboreal nesters ('birds')***. This group of approximately twenty transitory bird species visit and nest in Molonglo trees. Unlike other birds who depend on tree hollows or live in understory bushes, these birds spend their lives perching in the canopies. One longitudinal study of seventy-two trees (Figure 5.2, purple dots) within the region found that many members of this group exclusively visit large old trees (Le Roux, Ikin, Lindenmayer, Manning, et al. 2012). Arboreal nesters are indicative of a non-human group that is challenging for humans to study. They are small, mobile, and depend on features that are difficult to quantify without automated data collection and analysis. The key challenge for birds is to retain and obtain additional suitable homes.
3. ***Residents, planners, and ecologists ('humans')***. To ensure the long-term viability of the existing biological community, regulations asked Molonglo's developers to fund a research project to offset additional habitat losses (ACT Planning and Land Authority 2011). Researchers estimate that the 10,000 seedlings planted at the site will not develop the canopies of living mature trees for 172 years (Hannan et al. 2019). As an intermediate solution, ecologists investigate whether translocated dead trees and utility poles can imitate absent habitat structures (Figure 5.2, orange dots). In this paper, we consider humans as a fuzzy group that engages with common management practices. Human challenges include competing interests and the struggle to connect actions with ecological values.

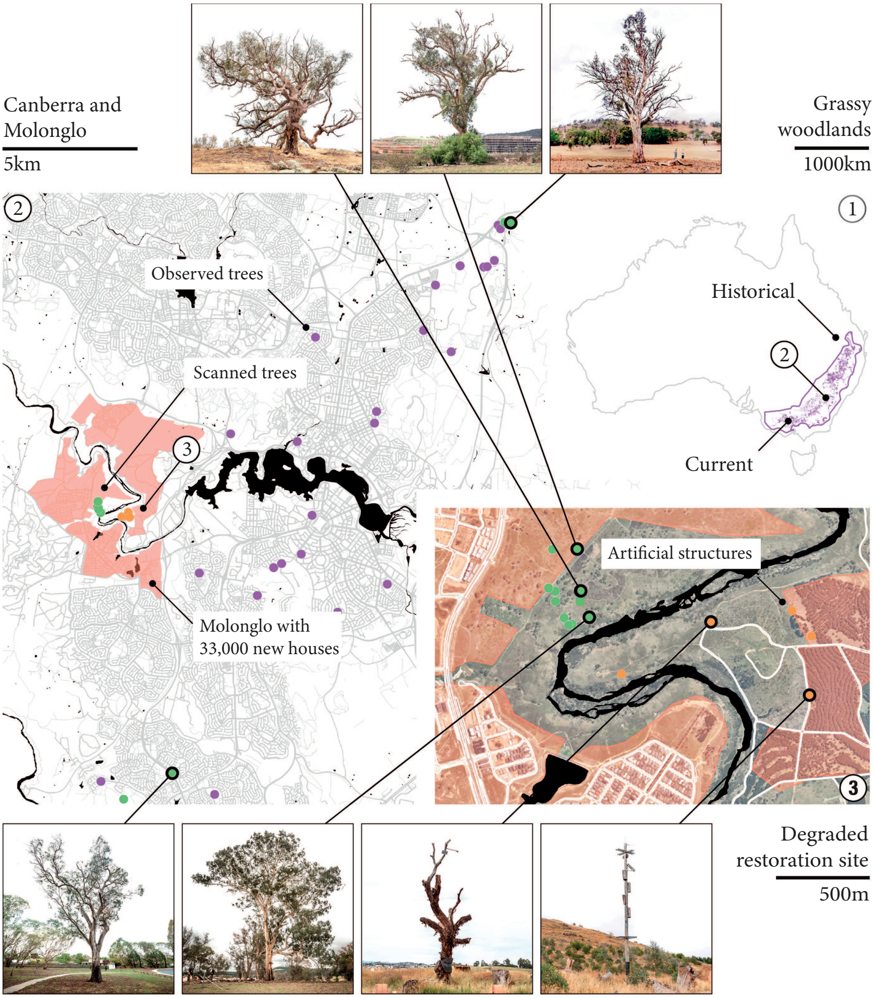

Figure 5.2 Case-study context. Top right: grassy woodlands extents (the outline: historical, shading: current, 2: Molonglo); Left: Molonglo in Canberra (orange: new development, 3: degraded restoration site), Bottom right, degraded restoration site. Image by the authors.

Future uncertainties for trees, birds, and humans provide a useful test case for approaches that seek to benefit all forms of life.

Members as stakeholders

This section outlines relationships among community members defined in the previous section by highlighting harms and benefits (Table 5.1). In our interpretation,

Table 5.1 Table of community relationships focusing on key stakeholders

	Trees and Birds	Humans and Trees	Humans and Birds
Far past (millions to 40,000 years ago)	**Australia's temperate grassy woodlands evolve.** Some trees learn to survive in sunny but dry and resource-poor conditions (Orians & Milewski 2007). Creatures that become birds grow large brains supported by energy-rich manna and pollen in trees (Kaplan 2015). Birds disperse pollen and seeds (Low 2014).	**Humans help the spread of trees.** The first humans hunt megafauna to extinction and inadvertently create a drier and fire-prone climate (Burney & Flannery 2005). Eucalypts thrive in these conditions and replace wet rainforests (Rule et al. 2012).	**Humans help the spread of birds.** Birds that depend on eucalypts spread into wet rainforests (Burney & Flannery 2005).
Past (just before the European arrival)	**Birds use old trees.** Birds use arboreal food resources and shelter in the canopies of old trees (Lindenmayer 2017). Trees use birds and other organisms to carry pollen and provide nutrients (Williams & Woinarski 1997).	**Humans support trees.** Mature trees grow in an open woodland. Saplings and grasses grow between trees (Gibbons et al. 2010). Indigenous land management is compatible with this landscape (Bliege Bird et al. 2008).	**Humans do not undermine bird resilience.** Humans hunt some birds and ignore others (Johnson 2016). Burning practices impact some birds (Burney & Flannery 2005).
Past (since the European arrival)	**Birds use remaining old trees.** Birds depend on old trees as populations shift and reduce (Manning et al. 2006; Stagoll et al. 2012).	**Humans destroy trees.** Humans use Australia's temperate grassy woodlands for cropping and livestock, removing most trees (Lindenmayer et al. 2014). Some old trees remain for windbreak and shade. Livestock prevent saplings from growing (Gibbons & Boak 2002).	**Humans undermine birds.** Humans alter landscapes through agriculture and urbanisation (Bradshaw 2012). Some birds adapt but habitat loss contributes to local extinctions (Department of Environment, Climate Change and Water NSW 2011).

Continued

Table 5.1. *Continued*

	Trees and Birds	Humans and Trees	Humans and Birds
Current (the consequences of the last 230 years)	**Bird resilience dwindles as old trees disappear.** Land use intensification results in a shortage of middle-aged trees (Manning et al. 2012). Populations of birds become smaller as habitat resources become scarce (Lindenmayer et al. 2013).	**Humans continue to reduce the population of surviving old trees.** Isolated old trees exist in farming and urban landscapes (Fischer et al. 2010). Many are not protected by legislation (Lindenmayer et al. 2013). Young eucalypts struggle to grow on grazed and cultivated lands (Gibbons & Boak 2002).	**Humans provide limited compensatory actions for birds.** Humans plant trees to support bird populations (Prober & Thiele 2005). While these trees grow, humans attempt artificial habitat-structures such as translocated dead trees and utility poles (Hannan et al. 2019).
Projected (under the business-as-usual)	**Tree-bird relationships fail.** Remaining old trees reach the end of their lives. Trees planted during revegetation initiatives are too young to support birds (Le Roux, Ikin, Lindenmayer, Manning et al. 2015). Australia's temperate grassy woodlands deteriorate into treeless pastures (Fischer, Zerger et al. 2010). Millions of hectares have no old trees (Manning et al.).	**Humans eliminate old trees.** Large old trees are functionally extinct (Gibbons et al. 2008; Le Roux et al. 2014). Models predict that Canberra's urban old trees will disappear within 80–300 years (Le Roux et al. 2014). Other models predict that surrounding paddock trees will disappear in the next 80 years (Gibbons et al. 2008).	**Remedial actions by humans are insufficient.** Habitat continues to contract. Ecosystems cannot return to past states (Gibbons & Lindenmayer 2007). Artificial structures provide limited support (Le Roux, Ikin, Lindenmayer, Bistricer et al. 2015).
Preferred (an alternative with outcomes supporting the continual functioning of all stakeholders)	**Trees and birds develop resilience.** Trees live their lives to the full. Trees can create and sustain the next generation of trees. Birds depend on trees for homes but also adapt to alternatives. Birds have an abundance of homes.	**Humans study trees as sources of innovation.** Humans acknowledge tree contributions. Trees remain in place even after death. New plantings grow bigger. Humans allocate resources and space to avert possible damage from old trees.	**Humans facilitate bird habitats.** Birds find new homes, shifting with climate change and living in cities. With the help of birds and trees, humans design better replacement structures.

relationships cast community members as stakeholders. Here, we describe a stakeholder as an individual or a group that can benefit or suffer from an action.

In summary, the challenge here is to understand the value of large old trees to birds, to demonstrate it to humans, and then use the communal abilities to design artificial replacement structures as an alleviation of acute shortage.

Seeking to reflect the community relationships discussed above, we understand participation as an umbrella term for modes of engagement that depend on capabilities of stakeholders. Here, the notion of more-than-human participation suggests important political consequences discussed in research on more-than-human care, justice, and traditional custodianship. Efforts towards earth jurisprudence (Bekoff 2017) and non-human rights (Milburn 2017; Blattner et al. 2019) provide characteristic examples. In design, projects that engage with plant agencies outline participation with beings that do not have brains or think like humans (Sheikh et al. 2021; Chang et al. 2022; Fell et al. 2022). We discuss ways to amplify productive community participation in the section on Amplified Relationships later in this chapter.

Stakeholder imagination

Our approach is to consider more-than-human designing in relation to communal imagination. Let us first explain that we understand imagination as a process that is common to all life. Today, dominant conceptualisations of imagination presume cognitive capabilities (Mitchell 2016; Picciuto & Carruthers 2016). These interpretations are human-centric and tend to exclude non-humans. By contrast, other research emphasises the embodied nature of perception and cognition (Varela et al. 1991). This work argues that all organisms experience the world subjectively. Living and evolving together, they relate by modifying themselves and others. Such interpretations allow us to adopt an ecocentric understanding of imagination. According to this understanding, imagination occurs in communities through multiple bodies, perceptions, practices, and places (Roudavski 2016). Biological studies also recognise that many organisms design their own environments as ecosystem engineers and niche constructors (Jones et al. 1996; Laland et al. 2016). Many of such biological innovations do not require cognition to create new ways to resist entropy (Avery 2012).

This expanded understanding of imagination involves the construction of a model world to represent reality that is not directly accessible to living beings. For instance, a living cell that admits a chemical compound into its interior or restricts it to the outside of its wall completes this action by comparing the signals from its senses to its model of the world (Barbieri 2008). Others discussed this model as the *Umwelt* (von Uexküll 2010), the phenomenal model, the perceptual model, an 'inside exterior' (Hoffmeyer 1998, p.40), 'self world', or the semiotic environment. We recognise this process as basal or primal imagination. Forms of imagination can differ in features and complexity between species with humans occupying multiple imagined worlds, as outlined in Table 5.2

Table 5.2. Processes for constructing imaginative worlds and example outcomes for select agents.

	Model-World Processes	Example Outcomes	Evidence
Birds	Cognition through embodied senses and behaviours. Individual and social learning. Local traditions through cultures.	Species A senses landscape features that species B or C cannot perceive. A bird selects a poor nesting site because urban cues are misleading.	(Aplin 2019; Battin 2004; Manning et al. 2006; Martin 2017)
Trees	Environmental awareness through senses. Memory through chemical pathways representing experiences. Learning through comparison and evaluation of stored experiences.	A tree protects its territory and wards off parasites by distinguishing itself from not-self. A group of trees construct social networks for common goals such as sharing water and nutrients.	(Beiler et al. 2010; Witzany 2018)
Humans	Expanded capabilities for cognition and memory through symbols and technologies. Limited ability to notice, study, or understand the lives of others.	Old trees may completely disappear in Molonglo and globally because humans fail to value them economically or aesthetically. Humans see old trees as sources of risk or sites of disease. Humans protect charismatic birds but fail not notice significant changes in their migration or feeding habits.	(Dee 2019; Le Roux et al. 2014; Roudavski & Davis 2020).

Furthermore, this imagination is always communal and situated because living beings find themselves in complex evolved ecologies of meanings, messages, and interpretations. Meanings are the products of collective agreements (Bruner 1990). In such context, meaning emerges as habits or patterns within lineages and imagination is always shared. Ecologists acknowledge the usefulness of such subjectivities for conservation (Manning et al. 2004; Goymann & Küblbeck 2020).

This communal imagination becomes closely related to design because living forms have goals. They strive towards individual and generational goals such as survival, procreation, and wellbeing. Here, it is important to repeat that individuals, groups, and whole cultures (including the best of human science) do not have a privileged access to reality. All labour under constraints of their perceptual abilities, information-processing frameworks, behavioural constraints, historical contingencies, and other limitations. Their interpretation of the world can be erroneous and harmful, as happens in ecological traps or outdated adaptations, such as those leading to human obesity.

This background leads us to a pragmatic, outcome-oriented definition of imagination as a more-than-human, shared ability to invent new forms of living. Such innovation by all concerned will be necessary in the unavoidably multiplying novel ecosystems. Designing cannot resolve interdependencies between environmental changes and stakeholder subjectivities without imaginative outcomes of more-than-human participation. We discuss novelty as one of such outcomes in the next section.

Communal innovation

In the context of design, a potentially useful product of imagination is innovation or an introduction of novelty in response to pressure. Innovations can be valuable in the changing circumstances, such as those that characterise human-modified environments, but they can also be harmful. Living communities can be aware of novelty, but innovations can also be inaccessible to the perceptions of stakeholders. For example, living beings might lack abilities to notice accumulations of gene mutations or amassing environmental change.

In contrast to such individual limitations, communal imagination reliably produces innovative templates (cf. ecofields; Maran & Kull 2014) of possible futures. These templates merge individual and collective abilities to confine possibilities, establish semiotic distinctions, and begin adjustments within existing phenotypic, developmental, behavioural, and other plasticities (Piersma & Gils 2011). Traces of such templates express as combinations of behaviours exhibited by community members, but complete knowledge of such templates is not possible for any individual.

And yet, such templates are not completely inaccessible. For example, numerical measurement and analysis that seek to invite perspectives of community members can reduce the uncertainty about their characteristics. All non-human stakeholders can contribute, for example, through presence or absence, bodily responses, and breeding successes. Combinations of stakeholder perspectives can yield patchwork approximations of possible futures in response to decisions that we interpret as contributions to design. This framework of communal imagination is useful because it can integrate existing infrastructuring devices of participatory design. For example, by applying ‘boundary objects’ (Star 2010; Star & Griesemer 1989) in non-human contexts, human designers can solicit bird responses to computational models or physical prototypes of habitat structures.

In our case study, the temperate zone that contains Molonglo no longer functions as a self-sustaining ecosystem and requires human interventions to offset the damage. In every situation, an ability to innovate is in tension with the capacity to change in response to pressure and to manage the ensuing impacts. Among our stakeholders, trees hold the value that humans fail to appreciate. A useful community innovation should be able to account for this value and seek to maximise it. For example, birds need to develop novel behaviours to live in the conditions they have not previously encountered. The inherited plasticity of organisms’ behaviours is the limit to these innovations. Harmful consequences can occur even within these limits. For example, birds can interpret novel opportunities as desirable without anticipating novel harms. Similarly, temporal and spatial feedback between human and non-human forces can trap entire landscapes in an ongoing damaged state (Lindenmayer et al. 2011). These examples demonstrate that imagination and innovation are not inherently positive forces, with risks increasing through the exclusion of stakeholders.

Multispecies cohabitation

The framework of more-than-human design can be useful in many situations. This chapter considers its application in the context of multispecies cohabitation in modified landscapes. All life exists in and is interlinked with structural and spatial settings. Acknowledging the importance of local expertise, human design approaches justified the focus on bioregional solutions (Crist 2020; Fanfani & Matarán Ruiz 2020). Emerging work in design understands that discounting of non-human expertise in local habitation can lead to significant losses (Parker, Soanes, et al. 2022). Plants, animals, and other organisms hold knowledge, provide services, and help to maintain complex mutualisms.

In the context of Molonglo and the south-eastern Australia's grassy woodlands biome, current practices already value the expertise of human residents, including farmers and traditional knowledge holders. Examples include farmers' contributions to weed control programmes (Firn et al. 2018), community workshops with residents to plan urban development (Molonglo Community Consultation Report 2012), and partnerships with Aboriginal Reference Groups to apply traditional ecological knowledge (Department of Environment, Climate Change and Water NSW 2011). Other jurisdictions sought to grant greater voice to whole situated eco-social systems, emphasising the primacy of the land or country (Country et al. 2016). We also accept that challenges of multispecies cohabitation will require inclusive participation.

As discussed, this participation occurs through informationally limited and evolutionary defined agents. These agents form novel societies that include humans, non-human biological beings, and artificial systems as envisaged in notions such as smart cities, smart villages, smart landscapes, or even Digital or Smart Earth. Our work seeks to extend emerging research on these topics including discussions of urban paradigms that support survival and wellbeing of non-human living beings (Forlano 2016; Foth 2017; Smith et al. 2017), considerations of circular-economy villages (Liaros 2021), and multispecies cohabitation in the context of farming (Liu 2019).

Innovation in practice

To illustrate this proposition, this section explores more-than-human innovation by focusing on a challenge that links trees, birds, and humans. It considers how community members perform three types of actions: 'design by', 'design for', and 'design with'. These roles simplify the complex real-world relationships in organisations and ecosystems. Despite the loss of nuance, this approach is useful because it contrasts distinct roles of stakeholders and extends existing design practices that seek to decentre humans (Forlano 2016). These roles demonstrate that amplification of non-human contributions to design is reasonable and feasible.

In our case-study, we emphasise the roles of:

- ***Trees as designers.*** Old trees mediate crucial ecological, chemical, and biological processes (Lindenmayer & Laurance 2016), acting as ecosystem engineers. We focus on habitation within their canopies. Over hundreds of years, old trees create complex habitat structures that are absent in younger trees or other parts of the landscape. This interpretation suggests that old ***trees design by providing habitats.***
- ***Birds as users and clients.*** Birds co-evolved with trees and this relationship shaped their bodies, cognition, and senses. Canopies of large old trees have diverse structural conditions. This diversity is necessary for birds to survive. For instance, birds depend on lateral branches for resting, fissured bark for food, and dead limbs for observation and hunting (Rayner et al. 2016). Birds are discerning clients who continuously assess their habitats. Thus, we can say that trees ***design for birds.***
- ***Humans as mitigators of their disruptive actions.*** Humans create artificial replacement structures for birds and take measures to protect old trees. However, humans find it difficult to study birds' needs or tree capabilities (Ehbrecht et al. 2017). Because of this, humans do not fully understand why birds prefer the canopies of old trees, and what branches they prefer. Human designers require the input from trees and birds to produce successful designs. Thus, humans fulfil supporting roles that we denote as ***designing with humans.***

The remaining component of our approach is information technology in support of more-than-human participation (Tomitsch et al. 2021; Romani et al. 2022; Sheikh et al. 2023). Here, we focus on the empowerment of non-human voices rather than on the amplification of human visions.

To explore the roles discussed above in keeping with this objective, we introduce an additional type of agent: an artificial system.[1] Limited now, such systems promise to become more autonomous with the development of AI. For our purposes, their autonomy is secondary. Instead, we focus on their capacity to ***amplify beneficial interactions between non-human designers and clients.***

The next sections demonstrate the practical feasibility of such artificial systems and their support for more-than-human design.

Findings: Workflow Operations

We discuss here, as a set of findings, four technical operations of our workflow that form key steps in translating non-human design innovation into communal imagination that can support more-than-human design.[2]

Capture

The 'capture' operation extracts and recognises meaningful features supplied by non-human agents such as birds and trees. We understand these features as structural traces of relationships and behaviours.

For example, we know that birds use horizontal leafless branches (Holland et al. 2024). Consequently, our project captures relevant information about trees. To do so, we gather high-resolution data about geometries of tree canopies and use machine learning to separate sets of points that represent wood and leaves (Belton et al. 2013) (grey tree model, Figure 5.3). We also recognise structural features of branches and find information about branch positions, orientations, radii, and connectivity (Hackenberg et al. 2015). We then specify rules to recognise features meaningful for birds, for instance, whether each branch is alive and determine its inclination, size, and exposure. This operation describes aspects of trees with much greater fidelity than unassisted observations by humans (green highlights, Figure 5.3). Resulting descriptions can quantify habitat structures provided by trees, making them analysable and comparable (coloured graph, Figure 5.3). This process can recognise contributions of important stakeholders such as large old trees and account for their individual characteristics.

Such processes can amplify signals of existing relationships for human interpretation and use, giving the voices of birds and trees greater significance. In this operation, the knowledge flows from trees, through birds, to humans in a form of a collaborative process.

Predict

The 'predict' operation extrapolates from limited observations to create computational models of relationships between birds and habitat structures.

Humans can observe bird behaviours, but this is a slow process. Birds are mobile and can use very large territories. Many are migratory and stay in one place for a limited time. They often have small bodies, and their behaviours vary with breeding cycles and between individuals. Fields observations of birds often take many years, but still produce sparse data.

To amplify the signal collected through field observations, our operations use statistical models to extrapolate and predict behaviours. To do this, we use data on bird–branch interactions collected in a multi-year study by ecologists at the Australian National University (Le Roux, Ikin, Lindenmayer, Manning, et al. 2015; Le Roux et al. 2018). These bird observations are part of an ongoing project that seeks to understand the contributions of large old trees, as described earlier. This research work documented the abundance and identity of bird species that came into direct contact with sample trees, as well as the radius, the angle relative to horizontal, and the dead or living status of each contact branch. Our collaboration with these ecologists continues, and further publications are forthcoming.

Using this observational data, we then created a set of models that represent bird behaviour. These models use observational data to make predictions for

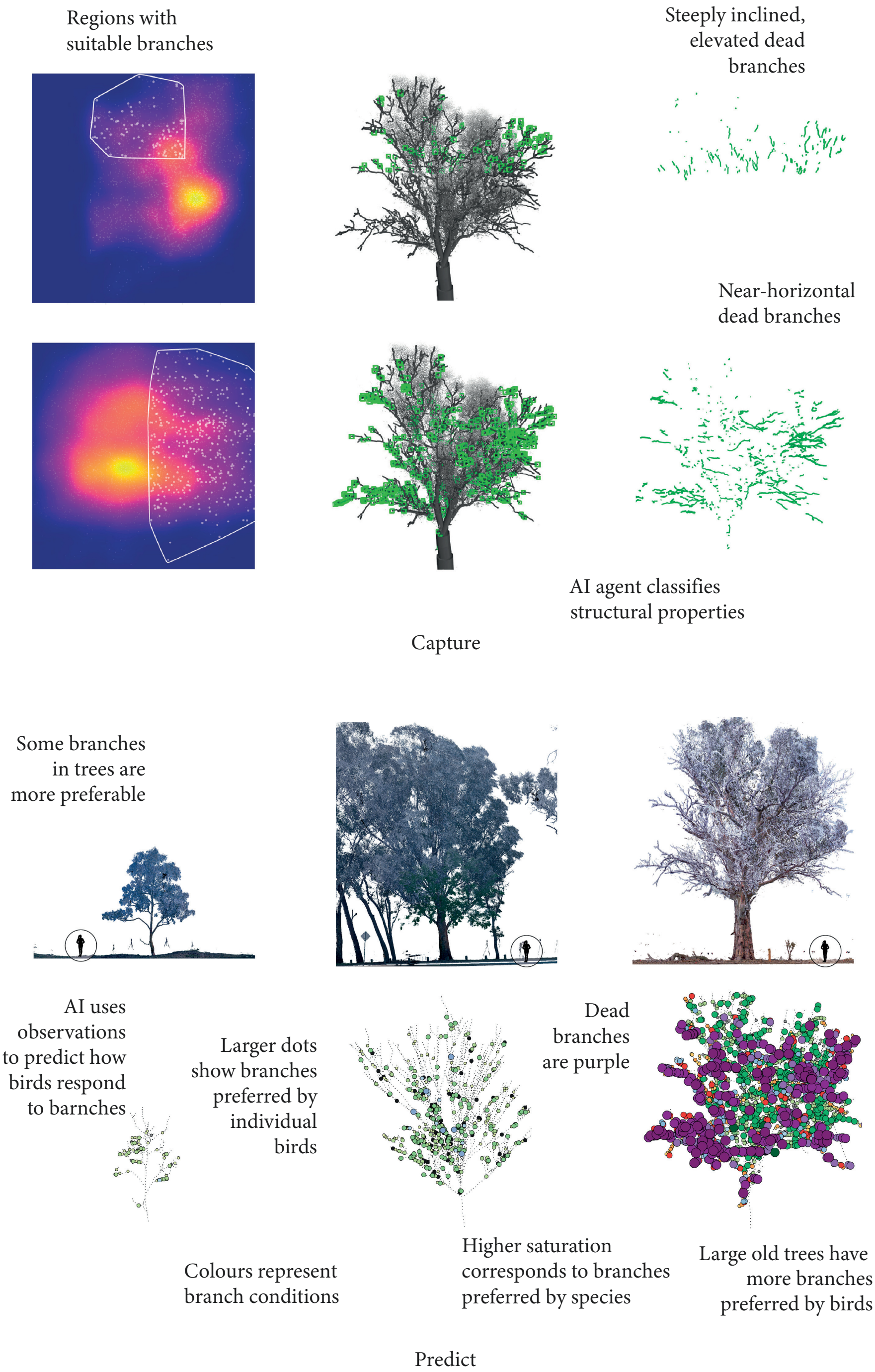

Figure 5.3 Top image: feature recognition and interpretation. Perch structures extracted from laser scans of large old trees. Bottom: predictions of bird preferences in trees. Features expressing potential bird-branch interactions in a young, middle-age and large old tree.

Image by the authors.

non-observed trees, allowing us to predict the likelihood of bird use for each branch. Features meaningful to birds include exposed dead branches (purple dots, Figure 5.3) that are easy to fly to and lateral branches (green dots, Figure 5.3) that are comfortable for perching.

This operation approximates birds' preferences for types of branches and makes it possible to numerically assess relative value of different habitat structures for birds. These estimates amplify preferences for birds, supporting their inclusion into design considerations.

Reconfigure

The 'reconfigure' operation generates artificial habitat structures and compares them with naturally evolved habitats. Our procedures can evaluate scans of natural trees, artificial habitat structures already installed in the field (Figure 5.4), and proposals for new designs (Figure 5.4).

We first establish a set of feature-rich design options using a semi-automated generative routine. Using this routine, we set the initial parameters, including points of attachment to existing structures and the material use constraints. The routine responds by generating an artificial canopy structure that matches specified constraints while ensuring structural stability.

We then select promising designs using an analysis routine that assesses their likely utility for birds. This routine works by extracting geometrical information from generated proposals, including angles, sizes, and visibility statuses of all artificial branches. After extraction, the routine predicts bird response to each artificial branch by comparing this information to the database of bird use described in the previous step.

Through iteration, this operation produces sets of site-specific habitat structures and supports comparative evaluation of virtual and physical designs.

Return

The 'return' operation supports iterative assessment of proposals in the field. All modelling includes simplifications and approximations. Therefore, possible artificial interventions should undergo field-testing. Our approach supports this via physical prototyping. Through their encounters with prototypes in the field, stakeholder groups such as arboreal nesters can provide feedback on the utility of designs (Figure 5.4, bottom image).

Materialisation of designs is a slow process. In response, we aim to reduce the barriers to field testing by using computationally assisted workflows for working with complex structures. These workflows use rapid digital fabrication routines and augmented reality construction. We have already tested a range of such fabrication and assembly approaches in field contexts at the scale of tree hollows in other case study settings (Roudavski & Parker 2020; Parker, Roudavski et al. 2022). The work at tree scales is ongoing, and we shall report the outcomes soon.

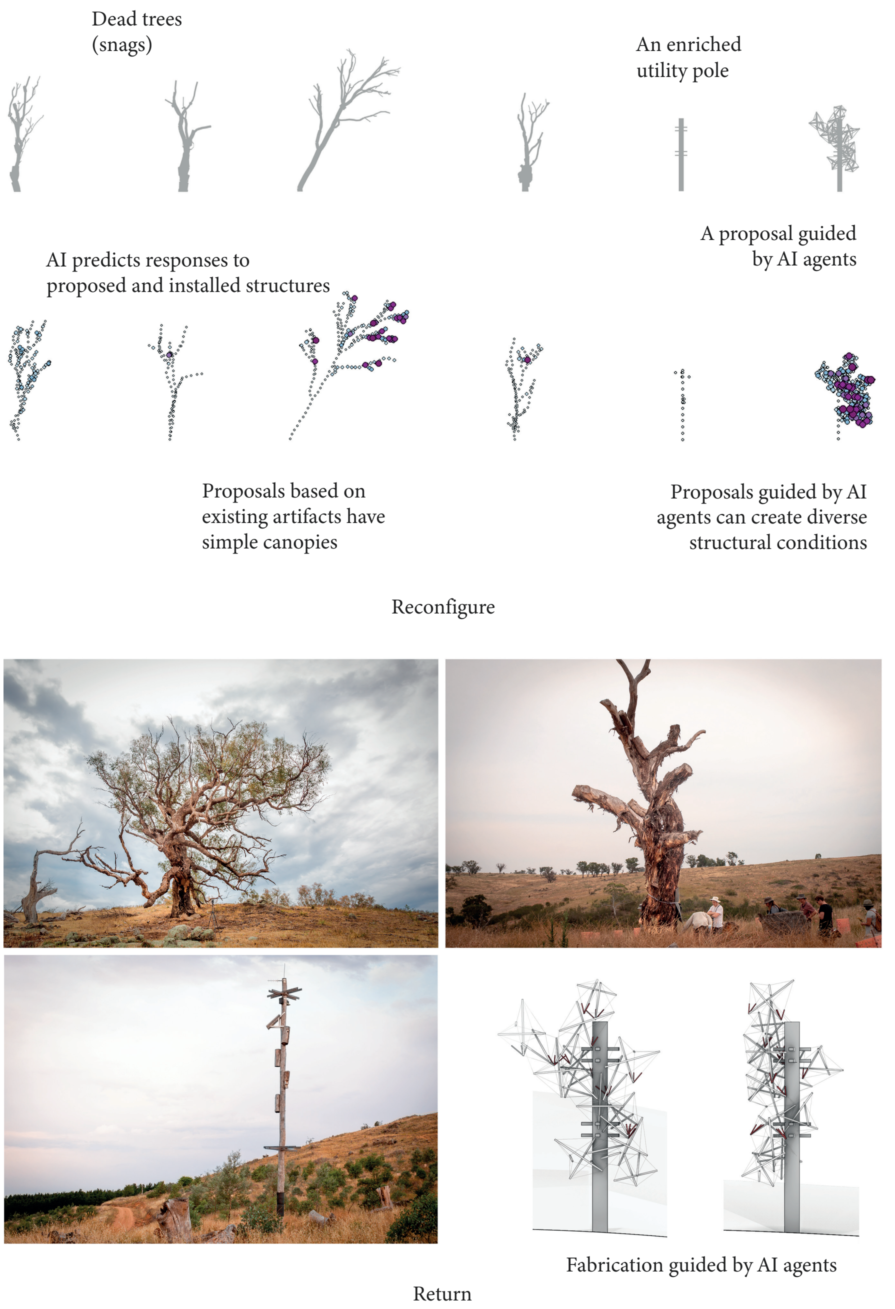

Figure 5.4 Top image: simulated bird preferences. A proposed tensile structure has considerably more resources than translocated dead trees or utility poles. Bottom: natural and artificial habitats at Molonglo. Clockwise from top left: a large old tree, a translocated snag with artificial enhancements, a utility pole with artificial enhancement, generated designs.

Image by the authors.

The return of knowledge materialised as functional structures to the field contributes to the maintenance and development of more-than-human community relationships, as we discuss in the next section.

Analysis: Workflow Outcomes

To analyse the findings, we return to the concepts discussed in the introduction. We first show that our technical operations can amplify collaborative relationships between stakeholders in more-than-human communities, and then indicate how this expansion can support better lives.

Amplify relationships for multispecies participation

The case introduced above affects birds, trees, and humans. We claim that our results support more-than-human design by amplifying existing and probing for novel relationships between these human and non-human stakeholders.

We first revisit the technical operations discussed in the Results (Table 5.3). We link them to community relationships that amplify the flow of meaningful information between stakeholders, seeking to address the unmet needs described in the Approach section.

Listen

Existing work on participatory approaches demonstrates that disadvantaged humans can benefit if more powerful humans acknowledge their existence, contributions, and needs. In an extension, our approach reframes trees as designers. They are survivors from past eras of richer mutualistic relationships and retain features that remain significant to others.

Current artificial structures are often made from found objects (snags or common industrial objects such as utility poles). These simple forms ignore subtle but important relationships between birds and trees. For instance, humans know that old trees provide hollows because hollows are easy to count. However, our group of birds do not nest in hollows but still depend on old trees. Such dependencies are harder to study.

In response, we develop operations that support listening to trees by capturing and interpreting numerical data that involve structural complexity and lateral branches. Figure 5.5 is an example that compares natural trees and artificial alternatives. We underlie the relative positions of these objects with a field that represents bird behaviour as observed by Hannan et al. (2019). This study shows that bird response to remnant trees is high (yellow) in contrast to translocated dead snags (green) and enriched utility poles (blue). The plot shows that dots match observational data that is newly available via our operations.

We describe data capture, processing, and feature recognition as a form of 'listening' because these operations produce quantitative and topological descriptions of tree structures that can appear surprising to humans, whose knowledge about

Table 5.3 Workflow operations to amplify communal imagination.

Technical operations	Amplified relationships	Stakeholder actions
Capture	Listen	Trees supply baseline examples of structural distributions that inform remedial efforts. Birds use trees in ways that are observable to humans. Humans set up the technical system and train the AI on categorised data. Artificial agents extract quantified features with high fidelity in ways that can surprise humans.
Predict	Consult	Trees supply canopies that differ with age and individual life histories. Birds accept or reject tree branches that are suitable for their needs. Humans perform detailed, long-term observations of birds and compare different trees. Artificial agents enable comparisons between trees by extrapolating patterns of bird actions.
Reconfigure	Provoke	Trees inform the design of replacement structures and provide the baseline for assessment. Bird behaviours guide the search for artificial canopies. Humans supply design provocations, setup the workflow, test, measure, and make selections. Artificial agents generate shapes, designs, iterate through versions in response to constraints or feedback, and inform construction.
Return	Support	Trees resist change, contribute to ecosystem functioning, and provide scaffolds for installations. Birds succeed or fail to use the designs and show what works and what does not. Humans choose sites, produce prototypes, install, monitor, interpret feedback, update models, and propose further designs. Artificial agents learn, propose new designs, and provide comparative toolkits.

trees and their community roles is far from complete. Such listening can highlight the importance of non-human community members, detail their contributions, and guide remedial efforts.

Consult

Participatory approaches argue that greater autonomy can support all stakeholders in resisting exploitation or inaction. Enacting this reasoning, our experiments demonstrate that humans can empower birds to express their preferences. As all lifeforms, birds have capabilities that make some forms of participation feasible and

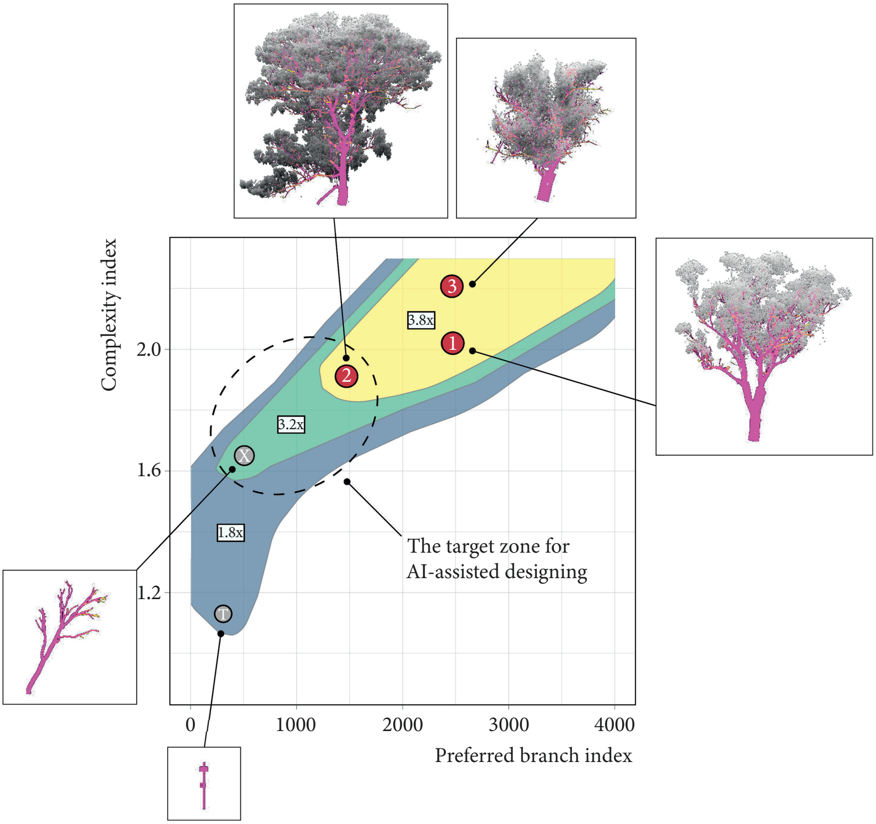

Figure 5.5 A comparison between naturally evolved (red dots) and artificial (grey dots) canopy structures.

Image by the authors.

others impossible. For example, birds cannot assess written briefs or review drawings, but can express preferences through everyday behaviours. However, translation of these expressed preferences into design actions is not straightforward because humans do not have the evolved bodies of birds, cannot experience bird perceptions, or understand nuances of bird actions.

In response, our ***predict*** operation exposes lifestyles, behaviours, and preferences of birds through quantitative data analysis. It amplifies humans' ability to 'consult' with birds about design options by extrapolating their bodily responses. We interpret this simulative statistical analysis is a form of consulting because it extrapolates observed interactions between community members into unobserved situations. Such interactions amplify traces of existing relationships and can illuminate their consequences under a diverse range of conditions, for example, by predicting the likely use of unobserved trees. This operation emphasises that birds are self-directed agents who are experts in their lives as well as valuable members of their communities.

Provoke

The need for communal imagination in response to the accelerating environmental change will only grow. In response, we develop artificial agents that generate designs and compare outcomes of multiple iterations. Artificial alternatives 'provoke' by disturbing the consultative process with novel options. These options modify relationships between stakeholders such as trees and birds while lending themselves to numerical evaluation. This evaluation supports iterative development of designs and redeploys historical innovation produced by non-human agents in novel ecosystems.

Figure 5.6 shows one approach where tree geometries guide the generation of artificial structures. These structures are more complex and varied than those possible through direct modelling by humans. They can support many microhabitats with varying exposures to the wind and sun, visibility, or perching comfort. The ***reconfigure*** operation allows community members to change their choices in response to feedback. For instance, it can retain features used by birds while addressing concerns such as constructability, material use, and costs.

Assessment of current practices (Prebble et al. 2021) demonstrate that quantitative systems can have an unfortunate effect of solidifying unjust relationships between human and non-human stakeholders. For example, digital mapping and database technologies can commodify tree lives for human exploitation. In contrast, our findings indicate that these techniques can also help by integrating human and non-human signals, increasing the diversity of options, and supporting the assessment of implications. In agreement with agnostic design (Di Salvo 2012), this approach accepts that friction between empowered stakeholders can be productive. Respect for the capabilities of others can generate new relationships while providing care through communication, trust, and respect (Wiesel et al. 2020).

Support

Our proposals depend on long-term experimental observations of prototypes in the field. Therefore, we align the ***return*** operation with the ***support*** for the processes of community imagination through forms of infrastructuring (Björgvinsson et al. 2012) discussed above. Data interpretation, simulation, and design, coupled with collaborative prototyping and testing in the field, are a form of 'support' because these processes empower a broad range of stakeholders, including trees and birds, to participate in long-term assessment and redesign. Future-oriented and evidence-based information exchanges between human and non-human community members build the capacity to cope with change.

The discourse on commons demonstrates that beneficial initiatives and successful designs cannot persist without long-term engagement (Huybrechts et al. 2017). This support can take the form of legislation, education, management guidelines, focused research, guaranteed funding, and other measures. The discussion of these issues is beyond the scope of this chapter. One way to encourage knowledge reuse and stakeholder empowerment is through the creation and sharing of novel datasets, workflows, and tools. To give one example, our techniques of data acquisition and analysis of old trees led to innovation in ecology and machine learning that

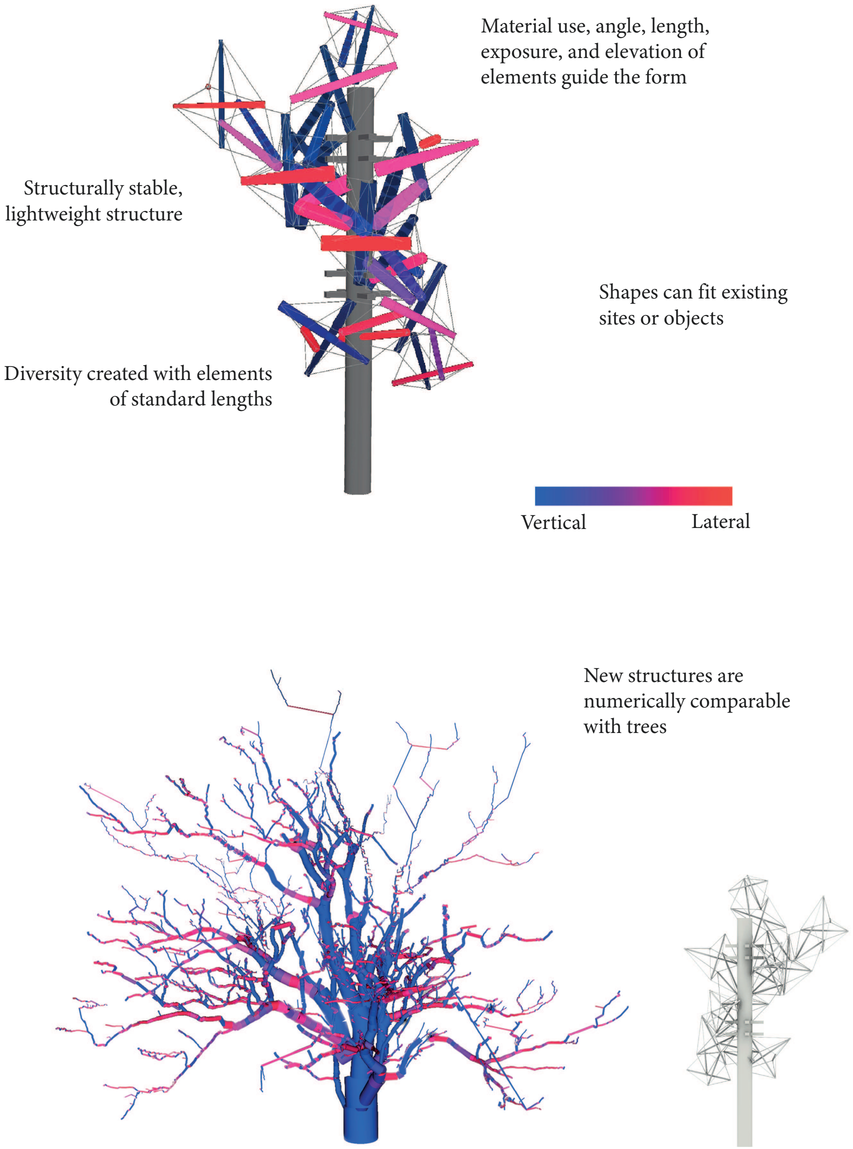

Figure 5.6 Design provocations and simulated stakeholder responses. Top: an artificial canopy structure. Red: lateral artificial branches comfortable to perch. Thicker lines: artificial branches hidden within the canopy. Thinner lines: exposed artificial branches. Bottom: distribution and quantity of lateral branches (red) in the canopy of a natural large old tree; model of artificial habitat-structure, right.
Image by the authors.

reconstructs trees as they are perceived by birds (Mirra et al. 2022). Further collaborations will be necessary to expand the benefits of more-than-human design to other sites and species at large scales and numbers.

Build better lives by imagining together

The second objective of this project was to illustrate how its techniques can support more equitable communities and help their members live better lives.

Existing approaches to environmental management already aim to support sustainability. In addition, work that focuses on bio-informed design seeks to learn from natural systems. However, such approaches see non-human lifeforms such as birds and trees as incompetent or aim to isolate innovations occurring in natural systems for human use, without compensation.

In most cases, humans undertake to manage the environment according to their wisdom. Non-human stakeholders have no power in decision making or innovation is response to change. In doing so, humans fail to distribute benefits and risks with equity. These approaches tend to produce benefits for humans but result in costs for the birds and trees. Examples of drawbacks include prioritisation of narrow timeframes that ignore long processes of arboreal habitat formation, misinterpretation of non-human needs, and failure to act in the face of available knowledge. These biases demonstrate the drawbacks of situations where communal imagination is interpreted by a limited number of powerful and predominantly human voices.

To illustrate advantages of more-than-human approaches, this chapter described birds and trees as innovators. Humans have disrupted the expression of non-human imagination such that the reversal to historical states is impossible. For example, Molonglo will soon have no old trees, even if many young trees are planted now. To support ecosystem integrity and ensure survival of vulnerable species, humans must provide artificial habitat structures. In such situations, access to historical and possible innovations produced by more-than-human communities can be crucially significant.

We illustrate some advantages of more-than-human design through two figures.[3] Figure 5.7 maps historical imagination produced by the ecological community (green) and the anthropogenic damage that made resulting patterns of cohabitation less useful (red). Figure 5.8 contrasts the scope of existing restoration approaches (orange) with more-than-human design (purple). The axes use logarithmic scales to show timescales (increasing vertically towards the top) and levels of complexity within communities (increasing horizontally towards the right). Colours show the degree of damage or restoration of capabilities.

These diagrams highlight that 1) damage done by humans spreads across the full spectrum of innovations (Figure 5.7); and 2) human remedial efforts cluster in the central region (Figure 5.8), failing to benefit from the complete richness of community interactions. Remedying the curtailed reach of current human actions, our approaches extend designing in ways that can expand the range of possible solutions.

The bottom left of Figure 5.8 provides a characteristic example. This region includes measurable outcomes of design options that existing approaches do not produce. For instance, current approaches to describe trees lack detail (c5). Similarly, typical designs for artificial habitat structures produce relatively simple forms (c6). Approaches within this region expand the set of imaginable designs. For example,

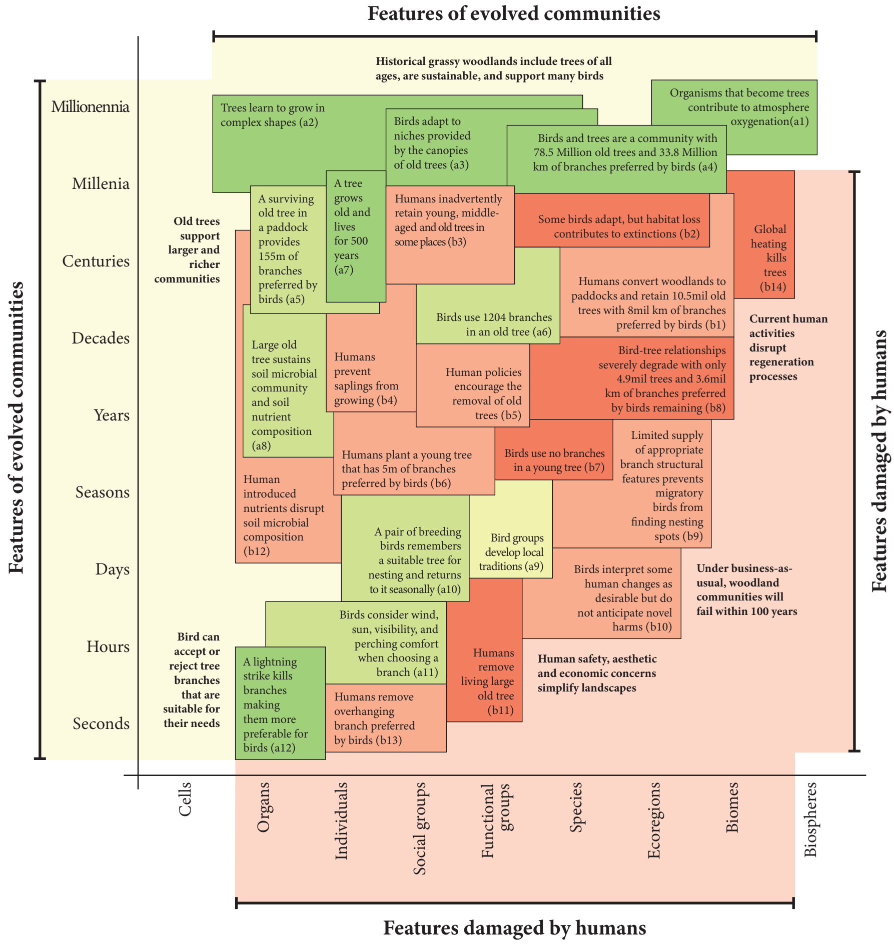

Figure 5.7 The ecological community's historical capacity for imagination (green) and the anthropogenic damage (red).
Image by the authors.

our operations collect more data (d1), create more solutions (d2), and account for more complex relationships (d5, d6), increasing diversity and complexity of possible designs. The expansion of communal imagination to include non-human concerns will increase the likelihood of better outcomes, improving the lives of all stakeholders.

These approaches establish a framework that can integrate a broad range of expressions by non-human agents, including presence and absence, bodily movement, physiological reactions, shapes of bodies, chemical residues, or marks left by use. These conditions occur in all species and environments. Consequently, while access to a greater set of possible innovations is demonstrably useful in our case study, it can also benefit other design challenges, irrespective of implicated lifeforms, sites, or anthropogenic damages.

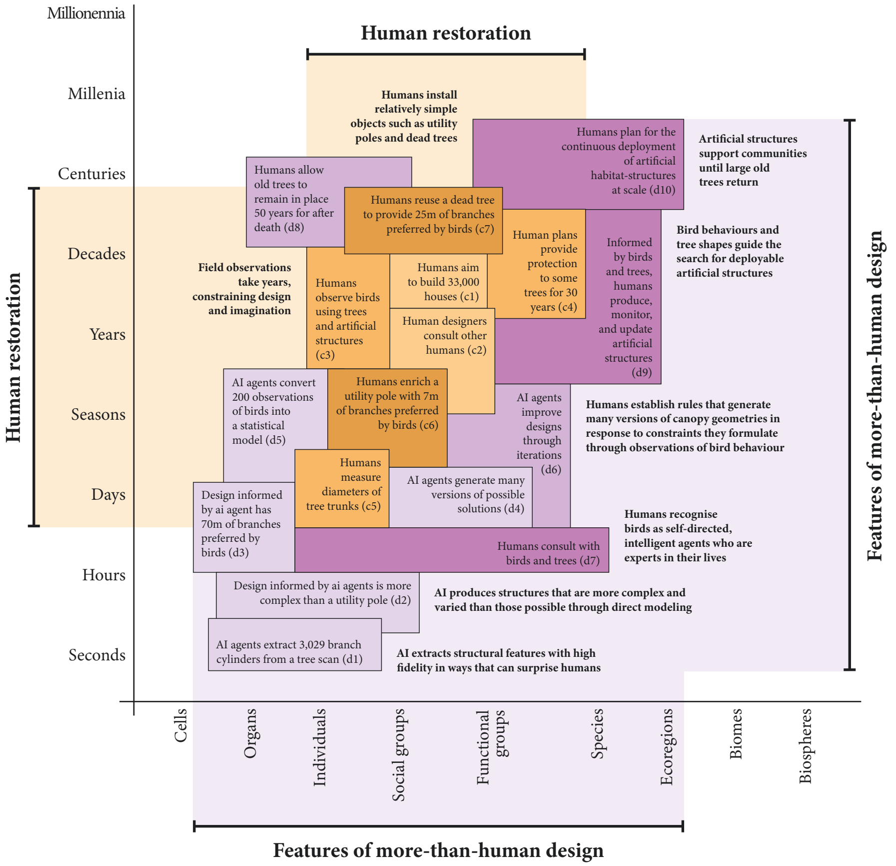

Figure 5.8 Existing restoration (orange) and more-than-human design that learns from nonhuman contributions (purple).

Image by the authors.

Conclusion: Communal Imagination *for*, *with*, and *by* Non-Human Beings

Seeking to encourage action that can address environmental crises, this chapter redefined the notion of community to include non-human lifeforms as empowered voices in communal imagination. To do so, we considered interrelationships between birds, trees, and humans that cohabit a degraded landscape.

This research helps to fill the gap in knowledge about practical techniques for collaboration with non-human beings, as well as the theoretical framing of more-than human design. To do this, our theoretical framework redefined habitual roles in design processes, giving humans supporting responsibilities, emphasising design contributions provided by trees, and describing birds as discerning clients. To substantiate this narrative, we have redefined the notion of community in more-than-human terms, demonstrated that non-human beings act as significant community members, demonstrated involvement of non-human stakeholders in design, and argued that human and non-human beings participate in the construction of shared imaginings.

We then discussed innovations as potentially useful outcomes of communal imagination and argued that assessment of their impact must involve all stakeholders, including non-humans. This involvement is especially important in application to multispecies cohabitation that depends on meaningful interpretation of local conditions by participating organisms. Seeking to demonstrate applications of this approach in practice, our case study presented aspects of non-human involvement as four operations.

We first described trees in detail and linked features of their branches to bird behaviour. This 'capture' operation recognises features or habitat structures that are meaningful to non-human stakeholders. We interpret this recognition as an opportunity to amplify non-human subjectivities, cultures, expertise, and useful innovations.

In the next step, we used descriptions of trees and observations of bird behaviour to model bird responses to unobserved trees or artificial structures. This 'predict' operation simulates non-human behaviour in response to habitat structures. This simulation acts as a form of consultation with non-human stakeholders by linking their simulated responses with existing and possible configurations of habitat structures.

Thirdly, we have automatically generated a variety of artificial structures and used simulated bird responses to assess the potential suitability of such designs. This 'reconfigure' operation offers a variety of analysable design for interrogation in the design process. We interpret the effect of this operation as a useful provocation that can highlight issues, consequences, and solutions that otherwise remain hidden.

Lastly, we provide routines that can support the assessment of the resulting designs in the field. This work is ongoing, with outcomes forthcoming. Through its reliance on detailed numerical descriptions, our approach enables side-by-side iterative assessment of multiple generations of artificial structures. Comparisons between trees and versions of their artificial replacements demonstrate the great value of natural structures, while making artificial structures more accountable in situations where other alternatives are not available. We interpret the introduction of artificial structures informed by our processes as a form of support for the processes of communal imagination because they give birds an opportunity to express their preferences and trees a chance to demonstrate the quality of their contributions to habitable spaces.

Implementation of the proposed workflows for artificial habitat structures will need further research. Practical applications will require streamlining data acquisition, analysis, and utilisation. Ethical concerns such as those pertaining to non-human privacy will also apply. Crucially, successful designs will depend on direct testing with birds and trees in the field.

We can characterise many limitations of data-driven workflows as forms of bias. This chapter does not focus on the details of technical aspects, but provides examples that can indicate challenges and directions for future research. Data acquisition bias can result from constraints on such aspects as misleading baselines because the environments humans can scan now are already degraded. Datasets describing behaviours of living organisms are often relatively small because field observations can be laborious and time-consuming, leading to data interpretation bias. Simplifications built into generative models that cannot express the full complexity of evolved precedents (e.g. tree shapes) result in misinformed generation of replacement shapes or in other design biases. Finally, difficulties in interpreting results of physical prototyping can lead to biases in implementation.

In spite of these limitations, our approach demonstrates the plausibility and promise of more-than-human participation. Current practices are so damaging and unjust that improvements to the *status quo* are easy. Even partial integrations of non-human voices can support more equitable communities and thus help their members live better lives. Growing interest in the practical implementation of this work at multiple sites demonstrates its potential to contribute, the acute need for improvements, and the growing readiness of human societies to take action towards more-than-human wellbeing.

Notes

1. We provide a more detailed description of our artificial agent in Supplementary Appendix A, which can be found at the following address: https://doi.org/10.5281/zenodo.8213429.
2. We provide supporting information on the results obtained by our AI agent in Supplementary Appendix B, see note 1.
3. We provide evidence in support of each element in these diagrams in Supplementary Appendix C, see note 1.

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